THE INFLUENCE OF TAPING AND TRAINING ON ASPECTS OF ANKLE PROPRIOCEPTION AND ATHLETIC PERFORMANCE

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DECLARATION

I declare that this thesis has been composed by myself and represents the results of my own research carried out whilst studying at the University of Salford from September 1994 to June 1999.

All sources of material have been acknowledged. None of the material has been used previously in application for a higher degree.

ABBREVIATIONS

ANOVA	–	Analysis of Variance
A/P	–	Anterior/Posterior sway
ATFL	–	Anterior Talofibular Ligament
CBOS	–	Central base of support
CFL	–	Calcaneofibular Ligament
CMRR	–	Common Mode Rejection Ratio
CNS	–	Central Nervous System
COB	–	Centre of Balance
COB_X	–	Centre of balance X- axis
COB_Y	–	Centre of balance Y- axis
COP	–	Centre of pressure
EMG	–	Electromyography
EC	–	Eyes closed
EO	–	Eyes open
L/R	–	Left/Right sway
MAP	–	Muscle Fibre Action Potential
MAUP	–	Motor Unit Action Potential
PTFL	–	Posterior Talofibular Ligament
SI	–	Sway index

ABSTRACT

ABSTRACT

Sports participation imparts a risk of injury. By considering the risk factors involved and taking appropriate action, many injuries can be prevented, or at least their severity minimised.

Among the many injuries sustained in sport, ankle injury is well substantiated to be one of the most prevalent, particularly ankle sprain in football. While ankle supports are commonly used in an attempt to decrease the risk of ankle injury, there are concerns over their effect upon performance and the actual mechanism of support. Taping is a universally accepted form of ankle prophylaxis, reportedly protecting the ankle by providing joint stability and enhancing proprioceptive input. Proprioceptive training is used in rehabilitation to reduce proprioceptive deficits and is beginning to be used as a tool in prevention, again by enhancing proprioception. However, despite their widespread use, the proprioceptive effects of both taping and training are unclear for healthy subjects.

An investigation was undertaken to confirm results from preceding studies in the literature, concerning the prevalence of ankle injury in football. By means of an injury survey over two football seasons, the high incidence of injury to the ankle was confirmed. This prompted exploration of the influence of taping and training by investigating the consequences of their use upon athletic performance, and their proprioceptive effect upon the ankles of healthy football players.

Neither taping nor training was shown to significantly affect athletic performance, so assuaging concerns over any detriment caused by their prophylactic use. Examination of their proprioceptive effects revealed a slight increase in postural sway with taping and proprioceptive training, though this was not overall statistically significant. Significance was seen in centre of balance positioning, with taping causing the centre of balance to shift to the left and proprioceptive training to the right in single leg stance and left in double leg stance. Consideration of electromyography results revealed varying changes in muscle activity due to taping and training dependent upon the muscle examined and its action in postural stability.

The conclusion is that both taping and training can be used without concern for impairment of performance but their overall effect on proprioception in the healthy player is still questionable. It may be that the sportsperson is at an optimum level of proprioception that cannot be improved. Nevertheless, knowledge of the proprioceptive level for the individual is useful for rehabilitation and there is still scope to further investigate this phenomenon, particularly in rehabilitation of the injured sportsperson. More importantly, the research paves the way for investigation into the effect of these prophylactic measures on incidence of injury. If either taping or proprioceptively training the healthy ankle can reduce the incidence of ankle injury in football, then their long-term use must be considered.

CHAPTER ONE

CHAPTER 1: INTRODUCTION

The reasons why people take part in sport are many. For the professional sports person it represents a way of life and a means of income, while for most other people the reasons are more likely to be health, fitness, recreation, the enjoyment of competition and the social interaction that it facilitates.

1.1 RISK OF INJURY

Participation in sport conveys a risk of injury to all, although some may be more vulnerable than others. A sports injury can be defined as: 'An injury occurring as a result of participation in sports having one or both of the following consequences: a reduction in the amount or level of sports activity, the need for medical treatment' (*de Bruijn 1991*). Injury most commonly results in time lost from participation in the sport, financial cost to the health services, indirect cost in terms of lost 'working' time and a welfare cost in terms of impaired quality of life to the individual. Thus, the consequences of sports injury can be seen to be of importance to all. Some injuries, such as slight cuts or bruises, can be dealt with by the individual or at least basic first aid. These are termed minor injuries. Conversely, other injuries may be so severe that they require expertise in a specialist field of medical care. Between these extremes are moderate injuries, those injuries that are not life threatening, but likely to prevent or inhibit the sportsperson from training and competing to their full potential. These moderate injuries thus assume a greater significance for the professional sportsperson, as they affect their livelihood as well as their state of health.

Sports injuries can also be broadly categorised into two types according to how they occur. The first is ACUTE, and is typically related to a specific incident. The second is GRADUAL and is an injury that develops slowly over time.

Both types of injury have contributing factors that may be either external (related to the type of sports activity, the manner in which the sport is practised and the environmental conditions and equipment), or internal (related to individual physical and psychosocial factors). Different sports and different forms of exercise place different demands upon participants (*Williams 1976*), nevertheless, the general predisposing factors of sports injuries are: -

- Lack of warm up; cold muscles, tendons and ligaments are less elastic than warm ones and hence more likely to tear when stretched.

- Inadequate fitness and physical weakness; if the individual is not fit enough for their chosen sport, the physical stresses that they experience during participation may cause injury. A lack of strength, speed, flexibility or endurance can all contribute towards injury.

- Inappropriate training; the correct training and level of fitness will reduce the risk of injury by making the sportsperson's body more able to withstand the physical demands of the activity.

- Lack of recovery; sport places physical stresses upon the body and if given adequate time to recover these stresses will act as a stimulus and cause the body to adapt to the stresses in a positive manner, making it fitter. However, if adequate recovery time is not allowed between training sessions and matches then the body is unable to recover fully. This can result in any minor damage to tissues not being fully repaired and as a consequence it will be damaged further during subsequent exercise sessions. Recovery also facilitates the replenishment of energy stores and fluid levels.

- Biomechanical imbalances and anatomical factors; an imbalance between muscle groups or bone lengths or the mobility at joints, can sometimes cause excessive stress to be placed on particular parts of the body, resulting in injury. This can also cause the individual to compensate for a problem in one part of the body, which can then result in problems in other areas.

- Inadequate skills and technique; a lack of skill can contribute to the risk of injury to an individual and their opponents.

- Inappropriate footwear; poorly designed and inappropriate footwear for the particular sport can contribute to injury, causing blisters or inflammation of tissues. Footwear that is worn out or provides inadequate cushioning can lead to injuries of the foot, knee, hip and back.

- Lack of protective safety equipment; protective clothing and equipment is particular to each sport depending on the nature of the sport and amount of physical contact involved.

- Inappropriate environment; in some instances the environment can contribute to the incidence of injury. Factors involved include the weather and playing surface.

- Breaking the rules; in most sports some rules are designed to reduce the likelihood of injury to players. These include rules on tackling, positioning of players and general conduct.

- Inappropriate opposition; in some cases the risk of injury is increased if the opposition is inappropriate, such as of a different standard.

- Prior injury; with appropriate training and rehabilitation it is usually possible for the sportsperson to get back to full fitness. If the rehabilitation regime is insufficient, this then means that the individual is then more at risk of a repeat injury.
  (*Bird 1997, Lysens 1984, Norris 1993, Taimela 1990, Williams 1976*).

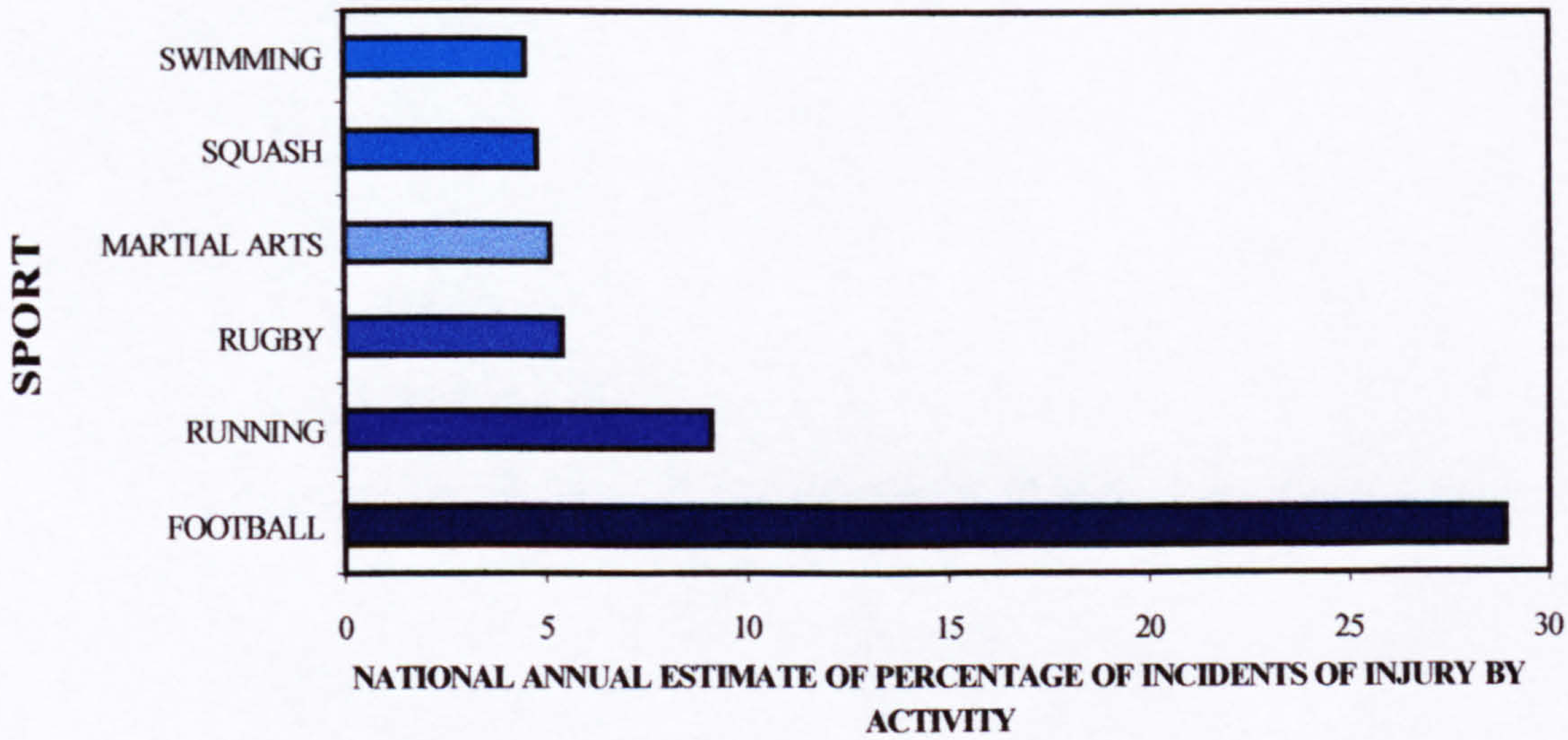
Considering these factors and taking appropriate action can help prevent many injuries, or at least minimise their occurrence or severity (*Bird 1997*). However, as sports injuries result from a complex interaction of identifiable risk factors at a given point in time, the prevention of sports injuries is a complex problem and a continuing challenge to preventative sports medicine (*Lysens 1984*).

1.2 INJURY INCIDENCE

The relationship between sports activities and the nature and number of sports injuries have been the subject of many studies (*Bedford 1984, Goldberg 1989, Tauton 1988, Tenvergert 1992*). However, these have tended to be population based surveys focusing concerns on hospital Accident and Emergency Departments. In a national study of the epidemiology of exercise-related injury, *Nicholl (1991b)* reported that in one year 19 million incidents resulted in new injuries, half of which resulted in injuries substantive enough to need treatment and prevent the injured taking part in their usual activities.

Each sport is seen to have its own characteristic profile of injuries and of all the sports cited by *Nicholl (1991a)*, football resulted in more than a quarter (28.9%) of all injury incidents (*Figure n° 11*).

Figure n° 11 Proportion of Injury Incidents in Vigorous Activity
(Taken from Nicholl (1991a))



1.3 INJURY IN FOOTBALL

Football provides a different profile from, say, running in that the majority of injuries in football occur during match play or competition, whereas three quarters of injuries to runners occur in training (*Reilly 1996*).

As football is a contact sport, players frequently sustain direct blows to the body during a block tackle or from a collision with another player. These result in contusion injuries or bone fractures. Indirect injuries result from forces generated within the musculoskeletal structures during an activity. Damage may be sustained to muscles, tendons, ligaments, joint structures and bone. These types of injuries often occur during early or late stages of a game due to inadequate warm-up, poor flexibility or fatigue (*Reilly 1996*). Overuse injuries in football are caused by continued or repetitive actions, or because of exposure of a structure to high loads, occurring as a result of training errors, biomechanical abnormalities, inadequate or inappropriate footwear and terrain.

1.4 RESEARCH QUESTIONS

It is self-evident to state that prevention is easier than cure and, the first step towards preventing injuries is identifying injury predisposition. Whilst some injuries can be prevented and risk of re-injury reduced, damage due to reckless play, especially by opponents cannot be anticipated.

As a means of taking a step towards preventing injury, particularly in football, in which the incidence is particularly high, this thesis will ratify information from preceding studies concerning prevalence of injury in football, focusing on the most common injury of ankle sprain.

Following the verification of ankle sprain injury as prevalent in football and so providing justification to focus on prophylactic measures for the ankle sprain, the thesis will investigate the influence of taping and proprioceptive training the ankle on aspects of proprioception and athletic performance.

Taping is a traditional method used for preventing injury, while conversely, proprioceptive training is a relatively new idea for prophylaxis, previously incorporated into rehabilitation regimes.

To sanction the use of either of these methods in prophylaxis, their effect on athletic performance is examined to rule out any significant negative effect on performance. The thesis will then proceed to examine the use of taping and proprioceptive training of the ankle with respect to the proprioceptive mechanism of support, to determine if there is an increase in proprioceptive activity at the ankle joint that can be attributed to either taping the joint or proprioceptively training the ankle and so promote their potential for use in reducing and preventing injury.

CHAPTER TWO

CHAPTER 2: INJURY IN FOOTBALL

Association football, often known as Soccer, is the world's most popular game (*Duke 1996*). Men's football was officially recognised in 1863 by the Football Association (FA), the governing body of English Football, and in 1888 the first professional league was established with 12 teams (*Lopez 1997*).

The overwhelming importance that is applied to professional football lies not only in its financial capacity, but also in the fact that large numbers of individuals in English society regard it as important (*King 1995*).

Football, in its various guises is the most popular team sport around the world (*Stokes 1994*). This popularity is part due to its simplicity and in part to its low cost as a participation sport. Undoubtedly, football has become the national sport in the vast majority of countries in the world. FIFA (Federation Internationale de Football Association), the world's governing body for football, claim the game is played by 200 million people in its 200 member nations (*http://www.fifa.com*). The game itself encourages fitness, physical skills and teamwork amongst players. However, all varieties of football involve physical contact, and this, coupled with the acceleration, deceleration and turning which football requires, results in a significant rate of injury (*Stokes 1994*).

2.1 BACKGROUND

In one year in England and Wales, an estimated 19 million sport and exercise related incidents result in new injuries, half of which need treatment or prevent the injured from taking part in their usual activities, with a reported additional 10 million incidents resulting in a recurrence of a previous injury (*Nicholl 1995*). Many of these injuries are unnecessary and the harm that they do, not only in terms of loss of earning capacity, but in terms of wasted effort and frustration is often quite disproportionate to their severity. In addition, the very circumstances under which they are sustained will make the patient liable to recurrence or further injury.

A study by *Nicholl (1995)* reported an estimated 8.6 million incidents of exercise related morbidity from football annually among the adult population in England and Wales. *Franke (1977)* estimated that, in Europe, football is responsible for 50% - 60% of all sports injuries and that 3.5% - 10% of all injuries treated in hospitals are due to football.

2.2 INTRODUCTION

In football, all players are under immense physical and psychological pressure to perform well in competitive matches and training, in order to maintain their team position and advance their sporting careers (*Lewin 1989*). Professional football is obviously a contact sport with injuries considered an occupational hazard. It is also a multi-million pound business and therefore there are great implications, to both the player and the club, of time lost from playing due to injury. This therefore needs to be kept to a minimum (*Lewin 1989*).

As football is a contact sport of world-wide appeal, there is a relatively high incidence of injuries (*Poulsen 1991, Tucker 1997*) and these football related injuries have become the object of increasing medical interest, as they include a wide variety of musculoskeletal and medical problems (*Keller 1987, Tucker 1997*).

2.2.1 Injury

At present, there is no universally accepted definition of what constitutes an injury, nor is there a generally accepted measurement of injury severity (*Luthje 1996*). Some studies regard all examples of physical damage caused by a sports related incident, whether or not they result in any incapacity to the athlete, to be an injury (*McMaster 1978*). Others have demanded medical treatment, or a one week time loss before an incident is counted as an injury (*Ekstrand 1983a, 1983b*). Many studies have recommended that some time loss from sports is necessary for an incident to be counted as an injury (*DeLee 1978, Ekstrand 1983a, 1983b, Keller 1987*).

In 1986 in Papendal, Holland, a group meeting under the aegis of the European Council agreed on the following definition of a sports injury: 'The injury should be acquired during a game or in practice, causing one or more of the following: reduction of activity, the need for medical treatment or medical advice, and/or negative social and economic consequences' (*Schmidt-Olsen 1991*).

Since different sports and different forms of exercise place different demands upon participants, each sport will have a characteristic profile of common sports injuries. For example, most of the injuries that occur in contact sports such as rugby are caused by collisions and are 'traumatic'. Conversely, in an activity such as marathon running, most of the injuries will be caused by the excessive repetition of a particular movement and result in a gradual overuse injury (*Bird 1997*).

2.2.1.1 Literature Review of Football Injury

The present football injury epidemiology literature relies upon a variety of definitions of what constitutes an injury, making it difficult to accurately compare studies that have been carried out relating to football injuries.

In most studies on injury in football, an injury is defined as an event occurring during scheduled training or matches which caused the player to miss the next game or training session (*Makay 1996*).

In studies by *McMaster (1978)* and *Nilsson (1978)*, every injury was reported. By doing so, a large proportion of minor injuries, including blisters and abrasions are reported. If these minor injuries are excluded, the data becomes more meaningful as shown by *Albert (1983)*, *Ekstrand (1982)* and *Sullivan (1980)*. They required injuries to be sufficiently significant to result in time being lost from practice or play before being included. This definition directs attention to those injuries most likely to have an important effect on the athlete's health and performance and is the definition that is adopted in the current literature (*Aranson 1996, Engstrom 1991, Luthje 1996, Mackay 1996, Nielsen 1989*).

Football, being a contact sport is characterised by short and quick movements such as sprinting, sudden acceleration and deceleration, cutting (sudden changes in direction), pivoting, shooting and kicking - all of which are contributory to the risk of injury (*Aranson 1996, Ekblom 1986*). As with all injuries, those in football are acute, recurrent or they arise from overuse, developing gradually from multiple minimal traumas (*Smodlaka 1979*).

Numerous studies state that football, like other contact sports, has an inherent risk of injury, both acute and overuse (*Surve 1994, Tucker 1997*). The age of the player, sex, whether they are amateur or professional, different playing surfaces, weather conditions, medical service and frequency of playing all affect the incidence and type of injury (*Luthje 1996*).

Studies that have included age as an aspect of the investigation into football injury have indicated that football carries a low risk of injury in the preadolescent and adolescent age groups. *Sullivan (1980)* found an injury rate of less than 1% in a group of players younger than 12 years. *McCarroll (1984)* reported on injury rates for football players aged 10 years and under at 1.9%, 12 years and under 3.1% and 14 years and under 5.3%. *McCarroll* also reported a 7.7% injury rate for high school players, increasing to 8.7% for players aged 19 years and under in a community league. *Maehlum (1984)* found that injuries peaked in the 20-24 year age group and then declined with increasing age.

The reasons for the increase in injury with age in football may be due to ball and body momentum, which can be expected to increase with age as the player becomes more skilled (*Keller 1987*).

Several epidemiological surveys have reported the incidence of football injuries (*Ekstrand 1983a, 1983c, Gazivoda 1986, Luthje 1996, Maehlum 1984, Nielsen 1989, Nilsson 1978, Sullivan 1980*), although as stated previously not all the studies are comparable due to the difference in the definition of the concept of injury.

A number of different ways have also been used to obtain the information (*Poulsen 1991*)

(a) Attendance at emergency departments (*Maehlum 1984, Smodlaka 1979, Stokes 1994, Tenvergert 1992*).
(b) Special sports injury clinics (*Nilsson 1978, Sullivan 1980*).
(c) Insurance claim reports (Pritchett 1981, *Roass 1979, Sandelin 1980)*.
(d) Questionnaires (*Weightman 1974*).

(e) Football leagues, clubs and teams (*Albert 1983, Bass 1967, Ekstrand 1983a, Luthje 1996, McGregor 1995, McMaster 1978, Nielsen 1989*).

Luthje (1996) found that the injury rate in the Finnish league for 1993 was 65%, which is comparable with a 72% injury rate reported by *Nielsen* and *Yde (1989)* and similar to the 69% rate reported by *Ekstrand* and *Gillquist (1983a)*. *Maehlum (1984)* reported that football injuries accounted for 28.4% of all sports injuries presenting to an emergency department, although this is a higher rate than previously quoted by *Ekstrand (1983a)* of football being responsible for 3.5% to 10% of all injuries treated in hospital, (originally from *Franke 1977*). Sports related injuries treated at the Department of Traumatology of the University Hospital of Groningen were assessed between 1982 and 1988 by *Tenvergert (1992)* and it was found that football accounted for approximately 36% of the total number of sports injuries treated each year. In an earlier study, reviewed by *Smodlaka (1979)*, from 19,233 sports injuries treated at the Traumatology Hospital in Zagreb from 1952 to 1969, 8,469 or 44% of injuries were found to be due to football.

A theme through many published studies is that the majority (60% to 95%) of injuries in football occur in the lower extremity (*Maehlum 1984, Poulsen 1991*). In an assessment relating to level of play, the lower extremity injuries were as follows;

64.7% - 68%	Youth	*Sullivan 1980 – Nilsson 1978, Schmidt-Olsen 1991.*
72.5% - 76%	Professional	*Albert 1983 – Luthje 1996.*
78% - 88%	Senior	*Ekstrand 1983a – Engstrom 1991.*

Of the lower extremity injuries, ankle sprains are found to be the most common (*Ekstrand 1983b, Engstrom 1991, Janda 1995, Lewin 1989, Maehlum 1984, Nielsen 1989, Nilsson 1978, Sullivan 1980*), accounting for 17% - 21% of all injuries (*Ekstrand 1990, Engstrom 1991*). Most of these relate to player factors, ¾ affecting ankles with a history of previous sprains and/or chronic instability (*Ekstrand 1983c*). However, in the study conducted by *Luthje (1996)*, thigh injuries at 22% were found to be the commonest lower extremity injury.

2.2.2 Prevention of Injury

The term 'prevention' is normally used in the context of sports injuries to refer to any measure that can stop an injury occurring. However, the process of prevention also plays an important role in arresting the exacerbation of a current injury and ensuring that the same injury does not re-occur (*Taimela 1990, Williams 1976*).

The aim of sports injury prevention is to reduce risk factors associated with the sport. Some strategies for reducing risk factors and preventing injury include : -

- Warm-up – Specific research into the benefits of warming-up in reducing the risk of injury is difficult due to the ethics associated with individuals exercising without warming-up; with the expectation that they are more likely to suffer from an injury. There is however, general agreement that an appropriate warm-up will greatly reduce the likelihood of injury. This is based upon the knowledge that cold muscles, tendons and ligaments are less elastic than warm ones and so are more likely to tear when stretched. Conversely, the additional elasticity of warmed-up tissues reduces the risk of both traumatic and overuse injuries (*Garrett 1996)*.
  General warm-ups involve the overall body temperature being raised by active exercise, increasing the temperature of the deep muscles and body core.
  Specific warm-up involves movements which are to be used in actual activity, but at a reduced intensity. Rehearsal of body movement takes place and the specific tissues directly involved in the activity are heated.
  The effects of warm-up are physiological, psychological and biomechanical. Physiological effects are largely due to increases in temperature, while psychological effects are mainly due to practice. Biomechanical effects are achieved by alterations in the tissue response to mechanical strain.

- Warm-down – On cessation of exercise it is important to reverse the process which occurred during warm-up as metabolic waste products formed during exercise will no longer be carried away from the work area with so much vigour. Instead, they will remain in the area causing pain. This is thought to be a possible cause of delayed onset muscle fatigue (*Byrnes 1985*). Flushing the area with fresh blood by performing a gentle warm-down can reduce this effect.

- Fitness – All components of fitness are required for injury prevention and it is important that training accurately reflects the physical demands of the sport. If individuals are not fit enough for their chosen sport, then the physical stresses that they experience during it may cause injury. A lack of strength, speed, flexibility or endurance can all contribute to towards injury.

- Training – The correct training and level of fitness will reduce the risk of injury by making the participants body more able to withstand the physical demands of the activity.

- Flexibility Training – Flexibility is the range of movement possible at a specific joint or series of articulations and the general absence of stiffness (*Reilly 1981*). For injury prevention, *Cureton (1941)* suggested that flexibility training may condition muscles, ligaments and fascia to greater tensile strength and elasticity, leading to injury prevention. *DeVries (1962)* argued that the maintenance of adequate joint mobility helps to prevent or relieve soft tissue pain. *Ekstrand (1982)* ascertained that muscle tightness may predispose athletes to certain injuries and suggested that the type of training programmes undertaken can affect the number of injuries suffered.

- Psychological Factors – Athletes or a certain psychological type may be more pre-disposed to injury and therefore total player management is necessary to be aware of outside influences that may affect performance.

- Recovery between Exercise Sessions – Sport and physical activity in general, places physical stress upon the body. If given adequate time to recover, these stresses will act as a stimulus and cause the body to adapt to the stresses in a positive manner; making it fitter. However, if adequate recovery time is not allowed between training sessions or matches then the body is unable to fully recover. This can result in minor damage to tissues not being fully repaired and as a consequence will be further damaged during subsequent exercise sessions; a cause of overuse injuries.

- Footwear – The footwear worn for sports must be comfortable, provide adequate traction, cushion the impact of the foot striking the ground and be designed for specific movements such as fast changes in direction. The footwear should provide specific support and include features which reduce the risk of injury pertinent to both the sport and the athlete.

- Clothing and Equipment – Protective clothing and safety equipment is used to reduce the risk of injury, such as shin guards, mouth guards and padding.

The high incidence of ankle injuries in some sports has led to the design of various ankle orthotic supports used for prophylactic purposes (*Feuerbach 1994*). The ideal ankle support device provides mechanical stability and proprioceptive feedback without limiting the normal range or function of the ankle. *Garrick (1977)* noted that the use of either high-top athletic shoes or prophylactic ankle taping decreased the frequency of sprains, most notably in those individuals with a history of prior sprain.

CHAPTER THREE

CHAPTER 3: INJURY DATABASE

This chapter aims to provide a background into the incidence of injury in football. The intent is to discuss relevant information from the literature and form a foundation on which to build the strategies for investigating the prophylactic use of taping and proprioceptive training in the prevention of ankle injury.

3.1 INTRODUCTION

It is becoming increasingly important to document the injuries and the treatment of professional footballers as it not only provides a profile on each player, but it also gives the club an indication of its strengths and weaknesses (*McGregor 1995*). A further benefit to detailing fitness and physiological levels of individual players is to provide a guide of pre-injury levels that can be used for rehabilitative purposes. It is difficult to prove that the number of games played increases the chance of injury for all players although this is widely accepted, as most professional footballers began football when very young, sometimes playing frequent and very competitive games as schoolboys. Therefore, it is difficult to know how much damage has been sustained prior to becoming professional and so acknowledge the underlying risk that may be involved for each player. It is also the case that some players with minor injuries keep playing for long periods before sustaining a significant serious problem, adding to the risk of injury incidence and to the severity of the injury sustained.

Although the incidence of football injuries has previously been evaluated and epidemiological surveys from several countries have outlined the types of injury involved in football (*Albert 1983, Ekstrand 1982, Luthje 1996, McMaster 1978*), due to the variation in definition of injury and the different types of populations involved, corroboration of this information was required to provide evidence as to the validity of carrying out further studies on the use of taping and proprioceptive training.

3.2 INJURY DATABASE LITERATURE REVIEW

This is a literature review of published data concerning football injuries at clubs and tournaments. It covers youth, senior, amateur and professional players. The majority of studies are European, with the remainder from America and the United Kingdom.

3.2.1 Incidence of injury

Analysis of injury incidence is a common factor in investigations into injury in football, though the incidence and risk of injury is reported in a variety of ways. Predominately studies describe incidence of injury per 1000 hours of play or exposure, with the exception of *Albert (1983)*, who defined incidence as the number of injuries divided by the number of involvement's by a single player in a complete training session or game. This gives an exposure rate of 0.0085 or 18 injuries/2114 exposures; a relatively incomparable value as the length of exposures is not stated. *Bass (1967)* gave incidence as risk hours; 136 players being at risk in a total of 1,236 competitive fixtures and since 11 players are involved in each match of one-and-a-half hours duration, a total of 20,394 player-risk-hours is produced, as 'virtually all injuries occurred in the competitive fixtures' (*Bass 1967*). The error seen in this and accounted for in the majority of following investigations, is the number of hours for which the player trains for and, therefore, is 'at risk'.

Lewin (1989), McMaster (1978) and *Poulsen (1991)* (*Table n^o 3.1*) all described their injury incidences as percentage game or training injuries, all showing a comparable majority percentage of injuries occurring during the more aggressive and competitive situations of matches.

Table n^o 3.1 Studies Describing Distribution of Injury as a Percentage of Match and Training.

PERCENTAGE OF INJURIES INCURRED IN TRAINING	PERCENTAGE OF INJURIES INCURRED IN A MATCH	STUDY	LEVEL	COUNTRY
34.4%	65.6%	LEWIN 1989	PROFESSIONAL	ENGLAND
42%	58%	McMASTER 1978	PROFESSIONAL	AMERICA
37%	63%	POULSEN 1991	SENIOR	DENMARK

In those studies that describe injury incidence per 1000 hours (*Table n° 3.2*), it can be seen in all cases that the incidence of injury is higher in the game situation than during training, although incidence and difference between the two situations varies from study to study.

Luthje (1996) found an injury rate of 1.8/1000 hours in training and 11.3/1000 hours in matches, a ratio of 6.2:1 injuries/1000 hours, compared to *Ekstrand (1983b)* who found 7.6/1000 hours in training and 16.9/1000 hours in matches, a ratio of 2.2:1 injuries/1000 hours.

Table n° 3.2 Studies Describing Distribution of Injury Per 1000 Hours of Play.

TRAINING	MATCH	STUDY	LEVEL	COUNTRY
5.9 +/- 1.1 /1000 hours	34.8 +/- 5.7/ 1000 hours	ARANSON 1996	ELITE	ICELAND
12.4 +/- 1.4 /1000 hours		ARANSON 1996	ELITE	ICELAND
7.6 +/- 2.1 /1000 hours	16.9 +/- 7.3 /1000 hours	EKSTRAND 1983a,b	SENIOR	SWEDEN
5/1000 hours	13/1000 hours	ENGSTROM 1990	ELITE (MALE)	SWEDEN
7/1000 hours	24/1000 hours	ENGSTROM 1991	ELITE (FEMALE)	SWEDEN
17.5/1000 hours		INKLAAR 1996	AMATEUR	HOLLAND
2.38/1000 hours		KIBLER 1993	TOURNAMENT – YOUTH	AMERICA
2.3/1000 hours (injured) 1.8/1000 hours (all)	14.2/1000 hours (injured) 11.3/1000 hours (all)	LUTHJE 1996	ELITE	FINLAND
3.6/1000 hours	14.3/1000 hours	NIELSEN 1989	SENIOR/YOUTH	DENMARK
14/1000 hours (boys) 32/1000 hours (girls)		NILSSON 1978	TOURNAMENT – YOUTH	NORWAY
3.7/1000 hours		SCHMIDT-OLSEN 1991	YOUTH	DENMARK
0.51/1000 hours (boys) 1.1/1000 hours (girls)		SULLIVAN 1980	YOUTH	AMERICA
3.65/1000 hours		WEIGHTMAN 1974	AMATEUR / PROFESSIONAL	ENGLAND

Differences between studies can be attributed to the difference in definition of injury and also to the season itself, which is shorter in both Finland and Iceland than in Western Europe, therefore allowing only a short time for rest and recuperation between games. *Aranson (1996)* in an Icelandic study found a high difference of incidence in injury between match and training 5/1000 hours and a high incidence in injury during matches 34.8/1000 hours. However, the incidence of injury per 1000 training hours is similar to the other studies (*Ekstrand 1983b, Engstrom 1990, Engstrom 1991, Nielsen 1989*).

Of those studies that gave incidence as a combined rate or were from a tournament, there is also a difference due to definition of injury; ranging from 0.51/1000 hours (boys) in a study of youth teams by *Sullivan (1980)* to 32/1000 hours (girls) in a study conducted at a tournament *Nilsson (1978)*. What is apparent from these studies is that female players are at a greater risk of injury, both at the youth and elite level (*Engstrom 1990, Engstrom 1991, Nilsson 1978, Sullivan 1980*).

Of all players taking part in each of the studies, on average 70% of those participating were injured (*Aranson 1996, Ekstrand 1983a, 1983b, Engstrom 1990, 1991, Inklaar 1996, Lewin 1989, Luthje 1996, McGregor 1995, Nielsen 1989, Schmidt-Olsen 1991*). For professional players this ranged from 65% of players injured over the course of a season (*Luthje 1996*) to 96% (*McGregor 1995*).

3.2.2 Type and location of injury

Injuries to the lower extremity account for the majority of injuries 64.7% - 95% (*Poulsen 1991, Sullivan 1980*), the ankle and the knee joint vying for the position of most frequently injured. On average 24.46% of injuries are to the ankle and 20.06% to the knee (*Table n°3.3*). Interestingly, in some of the more recent studies, the thigh has become more frequently injured; from 8% of injuries (*Engstrom 1990*) to 22% of injuries (*Luthje 1996, McGregor 1995*), an average of 17% of all injuries (*Table n°3.3*).

Sprains and strains are the commonest type of injury, on average 33% are sprains and 25% strains (*Table n° 3.4*) and therefore, approximately 50% of all types of injury seen in football (*Ekstrand 1983a, 1983b, Inklaar 1996, Kibler 1993*). Ankle sprains account for 42% - 93% of the sprains (*Ekstrand 1983a, 1983b,* *Poulsen 1991*) and so are seen as prevalent, representing on average 18% of injuries (*Table n° 3.5*).

Table n° 3.3 Percentage of Injuries to Joints of the Lower Extremity.

ANKLE	KNEE	THIGH	STUDY
24.6	17.6	11.3	ALBERT 1983
18.9	12.4	-	BASS 1967
17	20	14	EKSTRAND 1983a,b
22	33	8	ENGSTROM 1990
26	23	15	ENGSTROM 1991
23	22	-	INKLAAR 1996
13	15.8	21	KIBLER 1993
22.7	12.1	-	LEWIN 1989
17	19	22	LUTHJE 1996
13	23	22	McGREGOR 1995
36	18	22	NIELSEN 1989
24	21	18	NILSSON 1978
40	20	17.5	POULSEN 1991
23.1	26	-	SCHMIDT-OLSEN 1991
63.6	18	-	SULLIVAN 1980
24.46	**20.06**	**17.08**	**TOTAL**

Table n° 3.4 Percentage of Sprains and Strains in Football.

<table>
<tr><th>SPRAIN</th><th>STRAIN</th><th>STUDY</th></tr>
<tr><td>22</td><td>34</td><td>ALBERT 1983</td></tr>
<tr><td></td><td>29</td><td>ARANSON 1996</td></tr>
<tr><td>29</td><td>18</td><td>EKSTRAND 1983a,b</td></tr>
<tr><td>34</td><td></td><td>ENGSTROM 1990</td></tr>
<tr><td>34</td><td></td><td>ENGSTROM 1991</td></tr>
<tr><td>31</td><td>19</td><td>INKLAAR 1996</td></tr>
<tr><td>21.8</td><td>24.5</td><td>KIBLER 1993</td></tr>
<tr><td>48</td><td>21</td><td>NIELSEN 1989</td></tr>
<tr><td colspan="2">20</td><td>NILSSON 1978</td></tr>
<tr><td>42</td><td>30</td><td>SCHMIDT-OLSEN 1991</td></tr>
<tr><td>35</td><td></td><td>SULLIVAN 1980</td></tr>
<tr><td colspan="2">33</td><td>WEIGHTMAN 1974</td></tr>
<tr><td>33</td><td>25</td><td>AVERAGE : 49%</td></tr>
</table>

A sprain is an injury to a ligament caused by sudden over-stretching. As the ligament is not severed, it gradually heals, but this may take several months dependent upon the severity. A strain is an excessive stretching or working of a muscle, resulting in pain and swelling of the muscles.

Table n° 3.5 Percentage of Ankle Sprains Found in the Literature.

PERCENTAGE OF SPRAINS	PERCENTAGE OF INJURIES	STUDY
	13	ARANSON 1996
93	17.11	EKSTRAND 1983a,b
	19	ENGSTROM 1991
	23.76	NIELSEN 1989
42	17.64	POULSEN 1991
	18.1	**TOTAL**

In the more recent literature, it has become increasingly more common to attribute injuries incurred to category and severity (*Table n° 3.6, Table n° 3.7*). It is evident that acute or traumatic injuries are responsible for 70% of injuries and gradual or overuse injuries the remaining 30% of injuries (*Table n°3.6*). Differences in the percentage of overuse injuries in the literature is due to the inclusion of overuse injuries during the 'off season' (*Ekstrand 1983b, Engstrom 1990*). Overuse injuries sustained in 'off season' are felt to have a negative impact on the player's capability to achieve fitness by the start of the season (*Smodlaka 1979*). The higher proportion of acute injuries is due to the fact that the majority of injuries occur during match situations, where more body to body contact occurs and a more competitive approach is appropriate. Despite this fact, of those injuries sustained, the majority are only minor or moderate (*Table n° 3.7*) and so the player is absent from training and/or matches for less than one month (*Engstrom 1990*).

Table n° 3.6 Percentage Distribution of Acute and Overuse Injuries in Football.

ACUTE	OVERUSE	STUDY
91	9	ARANSON 1996
69	31	EKSTRAND 1983
35	65	ENGSTROM 1990
72	28	ENGSTROM 1991
65	35	INKLAAR 1996
94	6	LUTHJE 1996
65	35	POULSEN 1991
70	**30**	**TOTAL**

Table nº 3.7 Distribution of Football Injury by Severity.

MINOR (%)	MODERATE (%)	MAJOR (%)	STUDY
27	39	34	ENGSTROM 1990
49	36	15	ENGSTROM 1991
48	36	16	LUTHJE 1996
28	54	18	POULSEN 1991
38	**41.25**	**20.75**	**TOTAL**

3.2.3 Causal Factors

Nearly half of injuries incurred are due to contact, either with another player or the field (*Aranson 1996, Ekstrand 1983a, Kibler 1993*). Most contact injuries are caused by tackling or kicking (*Ekstrand 1983a, 1983b, Mackay 1996*), giving rise to knee and ankle sprains from tackling (*Aranson 1996, Nielsen 1989*) and muscle strains from kicking (*Aranson 1996*).

In those studies that analysed the distribution of injuries through player positions, no significance was found, assuming team formations of 1:4:4:2 (*Engstrom 1990, 1991, Luthje 1996*) or 1:4:3:3 (*Ekstrand 1983a*). However, although *McMaster (1978)* found injuries spread across all playing positions, it was stated that 'midfielders and forwards were most prone to injury'. *Sullivan (1980)* also found an exception to this theory, as in this study, goalkeepers accounted for 17.6% of injuries, while representing only 6% of the population at risk.

Peaks of incidence are found in the literature at match intensive periods (*Lewin 1989, Luthje 1996*) and at the beginning of the competitive season (*Ekstrand 1983a, 1983b, Engstrom 1990, 1991, Lewin 1989, Luthje 1996, Nielsen 1989*).

In the majority of studies, extrinsic factors such as weather, temperature and playing surface did not influence the injury rate, with 72% of injuries occurring at >10°C and 80% occurring on good grass surfaces (*Engstrom 1990, 1991*).

The information obtained from the literature was used to form a Questionnaire (*Appendix nº A1*) for the injury database study, in order to attain and confirm data about incidence, type and location of injury. This was then used to form a basis of evidence to contribute to the further studies on the effects of taping and proprioceptive training of the ankle.

CHAPTER FOUR

CHAPTER 4: THE ANKLE AND ATHLETIC PERFORMANCE

This chapter looks at the anatomy of the ankle joint, its ligaments and describes the ankle sprain. It then investigates the use of ankle taping as a prophylactic measure to prevent ankle sprains and the possible proprioceptive effect that this may have, along with a review of studies investigating the effect of taping on athletic performance.

4.1 THE ANKLE JOINT

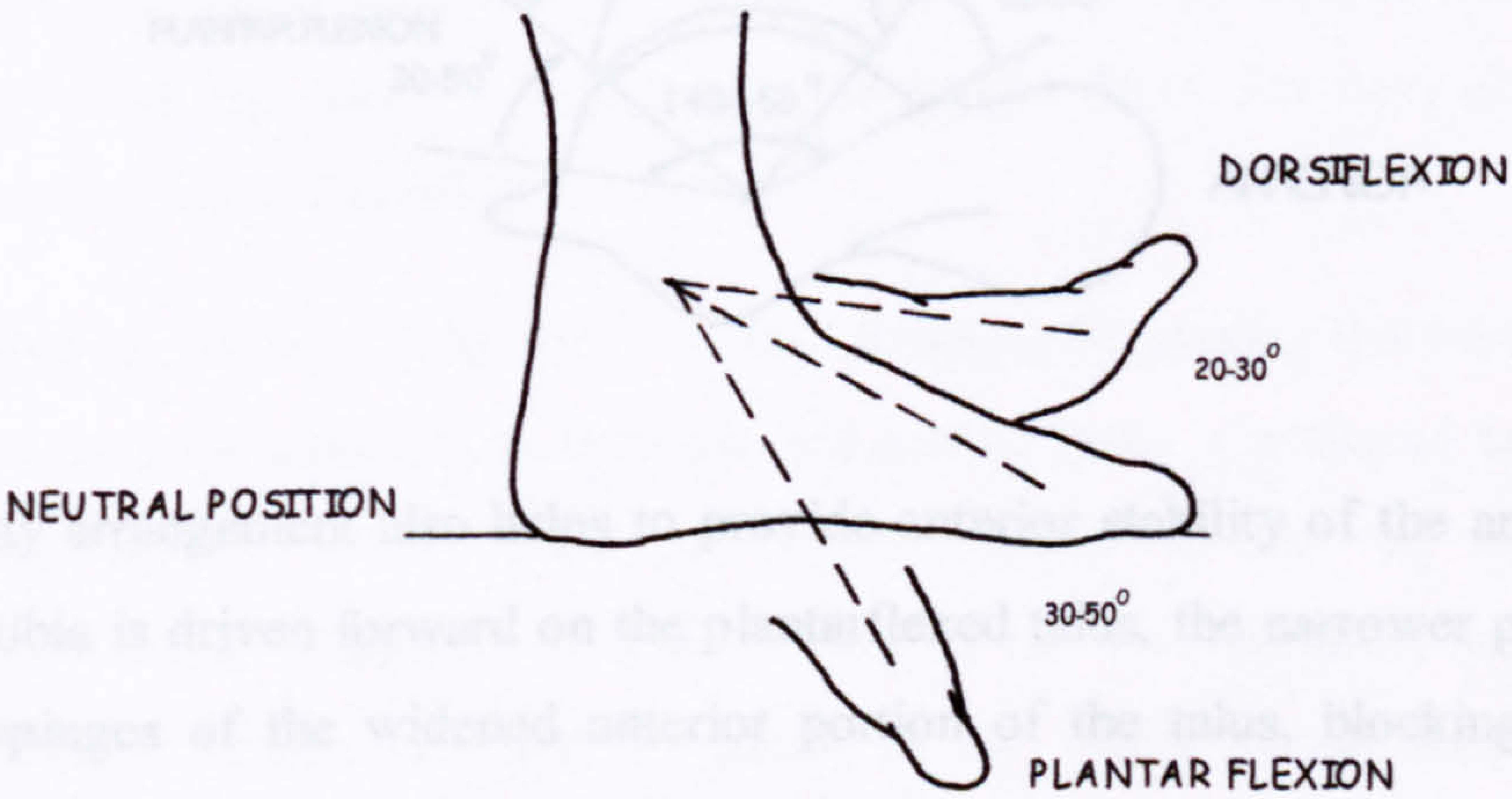
The ankle or talocrural joint consists of the articulations between the distal tibia, trochlea of the talus and distal fibula, forming the corresponding tibiotalar, fibulotalar and distal tibiofibular joints (*Donatelli 1996, Hunt 1988*).

The medial and lateral malleoli project downward to articulate with the sides of the trochlea. The lateral malleolus projects down to the level of the subtalar joint further than the medial malleolus and this provides greater bony stability for the lateral side of the ankle joint (*Mack 1982*).

The tibiotalar joint contains both the articulations between the large convex surface of the trochlea and the concave, distal tibia and that between the proximal facet on the medial surface of the body of the talus and the inner aspect of the medial malleolus (*Hunt 1988*). The superior surface of the talus bone is wedge shaped and influences the stability and orientation of the ankle joint axis during dorsiflexion and plantarflexion (*Hunt 1988*). The fibulotalar joint consists of the articulation between the large facet on the lateral surface of the talus and the inner aspect of the lateral malleolus. The distal tibiofibular joint is composed of the convex articulating surface of the inner aspect of the distal fibula with the corresponding concave surface along the inner aspect of the distal tibia (*Gray 1991, Inman 1976*).

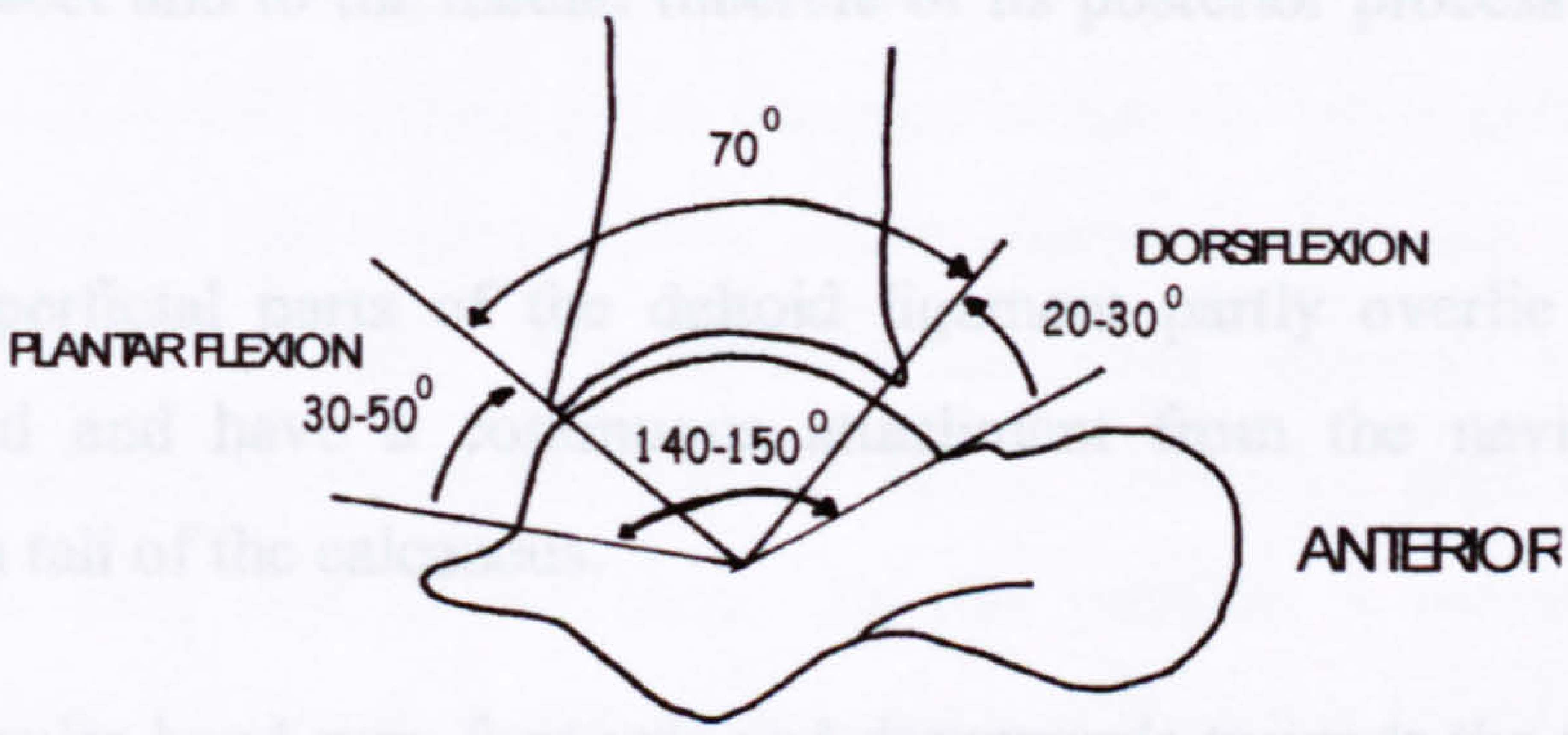
The ankle joint is a synovial hinge joint with defined rotational motion of dorsiflexion/plantarflexion (*Hunt 1988, Palastanga 1992*) occurring in the sagittal plane through a maximum range approaching 90^0 (*Figure n° 41*). In the normal standing position, the foot makes a right angle with the leg – the neutral position of the joint.

Figure n^o 41 Movement of the Foot in Plantar Flexion and Dorsiflexion



The anatomical position of the axis of the ankle joint is horizontal, but set obliquely to the frontal plane by 20^0 – 25^0, so that as the axis passes laterally through the joint; it also runs posteriorly. This obliquity is due to the outward rotation of the lower end of the tibia. This means that in dorsiflexion the foot moves upwards and medially over a range of 30^0 and the wider anterior portion of the talus is brought into contact with the narrower position between the malleoli. This means that the talus becomes gripped more tightly (*Mack 1982*), giving a 'wedge' effect. In plantarflexion the foot moves downwards and laterally, a range of 50^0 and the narrower posterior portion of the talus is brought into contact with the wider anterior portion of the tibia, which permits a small amount of free-play in the ankle joint as the 'wedge' effect in dorsiflexion is lost (*Mack 1982*), (*Figure n^o 42*). There is however, an individual variation in the extent of these movements (*Palastanga 1992*).

Figure n° 42 Range of Movement at the Ankle Joint



The bony arrangement also helps to provide anterior stability of the ankle joint. As the tibia is driven forward on the plantarflexed talus, the narrower part of the tibia impinges of the widened anterior portion of the talus, blocking forward dislocation of the tibia on the talus (*Mack 1982*).

4.1.1 Ankle Ligaments

Associated with the ankle joint is a set of strong collateral ligaments, 'designed' to resist the large forces that weight-bearing and locomotion impose upon them (*Reid 1992*). Medially is the deltoid ligament, while laterally there are three separate ligaments. Both sets of ligaments radiate downwards from the malleoli and both have a middle band attached to the calcaneus and anterior and posterior bands attached to the talus (*Palastanga 1992*).

4.1.1.1 Deltoid Ligament

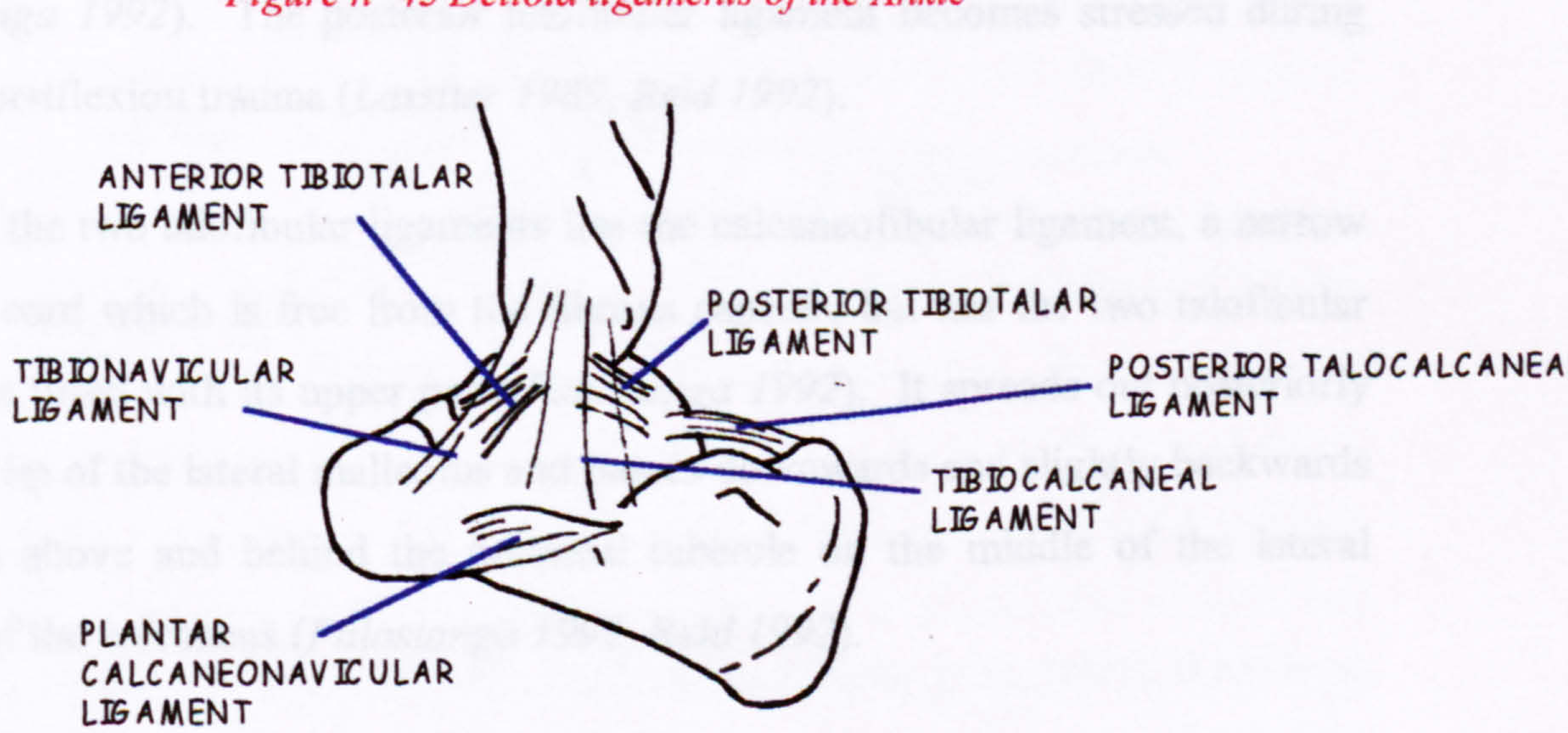
The deltoid ligament (*Figure n° 43*) resists lateral displacement of the talus (*Mack 1982*). It is roughly triangular and composed of several bands of fibres fused together, the various bands being differentiated by their distal attachments. It has deep and superficial parts, attaching at the tip of the medial malleolus at its apex, whilst the base forms a continuous attachment anteriorly from the navicular to the body of the talus posteriorly (*Basmajian 1982, Palastanga 1992*).

The deeper parts of the ligament are the anterior and posterior tibiotalar bands. The anterior tibiotalar band is the most anterior and runs obliquely forwards and downwards to attach to the medial part of the neck of the talus. The posterior tibiotalar band is the most posterior and thickest part of the deltoid ligament. Its fibres run laterally and backwards to the medial side of the talus under the tail of the articular facet and to the medial tubercle of its posterior process (*Palastanga 1992*).

The more superficial parts of the deltoid ligament partly overlie the anterior tibiotalar band and have a continuous attachment from the navicular to the sustentaculum tali of the calcaneus.

The tibionavicular band runs forwards and downwards towards the tuberosity on the navicular bone attaching to its upper and medial parts. Continued backwards, this band blends below with the upper medial border of the planar calcalneonavicular ligament. It is succeeded by the tibiocalcaneal band whose fibres descend almost vertically to attach to the whole of the length of the sustentaculum tali (*Palastanga 1992*).

Figure n° 43 Deltoid ligaments of the Ankle



4.1.1.2 Lateral Ligaments

The lateral collateral ligament is composed of three separate parts, the anterior and posterior talofibular ligaments and the calcaneofibular ligament (*Figure n° 44*).

The anterior talofibular ligament is the weakest and most often injured (*Lassiter 1989*). It originates at the tip of the lateral malleolus and stretches to the neck of the talus with its fibres running anteromedially (*Palastanga 1992, Reid 1992*). It is almost horizontal and relaxed in the neutral position and thus resists anterior shear. During plantarflexion the ankle becomes relatively less stable because the posterior portion of the talar trochlea, being narrower than the anterior part, occupies the ankle mortise. The anterior talofibular ligament also becomes tightened in plantarflexion and orientated almost vertically, thus being almost parallel to the long axis of the tibia. In this position it provides maximal protection against pathologic inversion movement in the ankle joint (*Reid 1992*).

The posterior talofibular ligament is a strong, thick ligament running almost horizontally (*Basmajian 1982, Lassiter 1989, Palastanga 1992*). It arises from the bottom of the malleolar fossa of the lateral malleolus and passes posteriomedially to the lateral tubercle of the posterior process of the talus. Above it lies the posterior tibiofibular ligament. In plantarflexion these two ligaments lie edge-to-edge, while in dorsiflexion they diverge medially (*Palastanga 1992*). The posterior talofibular ligament becomes stressed during forced dorsiflexion trauma (*Lassiter 1989, Reid 1992*).

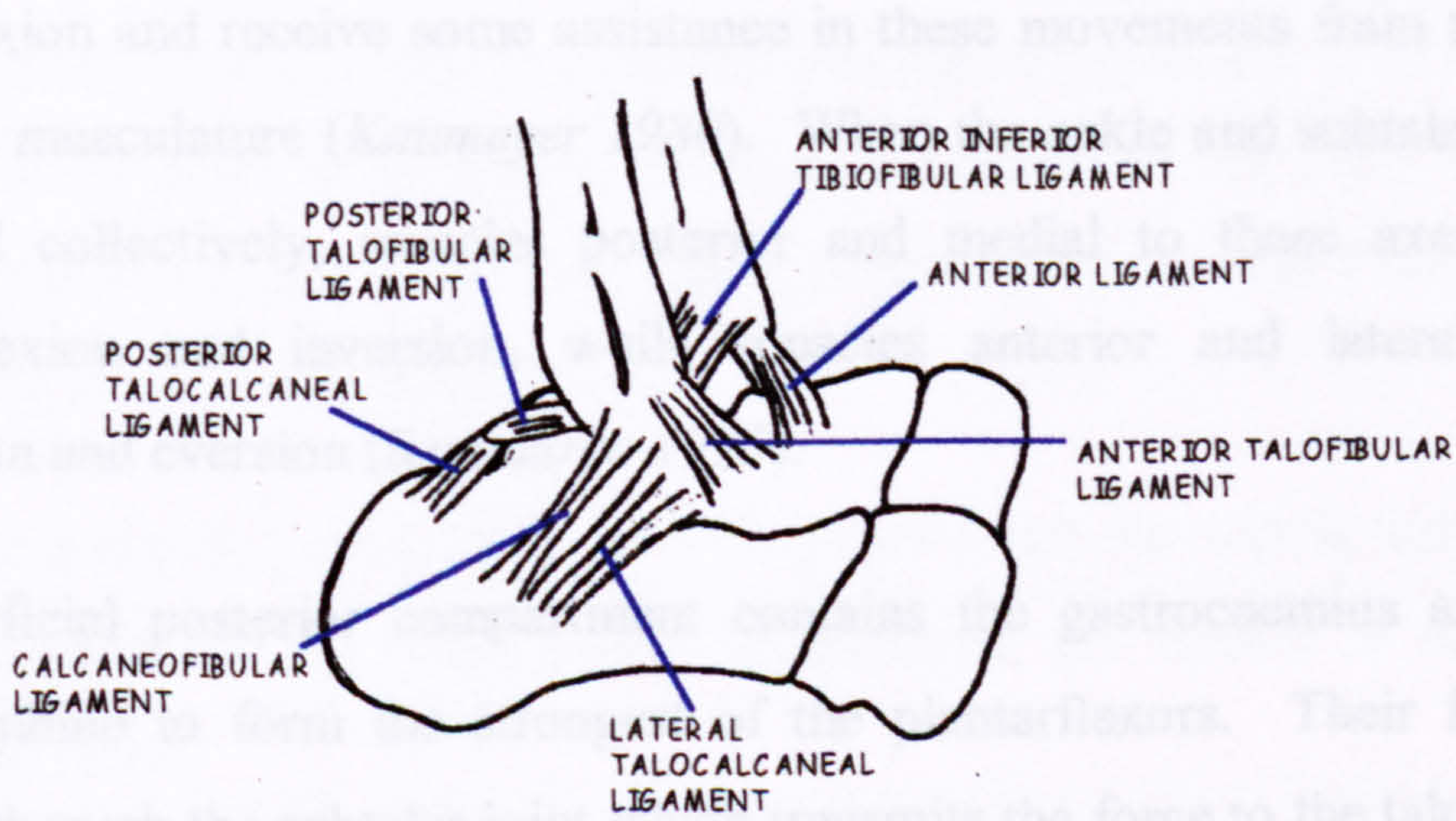
Between the two talofibular ligaments lies the calcaneofibular ligament, a narrow rounded cord which is free from the fibrous capsule, but has the two talofibular ligaments fused with its upper part (*Palastanga 1992*). It spreads out posteriorly from the tip of the lateral malleolus and passes downwards and slightly backwards to attach above and behind the peroneal tubercle on the middle of the lateral surface of the calcaneus (*Palastanga 1992, Reid 1992*).

The calcaneofibular ligament is slightly tensed in the neutral position and only moderately resists a pathologic inversion movement of the ankle. During plantarflexion, the ligament is orientated almost completely horizontally, stabilising the subtalar joint (*Reid 1992*).

The anterior and posterior ligaments of the ankle joint are localised thickenings of the joint capsule. The anterior ligament runs obliquely from the anterior margin of the lower end of the tibia to the upper surface of the anterior part of the neck of the talus. The posterior ligament has fibres arising from both the tibia and fibula, which converge to attach to the medial tubercle of the posterior surface of the talus (*Palastanga 1992*).

The tibiocalcaneal and tibionavicular bands control abduction of the talus, while adduction is controlled by the calcaneofibular ligament. The anterior tibiotalar band and the anterior talofibular ligament control plantarflexion, while the posterior tibiotalar band and the posterior talofibular ligament restrict dorsiflexion (*Palastanga 1992*). In combination, both the anterior and tibionavicular bands control external rotation and, together with the anterior talofibular ligament, internal rotation of the talus. The anterior talofibular ligament also provides significant resistance to varus tilt of the talus in all positions of flexion (*Palastanga 1992*).

Figure n° 44 Lateral Ligaments of the Ankle



The functional unit of the ankle also includes the subtalar joint, which is made up from the talus and calcaneus bones and is responsible for the conversion of the rotatory forces of the lower extremity (*Donatelli 1996*). Both the calcaneofibular and the talocalcaneal ligaments cross this joint (*Kaumeyer 1980*) and the key motions of inversion and eversion take place here (*Reid 1992*). There are three major ligaments of the subtalar joint in addition to the medial and lateral talocalcaneal ligaments; the anterior ligament of the posterior facet in the sinus tarsi, the interosseous talocalcaneal ligament, and the cervical ligament, which covers the lateral aspect of the sinus tarsi. The interosseous talocalcaneal ligament within the sinus tarsi prevents excessive eversion of the foot (*Sammarco 1995*). The ankle and the subtalar joints work together to translate the rotations in the foot about a sagittal plane (*Reid 1992*).

With physiologic loading, the mortise formed by the articular surfaces accounts for 30% of the stability in rotation and 100% during inversion and eversion (*Stormont 1985*). This fact means that the ankle may be unstable during the process of loading or unloading, but is usually stable once fully loaded (*Reid 1992*).

4.1.2 Musculature of the Ankle Joint and Lower Leg

The musculature that traverses the ankle supports the ligamentous structures in maintaining the stability of the ankle and subtalar joints.

The anterior and posterior muscle groups provide the strength for dorsiflexion and plantar flexion and receive some assistance in these movements from the medial and lateral musculature (*Kaumeyer 1980*). When the ankle and subtalar axes are considered collectively, muscles posterior and medial to these axes produce plantar flexion and inversion, while muscles anterior and lateral produce dorsiflexion and eversion (*Sammarco 1995*).

The superficial posterior compartment contains the gastrocnemius and soleus, which combine to form the strongest of the plantarflexors. Their function is mediated through the subtalar joint which transmits the force to the talus and foot (*Sammarco 1995*). The deep posterior compartment contains the tibialis posterior, which inverts and adducts the foot and flexes the ankle (*Sammarco 1995*). The lateral compartment contains the peroneal muscles, the strength of which is most important in the absorption of stress and so provides support to the lateral ligaments (*Kaumeyer 1980*). The anterior compartment contains the tibialis anterior, the major dorsiflexor of the ankle (*Sammarco 1980*).

The muscles involved in the research are the principal superficial muscles, functioning to maintain balance and postural control of the body during standing (*Figure n° 45*).

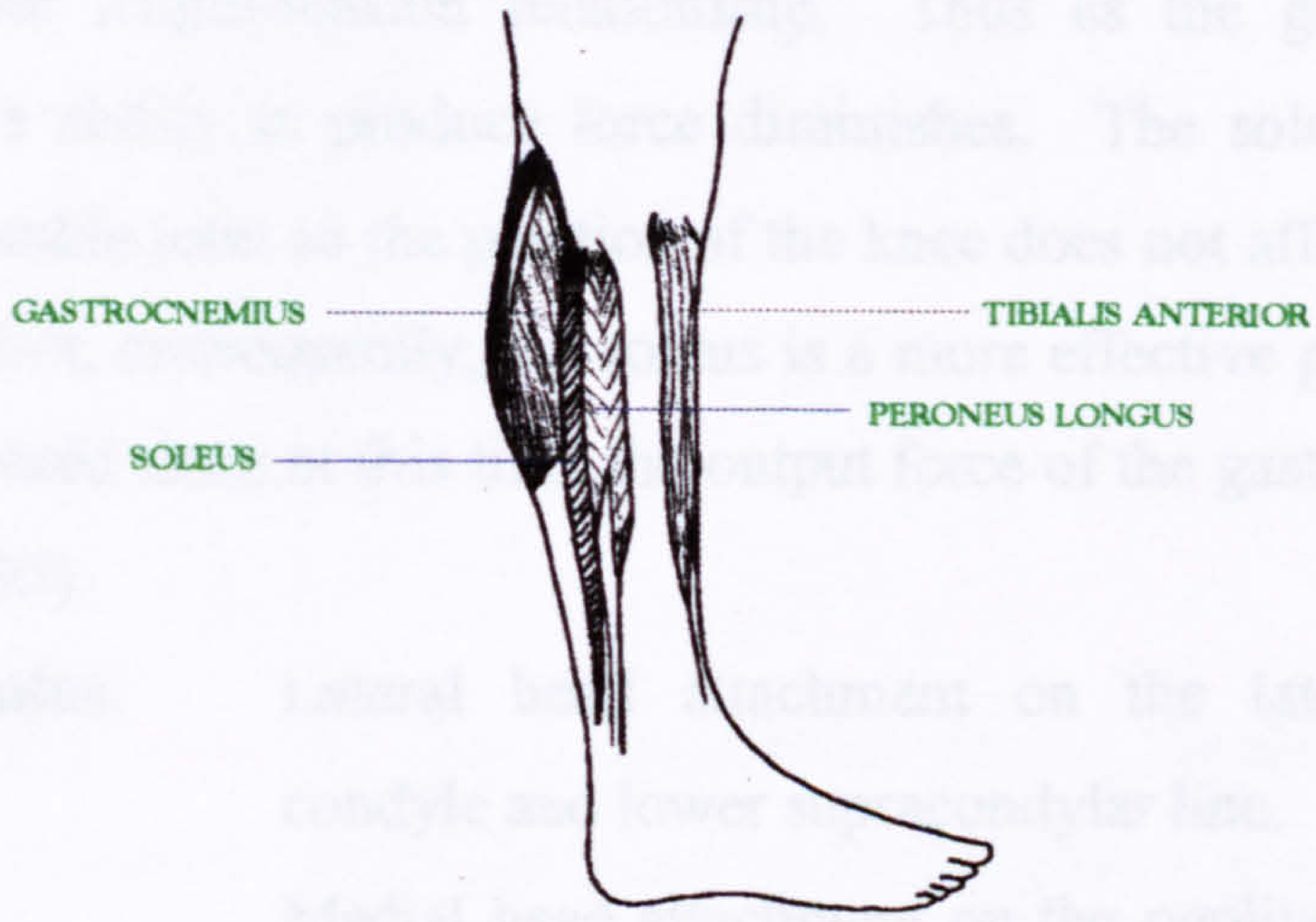


Figure n° 45 Muscles of the Lower Leg Studied by Electromyography

The special feature of muscle tissue is its ability to actively contract. The function of skeletal muscle is to a) shorten to produce movement of the body at joints (concentric movement) and b) to resist active stretching by external forces acting on it (eccentric movement) (*Marieb 1992*).

Skeletal muscle is only active when nerve impulses reach the muscle through the nerve supplying it. If the nerve supply is damaged, the muscle is unable to function (*Low 1996*).

The structure of the whole muscle is the combination of muscle and connective tissues, which both contribute to the function of the muscle when it is active. In a whole muscle, groups of contractile muscle fibres of varying diameter are bound together by fibrous connective tissue to form fasciculi. Further coverings of connective tissue bind the fasciculi together and an outer layer surrounds the whole muscle.

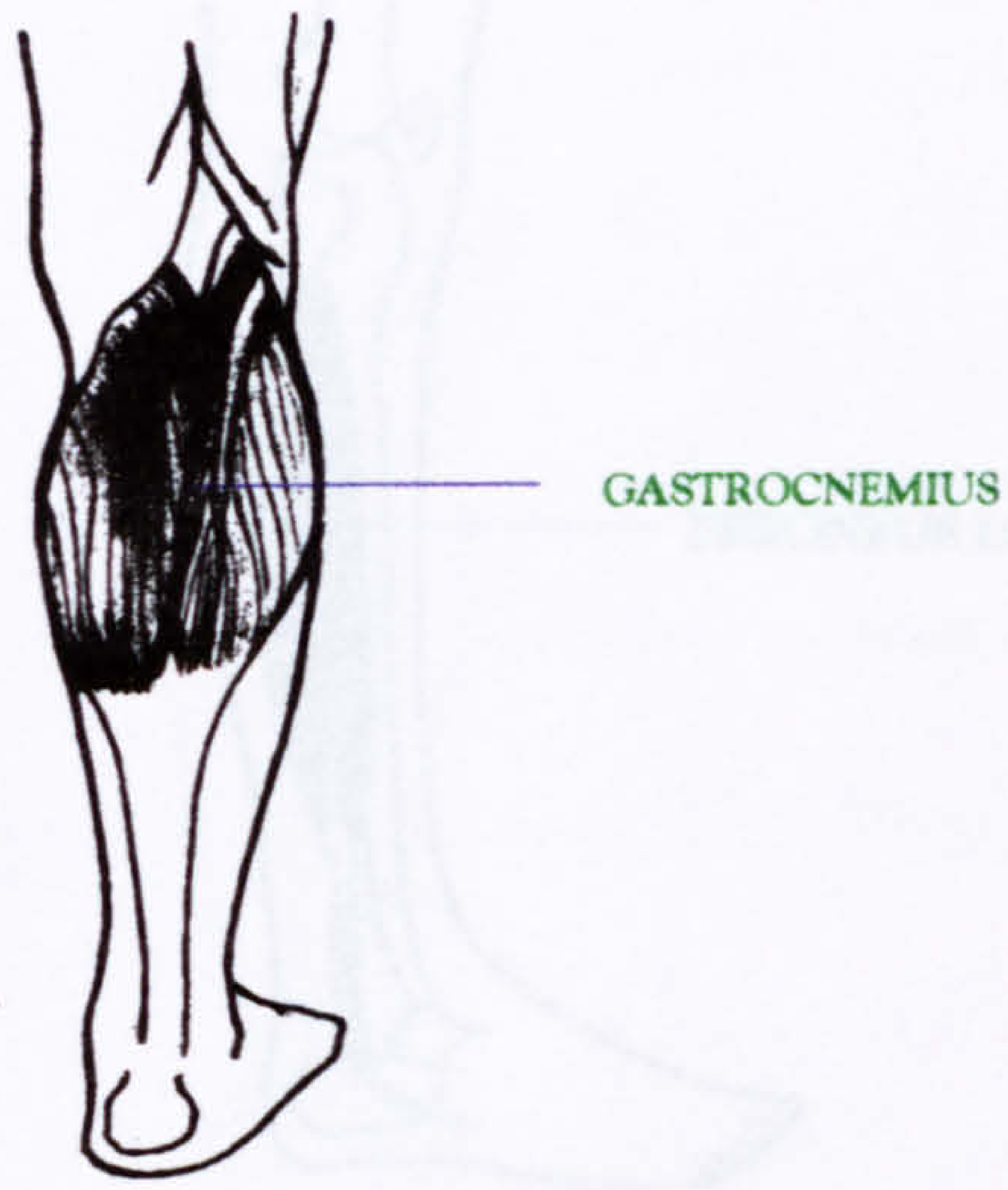
The portion of the lower extremity between the knee and the ankle joint is the site of origin for the muscles causing ankle motion and maintenance of stability of the ankle and subtalar joints.

The gastrocnemius (*Figure n° 46*) and soleus (*Figure n° 45*) muscles combine to form the triceps surae. Their function is mediated through the subtalar joint. They are the primary plantarflexors of the foot. Since the gastrocnemius also crosses the knee joint, it is more effective as a plantar flexor when the knee is extended due to the length-tension relationship. Thus as the gastrocnemius muscle shortens, its ability to produce force diminishes. The soleus however, only crosses at the ankle joint so the position of the knee does not affect its ability to plantar flex the foot, consequently, the soleus is a more effective plantar flexor when the knee is flexed since at this time the output force of the gastrocnemius is less (*Sammarco 1995*).

Gastrocnemius:	Lateral head attachment on the lateral femoral condyle and lower supracondylar line.
	Medial head attachment on the popliteal surface of the femur, above the medial condyle.
	Common tendon insertion with Soleus and Plantaris muscles into the Achilles tendon.
Function:	Plantarflexes the ankle joint.
	Assists flexion of the knee.
Soleus:	Attachments to the superior part of the posterior fibula.
	Soleual line on the tibia and deep fascia linking the fibula.
	Common tendon insertion into the achilles tendon.
Function:	Plantarflexes the ankle joint.
	Postural role in standing (*Bloomfield 1994*).

The soleus is placed to prevent the body falling forwards at the ankle joint during standing (*Palastanga 1992*).

Figure n° 46 Gastrocnemius Muscle



The peroneus longus (*Figure n° 47*) is a long slender muscle, the more superficial of the two peroneal muscles. Since the peroneus longus passes under the apex of the medial longitudinal arch, it functions as a sling to help support the arch. By its plantar insertion on the first metatarsal and medial cuneiform, it accentuates the curvature of the arch by flexing the first metatarsal on the medial cuneiform and the medial cuneiform on the navicular. This muscle also runs obliquely across the transverse arch to the medial border of the foot. Consequently, the transverse arch, which bridges between the two longitudinal arches, is supported. The peroneus longus plays a supportive role in actively tightening the lateral arch. Its primary functions are plantarflexion, abduction and eversion of the foot (*Sammarco 1995*).

Peroneus Longus:	Attachment on the upper part of the lateral fibula.
	Base of the fifth metatarsal and medial cuneiform via a groove for the tendon on the inferior surface of the cuboid.
Function:	Eversion of the foot (*Bloomfield 1994*).

In standing, the peroneus longus along with other surrounding muscles helps maintain the erect position. It controls sideways sway by pressing the medial side of the foot on the ground. This function is better seen when standing on one leg, when the peroneus longus works very hard to maintain the leg over the foot and prevent the body from falling to the opposite side (*Marieb 1992*).

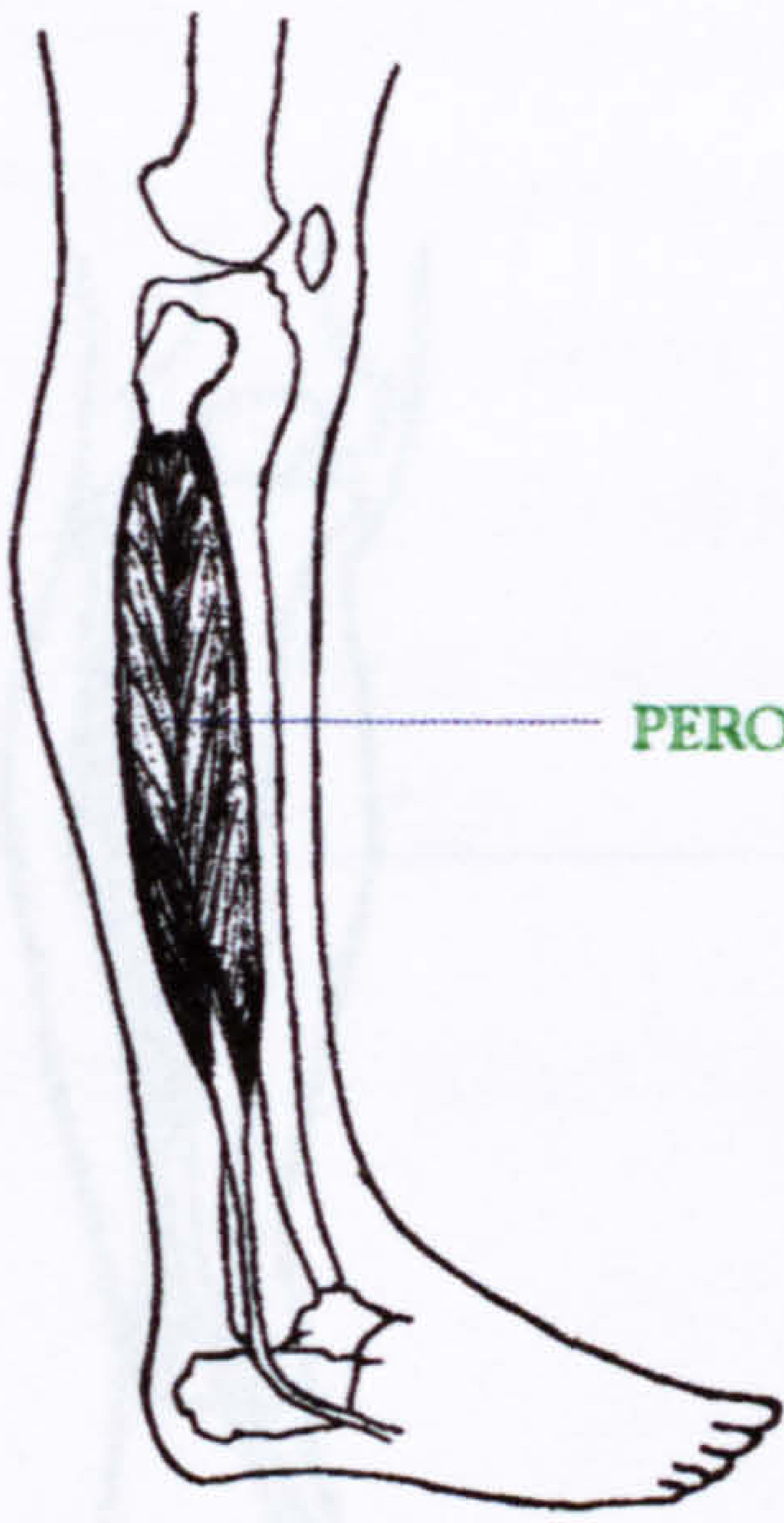


Figure n° 47 Peroneus Longus

The tibialis anterior (*Figure n° 48*) functions to dorsiflex the ankle and invert the foot. In inversion, this muscle supports the medial longitudinal arch of the foot. However, since the line of action of this muscle lies along the subtalar axis, its effectiveness in inverting the foot is minimal (*Sammarco 1995*).

Tibialis Anterior:	Attachments superior and lateral tibia and interosseous membrane.
	Medial surface of the medial cuneiform and base of first metatarsal.
Function:	Dorsiflexion of the ankle joint.
	Inversion of the foot (*Bloomfield 1994*).

As with the other muscles in the leg, the tibialis anterior is concerned with balancing the body on the foot. It works with the surrounding muscles to maintain body balance during activities of the upper part of the body, which change the distribution of weight (*Marieb 1992*).

Figure n° 48 Tibialis Anterior

4.1.3 Neurophysiology of the Ankle Joint

The ankle has its own protective mechanisms to prevent injury besides its anatomical structure. These strategies are components of the neurophysiology of the joint and include stretch reflex and proprioceptive mechanisms.

The central and peripheral nervous systems control the function of a joint. This includes the muscle stretch reflex, which is in part a protective mechanism for a joint to provide excessive range of motion (*Hume 1998*).

The neuromuscular system also has the potential to protect the ankle joint complex if there is pre-activation of muscle pairs about the joint. Antagonist muscle activity may increase or decrease to compensate for the changing effect of gravity in the variation of the muscle's effective length, loading direction and force level generated by the agonist muscles. Without muscle pre-activation, sudden inversion relies on the strength of the ligaments and the anatomical alignment, as the muscle reflex time is too long to prevent excessive inversion (*Hume 1998*).

The proprioceptive reflex system consists of mechanoreceptors in the ankle ligaments and the joint capsule. These are specialised end organs capable of converting some of the mechanical energy of physical deformation into nerve action potentials for transmission of the information pertaining to proprioception (*Sammarco 1995, Zimmy 1986*). Afferent nerves to the central nervous system connect the mechanoreceptors. In the central nervous system, these afferent nerves are connected to the muscles by the efferent system. After stimulation these muscles counteract the movements of the ankle, provoking impulses in the receptors of the ligaments (*Karlsson 1993*).

Proprioception is discussed in more detail in **CHAPTER 5.**

4.2 ANKLE SPRAIN

The term 'sprain' is defined as the over-stretching of a ligament without the disruption of the integrity of its fibres, or avulsion from its bony attachments (*Diamond 1989*). Ankle sprains are most probably the result of a sudden force that the body does not have sufficient reaction time to respond to appropriately (*Diamond 1989, Hunt 1988*). When ligaments resist tension forces they begin to elongate. Tension that is not restricted by muscle contraction must be restricted by ligaments and other non-contractile tissue until the muscle contracts with enough force to decrease joint tension. When strong unanticipated tension forces develop at a joint, ligaments are stretched rapidly and so if muscles do not respond rapidly enough to maintain the joint integrity, disruption of ligament, bone and joint may occur (*Diamond 1989*).

4.2.1 Inversion Sprains

Most ankle sprains in football occur by inversion; a figure of 70% has been reported by *Anglietti (1994)*. Similarly *Dufek (1991), Floriana (1976), Garrick (1975), Kaumeyer (1980), Lindenfeld (1988), Mack (1975), O'Donoghue (1970)* reported most ankle injuries to be inversion injuries.

As bony stability is greater laterally than medially, this predisposes the ankle towards inversion injury rather than eversion (*Mack 1982*). Once inversion is initiated, the ankle loses the bony stability of the neutral position and as inversion increases, the medial malleolus loses its stabilising factors and acts as a fulcrum for further inversion (*Garrick 1977, Mack 1982*).

Most inversion sprains occur when the foot is in some degree of plantar flexion and the anterior talofibular ligament (ATFL) is stressed (*Adamson 1997, Kaumeyer 1980*). The ATFL is injured first because it is perpendicular to the movement of the talus and less elastic and is stretched tighter than the other lateral ligaments in plantar flexion (*Bennett 1994, Colville 1990, Garrick 1975, Garrick 1997*). As the foot moves from plantar flexion to dorsiflexion, the calcaneofibular ligament (CFL) tightens, so as the severity of the inversion injury or the strength of the forces increases, the likelihood of a CFL injury in addition to ATFL injury increases (*Adamson 1997, Kaumeyer 1980*). It has been noted that 66% of sprains involve the ATFL alone and 20% involve the ATFL and CFL (*Adamson 1997*). The CFL will be injured separately if the foot is inverted with the ankle near the neutral position, since this ligament will be more nearly perpendicular to the stress in this position (*Kaumeyer 1980*).

Because the posterior talofibular ligament (PTFL) is the strongest of the lateral ligaments, isolated injury to the PTFL is unusual, but is often associated with posterior malleolar fractures which can contribute significantly to a tendency toward internal rotation and posterior instability when the ankle is loaded (*Adamson 1997*).

4.2.2 Eversion Sprains

Eversion injuries of the ankle involve the deltoid ligaments, which are stronger than the lateral ligaments and are thus seen less frequently, accounting for only 5% of ankle sprains (*Adamson 1997, Kaumeyer 1980*). The movement of eversion is much more limited due to the length of the lateral malleolus and any increased stress is limited by this bony block and frequently causes a compression fracture of the fibula (*Kaumeyer 1980*).

4.2.3 Sprain Classification

There is currently no standardised system for grading ankle sprain severity (*Lindenfeld 1988*). The following is an overview of the proposals of a number of authors (*Chorley 1997, Garrett 1976, McCluskey 1976b, McDowell 1994*).

- **Grade I/1st degree Sprains**

  Fewer than 25% of ligamentous fibres are torn

  No instability

  Mild pain and tenderness

  Little or no swelling

  Recovery 7-10 days

- **Grade II/ 2nd degree Sprains**

  25% - 75% of ligamentous fibres torn

  Slight to moderate instability

  Moderate pain and tenderness

  Moderate swelling and ecchymosis

  Expected recovery 2-4 weeks

- **Grade III/ 3rd degree Sprains**

  More than 75% of ligamentous fibres are torn

  Significant instability

  Marked pain and tenderness

  Marked swelling and ecchymosis

  Expected recovery 5-10 weeks

All authors agree on the relative stability/instability, associated pain and degree of swelling involved in the various classifications of ankle sprain and, in general, follow the RICE protocol treatment guidelines (Rest, Ice, Compression and Elevation).

4.2.4 Effect of Sprains on Muscles and Proprioception

Although primarily a bony ligamentous complex, there are a number of muscles and nerves that may be injured during ankle sprain (*Chorley 1997, Diamond 1989, Lindenfeld 1988*). Two of the peroneal muscles, the brevis and longus, originate at the lateral aspect of the middle third of the fibula and pass posteriorly to the lateral malleolus to insert at the base of the fifth metatarsal and heads of the first two metatarsals respectively (*Chorley 1997*). These muscles are the primary ankle evertors and during the action of inversion ankle sprain work hardest to bring the ankle back to its normal position by stimulation of the muscle proprioceptors (*Chorley 1997, Lindenfeld 1988*). The peroneals are often injured during inversion sprains, due to their position and action. The injury may result in a stretching of the proprioceptive fibres of the muscle, causing the ankle to be more susceptible to reinjury if rehabilitated insufficiently (*Diamond 1989, Lindenfeld 1988*).

4.3 EXTERNAL ANKLE SUPPORT

The ideal ankle support provides for mechanical stability and proprioceptive feedback without limiting normal range of motion or function of the ankle. Taping and braces are commonly used to prevent ankle injury and there is an increasing interest in the use of proprioceptive training for this purpose.

4.3.1 Literature Review of External Support of the Ankle to Prevent Injury

Epidemiological studies have tried to establish the ability of tape and braces to prevent acute ankle injury over a playing season or year (*Callaghan 1997*). The most commonly cited study on injury prevention is that of *Garrick (1973)*, which studied the effect of taping on 2563 basketball players with previous ankle sprains over two successive seasons. The study concluded that taping had a protective influence for preventing ankle sprains.

Ankle braces may also reduce the incidence and severity of acute ankle sprains in competition (*Bahr 1994*). The use of an Aircast stirrup in a control and experimental group in basketball was compared over two years. It was calculated that the brace significantly reduced the frequency of ankle injury; the players without the orthosis had three times the risk of ankle injury.

Tropp (1985b) studied the effect of an ankle brace compared with a proprioception programme in football players and a control group over a six month period. In previously uninjured players the incidence of ankle sprain was 3% for bracing, 5% for proprioception training and 11% for controls. However, if a player had previous ankle injuries, the incidences were 2% for bracing, 5% for proprioception training and 25% for controls. This indicated that both proprioception training and bracing had significantly lowered the incidence of ankle sprains, especially if the ankle had been previously sprained.

The preventive effect of braces on sprains in football players was confirmed by a later prospective randomised study conducted by *Surve (1994)*. This finding, also noted in laboratory studies by *Karlsson (1992)* was thought to be due to improving the defective stabilisation of the peroneii muscle group. Other studies have directly compared traditional taping methods and ankle braces in the prevention of acute ankle sprains.

A cadaveric study by *Shapiro (1994)* found that the use of ankle braces and tape affords a dramatic increase in the protection of the ankle by decreasing the resultant inversion caused by an applied force. As this was a cadaveric study, the dynamic effects of the stabilising muscles cannot be incorporated. Therefore only the intrinsic passive stability provided is measured.

Most, but not all epidemiological studies suggest that high-top shoes, athletic tape and orthoses are effective in reducing the incidence of ankle injuries, although the benefit does depend on the sport (*Ashton-Miller 1996*).

Garrick (1977) noted that the use of either high-top athletic shoes or prophylactic ankle taping decreased the frequency of sprains, most notably in those individuals with a history of sprain.

Lace-up braces have proven to be as effective as tape at restricting ankle range of motion (*Buschbacher 1993*) and they tend not to lose their supportive ability during exercise as tape does (*Bunch 1985, Gehlsen 1991*). One study found that they may decrease rates of ankle injury when used prophylactically (*Rovere 1988*). This non-controlled retrospective survey showed that the best results with lace-up braces were when used in conjunction with low-top shoes, allowing athletes to retighten the brace periodically during activity, thus providing more constant support.

Stover (1980) advocated the use of the Aircast® Airstirrup™ to supplement afferent stimuli at the site of ankle injury while the reparative process takes place. *Kimura (1987)* postulated that the air cells in the brace conform to the skin and so enhance cutaneous proprioceptive feedback. *Feuerbach (1994)* studied the effect of the Aircast® external support on unilateral postural sway in the coronal and sagittal planes. Unilateral stability was enhanced in both static and dynamic testing and it was also concluded that the brace enhanced afferent feedback, so improving postural stability.

Greene (1990a) evaluated volleyball players before, during and after three hours of play and compared taping with an external supportive device. While neither treatment restricted vertical jumping ability, the maximum loss of restriction with taping was seen at 20 minutes and was reduced from 41% to 15% of total inversion-eversion motion. The external support device was noted to maintain almost all of the initial restriction and only decreased from 42% to 37% of total restrictive inversion-eversion motion.

Given that external support may decrease performance and the effectiveness of the support restriction may change with use during exercise, it is important to understand the mechanism by which external supports act so that the positive effect can be utilised.

Hughes (1983) stated that the ultimate goal of any external support is to prevent inversion sprains through restriction of available inversion. It is assumed that by restricting active inversion the motion available to the athlete at extreme of inversion and will also be limited. *Miller (1990)* stated that adhesive tape offers protection against ankle sprains during activity and that laced stabilisers offer an equal amount of support with the benefit of their ability to be re-tightened frequently during activity. The Airstirrup has not been shown to provide significantly greater inversion restriction than taping or lace-on braces (*Hume 1998*).

A comparison of studies on ankle supports and their results is shown in *Table n° 4.1*. This table is an adaptation of reviews by *Callaghan (1997)* and *Miller (1990)*.

Table n° 4.1 A Comparison of Studies on Ankle Supports and their Results

AUTHOR OF STUDY	YEAR	ANKLE SUPPORT TESTED	RESULTS
RARICK	1962	4 Taping methods	After 10 minutes, up to 40% of tape's support was lost. Best taping technique was basketweave with stirrups and heel locks.
FUMICH	1981	Tape; Stirrup strips with heel locks and figure-8 locks	Tape weakens after 10 minutes of exercise and then provides minimal restriction.
HUGHES	1983	Tape; basketweave with heel locks Brace; semi-rigid orthosis	No difference in support
MYBURGH	1984	Tape; basketweave, stirrups and heel locks Brace; 2 types of elastic guard	Elastic guards provided no significant support. Post exercise, tape offered no significant support. Tape better to restrict non-weightbearing range of motion.
BUNCH	1985	Tape; basketweave with heel locks Brace; 5 lace-on braces	Ankle model used. Initially tape provides more restriction. Post exercise no difference between tape and lace-ons.
GROSS	1987	Tape; basketweave with heel locks and figure-8 Brace; Air stirrup	Air stirrup provides greater range of motion restriction for eversion. Both methods provide inversion support.
ROVERE	1988	Tape; closed basketweave, figure-8 and heel locks Brace; laced ankle brace	Risk of injury halved using orthosis rather than tape.
GREENE	1990	Tape; basketweave, figure-8 and heel locks Brace; Donjoy ALP	Donjoy ALP better at restricting non-weightbearing range of motion than tape.
FRANKEY	1993	Tape; Hinton Boswell, basketweave Brace; laced ankle brace	Hinton Boswell technique better than orthosis and other taping techniques to restrict non-weightbearing range of motion.
GROSS	1994	Tape; subtalar sling Brace; Donjoy ALP	No difference in non-weightbearing range of motion.
LINDLEY	1995	Tape; closed basketweave and stirrups Brace; Aircast Air Stirrup, Active ankle brace and Donjoy ALP	ALP showed decreased functional non-weightbearing range of motion
MACKEAN	1995	Tape; closed basketweave Brace; Swede-O Universal, Active ankle brace and Aircast Air Stirrup	Active ankle brace showed least overall performance impairment.
PARIS	1995	Tape; closed basketweave Brace; Swede-O Universal and Subtalar brace	Swede-O better than subtalar brace and tape to restrict non-weightbearing range of motion.
VERBRUGGE	1996	Tape; Gibney basketweave, stirrup and heel locks Brace; Aircast Air Stirrup	After 10 minutes , up to 40% of tape's support was lost. Best method of support was baskteweave with stirrups and heel locks.

4.3.2 Potentially Negative Effects of External support

There is little evidence to support the view that long-term use of either taping or braces for ankle support may result in detrimental effects to the tissues around the ankle or joints within the kinematic chain (*Callaghan 1997*). *Garrick (1973)* found no increase in the frequency of knee sprains occurring as a result of using high-top shoes and prophylactic taping. It was further commented that the increased likelihood of an ankle support causing a knee injury was overshadowed by the protection that the ankle support offered.

Other studies have used kinetic and kinematic analysis to evaluate the potentially negative effects of taping of the ankle. Contradictory results have shown that ankle taping can have disadvantageous secondary effects around the metatarsal heads in walking (*Carmines 1988*), or that neither taping nor braces causes any alteration in foot motion in running (*Hamill 1986*).

In addition to adverse effects on the lower extremity, it has been the opinion of some researchers that the potential benefits of wearing ankle braces to prevent ankle injury must be weighed against the possible detrimental effect on actual performance (*Mackean 1995*). The consensus is that various braces have little detrimental effect on sprint or agility tests, but the results for vertical jump tests are contradictory. However, these differences may be due to between study differences of sample size, types of sport analysed, age and proficiency of the athlete selected.

4.3.3 Proprioceptive Effect of External Supports

Although some limitation of ankle range of movement can be achieved with taping and bracing, it is doubtful whether taping and bracing will withstand the forces of an inversion sprain. As a result, some authors have investigated the protective role of taping and bracing in the chronically injured ankle preventing injury through proprioception (*Hamill 1986, Jerosch 1995, Karlsson 1992a, Lentell 1995, Robbins 1995*).

Jerosch (1995) compared two types of brace and a closed Gibney basketweave taping technique with figure-8 supplementation on unstable ankles. Although significant differences were found in angle reproduction before the test between stable and unstable ankles, concurring with results from *Lentell (1995)*, taping did not significantly improve this and no explanation for this was offered.

The Aircast Air-Stirrup has also been shown to facilitate joint proprioception in uninjured ankles with an anaesthetised lateral ligament complex. This improvement in joint position sense was thought to be due to the stimulation by the brace of the cutaneous receptors in the foot and leg, which might have increased the afferent feedback (*Feuerbach 1994*).

These studies assume that assessing ankle proprioceptive functions with non-weightbearing indicates that such methods of support will reduce the possibility of trauma to the ankle and foot in full weightbearing. Some studies have addressed this problem by comparing bracing with taping in the full weightbearing position. *Hamill (1986)* compared a Gibney basketweave with an unspecified brace and found no significant differences between the two types of support, concluding that neither tape nor brace affected foot motion. Functional full weightbearing outcome measures were recorded in healthy and injured subjects comparing a lace-up brace, the Aircast Airstirrup and a taping technique by *Jerosch (1995)*. Braces were found to improve the proprioception and functional ability of the injured and normal ankles, whereas the taping technique had no effect. Video analysis has been used to compare the effect of taping with various braces on dorsiflexion and plantar flexion of the ankle (*Lindley 1995*). Only the Donjoy ALP brace affected sagittal range of motion.

4.3.4 Key Effects of External Supports

This overview of external supports is adapted from *Callaghan(1997)*.

- Tapes and Braces
  - restrict range of movement
  - reduce reinjury rate
  - improve proprioception
  - limitation of movement is lost after exercise
  - no negative effect on most performance tests
  - little negative effect on other joints

- Braces
  minimal expertise needed
  reusable
  re-adjustable
  washable
  non-allergic

- Tape
  individually applied
  less bulky than brace
  athletes preference
  caters for unusual anatomy

4.3.5 The Effect of External Ankle Supports on Ankle Injury Rates

The effectiveness of external ankle supports in preventing injury would be indicated by epidemiological evidence that external ankle support use reduced injury (*Hume 1998*). Such research would require baseline injury information obtained before the application of external ankle support and periodic monitoring of a wide variety of variables during external ankle support use. Factors such as the frequency and intensity of training, the type of sport played, the cause of injury and the severity of injury would need to be considered. Due to the time, cost and effort required, few such prospective studies have been completed.

Garrick (1973) is often cited as evidence that taping can lead to a reduction in injury and that the use of preventive ankle taping offers protection for previously injured ankles. A limitation of this study was the due to the small proportion of players being injured, the numbers in each of the study groups were small and no detail of player position, skill level or playing time was provided. *Rovere (1988)* studied the effectiveness of wearing a laced stabiliser or taping in preventing ankle injuries and re-injuries. In this study, players were able to choose their own support and exchange it over time, therefore, results may be confused. Stabilisers can be re-tightened, which would return the amount of support to the initial application and in this study it is unknown whether the supports were re-tightened. The specific type or configuration of the tape or brace was not reported and there was no control of skill level or player position, nor any comparison with an unsupported ankle.

In a review of the use of prophylactic ankle braces for preventing lateral ankle sprains, *Reisberg (1992, 1993)* deemed that existing research was inadequate and not definitive enough to warrant confident use of particular supportive methods. More reliable scientific functional data and empirical conclusions were called for when researching the use of prophylactic ankle supports. In contrast to this, *Sitler (1992)* stated in a review of the effectiveness of external support in reducing injury; that although the clinical research regarding ankle supports was limited, it appeared that they were effective in reducing the incidence of acute ankle injuries. A clinical randomised study was then conducted (*Sitler 1994*) to prospectively determine the efficacy of a semi-rigid ankle stabiliser in reducing the frequency and severity of ankle injuries in military academy cadets. The ankle stabilisers were found to significantly reduce the frequency of ankle injuries, however, the reduction was dependent on the nature of the injury.

Prophylactic training programmes have been used in some cases in an attempt to determine what interventions are effective in reducing the incidence of ankle injury. A prophylactic programme used by *Ekstrand (1983c)* focused on training, equipment, tape, rehabilitation, exclusion, information and supervision. Although the programme was reported as being effective in reducing injuries by 75%, the effectiveness of individual components was not reported.

Proprioceptive/co-ordination training has been reported to be as effective as an orthosis in decreasing injuries in Swedish football players (*Tropp 1984, 1988a*), but the results can also be interpreted as indicating that the proprioceptive training is no better than tape in decreasing injury with conclusions based on a small sample size.

Surve (1994) studied the effect of the Aircast Airstirrup brace on the incidence of ankle sprains in senior football players during one playing season and it was concluded that the semi-rigid orthosis significantly reduced the incidence of recurrent ankle sprains in those football players with a previous history of ankle sprain.

The studies that have investigated preventive measures to reduce the frequency of ankle injuries in sport have failed to provide unequivocal evidence of the effectiveness of external ankle support. Several studies do seem to indicate that taping or bracing may be effective in reducing the ankle injury rate (*Ekstrand*

1983a, Garrick 1973, Rovere 1988, Sitler 1994, Tropp 1984, 1985b) particularly for athletes with previous injury. The effectiveness of ankle taping or bracing is dependent upon the athlete's level of ankle stability or previous injury (*Sitler 1994, Tropp 1985b*).

4.4 ANKLE TAPING

Tape has long been a popular prophylaxis within the sporting environment because of traditional beliefs that it is convenient to use and it is an effective form of protection against injury (*Ashton-Miller 1996, Pope 1987*).

4.4.1 Prophylactic Ankle Taping

Various intervention methods have been implemented to reduce the incidence of ankle sprains. Taping has been the most common method used to prevent ligamentous injuries of the ankle (*Bocchinfuso 1994, Hughes 1983, Libera 1972*) and has become the principal means of preventing ankle sprains in sport (*Beynnon 1991, Bullard 1979, Garrick 1977, Gross 1987b, Gross 1991, Laughman 1980, Robbins 1995, Rovere 1989, Shapiro 1994, Wilkerson 1991*).

The most basic function of taping is to restrict the range of ankle motion to prevent extreme and injurious ankle motions (*Ashton-Miller 1996, Fumich 1981, Laughman 1980, McCluskey 1976a, Norris 1983*), acting essentially as an external ligament without interfering with the normal joint mechanics (*Garrick 1973, Greene 1990a, Laughman 1980, McLean 1989, Seitz 1984*).

The ultimate objective of taping is to prevent the ankle ligaments from being stressed to the point of injury by externally limiting ankle inversion and eversion, while allowing functional dorsiflexion and plantar flexion to occur (*Buschbacher 1993, Greene 1990a, Hughes 1983*). It is assumed that by restricting active inversion-eversion motion, the movement available to an individual at the anatomical limits of motion will also be restricted (*Greene 1990a*).

It has been theorised that taping may act as a secondary ligament provided it is applied to areas of the skin which are relatively immobile and the tape is aligned in such a way as to prevent the extremes of physiological joint range, as in isolation, neither tape, nor the strength of the tape/skin interface would resist the predicted force required to rupture components of the lateral ligament (*Callaghan 1997, Laughman 1980, Pope 1987*). Also, when combined with the body tissues, taping improves the capacity to dissipate the energy associated with potentially traumatic forces away from the joint (*Hume 1988, McLean 1989*).

Although some limitation of ankle range of movement can be achieved with taping (a mechanical effect), there is some evidence that taping may have a proprioceptive effect (*Buschbacher 1993, Glick 1976, Shapiro 1994*). It is generally believed that taping unites the skin of the foot with the leg and so stimulates the skin receptors and facilitates muscle contraction (*McLean 1989, Sprigings 1981*), along with position awareness and orientation (*Andreasson 1985, Karlsson 1993, Pope 1987, Robbins 1995*).

It can be seen that there are several theories on the action/effect of prophylactic ankle taping. It is therefore necessary to clarify this area of prevention of injury in order to assess the efficacy of its use.

4.4.2 Disadvantages Associated with Ankle Taping

Although taping has been used to support ankles for over a hundred years (*Hughes 1983, Libera 1972*), some disadvantages have been highlighted. These include a decrease in ankle passive range of motion due to taping affecting functional performance in certain activities (*Ashton-Miller 1996, Burks 1991, Juvenal 1972, Mack 1982, Mayhew 1972*) and a proposed adverse effect on postural control (*Bennell 1994*).

Repeated daily application of tape in an athletic setting can also be costly due to the need for experienced personnel to apply the tape and the 'once-only' use that is associated with taping (*Pope 1987*). Repeated removal of adhesive tape can cause skin irritation and tape may also lose its effectiveness with prolonged activity (*Fumich 1981, Glick 1976, Greene 1990a, Larsen 1984, Laughman 1980, Mayhew 1972, Metcalf 1983, Myburgh 1984, Rarick 1962*).

The effectiveness of tape is lessened by;

1. The mobility of the skin over which the tape is applied.

2. Moisture accumulation between the tape and skin, which decreases the tape's adherence.
3. Tearing of fibres in the tape.

(*Hughes 1983*).

4.5 LITERATURE REVIEW OF THE ANKLE AND TAPING

The relatively high incidence of ankle sprain injury in relation to injuries of other joints and parts of the body and its associated effect on athletic participation and routine daily activities have resulted in numerous attempts to develop external support systems that provide protection against initial and recurrent sprain injuries (*Gross 1991*).

4.5.1 Literature Review of Taping Usage

Scientific literature on taping is virtually exclusively based on the ankle joint due to the high incidence of lateral ankle injuries and also the fact that the ankle joint is readily open to taping techniques that may have a mechanical limiting effect (*Firer 1990*) and/or a proprioceptive effect (*Glick 1976*).

Some of the earliest work on taping was done by *Quigley (1946)*, who showed that a considerable amount of protection was offered by regular use of 'ankle wraps'. These non-elastic bindings effectively limited lateral mobility without interfering with flexion or extension. Quigley believed that prophylactic taping would reduce injuries by at least 50%.

The possible mechanisms by which external support may provide stabilisation are:

a) by providing resistance to excessive range of movement; resulting in reduced strain on the ligaments (*Garrick 1977, Karlsson 1993, Norris 1994*);
b) by increasing muscle activation which may dissipate the force on the ligaments and tendons (*Karlsson 1993, Norris 1994, Surve 1994*);
c) by redistributing loads away from the ankle joint centre (*McLean 1989*);
d) by placing the rearfoot angle in a neutral position on landing (*Garrick 1977, Laughman 1980, Walsh 1977*);
e) by decreasing the rate of loading to reach the end range of movement (*Hume 1998*);

f) by acting to reinforce the ligaments by taking the force in their place (*Laughman 1980*).

4.5.2 Mechanical Effect of Taping

It is assumed that by restricting active inversion, the motion available to the ankle at the extreme of inversion will also be limited. So indications for taping are based on the assumption that some type of external support increases ankle stability by reinforcing the ligamentous structures of the ankle and restricting motion such as extreme inversion, the cause of most ankle injuries (*Hughes 1983, Hume 1998*).

Despite the widespread use of tape, there is a question of its efficacy and mechanism of joint support (*Beynnon 1991*). The initial advantage of taping is its custom fit and control of the support mechanism stiffness. However, with activity and due to the viscoelastic properties of tape, the support provided to the joint by taping decreases, dependent upon the level of activity, duration of sport and taping technique as measured by range of motion before, during and after exercise (*Beynnon 1991, Fumich 1981, Greene 1990a*).

One method of assessing whether an external support can prevent injury or protect against re-injury that has been utilised, is the examination of effects of support during particular movements thought to contribute to injury. Inversion and plantar flexion beyond normal range of movement have been cited as the primary mechanism for inversion sprains (*Alves 1992, Greene 1990b, Rarick 1962*).

Reduced range of movement may be achieved through external mechanical restriction provided by design characteristics of footwear and external support and by the material stiffness. Studies that have reported ankle motion to be significantly limited with tape include *Gehlsen (1991), Lyle (1992)* and *Scheuffelen (1993)*. However, when taping material stretches, or the limb sweats during exercise, tape is known to loosen. Several authors have investigated the effect of exercise on the ability of external supports to restrict range of movement, using a variety of supports and methods of investigation.

Resistance to external loads is afforded by passive and sometimes active muscular mechanisms during weightbearing (*Manfroy 1997*). The majority of studies have investigated passive ankle motion (*Alves 1992, Greene 1990b, Gross 1991, 1987b, Laughman 1980, Malina 1962, Vaes 1985*) with several others measuring active motion (*Andreasson 1995, Bauer 1988, Greene 1990a, 1990b, Hughes 1983*) or dynamic motion (*Hamill 1988, 1986, McIntyre 1983*). Movements most frequently measured at the ankle include inversion and eversion, total range of movement and less frequently, degree of talar tilt (*Vaes 1985*). Methodologies have used combinations of external support pre and post-exercise, with exercise periods ranging from 5 to 20 minutes.

In the main, studies have reported a significant decrease in range of movement restriction provided by the external support after exercise compared with when the support was first applied or without support after exercise. Of these studies, tape has been reported to significantly limit inversion before and after exercise by *Bauer (1988), Fumich (1981), Greene (1990a, 1990b), Gross (1991, 1987a, 1987b), Hughes (1983), Laughman (1980), Malina (1962), Myburgh (1984), Paris (1995), Rarick (1962), Sprigings (1981)* and *Vaes (1985)*. However, this motion restriction has been reported to lessen by 40% after exercise compared with the pre-exercise condition (*Bauer 1988, Fumich 1981, Gross 1991, 1987b, Hughes 1983, Laughman 1980, Malina 1962, Myburgh 1984, Paris 1995, Rarick 1962, Vaes 1985, Wilkerson 1991*), but this reduction was still significantly greater than without any tape support (*Bauer 1988, Fumich 1981, Gross 1991, 1987a, Vaes 1985*). For an overview of studies see *Table n° 4.2.*

Differences in methods of study must be kept in mind, as some studies have measured the decreased supporting strength of tape after exercise by passively moving the ankle with a fixed weight (*Malina 1962, Rarick 1962*) and others have used subject maximal effort (*Fumich 1981*). A criticism of both methods is that they indirectly evaluate the efficacy of taping by measuring the restriction of motion within the non-injurious range instead of the extremes of normal range prior to ligament rupture. This criticism is important since the protection required from taping occurs at these extremes.

Table nº 4.2 Overview of Studies Investigating Effect of Exercise on Tape Effectiveness.

STUDY	YEAR	Duration of Exercise	Results and Conclusions
MALINA	1962	5 minutes	With exercise ankle supports provided significantly less support than pre-exercise
RARICK	1962	10 minutes	Tape restriction to inversion plantar flexion decreased up to 40% t 50% after 10 – 20 minutes of exercise due to stretching and weakening of taped and decreased adhesion owing to sweating
LAUGHMAN	1980	15 minutes	26.7% decrease in inversion-plantar flexion post-application and 18.6% restriction post-exercise compared with pre-exercise
FUMICH	1981	2 – 3 hours	Tape reduces ROM to 10-14%, but loosening occurred after exercise. Resistance decreased 50% after exercise. Post exercise residual restriction provided by tape still greater than untaped.
HOCHMAN	1982	90 minutes	Following exercise, tape lost its support
HUGHES	1983	20 minutes	Decrease in support after exercise compared with original ROM.
MORRIS	1983	10 and 20 minutes	Inversion and eversion ROM significantly reduced with tape even after exercise. Tape less effective after 10 minutes but restriction after 20 minutes was still significant compared with pre-tape condition.
MYBURGH	1984	1 hour	Tape restricted joint motion by 20%-40% before exercise. After 1 hour only 10% residual restriction.
VAES	1985	30 minutes	Significant decrease in talar tilt which decreased but remained significant after exercise.
GROSS	1987	10 minutes	Inversion and eversion significantly reduced following application and exercise.
BAUER	1988	30 minutes	Taping ankle resulted in decreased ROM 41.6% restriction before exercise. After 30 minutes only 6.6% restriction.
GREENE	1990	10, 60 and 180 minutes	Tape restricted ROM by 41% initially, but restriction was only 15% after exercise. Maximal loss of restriction after 20 minutes of exercise.
WILKERSON	1991	2 – 3 hours	ROM decreased post tape application. Initial restriction of 40% decreased to 20 % after exercise.
GROSS	1991	10 minutes	Inversion and eversion significantly reduced following application and exercise.
FRANKENY	1993	15 minutes	50% of supporting strength lost after exercise.
BARTOLD	1993	30 minutes	Taping had maximal loss in restriction for inversion and eversion after 30 minutes of exercise.
GROSS	1994	10 minutes	Inversion and eversion significantly reduced post application and exercise. Eversion increased significantly following exercise post application.
PARIS	1995	15, 30, 45, 60 minutes	ROM decreased with application. Ankle inversion ROM significantly increased after 15 minutes.
METCALFE	1997	20 minutes	Restricted all ROM except plantar flexion.

It can be concluded that tape loses its restrictive ability to a significant extent with exercise, although there still may be more support at this time than without any tape at all, dependent upon the tape application technique. Research on different taping techniques by *Hughes (1983)* indicates that a Gibney-basket weave with a double heel lock retains 72.5% of the initial range of movement restriction, while other techniques are about 65% effective (*Hughes 1983, Libera 1972*). In several studies, *Andreasson (1980, 1983)* examined mechanical properties of tape and found from tensile tests, that tape breaks at a force of 75N per cm width. Elastic modules of 'elastic' tapes average 269N per cm width compared to 1280N per cm width for stiff tapes, assuming constant thickness. From these studies it was concluded that the mechanical support from tape is insufficient and therefore the role of tape could be to provide proprioceptive feedback rather than to support the ankle biomechanically (*Andreasson 1985, Buschbacher 1993, Freeman 1965, Glick 1976, Hergenroeder 1990, Karlsson 1985, Pope 1987, Robbins 1995, Shapiro 1994, Tropp 1985*).

4.5.3 Proprioceptive Effect of Taping

An additional or alternative approach and explanation of reducing range of movement and so stabilising the ankle joint by taping is that a change in muscle activity due to pressure on the tissues surrounding the joint occurs. Contraction of the muscles results in compression of the joint, thereby providing a stabilising effect (*Hume 1998*).

Change in muscle activity is facilitated by the adhesive tape stimulating the skin receptors, thereby improving proprioceptive function as well as the mechanical support (*Norris 1994, Surve 1994*). The magnitude, duration or timing of muscle activation has been reported to change with the use of external support (*Glick 1976, Fergusson 1973, Karlsson 1993, Scheuffelen 1993*), however, the question as to whether tape offers a proprioceptive stimulus is still controversial and a matter for further investigation. A study by *Sprigings (1981)* looked at the effect of a sudden inversion of the foot during weightbearing. No difference was found in the integrated EMG activity in the peroneus longus between the taped and non-taped ankle. The conclusion from this was that if an individual is wearing ankle tape, they learn to adjust the muscle control of the joint to prevent skin drag (*Sprigings 1981*).

Whether a support provides reaction to inversion by acting as a mechanical barrier, by directing force away from the joint centre by altering the joint posture, reducing stress on the ligaments by transferring the mechanical forces away from them and/or by increasing muscle activation through proprioception has still not been adequately determined despite the varied and numerous studies (*Hume 1998*). This indicates a need for the investigation of proprioception and the effect of taping.

4.6 ATHLETIC PERFORMANCE

The impact on athletic performance of any device is an important consideration when deciding on its use (*Verbrugge 1996*). Although ankle supports may prevent injury, many players believe that they will restrict athletic performance (*Pienkowski 1995*). This belief discourages its use and precludes the injury protection that it could provide (*Hume 1998*).

4.6.1 Literature Review of the Effect of Taping on Athletic Performance

The high incidence of ankle injury in athletic participation has resulted in efforts to develop external support systems that will provide protection against these injuries without hindering performance (*Gross 1994*).

Research conducted on the efficacy of external support including that of taping has so far been inconclusive. Most studies on ankle taping have focused on examining the change in range of movement or stiffness of the tape after application (*Bunch 1985, Fumich 1981, Glick 1976, Gross 1987b, Laughman 1980, Libera 1972, Myburgh 1984, Rovere 1988*).

The impact of taping on athletic performance is an important consideration and throughout the literature external support has been reported to have either no effect on performance in jumping, sprinting or shuttle activities (*Bocchinfuso 1994, Gross 1994, Jerosch 1997, Macpherson 1995, Paris 1992, Wiley 1996*), or to have and adverse effect on performance in running and jumping activities

(*Bennell 1994, Burks 1991, Greene 1990a, Mackean 1995, Metcalfe 1997, Paris 1992*).

As studies using the same performance tests of vertical jump and shuttle run have shown contrasting results, it is difficult to conclude whether one particular movement pattern is affected more by external ankle support than any other. Performance is important, and if an application hinders an athlete's performance or ability to compete, it will be discarded, irrespective of whether it is effective or not (*Burks 1991*).

Thomas (1971) reported that taping one or both ankles had no significant effect on a subject's time to complete an agility run that involved cutting manoeuvres (*Gross 1994*). *Burks (1991)* also reported that application of athletic tape resulted in decreased performance in the vertical jump and that performances for a 10-yard shuttle run and 40-yard sprint were adversely affected by the application of athletic tape. *Mayhew (1972)* found that taping athletes ankles decreased performance in the vertical jump and standing broad jump compared to their performance without tape. *Juvenal (1972)* similarly described a decrease in vertical jumping ability with taping.

The inconclusive nature of research into the effect of prophylactic support is however, negated by the fact that nowhere in the literature has it been shown that prophylactic taping or bracing improves performance.

A summary of the effect of different types of external support on athletic performance can be seen in *Table n° 4.3*.

Table n° 4.3 Effect of External Support on Performance (studies including taping highlighted).

STUDY	METHOD	RESULT
BERIAU 1994	Agility Course – Aircast® Sports Stirrup & Training brace, Swede-O ™ brace and Donjoy ALP.	Donjoy & Training brace significantly slower than for other conditions. Ankle braces produced slower agility times compared with no brace condition.
BOCCHINFUSO 1994	Vertical jump, 80-ft sprint, shuttle run and 4-point run – Active Ankle™ Training brace, Aircast® Sport Stirrup.	No effect on performance.
BURKS 1991	Broad jump, vertical jump, 10-yd shuttle run and 40-yd sprint – Swede-O ™ brace, Kallassy™ brace and tape.	Ankle taping significantly decreased performance in vertical jump, shuttle run and sprint. Swede-O™ in vertical jump, broad jump and sprint, Kallassy™ in vertical jump.
COFFMAN 1989	Vetical jump and speed test – ankle taping, Aircast® Sports Stirrup.	Vertical jump and speed significantly decreased with tape. Brace decreased speed.
GROSS 1994	40m sprint, figure-of-eight run and standing vertical jump – Donjoy ALP, Aircast® Sport Stirrup.	No significant effect.
GROSS 1997	40m sprint, figure-of-eight run and standing vertical jump – Donjoy ALP, Aircast® Sports Stirrup.	No significant effect on performance.
HOCHMAN 1982	Vertical jump after 90 minutes exercise – Ankle taping and Mikros™ brace.	No significant difference between different types of taping and ankle bracing.
MACKEAN 1995	Vertical jump, jump shot, sprint drill and submaximal treadmill run – Tape, Swede-O, Active Ankle ™ and Aircast®Sports Stirrup.	Vertical jump significantly lower with tape.
MACPHERSON 1995	Vertical jump, 40-yd sprint, 20-yd shuttle run – Aircast®Sports Stirrup™ and Donjoy RocketSoc™.	No significant effect.
METCALFE 1997	Vertical jump, agility test – tape, lace-up brace.	Vertical jump significantly decreased, as were performance times compared with no external support.
PARIS 1992	Speed, agility, balance and vertical jump – tape, Swede-O™, New Cross™, McDavid™.	Vertical jump significantly reduced by New Cross™. No other significant effects.
VERBRUGGE 1996	Agility run, 40-yd sprint and vertical jump – Aircast®Sports Stirrup, taping.	No significant effect.

Adapted from *Hume (1998)*.

CHAPTER FIVE

CHAPTER 5: PROPRIOCEPTION

The next two chapters set out to discuss proprioception and its measurement using postural stability and electromyography.

5.1 OVERVIEW OF PROPRIOCEPTION

The Latin word proprius means 'own' and in connection with perception defines proprioception as an awareness of oneself. Proprioception in fact describes an awareness of posture, movement, and changes in equilibrium and mechanical inertia that generate pressures and strains at a joint (*Donatelli 1996*).

Numerous investigators have observed that afferent feedback to the brain and spinal pathways is mediated by skin, articular and muscle mechanoreceptors (*Bastian 1988, Lephart 1997, McCloskey 1978*) and that proprioception contributes to the motor programming for neuromuscular control required for precision movements. Also observed is that proprioception contributes to muscle reflex, providing dynamic joint stability (*Lephart 1997*) in addition to the mechanical restraint provided by articular structures (*Kennedy 1982*).

The neural input that is provided by the peripheral mechanoreceptors as well as the visual and vestibular systems is all integrated by the central nervous system (CNS) to generate a motor response. These responses generally fall under three levels of motor control: spinal reflexes, cognitive programming and brain stem activity (*Lephart 1997*). In a situation in which a joint is placed under mechanical loading, reflex muscular stabilisation is stimulated through the spinal reflexes (*Guanche 1995*). The second level of motor control, located within the brain stem receives input from joint receptors, vestibular centres and visual input from the eyes to maintain posture and balance of the body (*Lephart 1997*). Cognitive programming involves the highest level of CNS function (motor cortex, basal ganglia and the cerebellum) and refers to voluntary movements that are repeated and stored as central commands. This awareness of body position and movement allows various skills to be performed without continuous reference to consciousness (*Lephart 1997*).

Proprioception encompasses two aspects of position sense: static and dynamic. Static sense provides conscious orientation of one body part to another. Dynamic sense gives the neuromuscular system feedback about the rate and direction of movement (*Laskowski 1997*). Thus, proprioception can be thought of as a complex neuromuscular process that involves both afferent input and efferent signals. This allows the body to maintain stability and orientation during both static and dynamic activities (*Laskowski 1997*). In general, however, it is the process by which the body can vary muscle contractions in immediate response to incoming information regarding external forces (*Hoffman 1995*).

There are two levels of proprioception: conscious (voluntary) and unconscious (reflex initiated). While conscious proprioception enables proper joint function in sports and activities, unconscious proprioception modulates muscle function and initiates reflex stabilisation of joints by way of the muscle receptors (*Lephart 1994*). Muscular activity and joint motion, either performed consciously or subconsciously, are the products of multi-site sensory input which is received and processed by the brain and spinal cord. The perception and execution of musculoskeletal control and movement are mediated primarily by the CNS. The CNS receives input from three main sensory subsystems; the somatosensory system, the vestibular system and the visual system (*Lephart 1998*).

5.1.1 Mechanoreceptors

Activation of joint mechanoreceptors is triggered by the deformation and loading of the soft tissues that compose the joint. This neural stimulation travels to the CNS for integration via cortical and reflex pathways. These mechanoreceptors demonstrate adaptive properties depending on a particular stimulus (*Grigg 1994*).

Quick-adapting (QA) joint mechanoreceptors, such as the Pacinian corpuscles, decrease their discharge rate to extinction within milliseconds of the onset of continuous stimulus (*Boyd 1954, Lephart 1997*). QA mechanoreceptors are thought to mediate the sensation of joint motion. Pacinian corpuscles are sensitive to the onset of sudden changes and pressure movements and are therefore stimulated by the initiation of, or termination of joint motion, rapid acceleration or directional change, or a rapid loading or change in tension applied to the capsuloligamentous complex. These receptors are located at ligamentous insertions of associated joint capsules and serve to initiate protective reflexes (*Sammarco 1995*).

Slow-adapting (SA) joint mechanoreceptors continue their discharge in response to a continuous stimulus (*Grigg 1994*); these receptors include Ruffini endings, Ruffini corpuscles and Golgi tendon organs. SA receptors are thought to play more of a role in joint position (*Johansson 1991*). Golgi tendon organs and Ruffini endings respond to constant pressures and slow changes and best yield information about body position as well as sensing motion and changes in the angle of rotation (*Sammarco 1995*). These receptors are sensitive to capsular stretching and serve to signal the proximity of a joint to the limits of motion (*Zimmy 1986*).

It has been suggested that muscle and joint mechanoreceptors are complementary to each other in providing afferent input in regard to limb position (*Baxendale 1988, Lephart 1997*). This relationship has been supported by the identification of neural components necessary for the sensation of motion (QA Pacinian corpuscles), joint position and acceleration (SA Ruffini endings and Ruffini corpuscles) and pain (free nerve endings) within ligamentous, cartilaginous and muscular structures of the joints (*Lephart 1997*).

Cutaneous receptors provide angle-related signals when the skin covering one side of a joint is stretched, or when the position of a joint brings skin surfaces into contact (*Burgess 1982, Grigg 1994*). Support for a role for cutaneous receptors in proprioception comes mainly from the fact that cutaneous afferent neurons, particularly slow-adapting afferents, in fact encode joint movements (*Grigg 1994*).

Similarity between cutaneous and joint receptors creates the potential to restore the loss of afferent proprioceptive input of the joint through cutaneous stimulation from a variety of external support devices (*Sammarco 1995*).

5.2 LITERATURE REVIEW OF PROPRIOCEPTION

There are two contradictory views of the physiology of joint proprioception, early works claimed that proprioception was a result of stimulation of joint mechanoreceptors only, and that muscle receptors had little involvement (*Boyd 1953, Browne 1954, Glencross 1982, Provins 1958*). *Grigg (1973)* worked towards a reversal of the joint mechanoreceptor theory, suggesting that some mechanism other than joint receptors was signalling position and velocity of movement and that this mechanism would be muscle spindles (*Glencross 1981*). In an unpublished paper, *Graham (1973)* concluded that previous evidence suggests that almost all proprioceptive information originates from receptors in the region of the joint capsule.

Previous research has highlighted the importance of feedback from capsular and ligamentous mechanoreceptors to the reflex stabilisation of the joint (*Freeman 1965*), perception of joint position and movement (*Wyke 1967*), muscle activation (*Stokes 1984*) and the control of muscle spindle systems (*Johansson 1991*) influencing the stability of the joint.

Freeman (1965) hypothesised that trauma to mechanoreceptors of the lateral ligaments can produce a proprioceptive deficit in the ankle. These investigations also hypothesised that the decrease in sensory input from these receptors may lead to faulty ankle joint positioning and could increase the probability of re-injury (*Feuerbach 1994*), resulting in partial deafferentation of articular mechanoreceptors leading to chronic ankle instability (*Freeman 1965*).

All authors come to the conclusion that beside the proprioceptive receptors of the joint capsule and ligaments, skin and muscle receptors give information about the position and movement of the joint (*Jerosch 1995*). The relation of the different receptors to the corresponding proprioceptive perception remains speculative because of the limited test conditions. Probably a complex interaction of several receptors is responsible for a precise proprioception of the ankle joint. The deficit of joint receptors caused by trauma cannot completely be compensated by other proprioceptors or exteroceptors (*Jerosch 1995*).

Historically, ankle injury rehabilitation and prevention have focused on muscular strengthening while neglecting the most common cause of functional instabilities, proprioceptive deficits (*DeCarlo 1986*). In recent years, more emphasis has been placed on proprioceptive ankle disk training, designed to assist in re-educating the proprioceptive mechanism to minimise co-ordination problems (*Freeman 1965, Gauffin 1988, Hoffman 1995, Tropp 1984, 1988a*). Proprioceptive deficits were originally quantitatively measured by *Freeman (1965)*, using a modified Romberg test. This test was used to subjectively and objectively measure proprioception. In more recent studies, stabilometry has been adopted as a common means of objectively determining and detecting proprioceptive deficits and qualitatively measuring proprioception (*DeCarlo 1986, Hoffman 1995, Tropp 1984*).

5.2.1 Literature Review of Investigative Measures of Ankle Joint Proprioception

Kinesthesia (sensory modality of touch that encompasses the sensation of joint movement) and joint position sense are components of proprioception. Functionally, kinesthesia is assessed by measuring the threshold to detection of passive motion, while joint position sense is assessed by measuring reproduction of passive and active positioning. The evaluation of reflex capabilities is often assessed by measuring the latency of muscular activation to involuntary perturbations via electromyographic interpretation. Functional assessment of the combined peripheral, vestibular and visual contributions to neuromuscular control is best accomplished through the use of balance and postural sway measurements for the lower extremity (*Lephart 1997*).

Diener (1984) examined the role of proprioception by ischaemic blocking of afferent fibres or regional anaesthesia and concluded that information from pressure and/or joint receptors in the foot plays an important role in postural stabilisation. *Hertel (1996)* induced anaesthesia of the lateral ankle joint and measured the effect on proprioception by assessing centre of balance and postural sway measurements. The findings suggest that inhibition of the joint afferent fibres adversely affects joint proprioception while subjects are weightbearing, but not while non-weightbearing, confirming the findings of *Diener (1984)* that information from joint and pressure receptors of the foot has an important role in postural stabilisation.

Other researchers also attempted to simulate joint deafferentation by injecting local anaesthetic into the ankle joint and also found that passive joint position sense decreases significantly following anaesthesia (*DeCarlo 1986, Feuerbach 1994, Konradsen 1993*).

Inferences regarding ankle joint proprioception from measurements of postural sway have been made by some investigators. These studies, in which attempts have been made to corroborate the hypothesis of *Freeman (1965),* have produced conflicting results (*Feuerbach 1994*). *Freeman (1965)* observed the amplitude of unilateral postural sway was greater when subjects attempted to balance on the injured ankle in comparison to the uninjured contralateral ankle. *Tropp (1984)* reported no difference in unilateral sway amplitude between injured and uninjured subjects. Those studies that have shown that lateral ankle sprains do have an adverse effect on postural sway include *Cornwall (1991), Garn (1988), Itay (1982), Lentell (1990)* and *Orteza (1992)*.

Garn (1988) investigated the effect of unilateral ankle sprains on cortical pathway measures of proprioception by measuring the ability of a subject to properly sense a passive movement or no movement state in the sagittal plane and also reported balance deficits on the injured side compared with the uninjured side. Deficits in the ability to actively replicate passive ankle and foot positioning in the sagittal plane was reported by *Glencross (1981)* while testing the sprained ankle versus the contralateral uninjured ankle.

Gross (1987a) reported that an increased probability of re-injury occurs as a result of a decrease in sensory input from joint receptors, leading to abnormal body positioning and diminished postural reflex responses.

In addition, the peroneal response to sudden inversion stress has been investigated by electromyography. This technique provides immediate feedback concerning the time to onset of the response of the peroneal muscles to an induced inversion stress. This is used as an indicator of the extent of proprioceptive function in the ankle joint and muscles (*Nawoczenski 1985*). It was also found by *Konradsen*

(1990) that chronic ankle instability resulted in a prolonged peroneal reaction time in response to sudden inversion stress when compared with age-matched controls, corroborated in studies by *Brunt (1992), Karlsson (1992b).* The study by *Nawoczenski (1985)* showed no statistical significance between injured and non-injured ankle peroneal response, though there was an indication of a trend in delay of motor response of the peroneals in the injured ankles.

Indirect examination of proprioception through measurements of postural sway has not produced a consensus regarding the effect of ligament injury on ankle joint proprioception (*Feuerbach 1994*). Conflicting results have also been reported when investigations directly examined proprioception by measuring the ability of injured and uninjured subjects to match reference ankle joint positions in two dimensions (*Feuerbach 1994*).

5.3 EFFECT OF INJURY ON PROPRIOCEPTION

Freeman (1966) proposed that the basic mechanism of ankle instability following joint injury develops due to the lesion of mechanoreceptors in the joint capsule and ligaments. These receptors are stimulated both by the static position and by motion of the joint (*Bullock-Saxton 1995*). *Freeman (1965)* also suggested that the afferent nerve fibres in the capsule and ligaments of the foot and ankle sub-serve reflexes which help to stabilise the foot during locomotion and that a sprained ankle can be considered as a partial deafferentated joint. *Bullock-Saxton (1995)* suggested that the 'give-way' foot is a result of impaired reflex stabilisation of the foot.

It is apparent that changes in the sensory input can cause alterations in muscle function. The likelihood that changes in sensory information contribute to damage or degeneration of a joint has also been supported (*Barrett 1991*). When considering a sprained ankle, it is reasonable to assume that a complete rupture, or repeated ruptures of the talofibular ligaments would result in damage to the receptors in the ligament and capsule, and that such damage would be likely to influence the afferent input from that region (*Schutte 1990*).

Postural stability in standing on one leg has been shown to be significantly decreased in untrained subjects following ankle sprain (*Tropp 1984*), implying some loss of integrity of the sensory motor system (*Bullock-Saxton 1995*). The notion that signals from muscle spindle afferents are important in minimising the consequences of small internal disturbances would imply that postural instabilities should increase when inputs from spindle afferents are eliminated (*Evarts 1981*).

Joint and muscle injury is associated with direct damage to the immediate tissue and atrophication due to the resultant immobility (*Glencross 1981*). Rehabilitation of the injury is associated with the recovery of 'normal' functioning inferred from the range of joint movement, attainment of normal strength and full use. However, it is likely that subtle changes or differences still exist in the injured limb; in particular proprioception may be distorted due to the direct injury of sensory receptors and breakdown of servo-control system. The implications of such damage are important, particularly in skilled performance, where proprioception plays an important role in the control, organisation and the timing of actions (*Glencross 1981*). If healthy subjects can increase their proprioception, then the incidence of functional disabilities may decrease (*Hoffman 1995*).

Acute adaptations to use have been shown to occur in both the muscle spindles and Golgi tendon organ pathways. This short-term activation adaptation increases the excitability of the motorneuron pool. The results of the relatively limited research on chronic adaptations of proprioceptors due to exercise has shown that on a micro-level, the intrafusal muscle fibres may show some metabolic changes but do not show hypertrophy (*Hutton 1992*).

Lateral ligament injuries of the ankle may result in various degrees of mechanical instability (*Brostrom 1965*). A major ankle inversion injury causes damage not only to the lateral ligaments of the talocrural joint, but also in varying degrees to the talocrural capsule, the capsule and ligaments of the subtalar joint, peroneal tendons and other supportive tissue of the lateral ankle (*Brostrom 1965, Holmer 1994, Konradsen 1998, Meyer 1988*). Proprioceptive nerve endings in these structures will also be damaged by the acute trauma (*Freeman 1967, Konradsen 1998, Newton 1982, Wyke 1972*).

Brand (1977) questioned the traditional view of ligaments as merely mechanical restraints and speculates that the neurosensory importance of the ligaments may approach that of their mechanical effect. Because voluntary movements initiated at the cerebral cortex may be too slow to prevent injury, it is speculated that short-loop or spinal reflexes may be capable of a more timely response. Triggering these protective spinal reflexes during an 'at-risk' manoeuvre may play an even greater role in joint stability than the voluntary response (*Laskowski 1997*).

Joint receptors have an important role in protecting the integrity of joints if they are unstable (*Grigg 1994*), feedback from muscles, joints and associated tissues mediated by proprioceptive reflex systems is required to adjust the motor program to irregularities (*Dietz 1992*). Injury to a joint may cause direct or indirect alterations in sensory information provided by mechanoreceptors as they are located within joint capsules, ligaments and joint structures (*Bullock-Saxton 1995, Schutte 1990*). Direct trauma may lead to ligament and capsule tearing, which may rupture the nerve fibres because they have less tensile strength than collagen. The consequent destruction of the messages to and from the joint receptors then causes deafferentation and proprioceptive loss (*DeCarlo 1986, Freeman 1965, Laskowski 1997, Schutte 1990*). It has been suggested that diminished sensory input from damaged articular mechanoreceptors at the ankle in turn may promote decreased motor control, leading to the clinical concern of functional instability (*Lentell 1995*).

5.4 PROPRIOCEPTIVE TRAINING

Central to the return of proprioception in ankle sprains is the integration of balancing and co-ordination exercises into the rehabilitation protocol. *Freeman (1965)* advocated early mobilisation and co-ordination training using balance board exercises, with a notable reduction in proprioceptive deficit. *Tropp (1984)* found a significant improvement in ability to balance on the injured ankle after a six week regimen of balance board exercises and *Glencross (1981)* summarised that rehabilitation was as much of a re-learning process as it was a physical recovery from sprain. The outcome of improved proprioception is to ameliorate the dynamic stability of the ankle joint and play a protective role.

The principle behind proprioceptive training is the same as that for proprioceptive rehabilitation; to retrain altered afferent pathways to enhance the sensation of joint movement. Proprioceptively mediated neuromuscular control of joints takes into account the three distinct levels of motor activation within the central nervous system. Reflexes at the spinal level mediate movement patterns that are received from higher levels of the nervous system. This action provides for reflex joint stabilisation during conditions of abnormal stress about the articulation and has significant implications for rehabilitation (*Kennedy 1982*). The use of exercises that facilitate dynamic joint stabilisation may result in the improvement of this neuromuscular mechanism.

The second level of motor control, located within the brain stem receives input from joint mechanoreceptors, vestibular centres and visual input from the eyes to maintain posture and balance of the body. Reactive neuromuscular activities that allow this pathway to process input from the afferent stimuli can be used to enhance brainstem function (*Lephart 1997*).

The highest level of central nervous function provides cognitive awareness of body position and movement in which motor commands are initiated for voluntary movements. Use of the cortical pathway allows movements that are repeated and stored as central commands to be performed without continuous reference to consciousness. Proprioceptive training is the type of activity that can enhance this function. Encouraging maximum afferent discharge to the respective CNS level must be the goal in stimulating joint and muscle receptors. To stimulate reflex joint stabilisation, which emanates from the spinal cord, activities should focus on sudden alterations in joint positioning that necessitate reflex neuromuscular control. Enhancing motor function at the brainstem level can be achieved by performing balance and postural activities, both with and without visual input (*Lephart 1997*).

Maintenance of functional joint stability of the ankle is suggested to be dependent upon dynamic neuromuscular control of excessive motion and would therefore benefit from proprioceptive training techniques (*Lephart 1998*). Proprioceptive training in pre-season conditioning has been shown to be of benefit as a preventative method (*Payne 1997, Tomaszewski 1991*) and a critical component of rehabilitation programs (*Burton 1993, Payne 1997, Tropp 1985b*).

5.4.1 Literature Review of Effect of Proprioceptive Training on Proprioception

Freeman (1965) reported that patients with ankle and foot sprains treated an average of five times with balance-board exercises had a significant reduction in proprioceptive deficits as evidenced by their standing ability on the injured leg improving (*Garn 1988*). *Tropp (1985c)* reported a significant improvement in subjects balance ability on the sprained ankle as measured by stabilometry, after a six-week regimen of balance-board exercises. Improved ankle stability with balance-board exercises may potentially be caused by increased muscle strength or improved co-ordination.

Thus, according to research proprioceptive training enables injured subjects to reduce proprioceptive deficits and increase postural control. However, the effects of proprioceptive training had not been researched in healthy subjects (*Hoffman 1995*), until the study by *Hoffman (1995)*. It was found that proprioceptive training in healthy subjects leads to a significantly decreased postural sway in both medial-lateral and anterior-posterior directions (*Hoffman 1995*). The incorporation of ankle disk proprioceptive training in rehabilitation has been proven to decrease functional instabilities of the injured ankle (*DeCarlo 1986, Garn 1988, Sahlstrand 1978*) and the incidence of re-injury (*Tropp 1984*). Therefore it seems reasonable to hypothesise that proprioceptively training the uninjured ankle may lend itself towards preventing injury by increasing the proprioceptive potential of the ankle.

5.5 PROPRIOCEPTIVE TAPING

Whereas taping was once thought to stabilise the ankle mechanically, this now seems unlikely considering reports that show no measurable stabilising effect of tape after as little as 20 minutes of exercise (*Perlman 1987*). Accordingly, ankle taping is now thought to prevent ankle injury mainly through improving the user's judgement of position and orientation of the plantar surface with respect to the leg. This theory supposes that uniting the skin of the foot with the leg by ankle taping provides cutaneous sensory cues of plantar surface position and orientation through traction of tape on skin. This information could be used in anticipation of foot contact with a surface; either to position the plantar surface before the support phase to attenuate forces causing inversion, or to command muscle support to sustain these forces, thereby preventing ligament loading, or both (*Robbins 1995*). There is support for the notion that traction of tape on the skin of the leg and foot is used to judge foot position (*Karlsson 1993, Robbins 1995*). Due to the different fitting characteristics of taping techniques, a variable stimulus of cutaneous receptors may be responsible for modulation of neuromuscular activity (*Scheuffelen 1993*).

5.5.1 Literature Review of Effect of Taping on Proprioception

Ankle proprioception is widely regarded as an important factor that affects susceptibility to ankle sprains but the precise mechanisms by which proprioceptive abilities may enhance ankle stability are not well understood (*Wilkerson 1994*).

Adhesive taping has been popular form of external support for a long time, however, recent studies have questioned the effectiveness of the taping over time with vigorous activity. *Rarick (1962)* found that 40% of the total support strength conferred by ankle taping was lost after 10 minutes of vigorous exercise. *Myburgh (1984)* reported no significant restriction of ankle motion after one hour of athletic activity with ankle taping. Although mechanical stability obtained by the taping may drop off quickly, the taping may continue to serve a role in proprioceptive feedback.

Glick (1976) using electromyographic analysis of runners, found that ankle taping allowed the peroneii muscle group to contract for a longer period of time at the pre-heel strike stage in four mechanically unstable ankles. From this it was concluded that tape stimulated the peroneal tendons without decreasing muscle tone, thus serving a dynamic action in addition to a mechanical one.

Karlsson (1992b) used a trapdoor mechanism on twenty subjects with chronic ankle instability. Evaluation of mechanical stability with stress radiographs discovered little difference in anterior drawer or talar tilt, either with or without taping. It was found that the Gibney basketweave technique significantly shortened the reaction time of the peroneii muscle group in the injured ankle, thus bringing it closer to times on the normal side. It was also noted that the more unstable the ankle, the greater the improvement. As well as the peroneii muscle group, deficits can be shown in tests for passive joint angle reproduction. This gives further insight into the complexity of functional instability of the ankle and the effect of external support.

Proprioception has also been evaluated by postural sway and single leg balancing tests. *Robbins (1995)* evaluated the effect of taping on estimation of perceived direction and amplitude on a surface slope in full weight bearing. In contrast with *Jerosch (1995)*, it was concluded that ankle taping did improve foot position awareness and so may have a role in the prevention of ankle sprain.

Bennell (1994) reported that for healthy subjects, the use of tape had a significantly detrimental effect on proprioception measured by postural sway. In comparison, the use of elastic bandage had no significant effect. Restriction of ankle movement was given as a possible explanation for the results, since postural control was impaired only by the ankle supports that limited ankle motion.

Robbins (1995) reported that attaching a piece of tape from the foot to the leg provided sensory cues to foot position and so improved foot position awareness and countered underestimation of foot position angle caused by athletic footwear. However, this improvement was still found to be poor in comparison with foot position sense when barefoot (*Robbins 1995*), therefore suggesting that most ankle injuries are not inherent to sport, but rather are caused by footwear. This provides evidence of the potential usefulness of ankle taping to judge foot position and increase proprioception.

Functional and proprioceptive capabilities of ankle joints of healthy subjects and those with unstable ankle joints have both been tested (*Jerosch 1995*). The influence on the ankle joint of taping during single leg stance, single leg jumping and angle reproduction tests was evaluated. Scores on the single leg-jumping course were better without any stabilising device. However, in the other two tests, scores with support were worse compared with the unsupported condition.

Differentiation of the results between injured and non-injured ankle joints shows higher improvement in the injured ankle joints with use of support. Positive influence was regarded as an effect of the additional proprioceptive and exteroceptive sensory perception (*Jerosch 1995*). The close contact of support to the skin probably gives an additional feedback regarding joint position (*Jerosch 1995*). Both ankle taping and the wearing of orthoses have been demonstrated to significantly decrease the amount of medial-lateral mobility of the ankle joint complex and diminish the incidence of repeated sprains (*Alves 1992, Lentell 1995, Tropp 1985a, Vaes 1985*).

The neural mechanisms underlying biomechanical function of ankle braces/taping however, have not been fully explained (*Nishikawa 1996*) and it is thought that ankle support applications may increase the afferent feedback from cutaneous receptors, which may in turn lead to an increased motorneuron excitability with external support, which may involve a motor control mechanism sub-serving their effectiveness (*Nishikawa 1996*).

5.6 SYNOPSIS OF PROPRIOCEPTION

- Proprioception is an awareness of posture, movement and changes in equilibrium, providing dynamic joint stability via muscular reflex encompassing static and dynamic position sense.
- The perception and execution of musculoskeletal control and movement are mediated primarily by the CNS receiving input from the proprioceptive, vestibular and visual sensory subsystems.
- Cutaneous and joint receptors possess the potential to restore loss of afferent proprioceptive input through stimulation.
- Functional assessment of the combined peripheral, vestibular and visual contributions to neuromuscular control is accomplished through balance and postural sway measurements of the lower extremity.
- Changes in sensory input from mechanoreceptors due to injury can cause alterations in muscle function and hence proprioception loss.

- Proprioception deficits may be rectified by balance and co-ordination exercises, retraining the afferent pathways to enhance the sensation of movement and neuromuscular control of the joint.
- Taping may provide a variable stimulus to cutaneous receptors responsible for the modulation of neuromuscular activity.

CHAPTER SIX

CHAPTER 6: MEASUREMENT OF PROPRIOCEPTION BY POSTURAL STABILITY AND ELECTROMYOGRAPHY

The previous chapter discussed what proprioception and the effect of injury and support/training methods on proprioception mean. This chapter follows on to discuss the measurement of proprioception of the ankle by investigations into postural stability and electromyography.

6.1 POSTURAL STABILITY

Proprioception is a distinct component of balance (*Mattacola 1997*). It is the ultimate neural input to the CNS from the mechanoreceptors in the joint capsules, ligaments, muscle tendons and skin. When these structures are subjected to mechanical deformities, action potentials are conducted to the CNS where the information can influence muscular response and position sense (*Mattacola 1997*). The integration of afferent neural input to the CNS contributes to the body's ability to maintain postural stability (*Mattacola 1997*).

Although a seemingly simple task, maintaining equilibrium or balance while standing upright is an important motor skill. Balance is a complex process involving co-ordination of multiple sensory motor and biomechanical components (*Guskiewicz 1996a*). The body of an apparently motionless, standing individual undergoes continuous automatic postural sway of which the person is unaware (*Irrgang 1994, Nashner 1976*), attempting to keep the centre of gravity over the base of support. These motions occur as both anterior-posterior and left-right oscillations, that is, in the sagittal and frontal planes. These compensatory movements of the centre of gravity ensure the maintenance of posture through the complex mechanisms of the central nervous system (*Berg 1989*).

Several strategies are used to maintain balance, including ankle, hip and stepping strategies. These strategies adjust the body's centre of gravity so that the body is maintained within the base of support to prevent loss of balance or falling (*Irrgang 1994*). The centre of gravity refers to a point in the body at which the total force of gravity is considered to act and that is projected vertically onto the support surface (*Nichols 1995*). Balance may be disturbed when its centre cannot be properly sensed or when corrective movements are not executed in a smooth and co-ordinated fashion (*Bernier 1998*). Motions at the ankle can compensate small disturbances in the centre of gravity. Anterior sway is counteracted by gastrocsoleus activity, which pulls the body posteriorly. Conversely, posterior sway of the body is counteracted by contraction of the anterior tibialis muscle (*Irrgang 1994*).

The three balance senses (vestibular, proprioceptive and visual) work in combination and are all critical to the execution of co-ordinated postural corrections. Impairment of one component is usually compensated for by the other two (*Bernier 1998*). Sensory organisation is a process by which all three senses receive input and a determination is made whether any of the input is misleading.

The postural control system operates as a feedback system with the musculature of the legs, feet and trunk using this feedback to allow the individual to stand erect against the forces of gravity (*Guskiewicz 1996a, Guyton 1986, Jansen 1982*). Feedback obtained from the visual, proprioceptive and vestibular sensors relay commands to the muscles of the extremities, which then generate appropriate contraction to maintain postural stability (*Guyton 1986, Nashner 1993*). Sports participation requires high-level postural control as volitional movements and external perturbations continually threaten the stability of the body during high-speed activities (*Bennell 1994*).

Mechanoreceptors provide information to the three movement systems (reflex, automatic and voluntary) which aid the regulation of balance. The myotatic stretch mechanism is the first mechanism to react. An externally imposed rotation or increased load to the joint triggers muscle spindles to increase activity in the muscle and improve muscle stiffness properties. The second system, which is the first effective response to control balance, comes from the automatic systems. They too are triggered by external perturbations. The third system involved in balance control is the voluntary system. Voluntary and automatic responses are often used in conjunction with each other, with automatic responses occurring first, followed by voluntary purposeful behaviours (*Nashner 1981*).

Various methods exist to measure postural stability encompassing functional balance tests using tilt-boards, one-footed balance and stepping tests. These tests can be evaluated solely by the clinician or using a variety of machines on the market. Machines such as the Chattecx Balance System (Chattecx Corporation), the Equitest (Neurocom International) and the Biodex Stability System (Biodex Medical Systems) evaluate static and dynamic balance using force plate stabilometry to measure body sway and centre of force elements of postural stability to enable definition of proprioceptive status and ability.

6.1.1 Measuring the Relationship between Postural Stability and Proprioception

Development of high technologic systems to assess the effects of musculoskeletal injury on balance has occurred in an attempt to quantify both static and dynamic components of proprioception (*Guskiewicz 1996b*). The method of evaluation is based on the notion that damage to joint proprioceptors after injury to the lateral ligamentous complex of the ankle diminishes afferent feedback from the injured joint, thereby resulting in increases in postural sway (*Freeman 1965*).

Tropp (1985c), when comparing a group of football players with previous ankle sprains to a control group of uninjured football players observed no increase in postural sway. Furthermore, no differences in postural sway were found between the involved and uninvolved ankles in a group of football players with a history of unilateral, recurrent ankle sprains (*Tropp 1985c*). However, significant increases in postural sway were observed by *Cornwall (1991)* when comparing patients with acute ankle sprains with uninjured controls as long as two years after their injuries.

6.1.2 Proprioceptive Training and Postural Stability

Empirical evidence exists suggesting that proprioceptive training techniques after acute and chronic ankle injuries are highly effective (*Lephart 1997*). It has been demonstrated that balance training enhances the ability to maintain upright standing posture in individuals with a previous history of ankle sprains (*Rozzi 1996*). It was also found that improvements in balance performance following a four-week training period appeared to be greater in individuals with previously reported ankle sprains as compared with uninjured participants (*Rozzi 1996*).

One way of measuring the effect of proprioceptive training on proprioception is to investigate the outcome on postural stability.

6.1.2.1 Literature Review of the Effect of Proprioceptive Training by Postural Stability Measurement

Few investigations into the effect of proprioceptive training on postural stability have been made. Of those in the literature, the length of training varies between six and twenty-four weeks though *Tropp (1988a)* found that no further effects on postural control were seen after ten weeks of proprioceptive training.

The method of proprioceptive training of the ankle joint in all cases was by a wobble-board and, in the investigations by *Mattacola (1997)* and *Balogun (1992)* also incorporated strength training.

In all studies, an increase in balance performance as evidenced by a decrease in postural sway was found (*Balogun 1992, Bernier 1998, Gauffin 1988, Hoffman 1995, Mattacola 1997, Tropp 1988a*). *Balogun (1992)* suggested that the increase in balance performance obtained using healthy subjects may be associated with improved joint mechanoreceptor functioning and that the wobble-board motion may stimulate the mechanoreceptor feedback mechanisms.

Despite these investigations, still remaining unanswered is the question of whether proprioceptive training influences injury incidence and whether the decreases in postural sway are due partially or solely to motor learning or to a physiological training effect.

6.1.3 External Support and Postural Stability

Ankle taping and bracing has been suggested to have a proprioceptive benefit (*Lephart 1997*). The theoretical rationale is that potentially injurious ankle inversion can be reduced by the use of an ankle support to enhance the neuromuscular response (*Loos 1984*). Some evidence suggests that tape and braces are effective in fulfilling the desired goal of reducing incidence of ankle injury (*Garrick 1973, Rovere 1988, Tropp 1985b*) by either mechanical restriction or proprioceptive mechanisms or a combination of both.

6.1.4 Literature Review of the Effect of Ankle Support on Postural Stability

Varieties of methodologies have been used to evaluate the effect of ankle support on postural control (*Friden 1989, Hamer 1992, Thompson 1984, Tropp 1984*). Most studies evaluate single-leg stance, although one study by *Calmels (1991)* tested subjects in the less challenging task of two-legged stance.

Measurement techniques have included the use of a force-platform (*Friden 1989, Tropp 1984*), statokinesimeter (*Calmels 1991*), instrumented wobble-board (*Hamer 1992*), digital balance evaluator (*Thompson 1984*) and visual observations (*Thompson 1984*).

Thompson (1984) reported ankle supports to have a detrimental effect on postural control, whereas *Friden (1989)* reported a positive effect. Other studies failed to find any significant effect of ankle support on postural control (*Calmels 1991, Hamer 1992, Tropp 1984*).

It is apparent that conflicts exist in the literature with regard to the effects of ankle support on postural control. These conflicting results may reflect differences in research design with the various methods chosen to assess postural steadiness (*Bennell 1994*), sampling differences of both normal and ankle injured subjects, the use of a variety of ankle supports, including various taping techniques and differences in testing protocols such as the addition of eye closure to the balance test and length of the balance trial.

Mechanical restriction of ankle joint motion, especially that of plantar flexion and inversion varies widely, depending on the type of support (*Bunch 1985, Greene 1990b, Gross 1987b*). Therefore, any difference in ankle support effects on postural control may reflect variations in the restrictive properties of such supports (*Bennell 1994*). The mediolateral axis corresponds to the direction in which inversion loading of the ankle lateral ligaments occur and therefore, the axis in which ankle supports aim to restrict motion (*Bunch 1985, Greene 1990b, Gross 1987b*).

It appears that many supports limit not only the extremes of movement where ligament damage occurs, but also the motion necessary for normal function. This may lead to alteration in normal movement strategies and subsequent deterioration in skill level (*Burks 1991, Juvenal 1972, Mayhew 1972, Robinson 1986*).

By examining the components of postural control, the finding that restrictive ankle supports impair postural control can be explained. In a simplified form, the postural control system consists of three levels: the input, central processing and the output. The three sensory systems (visual, vestibular and proprioceptive) provide input to the central nervous system. At the central level, the afferent information is processed to enable organisation of appropriate motor responses. Cognitive input at the central processing level forms part of the feed-forward system. This system enables body adjustments to occur prior to movement in anticipation of equilibrium changes (*Patla 1990*). The output of the system consists of postural movements necessary for stabilising upright stance.

The use of ankle support could feasibly influence the postural control system at the input or output level, leading to impaired functioning of the overall system and resulting in a measurable impairment in postural control. At the input level, ankle support may alter the nature or amount of proprioceptive input to the central nervous system. Proprioceptive input from the ankle is received from various receptors, including muscle spindles, Golgi tendon organs and joint and cutaneous receptors (*Proske 1988*). In the task of upright stance, this provides important information about the position of the body in relation to the support surface (*Nashner 1976*).

As well as affecting the input of the postural control system, restriction of ankle movement by ankle supports may also affect the output level of the system. The task of controlling posture in upright stance requires the output response of co-ordinated muscular activity across several joints. It has been proposed that this response occurs by specific spatial-temporal muscle activation patterns or strategies (*Duncan 1990, Horak 1990, Nashner 1977*). The most common response to subtle perturbations involves an ankle strategy (*Horak 1990*). In this strategy, moving the body primarily around the ankle joint restores equilibrium. Muscle activity begins in the ankle joint musculature and radiates proximally in sequence (*Nashner 1977*). By limiting ankle joint movement, the brace or tape may physically prevent a normal ankle strategy from being used and so the subject would then be forced to adopt an abnormal strategy in order to maintain balance, resulting in decreased postural control (*Bennell 1994*).

An explanation for the perceived detrimental effect of external supports on postural control in some reports is that important proprioceptive input normally induced by ankle motion is decreased as a result of the restrictive ankle support. By using electromyography and body sway measures, studies have confirmed the importance of ankle movement in providing proprioceptive information necessary for influencing rapid corrective responses (*Nashner 1976, 1983, Shumway-Cook 1986*). Another, though less likely theory, is that inaccurate, conflicting or overwhelming stimulation of the cutaneous receptors may be a factor responsible for a detrimental effect (*Watson 1987*). Underlying this suggestion is the assumption that cutaneous input is important for the stabilisation of upright posture. However, the relative contribution of cutaneous input to the postural control system is not clear (*Bennell 1994*). It is generally believed that information from the muscle spindles and Golgi tendon organs play an important role in postural control, whereas that from cutaneous receptors is of minor importance (*Diener 1984, Horak 1990, Mauritz 1980*). This implies that postural control would not be greatly impaired by any change in cutaneous input resulting from ankle support. Conversely, other researchers have concluded that cutaneous input does have an important role in assuring that postural movements are appropriate for the current biomechanical constraints of the surface or foot (*Horak 1990*). Even if cutaneous input is important for postural control, it is still not clear how this might explain the differential effects of different supports (*Bennell 1994*).

6.1.4.1 Literature Review of the Effect of Tape on Postural Stability

The effect of tape on postural control in both normal and injured ankles has been investigated (*Hamer 1992, Thompson 1984, Tropp 1984*). *Thompson (1984)*, using a modified Romberg Test to assess static balance, observed that tape adversely affected postural control in football players in the eyes closed condition. This result indicates that taping may have a detrimental effect when postural control is challenged to a greater extent by closing the eyes in a one-legged stance. When the eyes are open, visual input may be able to adequately compensate for any detrimental effects due to tape.

Other studies have failed to find that tape significantly altered postural control. *Tropp (1984)* tested football players with functional ankle instability as they balanced on a wobble-board with and without taped ankles – eyes open. A force platform was used to measure centre of pressure in the frontal and sagittal planes. No significant difference was found between taped and untaped ankle conditions, although there was a trend towards improvement when tape was applied.

Hamer (1992) tested subjects with an instrumented wobble-board and postural control was assessed by measuring the time in contact, the number of contacts and average time in contact that the wobble-board made with a metal base plate. It was determined that ankle taping had no significant effect on postural steadiness before, during or after fifteen minutes of exercise. Similarly, *Thompson (1984)* reported that when a digital balance evaluator was used to assess dynamic balance, tape had no significant effect on postural control, contrasting with the negative effect of tape observed when static balance was tested.

From these studies, it appears that ankle tape has no effect on postural control when eyes are open (*Hamer 1992, Tropp 1984*). However, when postural control is challenged in one-legged stance with the eyes closed, some evidence is available to show that tape has a detrimental effect (*Thompson 1984*).

6.1.4.2 Literature Review of the Effect of a Brace on Postural Stability

Friden (1989) used stabilometry to measure postural equilibrium control in the frontal plane during single leg stance for healthy controls and subjects with unilateral ankle injury, both with and without an ankle brace. When the brace was used, none of the parameters showed any significant difference compared with the injured leg; however, body sway allowed discrimination between injured and uninjured legs.

Kinzey (1997) reported on subjects with no history of ankle injuries wearing ankle braces. It was expected that wearing a brace would improve proprioception, which would be evident as a decrease in the movement of centre of pressure. The reported results were that wearing a brace caused the subject's average centre of pressure to increase in both the anterior and lateral directions, without increasing the total path travelled. The authors gave three reasons to provide explanation of these seemingly adverse effects. The first being that the braces force the subject's ankle into a dorsiflexed and everted position, resulting in the subjects feeling that they are falling forward and, so to keep from falling, the invertors and plantar flexors contract concentrically, causing the centre of pressure to travel more anteriorly and laterally (*Kinzey 1997*). This concentric contraction is met with the resistance of the brace and therefore, the subject never overcorrects and is constantly fighting the feeling of falling forward by contracting the invertors and plantar flexors.

Secondly, the ankle braces force the subject into a position that requires the large plantar flexors and assisting invertors to control the position via eccentric contractions. This explanation contradicts the first because the subject is comfortable in the new position and uses eccentric muscle contractions to control the centre of pressure movement.

The third explanation is that the brace provides a strong mechanical restriction that causes the subject to change the strategy used to control posture. Normal adults prefer to control posture using the muscles that cross the ankle joint (*Horak 1987*). This ankle strategy allows subjects to respond to most low-level postural disturbances without much centre of pressure displacement. However, if rapid changes in the centre of pressure displacement are necessary, movement at the hip is often used. The hip strategy flexes the trunk to control posture and the resulting position of the centre of pressure is more anterior.

Bennell (1994) concluded that ankle bracing adversely affects the postural control of normal subjects. This may be true when the sensory systems (proprioceptive, visual and vestibular) controlling posture are affected by the ankle brace alone. During test conditions that confuse or eliminate the visual or proprioceptive inputs, ankle bracing was not found to affect postural stability. This finding suggests that the adverse effect on postural control attributed to ankle bracing is not strong enough to alter the integration of the systems controlling posture when the conditions are abnormal.

6.1.5 Synopsis of Postural Stability

Studies by *Byl (1991)* and *Murrell (1991)* have shown that postural sway is inversely proportional to stationary balance, where stationary balance represents the centre of gravity over the base of support when the body is not moving. Balance measuring systems have been used clinically to measure postural sway in the elderly (*Lord 1991, Patla 1990*), patients with low back dysfunction (*Byl 1991*), athletes (*Tropp 1984*) and patients with neurological disorders (*Daley 1983, DiFabio 1991*).

Proprioception is one of three senses critical to the execution of co-ordinated postural corrections or postural stability. Feedback from these proprioceptive, visual and vestibular senses, relays commands to the muscles to generate appropriate contraction to maintain balance. Thus one way of examining whether external factors have an effect on proprioception, is to measure the outcome of their influence on postural stability.

It is still not known whether the change in balance ability seen during bracing/taping is due to a change in muscle activity about the ankle joint, or the mechanical properties of the external support. Along with this, there is interest in the notion that proprioceptive balance training will enhance the ability to maintain upright standing posture and consequently improve proprioception.

This therefore warrants investigation into the outcome of both taping and proprioceptive training of the ankle on postural stability as a measure of proprioception. It also sanctions investigation into the muscular response of the ankle to taping and training in an effort to explore their proprioceptive effects and the connotations that this may have in the decision to use prophylactic support.

6.2 ELECTROMYOGRAPHY (EMG)

Electromyography is a technique for recording the changes in potential of skeletal muscle that occur when it is triggered by a motor nerve to contract and as such, is the only method of objectively measuring when a muscle is active (*Basmajian 1985*).

Muscle activity is essentially composed of depolarisation and repolarisation of the surface membrane of the muscle fibre. The cellular unit of contraction is the muscle fibre, but it is the sarcolemma or fibre membrane that is responsible for the transmission of an impulse to the interior of the fibre where the actual response of the contractile mechanism occurs. The point at which a terminal ending of a nerve fibre ends on the muscle fibre is situated on the sarcolemma and the ionic flow between the nerve ending and the sarcolemma initiates depolarisation (*Clarys 1993*).

The muscle cells are arranged in muscle fibres that connect to tendons at opposite ends of the muscles. Small groups of fibres contract at the same time because the terminal branches of the same axon supply them. A nerve cell body, its axon and terminal branches constitute a motor unit (*Clarys 1993*). An impulse descending the nerve axon will activate all muscle fibres innervated by the same axon, almost simultaneously. When depolarisation of a muscle fibre occurs, it propagates in both directions along the fibre and, accompanied by a movement of ions, generates an electrical field in the vicinity of the muscle fibres. The EMG signal indicates motor unit activation; the electrical signal propagating from a single motor unit is in the form of a train of individual spikes (*DeLuca 1979*).

The detected waveform resulting from this event is a muscle fibre action potential (MAP). The spatio-temporal summation of the MAPs from all of the fibres of a given motor unit is a motor unit action potential (MUAP) and a repetitive sequence of MUAPs is a MUAP train (*Basmajian 1985*). The EMG signal recorded is a modified version of this physiological signal.

The spatio-temporal nature of the EMG is illustrated by the manner in which muscle force is modulated in normal motor activities. An increase in the force generated by a muscle is produced by a combination of two mechanisms (1) an increase in the discharge frequency or a firing of each neuron and (2) an increase in the number or active motor units (*Hillstrom 1995*). The first mechanism represents a temporal recruitment and hence muscle action potentials are generated at faster and faster rates. The latter describes a spatial recruitment as increasingly more motor units contribute to the contraction. The recruitment scheme employed to modulate force appears to vary from muscle to muscle, though in general, smaller muscles appear to rely primarily on firing rate and larger muscles rely primarily on motor unit recruitment to modulate force (*Hillstrom 1995*).

EMG allows the study of changes in muscular activity during skill acquisition as a result of training or additions to the 'natural' form of the body, such as different footwear or orthoses. EMG enables the assessment of the sequential and temporal order of muscle activation and provides an objective method of validating any assumptions made in modelling the dynamics of the human musculo-skeletal system.

6.2.1 Surface Electromyography

From the surface, the EMG signal is detected with a pair of electrodes separated from the skin by an electrolyte that has a homogeneous dispersion of cations and anions. In this way, the metallic electrodes may sense the changing distribution of charges occurring about the muscle fibres.

The surface electrode recording produces a signal representative of the overall electrical manifestation of the contracting muscle and is the grand average of the underlying electrical activity.

6.2.1.1 Electrodes

The electrode is the first link in the recording chain and whilst indwelling electrodes are essential for the study of deep muscles and for isolating small numbers of motor units, surface electrodes are ideal for measurement of activity in superficial muscles along with being safer, easier to use and more acceptable to the subject (*Grieve 1975*).

6.2.1.2 Electrode Placement

A common earth and two detector electrodes are used for each muscle. Two detector electrodes are necessary because otherwise the EMG signal would be swamped by mains hum. When using surface electrodes, the skin resistance should be reduced as much as possible. This is done by first shaving the area and then thoroughly cleansing and degreasing it using a clean tissue moistened with acetone.

The two detector electrodes should lie over the visual midpoint of the contracted muscle, with the orientation of the electrode pair being on a line parallel to the direction of muscle contraction (*Zipp 1982*), then each electrode will essentially see the same voltage at the same time (*Hillstrom 1995).*

The passive surface electrode is the most common type of electrode used and usually comprises of a disk of silver/silver-chloride, up to 1cm in diameter used in combination with chloride containing conducting gels, as these electrodes are good for low polarisation voltages. The surface electrode provides a general representation of muscle activity, although cross-talk may occur, which is when signals from muscles other than those being investigated are recorded at the electrode site through volume contraction (*Hillstrom 1995*). Inter-electrode spacing of 1cm is used for surface electrodes, as this spacing is compatible with the architecture of most muscles in the human body (*Hillstrom 1995*).

The electrode/electrolyte interface acts as a high pass filter discarding some of the lower frequencies. The bipolar configuration changes the biphasic nature of the depolarisation/repolarisation wave to a triphasic one (*Winter 1979*) and acts as a band-pass filter by removing some low and some high frequency content.

6.2.1.3 EMG Amplifiers and Cables

Amplifiers provide linear amplification of the EMG signal recorded at the electrodes. The frequency response of the amplifier is determined by the frequencies of the EMG signal. Typical values of bandwidth for surface electrodes are 10 Hz to 1000 Hz, with most of the signal in the range 20 Hz to 200 Hz, which also contains mains hum at 50 Hz.

The amplifier gain, which is the ratio of output voltage to input voltage, should ideally be variable in the range of 100 to 10000 to suit the recording device. The input signal will ordinarily be in the range of 0.1mV (for a single MAP) to 5mV (*Winter 1979*).

The importance of skin resistance can be minimised by using an amplifier with high input impedance (at least 100 times the skin resistance).

The use of a single electrode would result in the generation of a biphasic repolarisation wave, which would also contain common mode mains hum at approximately 100mV. By recording the difference in potential between two electrodes, the hum is largely eliminated and the wave becomes triphasic in nature. The smaller the electrode spacing, the more closely the triphasic wave approximates to a time derivative of the single electrode wave. The use of a differential amplifier (battery powered) enables hum to be removed as it is picked up commonly at each electrode because of the body acting as an aerial. In practice, perfect elimination is not possible and the preferable Common Mode Rejection Ratio (CMRR) is 80dB or more.

Cables can cause problems known as movement artifacts with frequencies up to 10 Hz. The use of high-pass filtering and high quality shielded cables along with careful taping of the cables to reduce their movement can minimise these.

6.2.2 EMG and Muscle Tension

As a muscle's tension is regulated by varying the number and firing rate of the active fibres, and as the amplitude of the EMG signal depends on the same two functions, it is reasonable to speculate that a relationship does exist between muscle tension and EMG (*DeLuca 1990*). Assuming this is the case, assessment of proprioception via EMG is deemed to be a rational supposition as stimulation of mechanoreceptors causes alteration in muscle function and variation in muscle tension as a consequence of a change in the number and firing rate of active fibres in the muscle directly affecting EMG output.

6.2.3 Literature Review of EMG Measurement of Proprioception

Increasing research has been directed at electromyography (EMG) of ankle musculature in reflex stabilisation responses to postural sway (a component of proprioception) in the frontal coronal and sagittal planes (*Sammarco 1995*). *Dietz (1982)* demonstrated the role of spinal stretch reflexes in equilibrium by measuring EMG responses of the anterior tibial tendon when individuals were subjected to an anterior sway on a balance board. They noted co-ordinated right to left leg muscle activation at a spinal level to provide a symmetric leg muscle EMG during balancing.

DiFabio (1991) contradicted prior findings that muscle patterns were pre-programmed and centrally driven. Subjects were tested using a forward body sway test and a hand-held response keypad to signal the onset of postural disturbance. EMG measurements were simultaneously obtained from the gastrocnemius muscle. The authors felt that surface orientation information obtained from the ankle contributed to an 'online' correction of a wide range of postural disturbances. They proposed that balance was an automatic neuromuscular response of proprioception that was peripherally driven and occurred on a subconscious level.

Not all studies have correlated a latency of peroneal muscle activity with proprioceptive deficits in injured ankles. *Isakov (1986)* found no significant difference in peroneal EMG activity with sudden inversion displacement in either previously sprained or unsprained ankles. The authors concluded that contraction of peroneal musculature was due to an arc stretch reflex and played no role in ankle joint protection; mechanical damage was felt to occur before recruitment. This notion was supported by *Nawoczenski (1985)*, who noted a trend in delay of peroneus longus motor response that was not statistically significant when compared with that in uninjured ankles using an inversion stress test.

6.2.3.1 Literature Review of the Effect of External Support on EMG Measurement of Proprioception

Sprigings (1981) undertook an investigation into the effectiveness of external supports in influencing the role of a primary everter during the application of an ankle inverting torque by EMG analysis of the peroneus longus. Subjects performed a backward step-down movement, during which a trapdoor in the lower platform collapsed to form a potential ankle-inverting angle of 30°. It was concluded that preventive ankle strapping had no statistically significant effect on the tension developed in the peroneus longus during a quick inversion of the ankle joint. Also concluded was that external support did not take the place of muscle activity in the peroneus longus during the ankle inverting step. Therefore, taping did not prevent the ankle everters from being exercised during an activity. *Felton (1981)* also found that preventive ankle taping had no statistically significant effect on the tension developed in the peroneus longus muscle during a quick inversion of the ankle joint and thus no proprioceptive effect.

Karlsson (1992b) examined the effect of ankle taping on reaction time of the peroneus muscles by electromyography after a simulated ankle sprain on a tilting trapdoor. The study was undertaken on both ankles of athletes with unilateral ankle instability and found that the reaction time was significantly slower in the unstable ankle than in the stable contralateral ankle. With tape, the reaction time was significantly shortened in the unstable ankle and the greatest improvement in reaction time was achieved in ankles with the highest degree of mechanical instability. The study concluded that the tape has an effect on the proprioceptive function of the ankle as evidenced by the reduction in reaction time of the peroneal muscles during inversion torque, with tape.

6.2.3.2 Literature Review of the Effect of Proprioceptive Training on EMG Measurement of Proprioception

In the literature to date, there does not appear to be any investigation into the effect of proprioceptive training on proprioception as measured by EMG. However, a study by *Soderberg (1991)* investigated the magnitude and temporal features of tibialis anterior, peroneus longus and gastrocnemius muscle activity during exercises performed on a Biomechanical Ankle Platform System (BAPS) board by subjects with normal and chronically sprained ankles.

The study establishes that both the magnitude and duration of response do not differ when healthy subjects are compared with subjects with chronically sprained ankles, and concludes that therapists could use this information to exercise patients in certain ranges of movement on the balance board to instigate higher levels of activity in certain muscles.

With this conclusion in mind, it would appear to be useful to use electromyography to investigate the effect of proprioceptive training on postural stability as a measure of proprioception, to clarify whether the proprioceptive training of healthy ankles does result in higher levels of activity in the muscles of the lower leg.

6.2.4 Electromyography Summary

Electromyography is a technique used for measuring muscle activity and appraising changes in that activity. There is debate concerning the use of EMG in the assessment of proprioception since stimulation of mechanoreceptors causes alteration in muscle function and variation in muscle tension. This consequently results in a change in the number and firing rate of active fibres in the muscle, which is depicted in the EMG output.

CHAPTER SEVEN

CHAPTER 7: PROCEDURES AND EQUIPMENT

This chapter explains and qualifies the use of equipment and various procedures throughout the study.

7.1 OVERVIEW OF STUDY

The research study is concerned with the idea of proprioception and prevention, foremost, the prevention of ankle injury in football, by either taping or proprioceptively training the ankle.

Over the course of a season in football, a variety of injuries are sustained, predominantly in the lower limb (*Ekstrand 1983b*). Therefore, prevention of injury is an important topic for research. The consequences of injury in football are, among others, a loss of team continuity in a game and time lost to both the player and the club with regard to rehabilitation and training, which may also have further consequences. Thus, there is a need to reduce the incidence of injury, especially within the professional game.

To establish a background for the research and confirm previous reports on football injuries, a survey of injuries occurring at a professional football club over two seasons was undertaken. The results from this first part of the study will provide a basis for investigating the influence of taping and proprioceptive training on ankle proprioception and thus determine an effect of their possible use in prophylaxis.

As the literature highlights ankle sprains as the most common injury to occur in football (*Schmidt-Olsen 1991, Sullivan 1980*), increasing attention has been focused on protection of the ankle during participation. Despite the widespread use of tape in this capacity, few studies have been concerned with the effect on athletic performance as a prophylactic device. Of those studies that have evaluated the effectiveness of tape under various experimental conditions, a consensus of opinion has not been reached regarding whether or not taping affects athletic performance significantly. It is however generally agreed that tape loosens with exercise (*Beynnon 1991, Fumich 1991, Greene 1990a*). With tape loosening, comes a concomitant decrease in mechanical restriction, which raises the question of a possible proprioceptive effect of tape. If taping is proved to have a beneficial proprioceptive effect at the ankle when used for prophylaxis, this may also suggest that proprioceptive training would influence ankle proprioception in healthy subjects and thus be a useful tool in prevention of injury.

If there is a possibility of using either means to prevent injury, their effect upon performance should be investigated to rule out any negative effects that they may have and the actual proprioceptive influence of both taping and proprioceptive training must be examined to enable clarification for their best use.

7.2 PROCEDURE FOR INJURY DATABASE

A survey of injuries was conducted over the 1996-1997 and 1997-1998 football seasons at a second division club in the National Football League investigating injuries incurred by both professional and youth players. The results were then compiled into an injury database from which important facts and trends could be determined.

The survey took the form of a questionnaire, which was filled in by the physiotherapist at the football club when he was presented with an injured player that fitted the criterion for inclusion.

For the 1996-1997 season, for an injury to be included in the survey it had to have occurred either during training or a match and result in absence from training or a match. For the 1997-1998 season, in addition to the fore mentioned definition, inclusion also required a minimum of three days treatment. The reason for this was to highlight the impact of more severe injuries. The same questionnaire was used in both seasons, but as it was filled in post-injury rehabilitation, some information was unobtainable.

The injury questionnaire (*Appendix A1*) took the form of tick boxes to enable fast completion and consistency of results. Included in the information requested was the team the injured player was playing for or training with at the time of injury, their playing position and whether they were injured during a match or in training. This enabled the information to be segregated into First/Reserve team and Youth team, so that injury incidences at the two levels of play could be investigated as well as highlighting injuries incurred by players at different positions. The questionnaire also asked for the type and location of injury to the player, the activity of the player at time of injury as well as external factors such as the day, month and weather conditions. The information obtained was used to compile injury incidence information and highlight any trends in incurred injuries.

Once the questionnaires had been completed by the physiotherapist, they were collected every month and the information from them collated and entered into Paradox (Borland Intl. Inc 1994), a database software package. The database was then used to provide information on injury incidence levels and the seasonal occurrence of injuries, along with more in-depth facts such as the type of injury sustained and activity at time of injury.

7.3 METHODOLOGY FOR ATHLETIC PERFORMANCE TESTS

An important consideration for any prophylactic measure is whether it has an effect upon performance. As other studies have assessed athletic performance, these were used as a basis for deciding which tests to use in order to be able to compare reports and discern the most useful information.

Four tests of athletic performance were chosen in order to investigate the effect of taping and proprioceptively training the ankle. These were vertical jump, broad jump, sprint run and shuttle run. Although these tests cannot all be directly related to performance in football, they do assess aspects of performance abilities that if affected by prophylactic measures may result in a change in overall performance ability of the player.

7.3.1 Performance Tests

Vertical Jump

This test measured the difference between the standing reach and the jumping reach of a subject. The subject chalked the fingers of their right hand and then standing perpendicular to a wall facing to the left, they reached up and marked their maximum reach on the wall. Next, from the same position, the subject jumped as high as possible and again marked their maximum reach on the wall with their chalked fingers. The distance between these two marks was measured to the nearest 0.5cm. The average of two such tests was the vertical jump height.

Broad Jump

This test measured the distance jumped by a subject from a double-footed standing start. A line was drawn on the floor of the gymnasium, which the subject stood behind. With their feet together, toes up to the line, the subject then jumped as far forward as they could, landing on two feet and remaining standing. The floor was then marked at the furthest point that the toes reached. The distance from the standing line and the marked line was measured to the nearest 0.5cm. The average of two such tests gave the broad jump result.

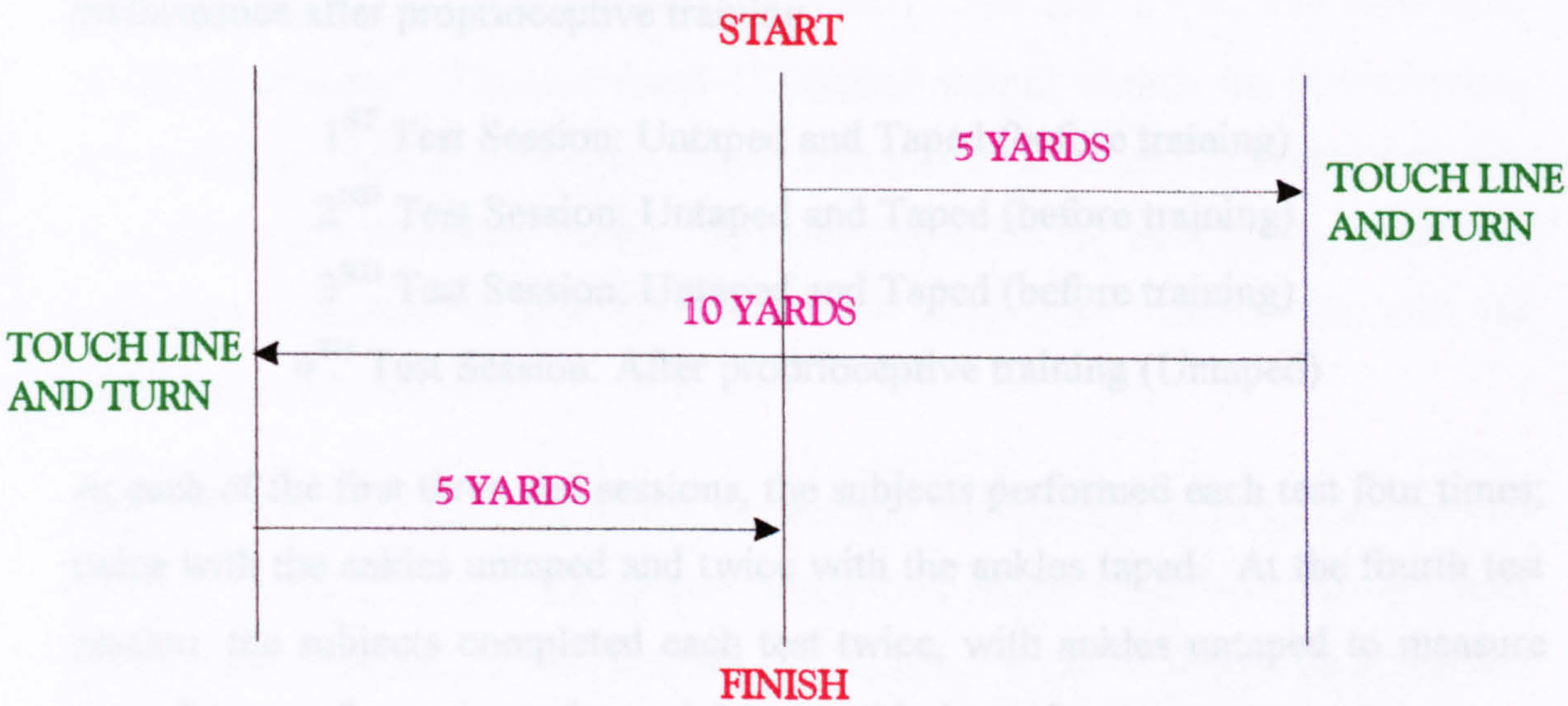
Sprint Run (40 yards)

The sprint run measured the time taken for the subject to sprint a distance of 40 yards. This test took place outside, on a tarmac surface in an enclosed area. A line was drawn on the ground (start line) and a distance of 40 yards was measured, a finish line marking this distance. The subject stood behind the start line and on the signal of the investigator's arm dropping, they sprinted as fast as they could until they passed the finish line. A stopwatch measured the sprint run time. Timing began from the same start signal as the subject, to the point at which the subject crossed the finish line to the nearest 0.01 of a second. The average of two such tests gave the sprint run time result.

Shuttle Run

The shuttle run test was a measure of the time taken by the subject to complete a 20 yard shuttle run (*Figure n° 71*), adapted from *Bocchinfuso (1994), Burks (1991), MacPherson (1995)*.

Figure n° 71 Shuttle Run



Three lines were marked on the ground, a distance of 5 yards between the lines as illustrated above. The middle of these three lines was the start and finish line. The subject stood to the left of the start line, facing the investigator and on the start signal (the investigator dropping their arm), turned and ran 5 yards to their left, bending and touching the line. Then turning, the subject ran 10 yards in the opposite direction, crossing the middle line to the furthest line which as before, they then touched and again turning ran back crossing the finish line. The time from the start signal to the subject crossing the finish line was recorded to the nearest 0.01 of a second using a stopwatch. The average of two tests gave the subject shuttle run time.

7.3.2 Athletic Performance Subjects

Twenty subjects from the youth squad of a second division football club, all of whom denied prior ankle injury within the last year, volunteered to participate in the study. The mean age of the subject group was 17.5 years, the mean weight 72.29Kg and mean height 170.92cm. All subjects completed an informed consent form (*Appendix n° A2*).

7.3.3 Athletic Performance Test Procedure

Testing was performed on three separate occasions to compare conditions of ankles untaped and ankles taped and then on one further occasion to test athletic performance after proprioceptive training.

1^{ST} Test Session: Untaped and Taped (before training)
2^{ND} Test Session: Untaped and Taped (before training)
3^{RD} Test Session: Untaped and Taped (before training)
4^{TH} Test Session: After proprioceptive training (Untaped)

At each of the first three test sessions, the subjects performed each test four times; twice with the ankles untaped and twice with the ankles taped. At the fourth test session, the subjects completed each test twice, with ankles untaped to measure the influence of proprioceptive training on athletic performance.

There were approximately seven days between each of the first three test sessions and six weeks between the third and fourth test session. During this six-week period, the proprioceptive training program was carried out.

A pre-test was conducted to allow the subjects to become familiar with the performance test requirements and the procedure for data collection.

To minimise any effects upon performance due to subject fatigue, a loosening of the tape with exercise or any learning effect induced by repeated testing, the performance tests were carried out in rotation as illustrated by *Table n^o 7.1*.

Table n^o 7.1 Order of Performance Tests by Test Session and Test Condition

TEST SESSION	*Test Session One*		*Test Session Two*		*Test Session Three*		*Test Session Four*
Test Condition	**Untaped**	**Taped**	**Taped**	**Untaped**	**Untaped**	**Taped**	**Trained**
PERFORMANCE TEST	Vertical Jump	Shuttle Run	Vertical Jump	Broad Jump	Sprint Run	Broad Jump	Shuttle Run
	Broad Jump	Sprint Run	Shuttle Run	Sprint Run	Shuttle Run	Vertical Jump	Vertical Jump
	Sprint Run	Broad Jump	Sprint Run	Shuttle Run	Vertical Jump	Shuttle Run	Broad Jump
	Shuttle Run	Vertical Jump	Broad Jump	Vertical Jump	Broad Jump	Sprint Run	Sprint Run

As shown in *Table n° 7.1*, in test session one, players completed all performance tests Untaped and then Taped, in test session two, all tests were first completed Taped and then Untaped and vice versa in test session three.

Before the start of each test session, the subject completed a warm-up supervised by the investigator. This consisted of jogging around a track for five minutes, followed by stretching exercises to make sure that all muscles were fully warmed-up, with a good flexibility range. Sub-maximal trials for each performance test were also conducted so that the subject was completely comfortable with the requirements of each test.

Subjects completed each test twice, the average score being taken as the criterion measure. Subjects rested for approximately two minutes between repeated tests and ten minutes between the different performance tests. It should be noted that each subject completed the tests in isolation from fellow subjects and received no verbal encouragement during testing in order to remove any influence that these factors may have upon performance.

As previously stated, testing was completed in experimental conditions of ankles untaped, both ankles taped and after a six-week proprioceptive training regime.

7.3.4 Taping Method

Taping a joint increases mechanical joint stability directly, but may also increase proprioceptive signals that are thought to be important in the regulation of the tone of muscles, which normally helps to ensure stability (*MacDonald 1994*).

The objective of the taping method was to offer bilateral ankle stability with specific reinforcement of the lateral ligaments, restricting inversion and some eversion while allowing almost full range of dorsiflexion and plantar flexion.
For the tape application, the subject sat with knees extended and the ankle held at 90° over the edge of the table, making sure that the legs were supported mid-calf. The area to be taped was cleaned, shaved and dried to allow good contact with the skin. For the same reason, no pre-wrap was used. The tape used was 3.8cm elastic adhesive bandage, which while providing support allows flexibility at the joint.

1. Using light tension, two overlapping, circumferential anchor strips were applied at the forefoot and two below the calf bulk at the musculotendinous junction (*Figure n° 72*).

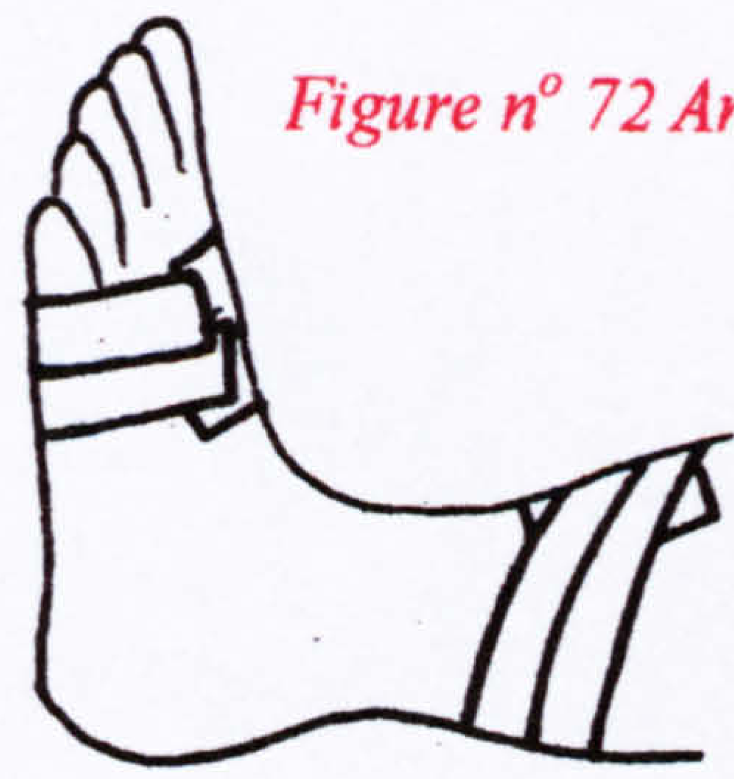


Figure n° 72 Anchors

Figure n° 73 1st Stirrup Application

2. A stirrup was applied starting from the upper anchor medially, passing under the heel, pulling up with tension and ending on the upper anchor laterally with the ankle kept at 90° throughout (*Figure n° 73*).

3. A second stirrup was applied as before, but beginning and ending more anteriorly, pulling up strongly on the lateral side.

Figure n° 74 Stirrup Application

4. A third stirrup was applied, again as before but beginning and ending more anteriorly than the second (*Figure n° 74*).

5. A proximal anchor was applied as in 1. (*Figure n° 75*).

Figure n° 75 Anchors and Stirrups

6. A first heel-lock was applied, beginning on the anterior shin, passing towards the lateral aspect of the ankle, continuing behind the Achilles Tendon, around and under the heel (*Figure n° 76*) and then pulled up over the lateral side, applying strong tension and fixing securely to the lateral upper anchor (*Figure n° 77*).

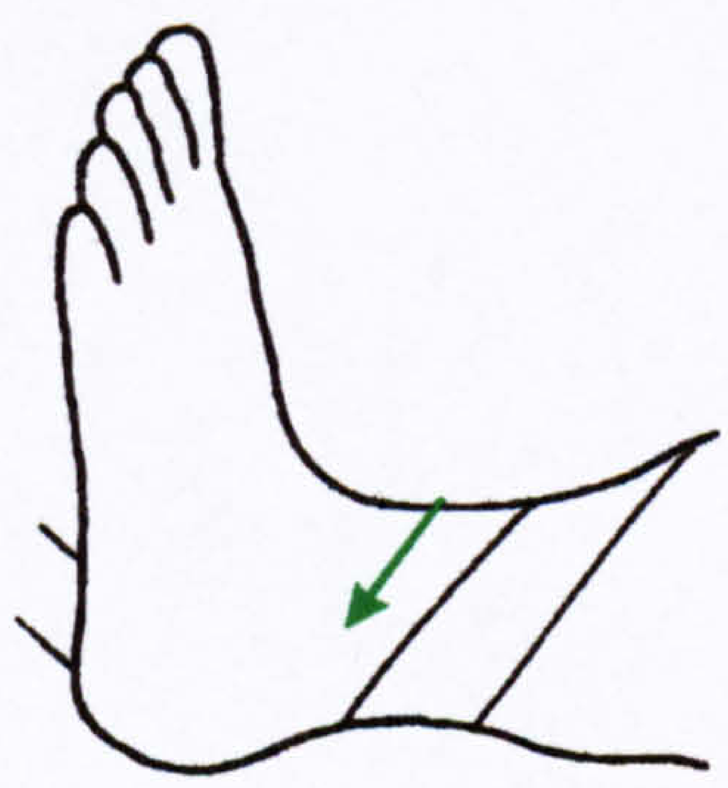
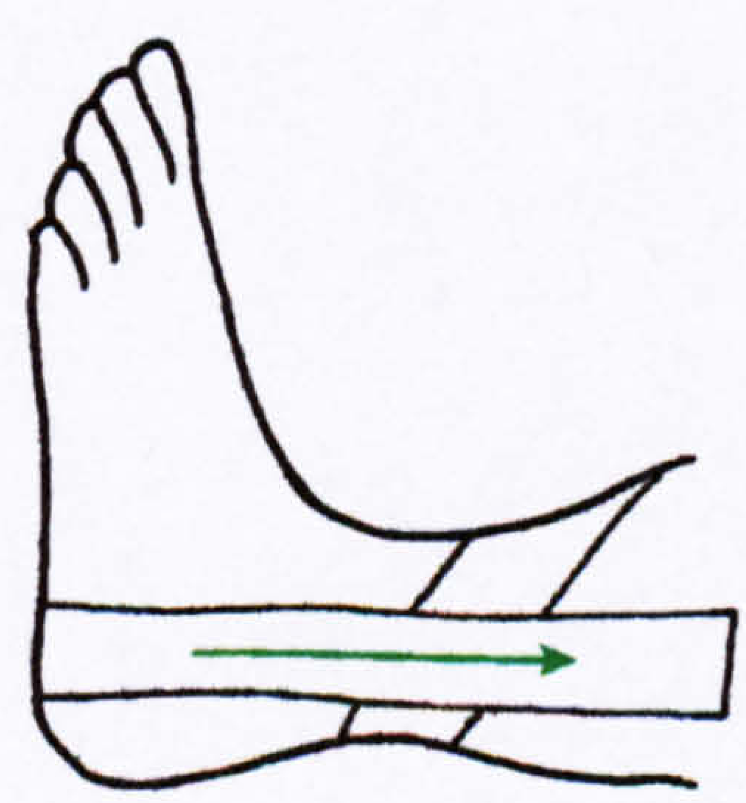


Figure n° 76 & Figure n° 77
Lateral Ankle-lock



7. The lateral ankle lock was repeated.

8. A medial ankle-lock was applied, starting and finishing on the medial side for added stability, applying only medium tension when pulling up on the medial side (*Figure n° 78*).

Figure n° 78 Medial Ankle-lock

9. A figure-8 was applied to close and reinforce the ankle. Starting anteriorly, crossing medially without tension, the tape was brought down towards the medial aspect of the ankle and passed under the foot. It was then pulled up with full tension over the lateral side before crossing the ankle anteriorly with less tension. The tape was then brought horizontally behind the Achilles tendon and finished anteriorly, crossing the starting point of the figure-8 (*Figure n° 79*).

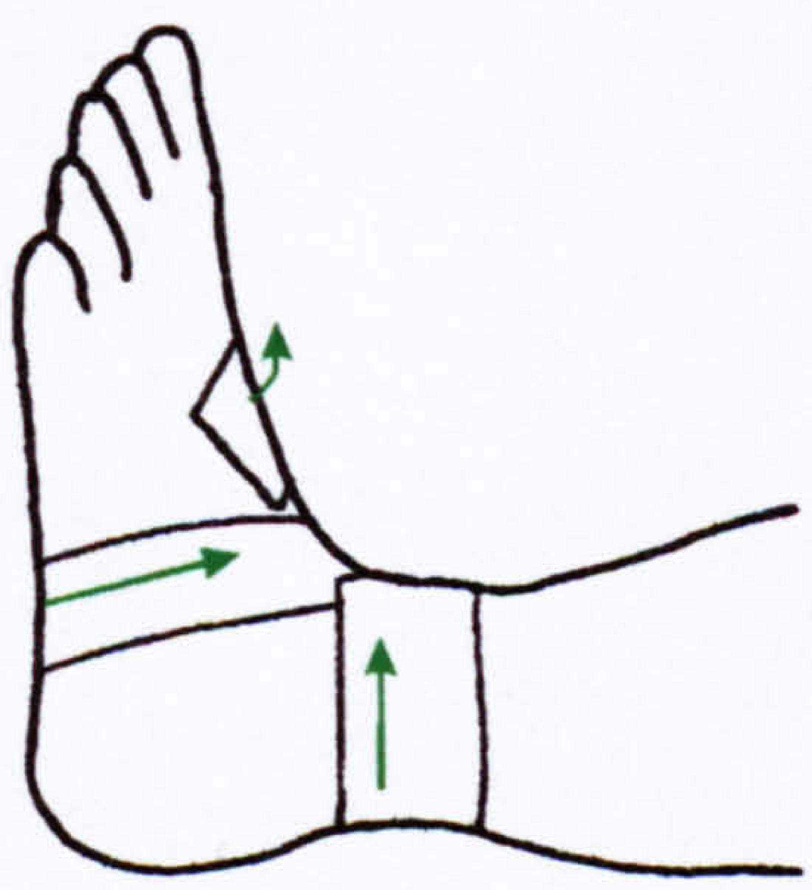


Figure n° 79 Figure-8 Taping Application

7.3.5 Proprioceptive Training Program

The proprioceptive training program was devised to progressively educate muscles and receptors in the lower leg, concerned with ankle joint motion and stability and to improve proprioception. The program consisted of three types of exercises (single leg balance, tilt-board and dynamic balance). Each exercise progressively became more difficult throughout the six-weeks in order to increase the proprioceptive ability of the ankle.

Exercises were performed three times a week, over the six-week period under supervision by the physiotherapist at the football club. The subjects performed the tests at the same time each day in the gym before training. This was to ensure compliance and accurate completion of all tasks and also to monitor proprioceptive progression.

Week One:

Single Leg Balance

Close both eyes and balance on one foot, without touch-down of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

Tilt-board/Wobble-board Training

On the tilt-board (a rectangular board approximately shoulder width in length and foot length in width fixed onto a rocking foot), balance on both feet without the sides of the board touching the ground, for 60 seconds.

Dynamic Balance

Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.

Week Two:

Single Leg Balance

(1) Close both eyes and balance on one foot, without touch-down of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

(2) Using the mini-trampoline, with eyes open, balance on one foot, without touchdown of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

Tilt-board/Wobble-board Training

On the tilt-board, balance on both feet without the sides of the board touching the ground, for 60 seconds.

Dynamic Balance

Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.

Week Three:

Single Leg Balance

(1) Close both eyes and balance on one foot, without touch-down of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

(2) Using the mini-trampoline, with eyes open, balance on one foot, without touchdown of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

(3) Using the mini-trampoline, close both eyes and balance on one foot, without touchdown of the opposite foot for a period of 60 seconds. Repeat for the other foot.

Tilt-board/Wobble-board Training

On the tilt-board, balance on one foot without the sides of the board touching the ground, for 60 seconds.
Repeat for the other foot.

Dynamic Balance

Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.

Week Four:

Single Leg Balance

(1) Using the mini-trampoline, with eyes open, balance on one foot, without touchdown of the opposite foot, for a period of 60 seconds. Repeat for the other foot.

(2) Using the mini-trampoline, close both eyes and balance on one foot, without touchdown of the opposite foot for a period of 60 seconds. Repeat for the other foot.

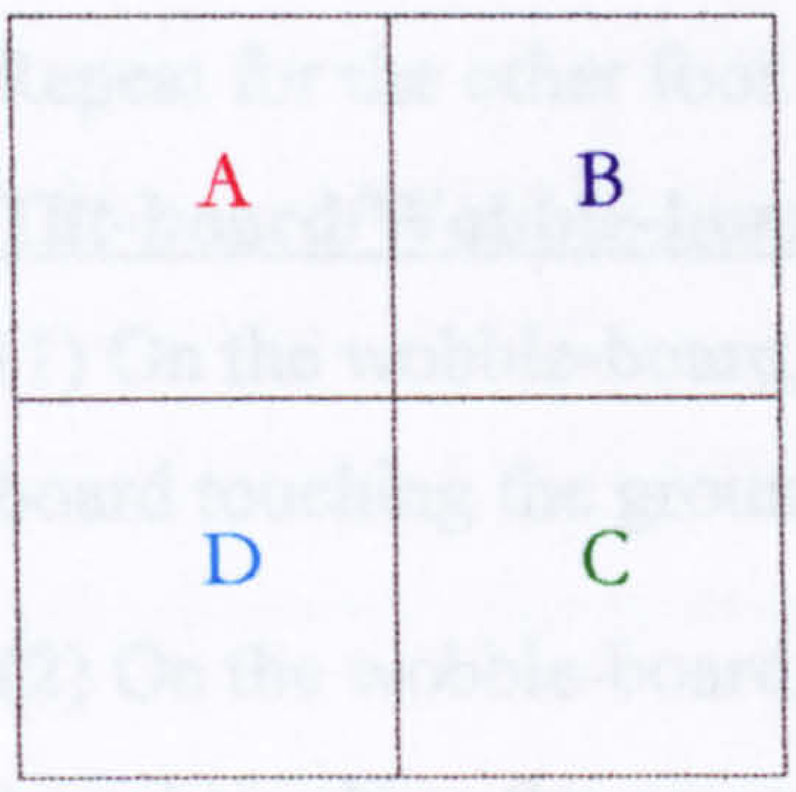
Tilt-board/Wobble-board Training

On the tilt-board, balance on one foot without the sides of the board touching the ground, for 60 seconds.

Repeat for the other foot.

Dynamic Balance

(1) Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.



(2) On one foot hop clockwise, then anticlockwise around the square – ABCD then DCBA.

Then hop diagonally – ACBD then DBCA then ACBD and finally DBCA.

Repeat on the other foot.

Week Five:

Single Leg Balance

Using the mini-trampoline, close both eyes and balance on one foot, without touchdown of the opposite foot for a period of 60 seconds.

Repeat for the other foot.

Tilt-board/Wobble-board Training

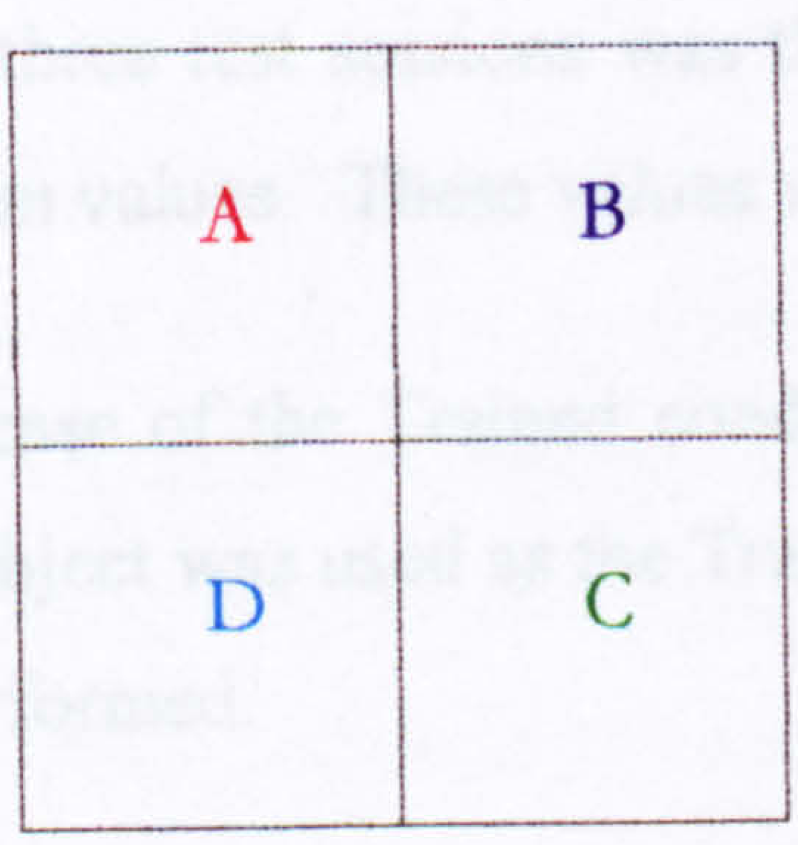
(1) On the wobble-board (a circular surface of radius 20 cm underneath which is a half sphere), balance on both feet without the sides of the board touching the ground, for 60 seconds.

(2) On the wobble-board, balance on one foot without the sides of the board touching the ground, for 60 seconds.

Repeat for the other foot.

Dynamic Balance

(1) Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.



(2) On one foot hop clockwise, then anticlockwise around the square – ABCD then DCBA.

Then hop diagonally – ACBD then DBCA then ACBD and finally DBCA.

Repeat on the other foot.

Week Six:

Single Leg Balance

Using the mini-trampoline, close both eyes and balance on one foot, without touchdown of the opposite foot for a period of 60 seconds.

Repeat for the other foot.

Tilt-board/Wobble-board Training

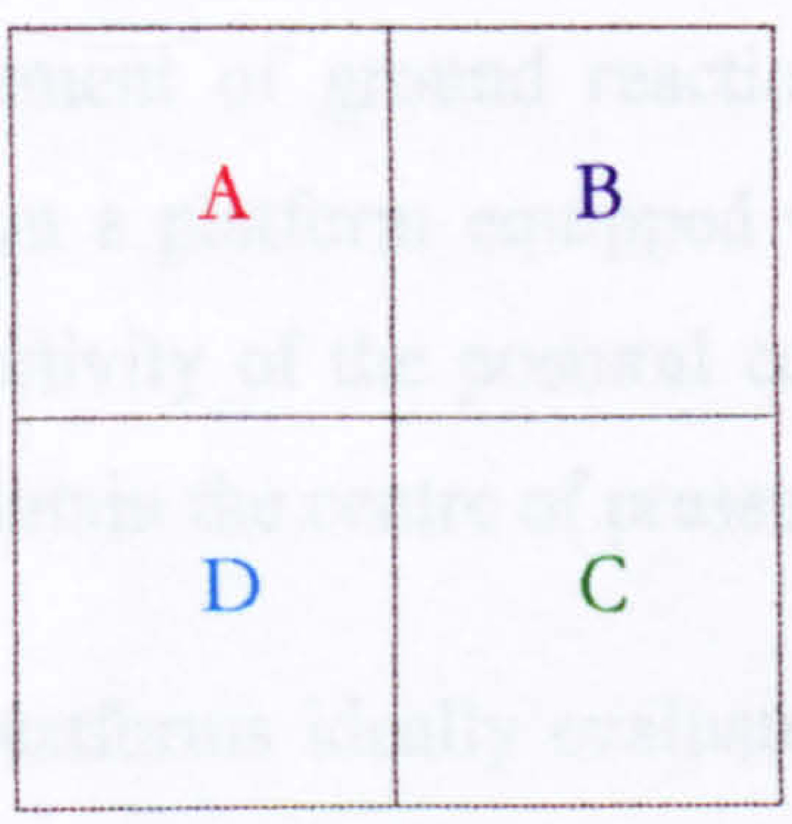
(1) On the wobble-board, balance on both feet without the sides of the board touching the ground, for 60 seconds.

(2) On the wobble-board, balance on one foot without the sides of the board touching the ground, for 60 seconds.

Repeat for the other foot.

Dynamic Balance

(1) Standing on one foot, throw a Size 5 football against a wall 3 yards away, above the horizontal line on the wall. Repeat 50 times continuously. Repeat for the other foot.



(2) On one foot hop clockwise, then anticlockwise around the square – ABCD then DCBA.

Then hop diagonally – ACBD then DBCA then ACBD and finally DBCA.

Repeat on the other foot.

7.3.6 Athletic Performance Tests Data Analysis

Within each test session, the average score of the repeated tests gave the criterion measure for the subject. For Untaped and Taped conditions, the criterion measure for the three test sessions was then averaged to give overall Untaped and Taped condition values. These values were then used for statistical analysis.

In the case of the Trained condition, the average score of the repeated tests for each subject was used as the Trained condition values on which statistical analysis was performed.

Data analysis was carried out using SPSS (Version 6.0). The analysis took the form of ANOVAs with repeated measures on the independent variable of testing condition: Untaped/Untrained, Taped and Trained.

Separate t-test analysis for paired samples was also conducted, to investigate the effect of Taped and Trained conditions upon performance in comparison with the Untaped/Untrained condition. All statistical analyses looked for significance at the 0.05 level, that is a 95% confidence that results obtained are not due to chance. Test-retest reliability was assessed by Pearson's correlation coefficients.

7.4 PROPRIOCEPTION PROCEDURE

The test of proprioception was undertaken by measurement of postural stability using the Chattecx Balance System and measurement of muscle activity by electromyography (EMG).

The most widely used method for measuring posturography is based on the measurement of ground reaction forces and centre of pressure as the subject stands on a platform equipped with force transducers. This method studies the entire activity of the postural control system by observing how well the subject can maintain the centre of pressure within the foot support base (*Barin 1992*).

Force platforms ideally evaluate four aspects of postural control: steadiness, the ability to keep the body as motionless as possible, also considered a measure of postural sway; symmetry, the ability to distribute weight evenly between the two feet in an upright stance; dynamic stability, the ability to transfer the vertical projections of the centre of gravity around a stationary supporting base (*Goldie 1989*); and dynamic balance, the measurement of postural responses to external perturbations (*Guskiewicz 1996a*).

The ability to maintain balance during standing on a single leg or both legs depends on the integrity of the visual, vestibular and nervous systems. In the presence of an intact vestibular system, standing with eyes closed depends mostly on the normal function of the various proprioceptive receptors (*Barrett 1991, Isakov 1992*). *Judge (1993)* noted an absence of a correlation between double-leg stance and single-leg stance measurements, suggesting that both postures measure different aspects of balance function. It was concluded that double-leg stance measures reflect the integrity of the proprioceptors, muscle stretch receptors, vestibular system, vision and motor control of postural muscles, but they do not require substantial strength or activation of muscle (*Judge 1993*). In contrast, single-leg stance requires active contraction of several muscle groups in addition to the systems involved in double-leg stance (*Judge 1993*).

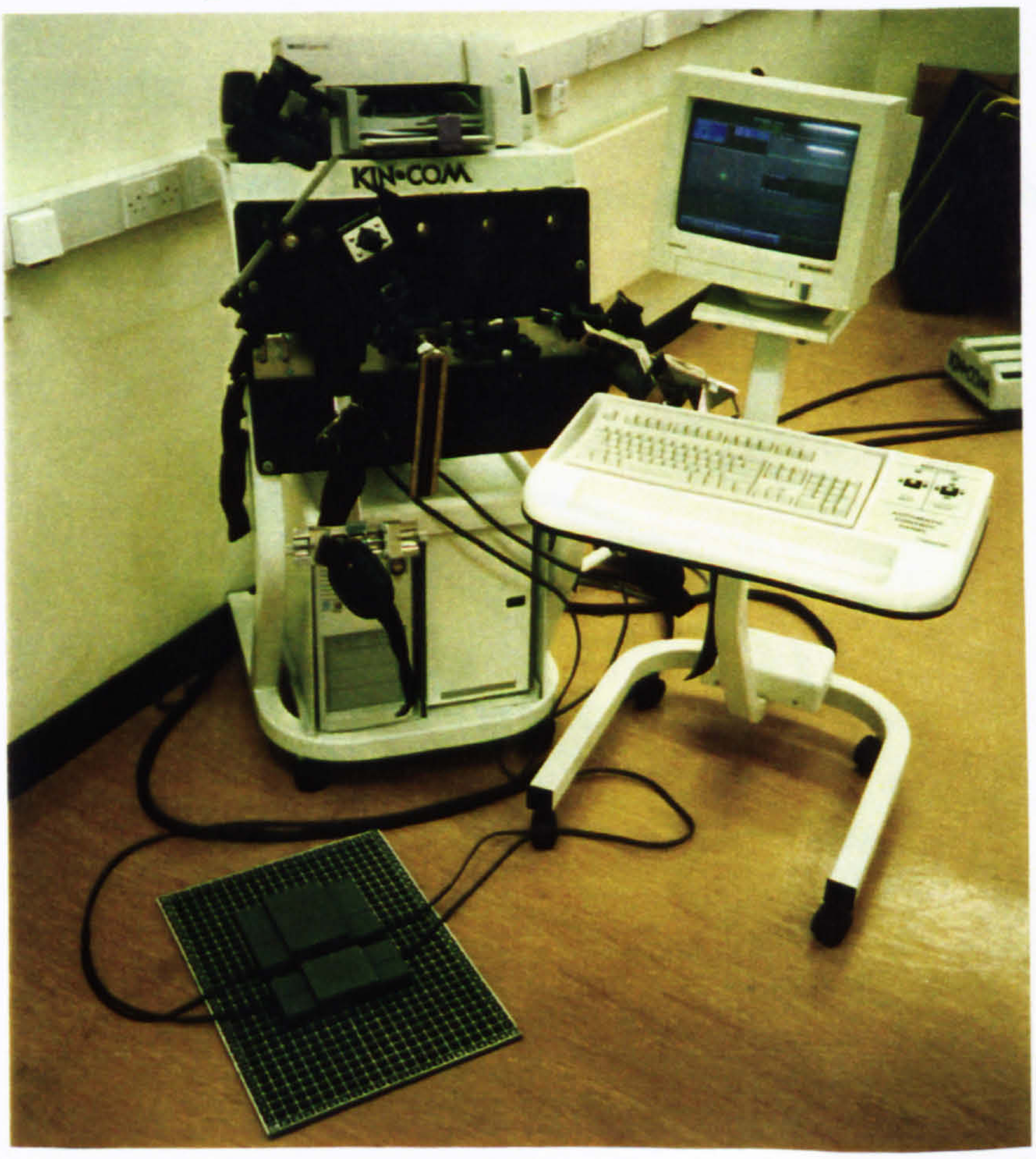
It was therefore decided to measure muscle activity by EMG during the standing balance tests as a further means of identifying proprioceptive changes that may be introduced by the test conditions.

The aim of this part of the study was to deduce by measurement of posturography and electromyography, the influence of both taping and training upon ankle proprioception.

7.4.1 Chattecx Balance System

Chattecx Balance System® from the Chattecx Corporation – part of Chattanooga Group Inc. Hixson TN (*Figure n° 710*).

Figure n° 710 The Chattecx Balance System



The principle of balance testing and training is to measure the centre of balance, postural sway and limits of postural stability. Measures of postural stability provide quantitative information about the function of the sensorimotor system involved with postural control.

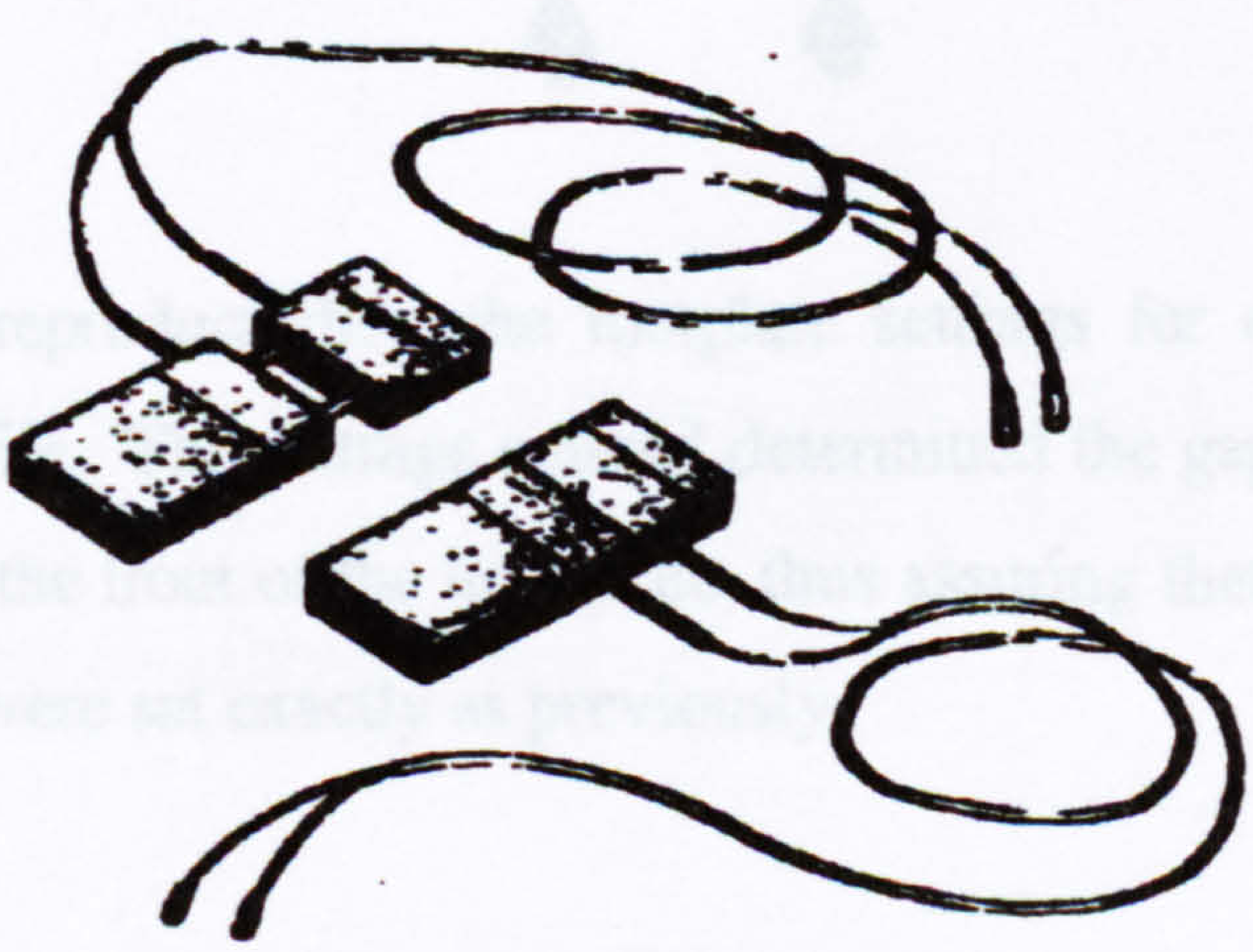
It is well known that visual information plays an important role in the regulation of posture. So a person standing eyes open will exhibit spontaneous postural sway which will increase in amplitude when the eyes are closed. With a static eyes closed balance test, the role that the proprioceptive system plays in the control of posture is being measured.

The principle of balance assessment is the measurement of body weight distribution while the subject stands on four footplates provided with electronic pressure transducers. The distribution of pressure over the four footplates shows fluctuations of weight displacements that reflect the amount and direction of postural sway in forward, backward and left and right directions. In addition, the mean centre of pressure and the percentage of time the instantaneous centre of pressure falls within the normalised five, ten, twenty, forty and sixty percentiles of body weight are computed, indicating the tendency of the preferred location of the centre of gravity in relation to the supporting area.

7.4.1.1 Footplates

Two pairs of independent force transducers, one pair for forefoot and heel of each foot comprise the footplate base (*Figure n° 711*).

Figure n° 711 Chattecx Balance System Footplates

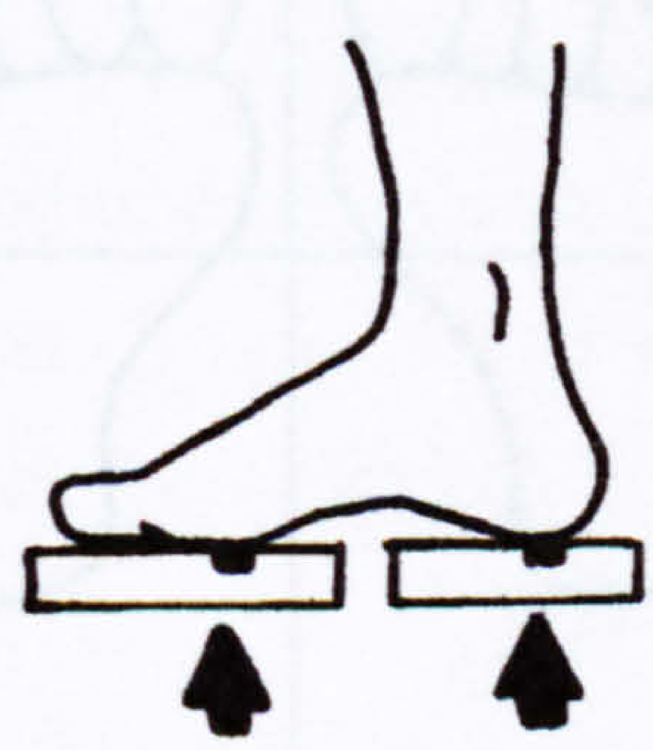


The gap between the forefoot and heel transducers is adjustable so that the plate can accommodate different foot sizes. Similarly, the distance between the two pairs of transducers is variable to enable stance at different base of support areas. Each footplate is sensitive to 5.29mV/kg to a maximum load of 170kg at a standard sample rate of 100Hz (100 samples /second) (*Chattecx Balance System Literature*). The device consists of full-bridge strain gauges whose signals are amplified by instrumentation amplifiers and transmitted to the computer for analysis. Each section of the loadcell can measure up to 54kg maximum and is calibrated to a zero reading each time the system is powered up. This self-calibration procedure eliminates the need for periodic calibration due to electronic drift or minor mechanical deformation.

7.4.1.2 Setting the Footplates

The subject stood next to the left footplate. The centre line from the toe plate was placed opposite the ball of the foot. The heel plate was then moved towards the toe plate until its centre line was opposite the centre of the subject's heel. The subject then stood on the footplate to confirm the centre lines were in the correct position (*Figure n° 712*).

Figure n° 712 Positioning of the Foot on the Footplate showing Positioning of the Centre Lines



In order to assure reproducibility, the footplate settings for each subject were stored in their data file. The settings entered determined the gap between the rear of the toe plate and the front of the heel plate, thus assuring that the footplates for a returning subject were set exactly as previously.

7.4.1.3 Double Stance Settings

Two double stance settings were used; feet together (Narrow) and feet apart (Wide).

For the feet together setting, the footplates were set as in **Section 7.4.1.2** and the corresponding right footplate was moved directly parallel to the left footplate as shown in *Figure n° 713*, so that the theoretical distribution of weight in this stance is 25% of the subject's body weight through each footplate section as shown in *Figure n° 714*.

Figure n° 713 Positioning of the Footplates for Feet Together Double Stance

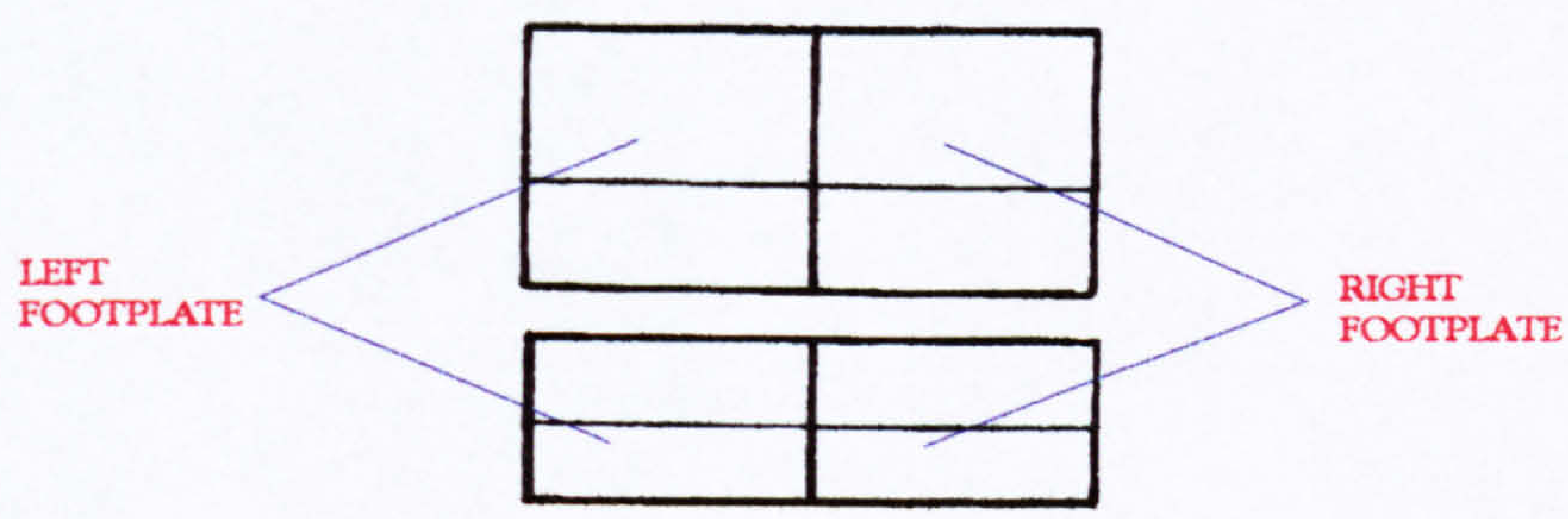
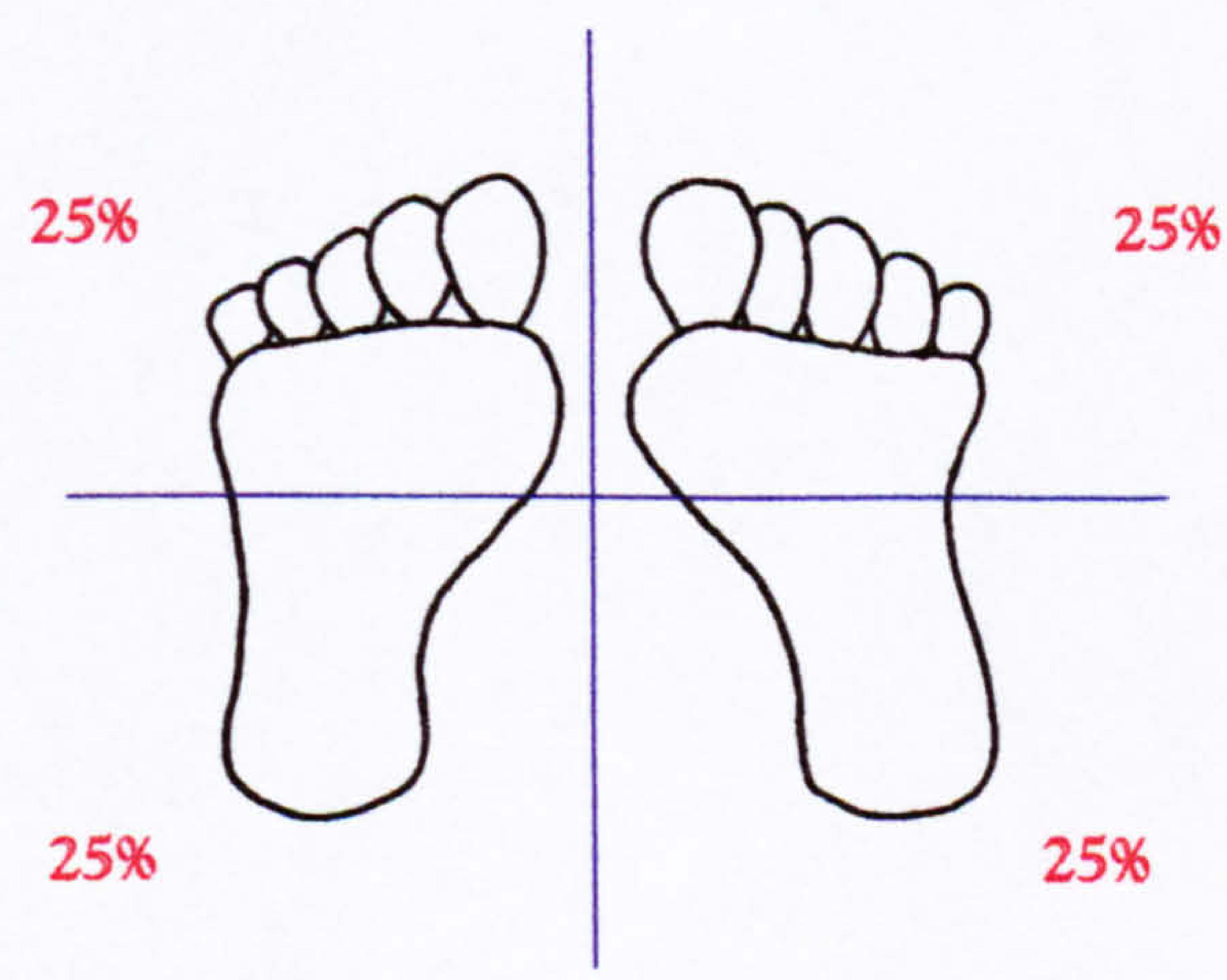


Figure n° 714 Distribution of Weight in Feet Together Double Stance



For the feet apart setting, the footplates were set as in **Section 7.4.1.2** this time the corresponding right footplate was moved parallel to the left footplate, but at a distance of 12cm apart (roughly shoulder width apart) *Figure n^{os} 715* and *716*.

Figure n° 715 Footplate Positioning for Feet Apart Double Stance

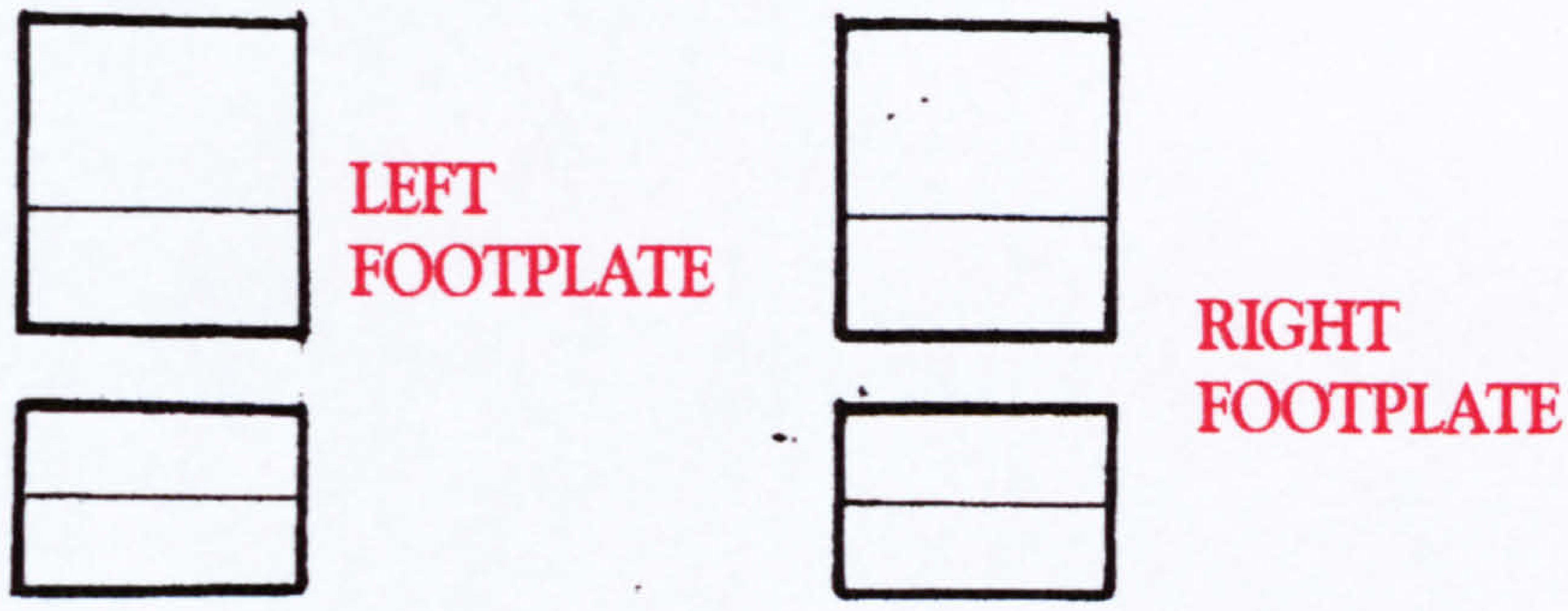
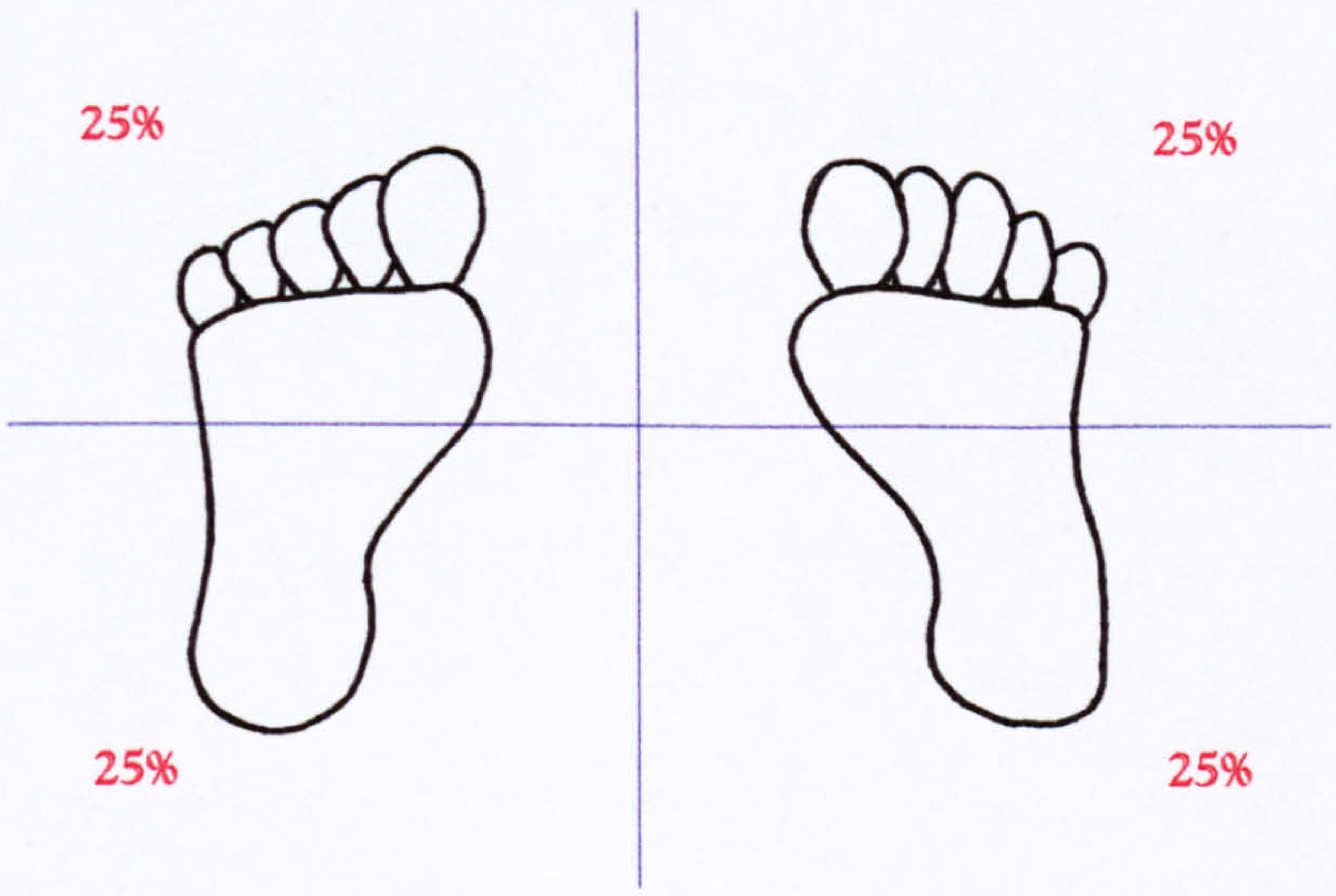


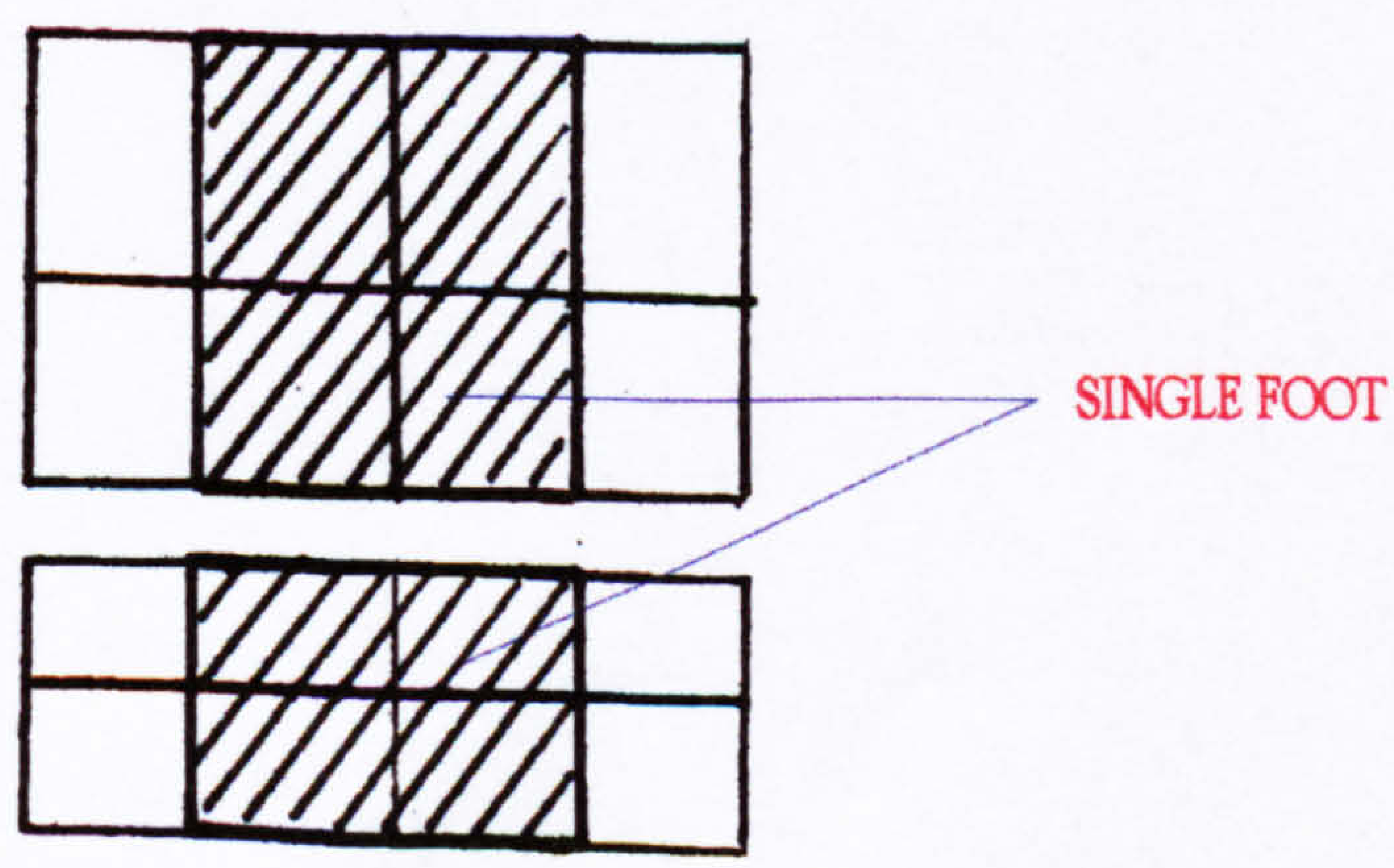
Figure n° 716 Weight distribution in Feet Apart Double Stance



7.4.1.4 Single Stance Settings

Single stance setting was the same as for double stance, feet together (**Section 7.4.1.3**) with the addition of another footplate set placed over the left and right pair, to form a single footplate set *Figure n° 717*. The theoretical distribution of weight in single stance is shown in *Figure n° 718*.

Figure n° 717 Footplate Positioning for Single-leg Stance



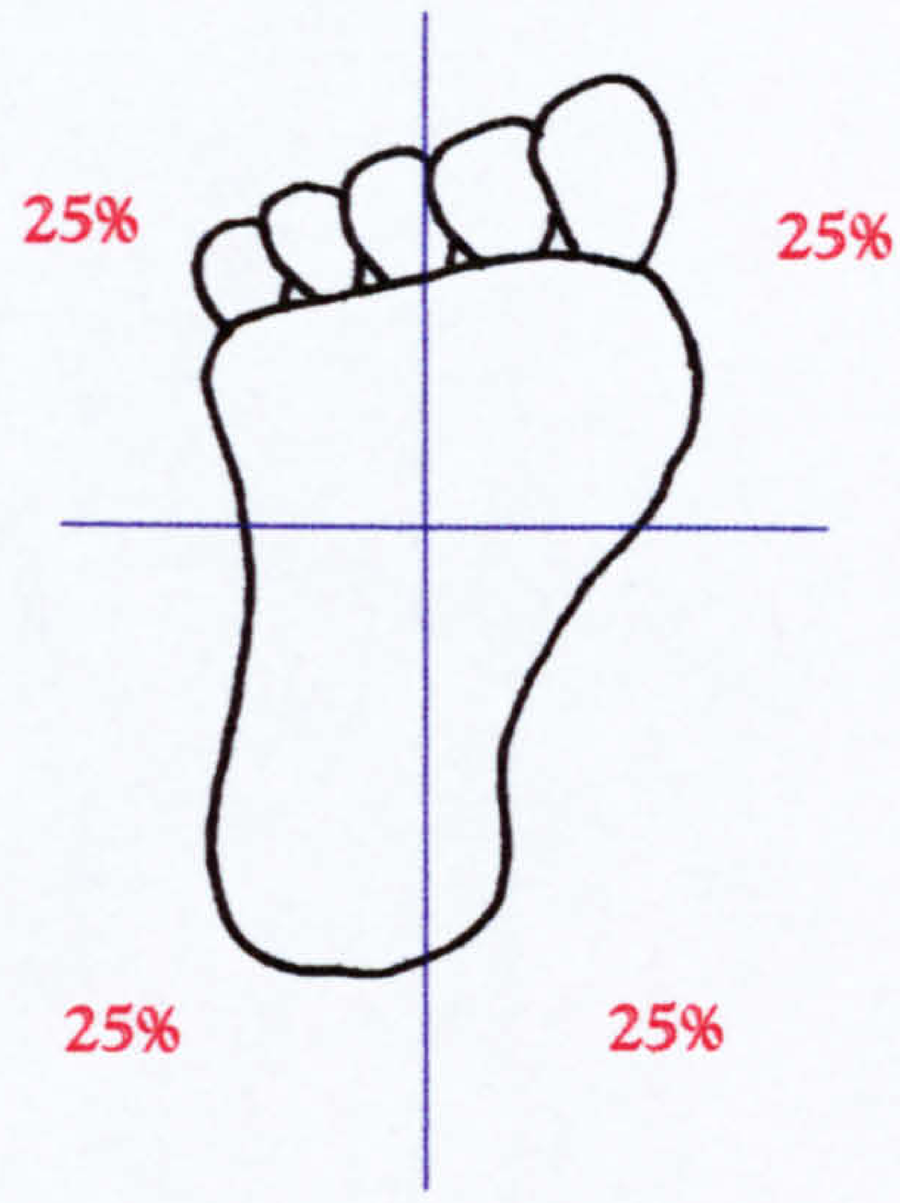


Figure n° 718 Weight Distribution in Single-leg Stance

7.4.1.5 Postural Stability Evaluation using the Chattecx Balance System

Each test evaluated three aspects of balance defined as follows: -

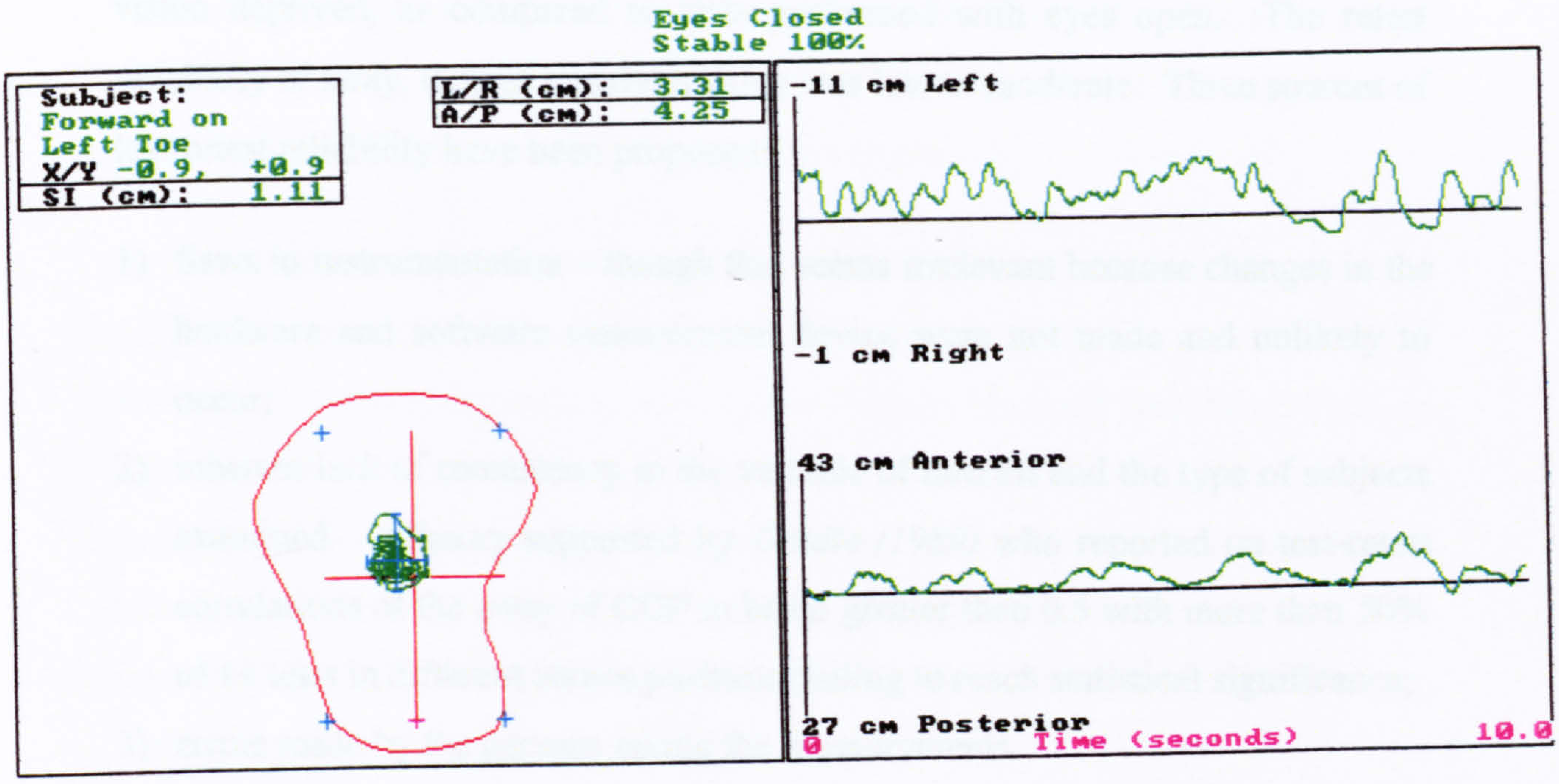
1. Centre of Balance (COB) – where the average x and y co-ordinates are plotted using the 'normal' COB as a reference point, where 'normal' COB is the point between the feet where the ball and heel of each foot has 25% of the body weight (*Figure n^{os} 714* and *716*). The subjects COB is indicated graphically on the monitor by a red '+' and numerically as x and y co-ordinates. COB is defined as the centre point of vertical foot pressure throughout the 10-second trial. The centres of balance measurements are expressed as points on an x-axis (left/right) and y-axis (anterior/posterior) grid.

2. Sway Index (SI) – this is a numeric value of the standard deviation of the time and distance the subject spent away from their COB. It is a measure of the degree of scatter of the data about the subject's centre of balance.

3. Sway distance – this is a measure of the maximum anterior/posterior (A/P) and left/right (L/R) movement in centimetres away from the subjects COB.

A typical test result directly from the balance system is shown in *Figure n° 718*. This shows x and y co-ordinates along with the overall sway index and individual L/R and A/P sway distances.

Figure n° 719 Typical Output of Results from the Chattecx Balance System



The left-hand section shows the outline of the foot, with a red cross marking the theoretical centre of balance. The four blue crosses represent the edges of the four transducers. The pattern of postural sway is superimposed upon this template, with the maximum A/P and L/R sway distances marked by a blue cross at the centre of this pattern. The separate patterns of L/R and A/P sway over the ten second balance period can be seen in the right-hand section.

7.4.1.6 Chattecx Balance System Reliability

Mattacola (1995) investigated inter-tester reliability of the Chattecx Balance System during single and double leg static and dynamic testing. Mean values of postural sway ranged from 0.28cm to 1.72cm and from 0.65cm to 1.70cm for double-leg and single-leg stance respectively. Intraclass Correlation Coefficients (ICCs) and (standard errors of measurement in centimetres) ranged from 0.41 (0.21) to 0.90 (0.06). *Byl (1991)* investigated both intra-tester and inter-tester reliability of the system and reported correlation coefficients of 0.92 and 0.90 respectively, comparable to those of *Mattacola (1995)*.

Test-retest reliability for static balance testing was investigated by *Dickstein (1993)* using values of Pearson product moment correlation coefficients for variables of sway in both the x and y directions.

For overall sway, test-retest correlations were lower for the tests performed with vision deprived, as compared to tests performed with eyes open. The retest reliability of sway, though mostly positive was low to moderate. Three sources of low retest reliability have been proposed:

1) flaws in instrumentation – though this seems irrelevant because changes in the hardware and software measurement device were not made and unlikely to occur;
2) inherent lack of consistency in the variable of interest and the type of subjects examined – a theory supported by *Goldie (1989)* who reported on test-retest correlations of the sway of COP to be no greater than 0.5 with more than 50% of 14 tests in different stance positions failing to reach statistical significance;
3) errors made by the persons taking the measurements.

The reason behind the unamenability of sway to high positive test-retest correlations may stem from a large repertoire of balance strategies that one can employ while still maintaining the overt stance position required by the study protocol (*Dickstein 1993*).

In contrast to sway, test-retest correlations for COB_X were positive and in the majority of tests statistically significant (79%), while COB_Y values of the obtained correlations were all positive and statistically significant. This indicates that despite the inability to detect differences in COB_Y in various testing positions, measurement consistency between the same test in two evaluations was high. A study by *Nichols (1995)* also investigated test-retest reliability of the Chattecx Balance System. COB_X and COB_Y were again found to demonstrate acceptable levels of reliability with ICCs ranging form 0.60 to 0.97.

Irrgang (1992) measured postural sway during unilateral stance on a stable platform. The results indicated reasonable reliability within and between days for stable non-moving measures of balance as were used in this study.

As maintaining postural stability involves integrating multiple physical components. The wide range of reliability coefficients in different stance situations is probably related to this multifaceted system. For example, concentration may be compromised due to extraneous factors such as visual or audible disturbances. Also, variations in mental status may vary from test to test. Controlling for these disturbances may improve the reliability of measurement. Another factor that may affect reliability is a learning effect, so the number of trials for each position should be kept to a minimum.

As the studies in the literature have reported acceptable levels of both test-retest reliability and also within and between day testing reliability for stable non-moving measures of balance, it was assumed results obtained from three trials on one day would be comparable to results from three trials on a future day. To control for any outside disturbances, all testing was conducted in a performance laboratory with closed access and only the investigator present. Although little learning effect was expected to be presented over three trials, the results from the three trials were averaged.

7.4.2 EMG Instrumentation

EMG was measured using the BIOPAC Systems Inc, (Goleta CA) MP100WorkStation (MP100WS). The MP100 is a complete, modular, expandable data acquisition system which functions as an 'on screen chart recorder' (*BIOPAC Systems Inc. 1994*).

The system used consisted of the following modular components (*Figure nº 720*);

UIM100: Universal Interface Module – this connects the amplifiers to the MP100 interface and provides a direct link to the MP100's analog and digital inputs and outputs. It consists of sixteen analog input channels plus two analog output channels.

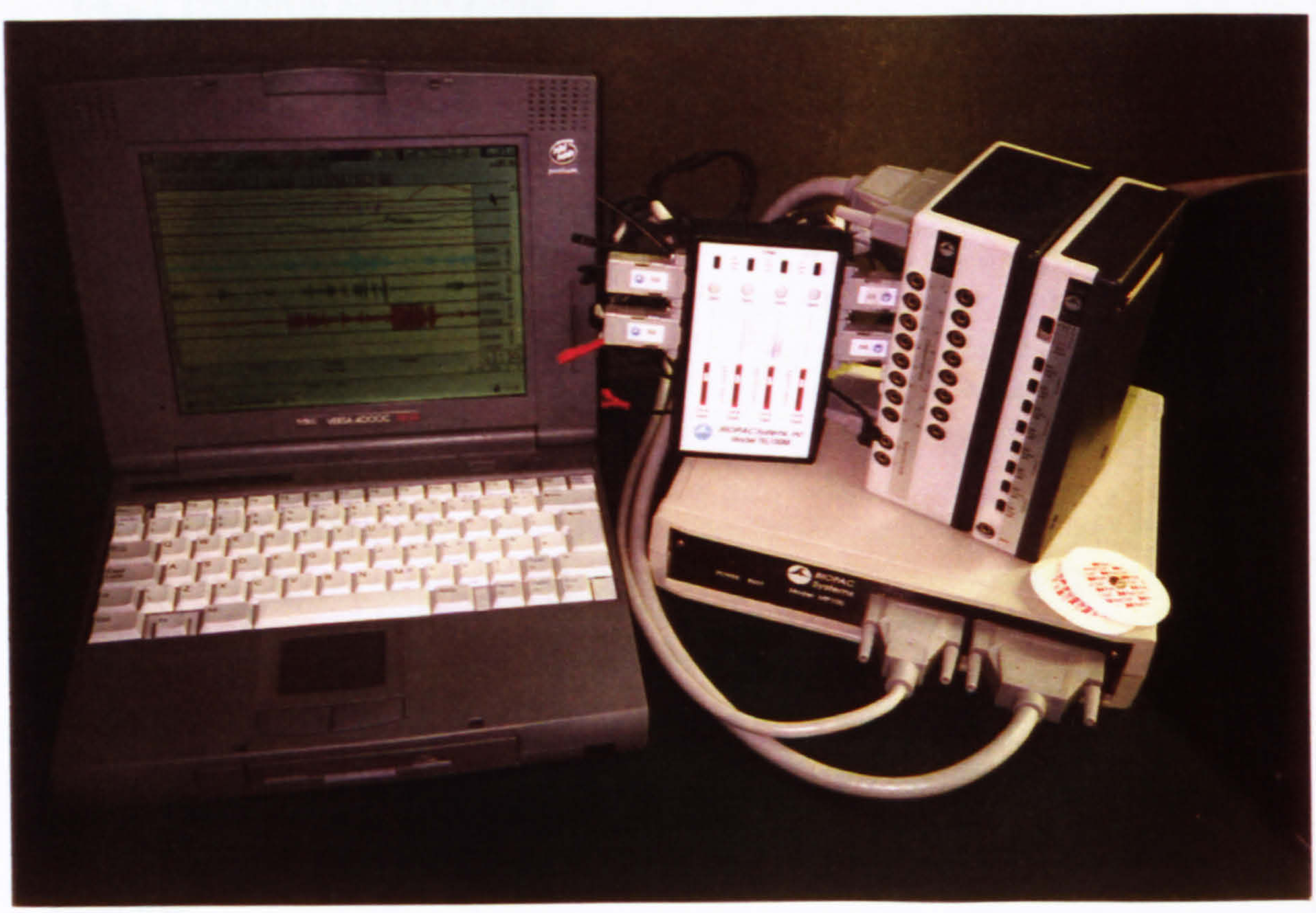
EMG100A: Electromyogram Amplifier – this is specifically designed for amplification of general muscle activity and is a single channel, high gain, differential input, biopotential amplifier and has a built in drive capability for use with shielded electrode leads. Shielded leads are typically required, as the EMG100A has a frequency response that extends through the 50/60Hz interference bands.

TEL100: Remote Monitoring Module Set – includes a portable transmitter, able to convert up to four channels of data into a modulated data stream. This stream then travels over a single lightweight cable to the receiver module. The receiver module then de-modulates the data and sends it to the MP100 for recording and analysis.

TEL100M: Four Channel Portable Transmitter – measures 3.5" x 5.75" x 1.25" and needs 2" clearance on each side for electrode attachment. A belt clip enables this to be worn by the subject. The transmitter picks up, amplifies and transmits up to four channels to the TEL100D Receiver Module. The transmitter includes independent filtering, offset and gain controls for each data channel. The electrodes plug into four 9-pin connectors (two on each side of the transmitter).

TEL100D: Four Channel Receiver Module – works with the MP100 system.

Figure n° 720 The MP100WS



The TEL100 module set is a modulation/demodulation system. The modulation process occurs in the TEL100M, the demodulation process occurs in the TEL100D. The TEL100M amplifies and filters the four input channels. After amplification the channel signals are time division multiplexed (TDM) into a single transmission channel and are sent to the TEL100D. The TDM process intrinsically samples the four input channels at a rate of 2000Hz /channel. This sampling process is independent of the MP100 system as it occurs in the TEL100M module. Prior to the TDM process, the four input channels are low-pass filtered at 500Hz. The TDM process always samples at 2000Hz for each channel and each channel's maximum bandwidth is 500Hz.

The TEL100D demodulates the transmission from the TEL100M and incorporates 30Hz low-pass filters for removing noise or 50/60Hz hum from the four input channels. The TEL100D produces a +/- voltage range analog output for each channel which are then sampled by the MP100.

7.4.2.1 Technical Specifications

These are the technical specifications for the MP100 modular system;

	Analog Inputs	Analog Outputs
Channels	16	2
Input Voltage Range (FSR)	+/- 10V	
Output Voltage Range (FSR)		+/- 10V
A/D Resolution (bits)	16	
D/A Resolution (bits)		12
Accuracy (%FSR)	+/- 0.003	+/- 0.02
Input Impedance (Ω)	1.0M	
Output Impedance (Ω)		100
Output Drive Current (max)		+/- 5mA

Amplifier

Type; Differential Input

Input Impedance 2MΩ (differential

Common Mode Input Impedance 1000MΩ min (50/60Hz)

Common Mode Rejection Ratio 100dB min (50/60Hz)

Common Mode Input Voltage Range +/- 10V

Output; normal, integrated output

TEL100

Gain settings x500, x1000, x2000, x5000

Upper Frequency Response 4000Hz

Lower Frequency Response 10 or 100Hz

Noise Voltage 2.0μV (rms)

Channel Bandwidth 500Hz

Signal/crosstalk ratio 65dB min

Signal/noise ratio 65 dB min

Signal Transmission ratio >200 feet.

7.4.3 Proprioception Evaluation Subjects

Although the intention was to use the same subjects that completed the athletic performance tests, this was not possible due to the final logistics of the study, the football season and other extraneous factors. Despite this, subjects did come from the same population as those previously studied.

The subjects were healthy male footballers from a second division club in the National Football League. All subjects voluntarily participated in the study and signed informed consent forms (*Appendix n° A2*).

Subjects were randomly assigned into two groups. Subjects (n = 10) assigned to Group One underwent measurements of postural stability and muscle activity with and without both ankles taped. For the taping procedure see **Section 7.3.4.** The subjects (n = 12) assigned to Group Two were tested before and after a six week proprioceptive training regime. For the training procedure see **Section 7.3.5.**

The physical characteristics of the sample are presented in *Table n° 7.2.* An F-test for equal variances between groups showed that variances are equal, thus the two groups comparable.

Table n° 7.2 Physical Characteristics of Subjects in Proprioception Analysis (n = 22)

VARIABLE	GROUP 1 (TAPING) n = 10	GROUP 2 (TRAINING) n = 12
	MEAN (SD)	**MEAN (SD)**
AGE (years)	25 (6)	21 (5)
WEIGHT (Kg)	77 (10)	72 (6)
HEIGHT (cm)	181 (6)	178 (5)

7.4.4 Postural Stability Procedure

The aim of this part of the study was to measure postural stability of two groups of subjects. One group was tested with ankles Untaped and Taped the other group was tested with ankles Untrained and Trained. The taping and training methods used were the same as those used for the athletic performance tests (**Section 7.3.4** and **Section 7.3.5** respectively).

Before testing, subjects performed a short warm-up consisting of jogging and stretching to loosen the muscles, increase joint flexibility and stimulate receptors. In the case of testing with ankles taped, warm-up was done after the tape had been applied. This was to loosen the tape to simulate the process of loosening that occurs during sporting activity and to produce results more indicative of a proprioceptive response to taping than that of a mechanical response.

Prior to data collection, the procedure was explained to the subjects and their age, weight and height were recorded.

For both groups, balance performance with eyes open and eyes closed was assessed in four stance positions: single-leg (Left), single-leg (Right), double-leg feet together (Narrow) and double-leg feet apart (Wide). In all cases, the eyes open measurements were completed before the eyes closed. To reduce learning effects and over familiarity with the balance procedure, the order of stance position tested was randomised.

All measurements were taken by the same person to control for inter-tester reliability. The test was administered with shoes on to simulate sporting conditions in which the footwear may offer some degree of support.

7.4.4.1 Single-leg Stance Stability Measurement

For this test, postural stability while standing on one leg was measured using the Chattecx Balance System. Stability on both left and right legs was measured.

First of all, the footplates were adjusted to fit the subject as described in **Section 7.4.1.4**. The subject was then instructed before standing on the footplates that for this test they would be asked to complete six trials of standing balance on one leg (right or left), each lasting 10 seconds. This would involve three trials of standing with eyes open and three with eyes closed. The test was then repeated for the contralateral leg.

For the eyes open trials, the subject was instructed to stand on the footplates, raise the contralateral leg, with the knee flexed at approximately 45° and hold their arms loosely by their sides. They were asked to concentrate on looking at a cross, marked on the wall one metre in front of them at eye level. Once confident that they were balanced to say 'GO'. This was the indicator to start measurement recording.

For the eyes closed trials, the subject was to do exactly as in the eyes open trials and once balanced, they closed their eyes and said 'GO', this was the indicator for starting measurement recording.

Between each trial, the subject was rested for thirty seconds while the measurements were saved and between eyes open and eyes closed, the subjects were rested for one minute.

7.4.4.2 Double-leg Stance Stability

The footplates were adjusted as described in **Section 7.4.1.3**, appropriate for the stance position being tested (either Narrow or Wide). The subject was then instructed before standing on the footplates that for this test they would be asked to complete six trials of standing balance on two legs, each lasting 10 seconds. This would involve three trials of standing with eyes open and three with eyes closed.

For the eyes open trials the subject was instructed to stand on the footplates, holding their arms loosely at their sides and to concentrate on a cross marked on the wall at eye level, one metre in front of them and once confident that they were balanced to say 'GO'. This was the indication to start measurement recording.

For the eyes closed trials, the subject was to do exactly as in the eyes open trial, but once confident that they were balanced to close their eyes and then say 'GO', used as the indication to start measurement recording.

Between each trial the subject was rested for thirty seconds to enable measurements to be saved and between eyes open and eyes closed the subject was rested for one minute.

7.4.5 Electromyography Procedure

Electromyographic measures were included in the test protocol in order to investigate muscle activity related to the process of postural stability and therefore, ascertain any effect that taping or proprioceptively training the ankle had on muscle activity, as a measure of proprioception.

EMG measured the muscle activity during the postural stability tests. This was done via the BIOPAC EMG System incorporating Acknowledge 3.2 software, in an attempt to obtain information regarding magnitude and activation of muscles in the lower leg directly related to the ankle joint as a function of postural stability before and after taping and proprioceptive training.

EMG measurements of four lower-leg muscles: gastrocnemius, peroneus longus, tibialis anterior and soleus, were recorded simultaneously with the balance performance tests. The leg from which the EMG was recorded was the weightbearing leg in single stance and the dominant leg in double stance. Dominance was ascertained by asking the subject which foot they would normally kick a football with and, this was chosen as the testing leg in double stance. The reason for choosing this leg for measurement was, that if this leg is used to kick the ball, the contralateral leg is more commonly used as the support leg and could therefore be assumed to be more stable 'proprioceptively', and so less influenced by either taping or proprioceptive training.

For the data acquisition, electrodes were placed on the muscle bellies of the four muscles to be tested: gastrocnemius, peroneus longus, tibialis anterior and soleus. The electrodes used were 3M red dot Ag/AgCl monitoring electrodes with micropore tape and solid gel (reference 2239).

Two detector electrodes were used for each muscle, necessary to prevent the EMG signal being swamped by mains hum. First shaving the electrode area and then thoroughly cleansing and degreasing it using a clean tissue moistened with acetone reduced the skin resistance. The placement of the two detector electrodes was so that they lay over the visual midpoint of the contracted muscle, with the orientation of the electrode pair being on a line parallel to the direction of the muscle fibres, an inter-electrode spacing of 1cm was used. One common earth electrode was used for the four muscles this was placed on the lateral side of the knee.

Once connected, the subject was instructed to walk a short distance of five metres to check for muscle activity pick-up by the electrodes. Before the trials began, a sample rate of 1000 samples per second was set for a period of ten seconds, this was so that EMG data collection could be run in conjunction with the postural stability trials.

As EMG data acquisition was in association with postural stability measurements, collection began on the command of 'GO' from the subject as in **Sections 7.4.4.1** and **7.4.4.2**. Although the EMG was recorded for each balance trial, it was decided to only save the trace for the second test of each trial due to the large size of the files, along with equipment and time constraints. The second test of each trial was selected, as it was believed this test would give the most representative and comparable results, with little learning effect involved.

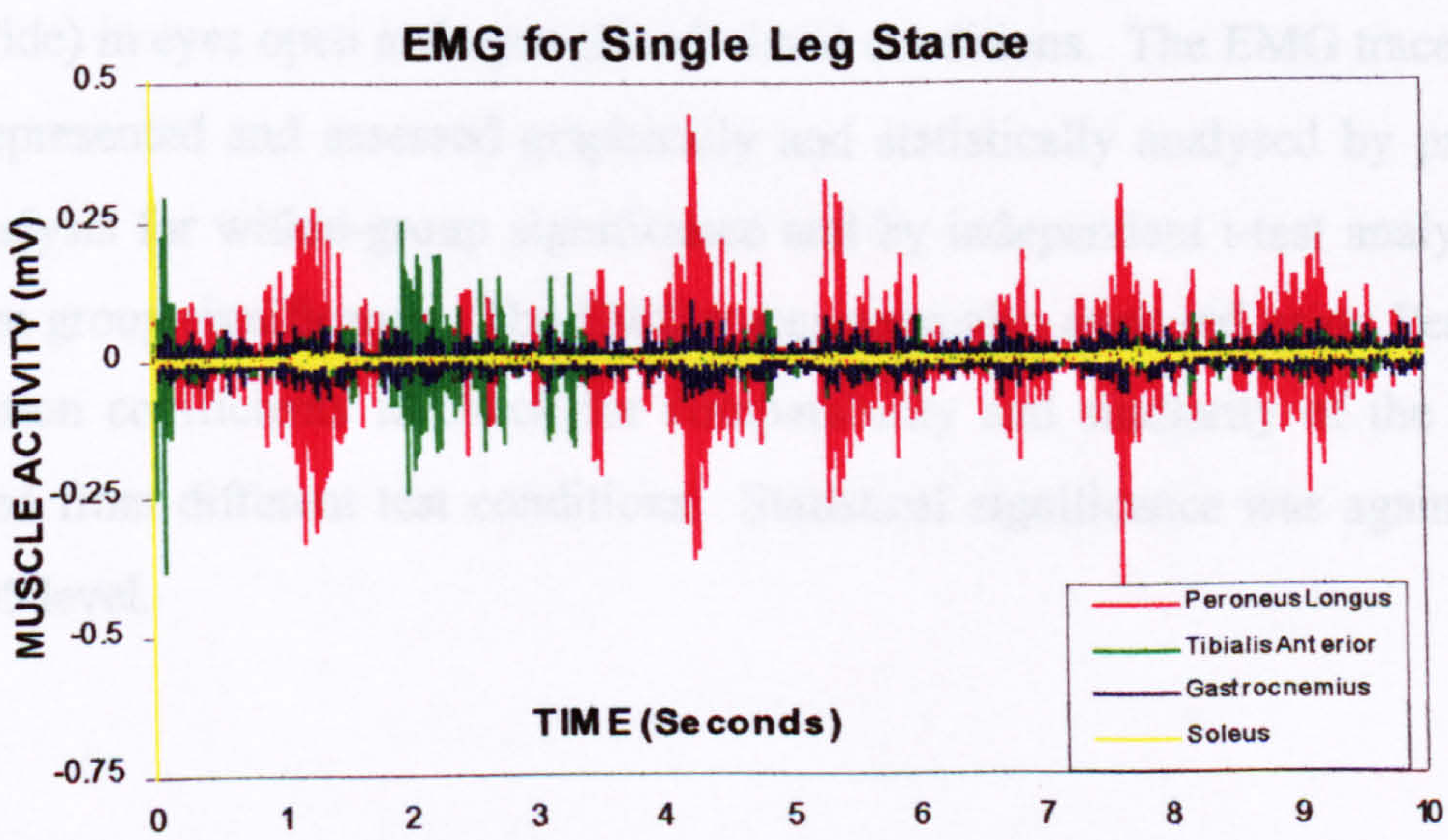
7.4.6 Proprioception Data Analysis

The SPSS statistical package (version 6.01 SPSS Inc.) was used for statistical analysis of the postural stability measurements. For each subject in all of the test and stance conditions, means were calculated over the three trials for measures of centre of balance (COB_X and COB_Y), sway index and left/right and anterior/posterior sway. These values were then used to test the influence of taping and training on postural stability.

The statistical analysis of the results was conducted using repeated one-way analysis of variance (ANOVA) and three-factor repeated measures ANOVA for each of the parameters. Visual condition (eyes open or closed), test condition (Untaped/Untrained, Taped or Trained) and stance position (left, right, narrow or wide) were the within subject factors. Probability values were adjusted by the Geisser-Greenhouse method in the repeated measures design. T-test analysis was also conducted for the two groups, paired t-test analysis was used to analyse within subject factors and independent t-tests to analyse between subject factors.

EMG measurements were converted to text files within Acknowledge software. The text files were then opened within Microsoft Excel for manipulation and analysis. An example of the raw EMG data is given in *Figure n° 721*. This shows muscle activity in each of the four muscles, tested over a ten-second balance period on the right leg with the eyes closed.

Figure n° 721 An Example of Raw EMG Data



The muscle activity of each individual muscle was analysed separately for test and stance conditions. The EMG trace over the ten second balance period consisted of 10 000 data points due to a sample rate of 1000/second.

The first part of EMG data analysis consisted of removing the first five and last five data points from each EMG trace. This was to remove spikes in the trace due to commencement and completion of data acquisition. Then the maximum and minimum peak values for each subject trace were noted. These values were used to find the corresponding mean values for each visual condition within each stance and test position. Statistical analysis was conducted on each group using paired samples t-tests to investigate within-subject factors of the taping and training groups, with statistical significance set at the 0.05 level.

The second part of the EMG data analysis began by sorting the data points of each individual EMG trace into ascending numerical order. Then for each group, stance and test condition, each data point was averaged across the group to give one mean EMG trace of 10 000 data points for test conditions. Thus, an average EMG trace was obtained for Untaped, Untrained, Taped and Trained in stance positions of single-leg (Left), single-leg (Right), double-leg (Narrow) and double-leg (Wide) in eyes open and eyes closed visual conditions. The EMG traces were then represented and assessed graphically and statistically analysed by paired t-test analysis for within-group significance and by independent t-test analysis for between group significance. The EMG traces were also analysed using Pearson's correlation coefficients to check for comparability and similarity of the results obtained from different test conditions. Statistical significance was again set at the 0.05 level.

CHAPTER EIGHT

CHAPTER 8: RESULTS

8.1 INJURY DATABASE RESULTS

An injury database was compiled over the course of two seasons from questionnaires completed by the physiotherapist at a second division National Football League club. The purpose of the database was to confirm results from other studies in the literature investigating the frequency and location of injuries in football with the intention of providing evidence of the high incidence of ankle injury in football to warrant the further research in this area.

The database was complied over two seasons, but with a change in the definition of injury between the two seasons. The first period was the 1996 – 1997 football season, starting with pre-season training in July 1996 and ending with the last match at the beginning of May 1997. For this period, an injury was defined by the player being unable to participate in a match or training session because of an injury incurred in football. Injuries incurred by both the youth and professional players at the club were recorded.

The second period was the 1997 – 1998 football season, again starting with pre-season training in July 1997 and ending with the last match at the beginning of May 1998. For this second period, an injury was defined as requiring a minimum of three days treatment. The change in injury definition was to highlight the impact of more severe injuries, leading to significant time lost from play and also, due to a change in the data collection procedure. Injuries incurred by both youth and professional players were again recorded.

Due to the change in definition of injury and the data collection procedure, results from the two periods are reviewed and discussed separately.

8.1.1 The 1996 – 1997 Football Season

During the season, a total of 42 players were at risk of injury in the club. This was made up of 26 First and Reserve squad players (also split into First team and Reserve team) and 16 Youth team players.

8.1.1.1 Incidence of Injury

From the population at risk, only one player remained uninjured throughout the period of study, the remaining 41 players incurring a total of 84 injuries.

The incidence of injury for the individual player in the club was calculated from proportional representation of players in training and matches, dependent upon the team played in over the period of study. This gave 2.5 injuries per 1000 hours of football; 5.85 injuries per 1000 match hours and 1.39 injuries per 1000 training hours. This constituted an average of one injury every 2.7 matches and 5.7 training sessions. The full breakdown of injury incidence is detailed in *Table n^{os} 8.1*(a), *(b)*, *(c)* and *(d)*.

Table n° 8.1(a) Injury Incidences in the 1996/1997 Period

INCIDENCE OF INJURY	96/97 PERIOD
NUMBER OF PLAYERS AT RISK	42 Players
LENGTH OF PERIOD OF STUDY	10 months
NUMBER OF PLAYERS INJURED	41
NUMBER OF INJURIES	84

Table n° 8.1(b) Overall Injury Incidence for the 1996/1997 Period

CLUB AND TEAM	OVERALL INCIDENCE OF INJURY per 1000 HOURS *(for each player)*
INCIDENCE OF INJURY (club)	2.5 injuries /1000 hours
INCIDENCE OF MATCH INJURY (club)	5.85 injuries /1000 match hours
INCIDENCE OF TRAINING INJURY (club)	1.39 injuries /1000 training hours
FIRST TEAM	3.88 injuries /1000 hours
RESERVE TEAM	1.31 injuries /1000 hours
FIRST/RESERVE SQUAD	2.55 injuries /1000 hours
YOUTH TEAM	3.61 injuries /1000 hours

Table n° 8.1(c) Incidence of Match Injury for the 1996/1997 Period

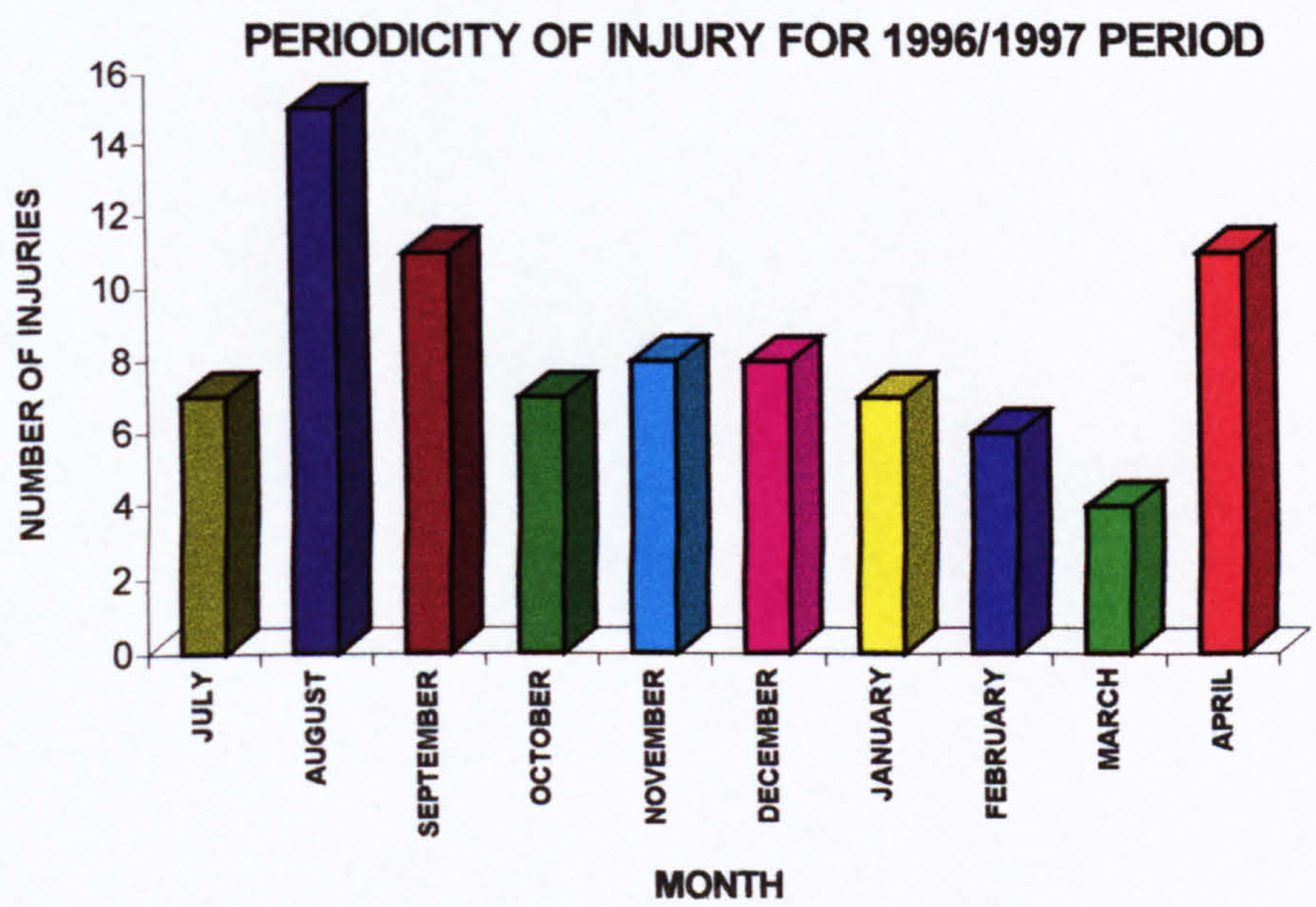
TEAM	INCIDENCE OF MATCH INJURY per 1000 HOURS *(for each player)*
FIRST TEAM	20.35 injuries /1000 hours
RESERVE TEAM	9.93 injuries /1000 match hours
FIRST/RESERVE SQUAD	8.46 injuries /1000 match hours
YOUTH TEAM	19 injuries /1000 match hours

Table nº 8.1(d) Incidence of Training Injury for the 1996/1997 Period

TEAM	INCIDENCE OF TRAINING INJURY per 1000 HOURS (for each player)
FIRST TEAM	1.28 injuries /1000 training hours
RESERVE TEAM	0.64 injuries /1000 training hours
FIRST/RESERVE SQUAD	0.96 injuries /1000 training hours
YOUTH TEAM	2.08 injuries /1000 training hours

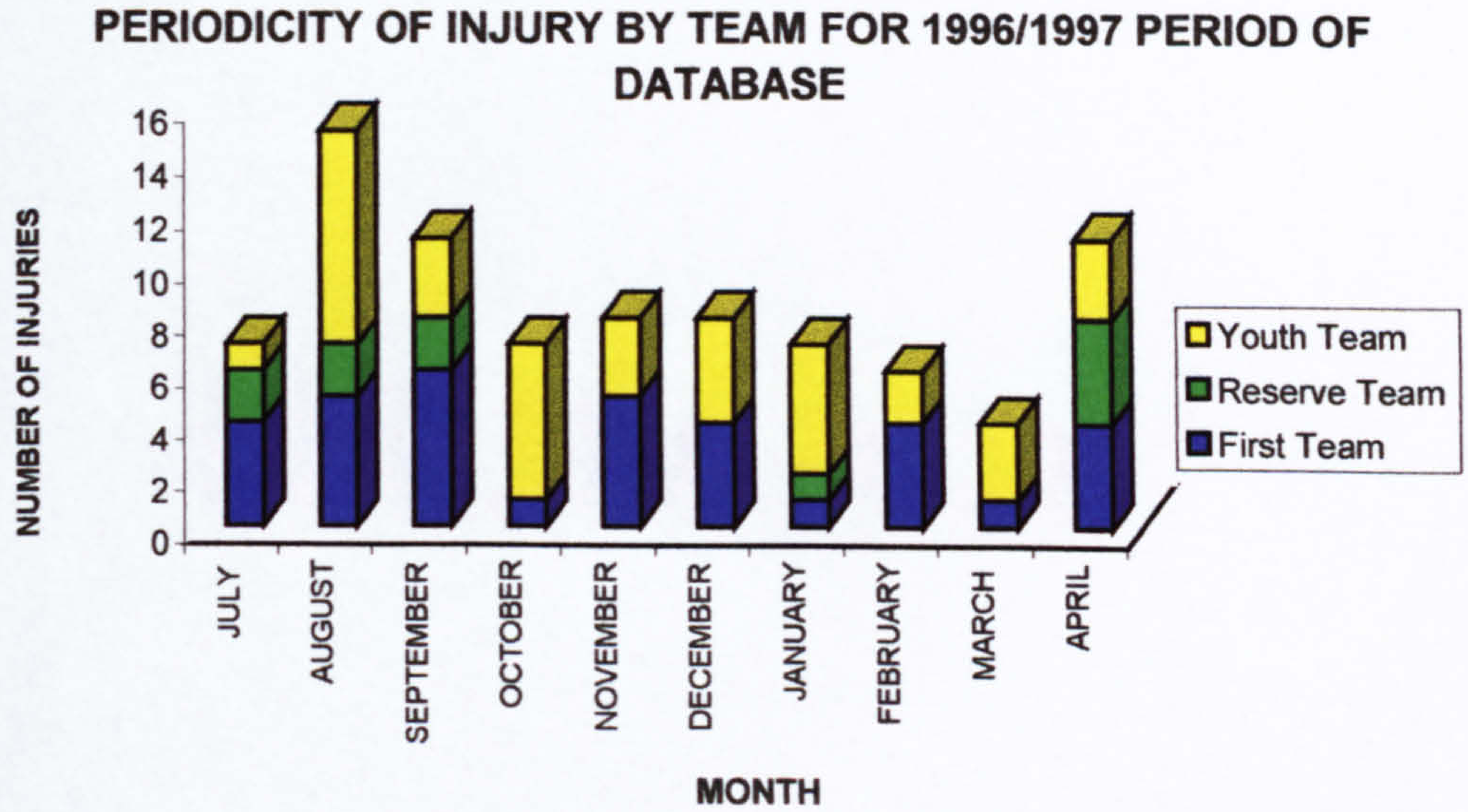
The periodicity of injury occurrence is shown in *Figure nº 81*. This shows three peaks of incidence; at the beginning of the competitive season (August/September), during the period over Christmas (November/December) and at Easter (April); both match intensive periods in the league programme.

Figure nº 81 Periodicity of Injury for 1996/1997 Period of Database



Analysis of injuries incurred by players in the different teams across the period of study shows these peaks of incidence more directly related to time of season and matches. The reserve team is noted to have fewer injuries, however, these injury incidences still occur at the peak areas previously indicated. The team injury incidence over the period is illustrated in *Figure nº 82*.

Figure n° 82 Periodicity of Injury by Team 1996/1997 Period



8.1.1.2 Type and Location of Injury

Strains and sprains were the most common type of injury to be incurred by the players, accounting for 63% of all injuries recorded (*Table n° 8.2*). A sprain is an injury to a ligament caused by sudden over-stretching. As the ligament is not severed, it gradually heals, but this may take several months dependent upon the severity. A strain is an excessive stretching or working of a muscle, resulting in pain and swelling of the muscle.

Injuries to the lower leg (18%) constituted the most frequently injured body part, followed closely by injury to the knee (15%) and ankle (13%). The localisation of injury is shown in *Table n° 8.3*. The side affected by injury was not significant, with left and right sides injured 52% and 44% respectively (*Table n° 8.4*).

Table n° 8.2 Type of Injury Incurred over the 1996/1997 Period

Injury Type	*1996/1997 Period*	
	N° of Injuries	*Percentage of Injuries*
STRAIN	35	42%
SPRAIN	18	22%
CONTUSION	10	12%
ABRASION	8	10%
OVERUSE INJURY	5	6%
FRACTURE	2	2%
LACERATION	2	2%
UNKNOWN	2	2%
DISLOCATION	1	1%
OTHER	1	1%

Table nº 8.3 Injury Location over the 1996/1997 Period

Body Part Injured	1996/1997 Period	
	Nº of Injuries	Percentage of Injuries
LOWER LEG	15	18%
KNEE	13	15%
HAMSTRING	12	14%
ANKLE	11	13%
THIGH	8	10%
PELVIS/GROIN	8	10%
FOOT	4	5%
TOE	3	4%
VERTEBRAE	3	4%
BACK	2	2%
FINGER	1	1%
HIP	1	1%
ABDOMEN	1	1%
SHOULDER	1	1%
NECK	1	1%
HAND	-	-
UPPER ARM	-	-
CHEST	-	-
OTHER	-	-

Table Nº 8.4 Distribution of Injury by Side Affected for the 1996/1997 Period

Period of Database	1996/1997 Period		
Injured Side	LEFT	RIGHT	Not Applicable
Nº of Injuries	44	37	3
Percentage of Injuries (corrected)	52% (54%)	44% (46%)	4%

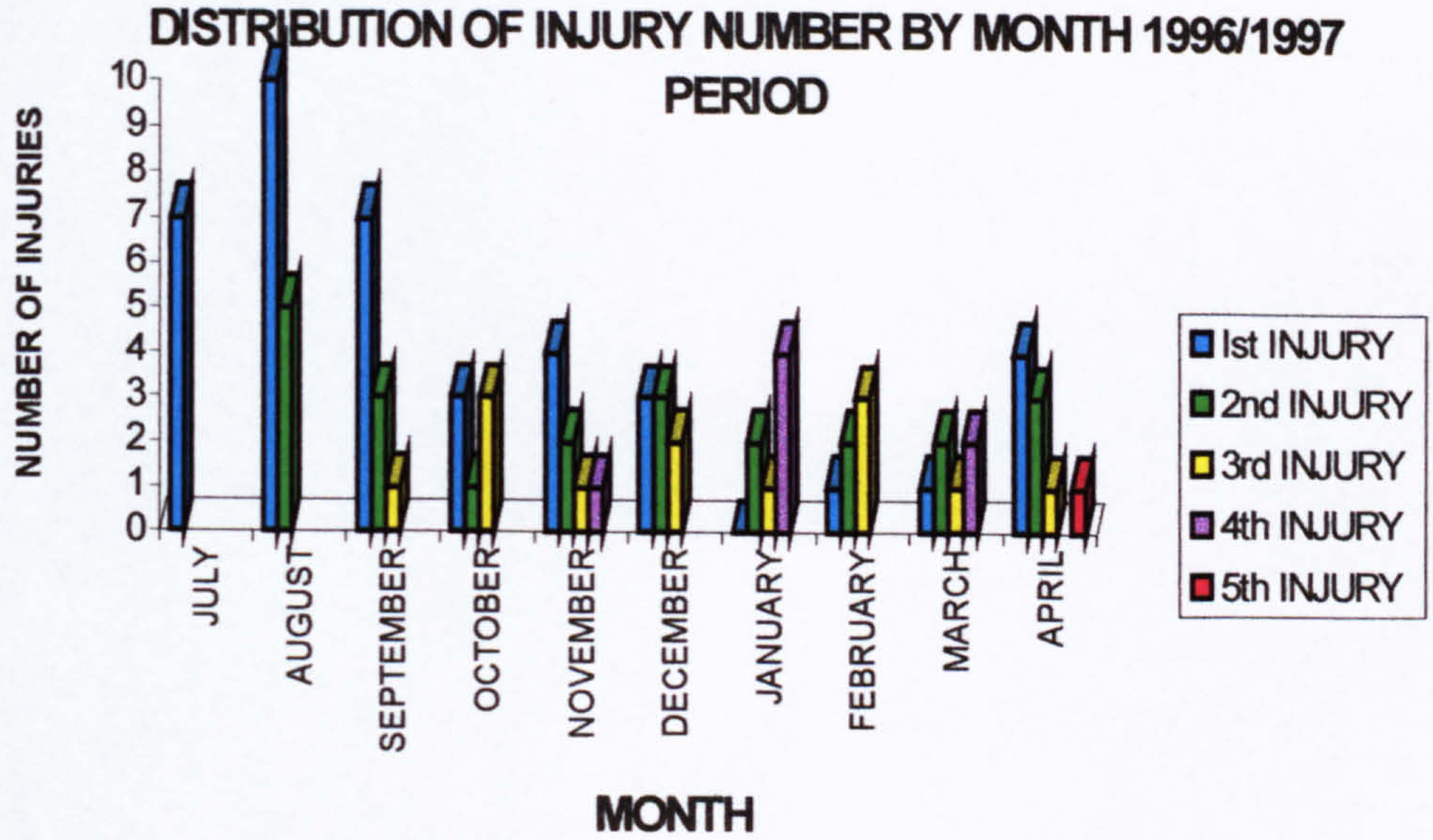
8.1.1.3 Incidence of Re-injury

Of the 84 injuries, 11% were re-injuries (*Table nº 8.5*); most often to the lower leg (33%) and hamstring (33%). Seven of the re-injuries occurred 1 – 6 months after the first injury and two occurred 6 – 12 months after (*Figure nº 83*).

Table nº 8.5 Number of Re-injuries in 1996/1997 Period

INJURY NUMBER	Nº OF INJURIES	Nº OF RE-INJURIES	PERCENTAGE OF RE-INJURIES
1st Injury	41	-	-
2nd Injury	23	5	21.74% of 2nd injuries
3rd Injury	12	-	-
4th Injury	7	3	42.86% of 4th injuries
5th Injury	1	1	100% of 5th injuries

Figure n°83 Distribution of Injuries (1996/1997) by Injury Number and Month



8.1.1.4 Team and Player Position Factor Analysis

From the 84 injuries, players in the First team incurred 35 injuries, players in the Reserve team 11 and Youth team players 38. The distribution of injury by position is shown in *Table n° 8.6.* The injury rate percentage relative to position in relation to a 1:4:4:2 formation of players is illustrated in *Figure n° 84*. This provides evidence of no significant difference (Chi square) in the distribution among different player positions.

Table n° 8.6 Distribution of Injury by Position for 1996/1997 Period

POSITION	*TOTAL NUMBER OF INJURIES*	*Number of Injuries for First Team*	*Number of Injuries for Reserve Team*	*Number of Injuries for Youth Team*
Goalkeeper	3	1	1	1
Defender	31	10	7	14
Midfield	30	14	3	13
Forward	20	10	-	10

Figure n° 84 Pie Chart Illustrating Injury Rate Relative to Position

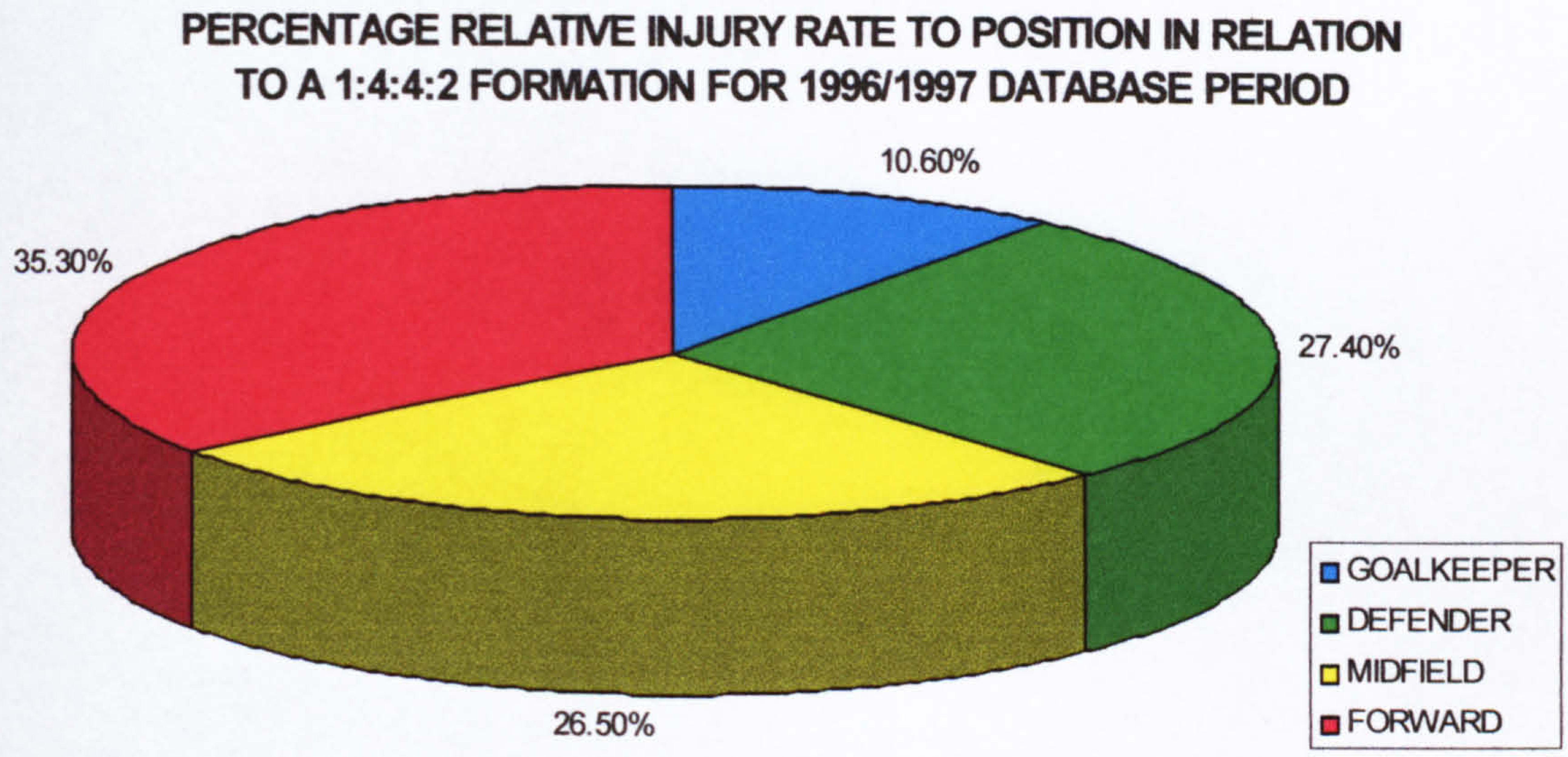


Table n^{os} 8.7(a), (b), (c), (d) detail the location of injury by position. As shown, the most frequent injury to a defender was to the lower leg (19%), midfield to the hamstring (22%) and knee (22%) and to a forward player the ankle (33%).

Table n° 8.7(a) Location of Injuries in Defenders 1996/1997 Period

POSITION	LOCATION OF INJURY	NUMBER OF INJURIES	PERCENTAGE OF POSITION INJURIES
DEFENDER	LOWER LEG	6	19%
	PELVIS	5	16%
	KNEE	3	10%
	HAMSTRING	3	10%
	ANKLE/TOE/THIGH/FOOT/ VERTEBRAE	2	6.5%
	HIP/SHOULDER/NECK/BACK	1	3.125%

Table n° 8.7(b) Location of Injuries in Midfield Players 1996/1997 Period

POSITION	LOCATION OF INJURY	NUMBER OF INJURIES	PERCENTAGE OF POSITION INJURIES
MIDFIELD	HAMSTRING	7	22%
	KNEE	7	22%
	LOWER LEG	5	16%
	THIGH	4	12.5%
	ANKLE	3	9.25%
	PELVIS	3	9.25%
	FOOT/ABDOMEN/TOE	1	3%

Table n° 8.7(c) Location of Injuries in Forwards 1996/1997 Period

POSITION	LOCATION OF INJURY	NUMBER OF INJURIES	PERCENTAGE OF POSITION INJURIES
FORWARD	ANKLE	6	33%
	LOWER LEG	3	16.5%
	KNEE	3	16.5%
	THIGH	2	11%
	HAMSTRING	2	11%
	BACK/FOOT	1	6%

Table n° 8.7(d) Location of Injuries in Goalkeepers 1996/1997 Period

POSITION	LOCATION OF INJURY	NUMBER OF INJURIES	PERCENTAGE OF POSITION INJURIES
GOALKEEPER	VERTEBRAE	1	33.3%
	FINGER	1	33.3%
	LOWER LEG	1	33.3%

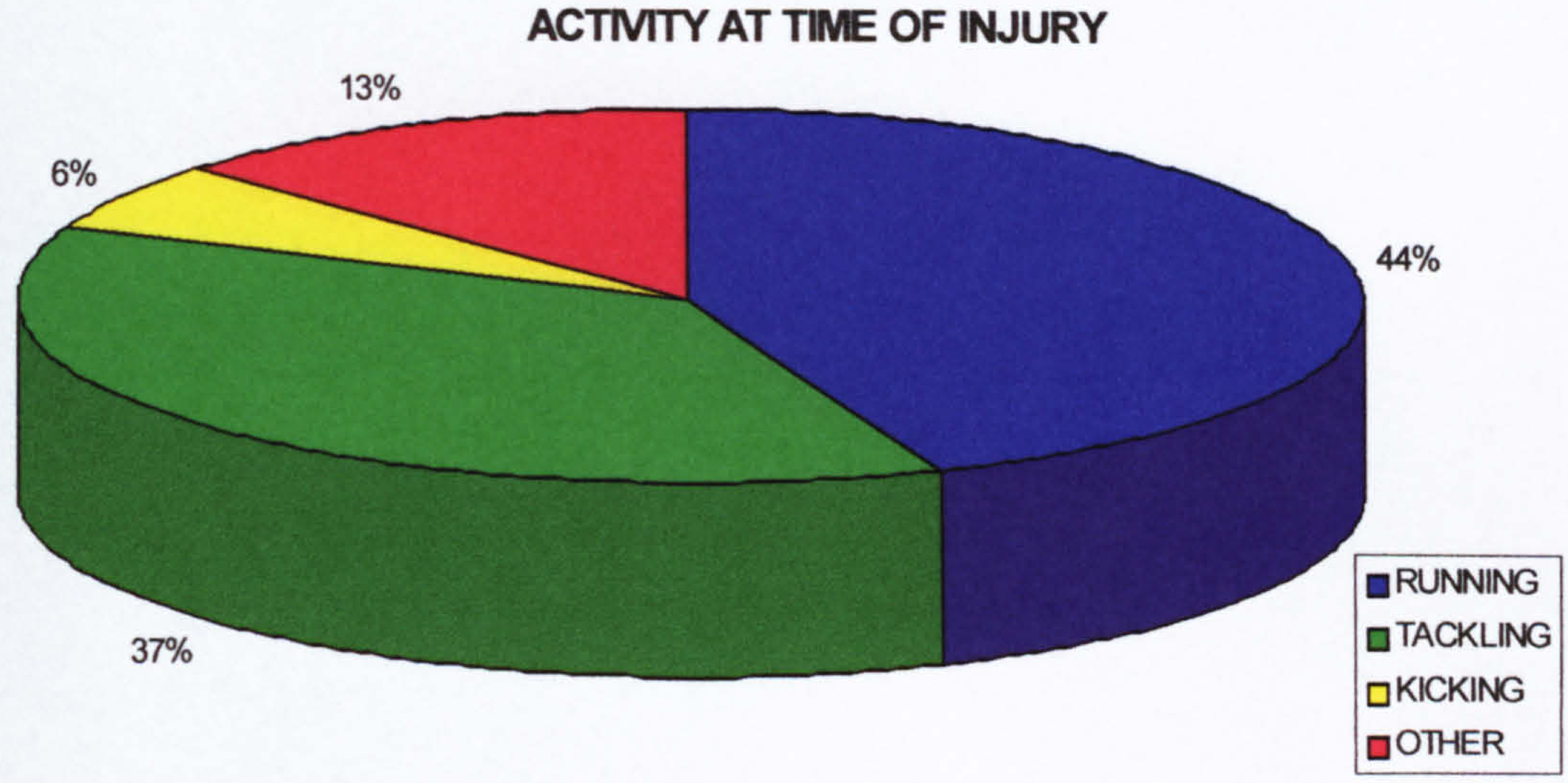
8.1.1.5 Activity at Time of Injury

A total of 58% of injuries were incurred during matches and 42% in training sessions (*Table n° 8.8*). In 32 (37%) cases, the injured player did not continue to take part in the activity. The activity at time of injury was running in 44% and tackling in 37% of cases (*Figure n° 85*).

Table n° 8.8 Distribution of Injuries between Matches and Training 1996/1997 Period

TEAM	N° of Injuries Occurring during Training	N° of Injuries Occurring During Matches
CLUB	35 (42%)	49 (58%)
FIRST TEAM	10 (30%)	25 (70%)
RESERVE TEAM	5 (45%)	6 (55%)
YOUTH TEAM	20 (52%)	18 (47%)

Figure n° 85 Pie Chart Illustrating Activity at Time of Injury during 1996/1997 Period



When injury occurred in a match situation, incidence was evenly distributed between the first and second half of the match (*Table n° 8.9*).

Table n° 8.9 Distribution of Injuries between First and Second Half of Match (1996/1997)

TEAM	N° of Injuries in First Half of Match	N° of Injuries in Second Half of Match
CLUB	22 (45%)	27 (55%)
FIRST TEAM	10 (40%)	15 (60%)
RESERVE TEAM	2 (33)	4 (67%)
YOUTH TEAM	10 (50%)	8 (44%)

8.1.1.6 Miscellaneous Injury Factors

Day and time of injury, along with field surface and weather conditions were recorded and the results are displayed in *Table n^{os} 8.10, 8.11, 8.12* and *8.13*.

Table n° 8.10 Distribution of Injuries by Day of Week over 1996/1997 Period

Day	Number of Injuries 1996/1997 Period	Percentage of Injuries 1996/1997 Period
MONDAY	12	14%
TUESDAY	7	8%
WEDNESDAY	8	10%
THURSDAY	12	14%
FRIDAY	13	15.5%
SATURDAY	28	33.5%
SUNDAY	0	-
NOT RECORDED	4	5%

Peaks of injury incidence occur on Saturdays; when the majority of league matches are played and at time periods between 9am and 12pm when training is usually executed and 3pm and 6pm the time of afternoon matches.

Table n^o 8.11 Distribution of Injuries by Time of Day over 1996/1997 Period

Time of Day	Number of Injuries 1996/1997 Period	Percentage of Injuries 1996/1997 Period
6am – 9am	2	2%
9am – 12pm	33	39%
12pm – 3pm	5	6%
3pm – 6pm	30	36%
6pm – 9pm	8	10%
9pm – 12am	2	2%
Unknown	4	5%

Playing conditions at the time of injury were in the main dry (65% clear weather and 56% dry field surface).

Table n^o 8.12 Field Surface Condition at Time of Injury 1996/1997 Period

Field Surface Condition	Number of Injury Incidences	Percentage of Injuries
DRY	47	56%
WET/MUD	31	37%
FROZEN	1	1%
UNKNOWN	5	6%

Table n^o 8.13 Weather Conditions at Time of Injury 1996/1997 Period

Weather Condition	Number of Injury Incidences	Percentage of Injuries
CLEAR/CLOUDY	55	65%
RAIN	22	26%
SNOW	3	4%
UNKNOWN	4	5%

8.1.2 The 1997 – 1998 Football Season

During this second period, a total of 39 players were at risk of injury. This was made up of 25 First and Reserve squad players and 14 Youth team players.

8.1.2.1 Incidence of Injury

From the population at risk 12 (31%) players remained uninjured throughout the period and the remaining 27 (69%) incurred 50 injuries (*Table n^o 8.14*).

Table nº 8.14 Distribution of Injury in Population at Risk for 1997/1998 Period

Team and Condition	Number of Players	Percentage of Players
Club Players – Uninjured	12	31%
First/Reserve Players – Uninjured	7	13%
Youth Players – Uninjured	5	18%
Club Players – Injured	27	69%
First/Reserve Players – Injured	18	46%
Youth Players – Injured	9	23%

The incidence of injury for the individual player was 1.51 injuries per 1000 hours of football; 4.04 injuries per 1000 match hours and 0.78 injuries per 1000 training hours. This gave an incidence of one injury occurring every 4.23 matches and every 11 training sessions for the population. The full details of injury incidence are presented in *Table nº 8.15(a), (b), (c)* and *(d)*.

Table nº 8.15(a) Injury Incidences in the 1997/1998 Period

INCIDENCE OF INJURY	96/97 PERIOD
NUMBER OF PLAYERS AT RISK	39 Players
LENGTH OF STUDY PERIOD	11 months
NUMBER OF PLAYERS INJURED	27
NUMBER OF INJURIES	50

Table nº 8.15(b) Overall Injury Incidence for the 1997/1998 Period

CLUB AND TEAM	OVERALL INCIDENCE OF INJURY per 1000 HOURS *(for each player)*
INCIDENCE OF INJURY(club)	1.51 injuries /1000 hours
INCIDENCE OF MATCH INJURY (club)	4.04 injuries /1000 match hours
INCIDENCE OF TRAINING INJURY (club)	0.78 injuries /1000 training hours
FIRST/RESERVE SQUAD	1.86 injuries /1000 hours
YOUTH TEAM	1.3 injuries /1000 hours

Table nº 8.15(c) Incidence of Match Injury for the 1997/1998 Period

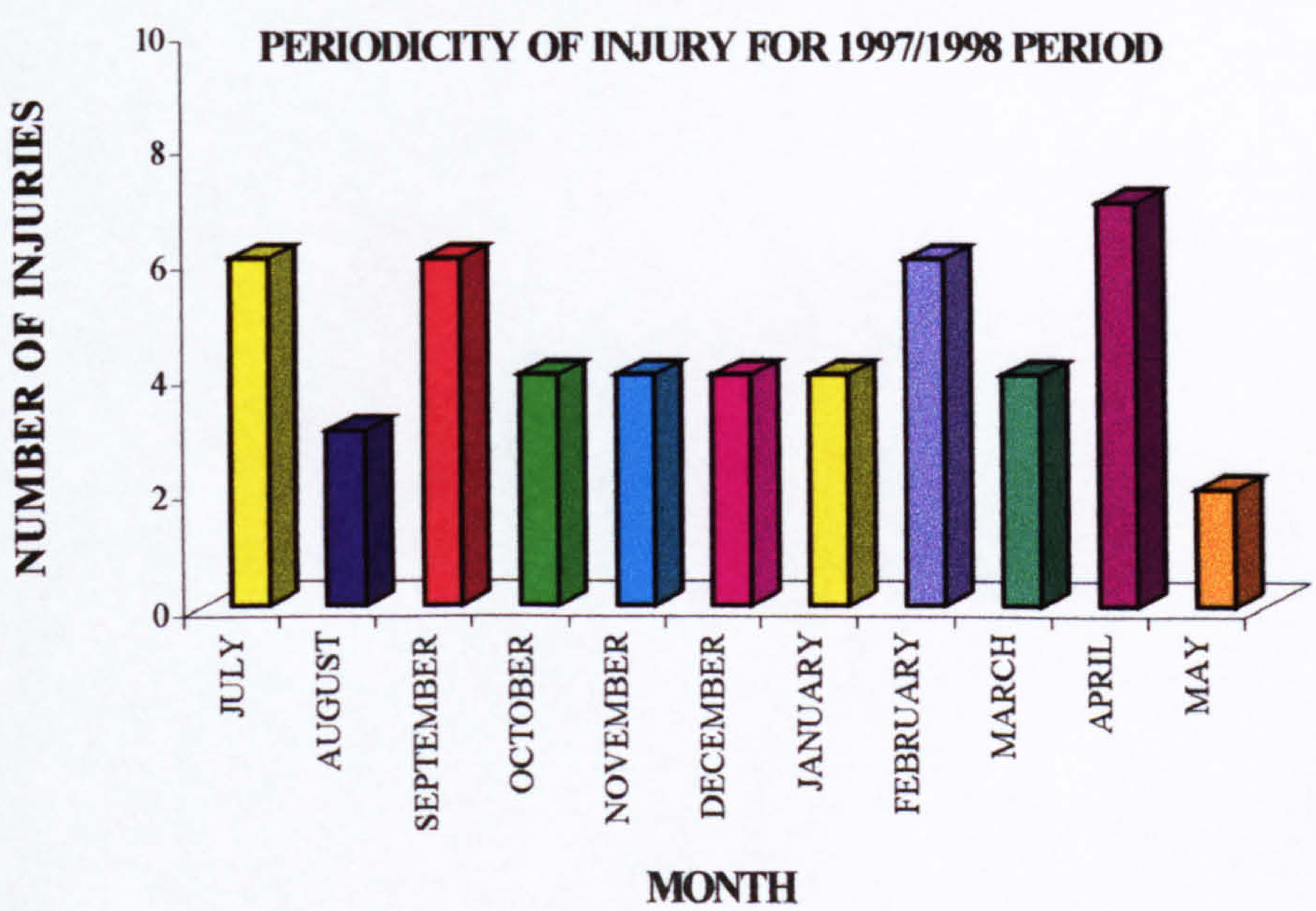
TEAM	INCIDENCE OF MATCH INJURY per 1000 HOURS *(for each player)*
FIRST/RESERVE SQUAD	6.45 injuries /1000 match hours
YOUTH TEAM	10.58 injuries /1000 match hours

Table nº 8.15(d) Incidence of Training Injury for the 1997/1998 Period

TEAM	INCIDENCE OF TRAINING INJURY per 1000 HOURS *(for each player)*
FIRST/RESERVE SQUAD	0.91 injuries /1000 training hours
YOUTH TEAM	0.54 injuries /1000 training hours

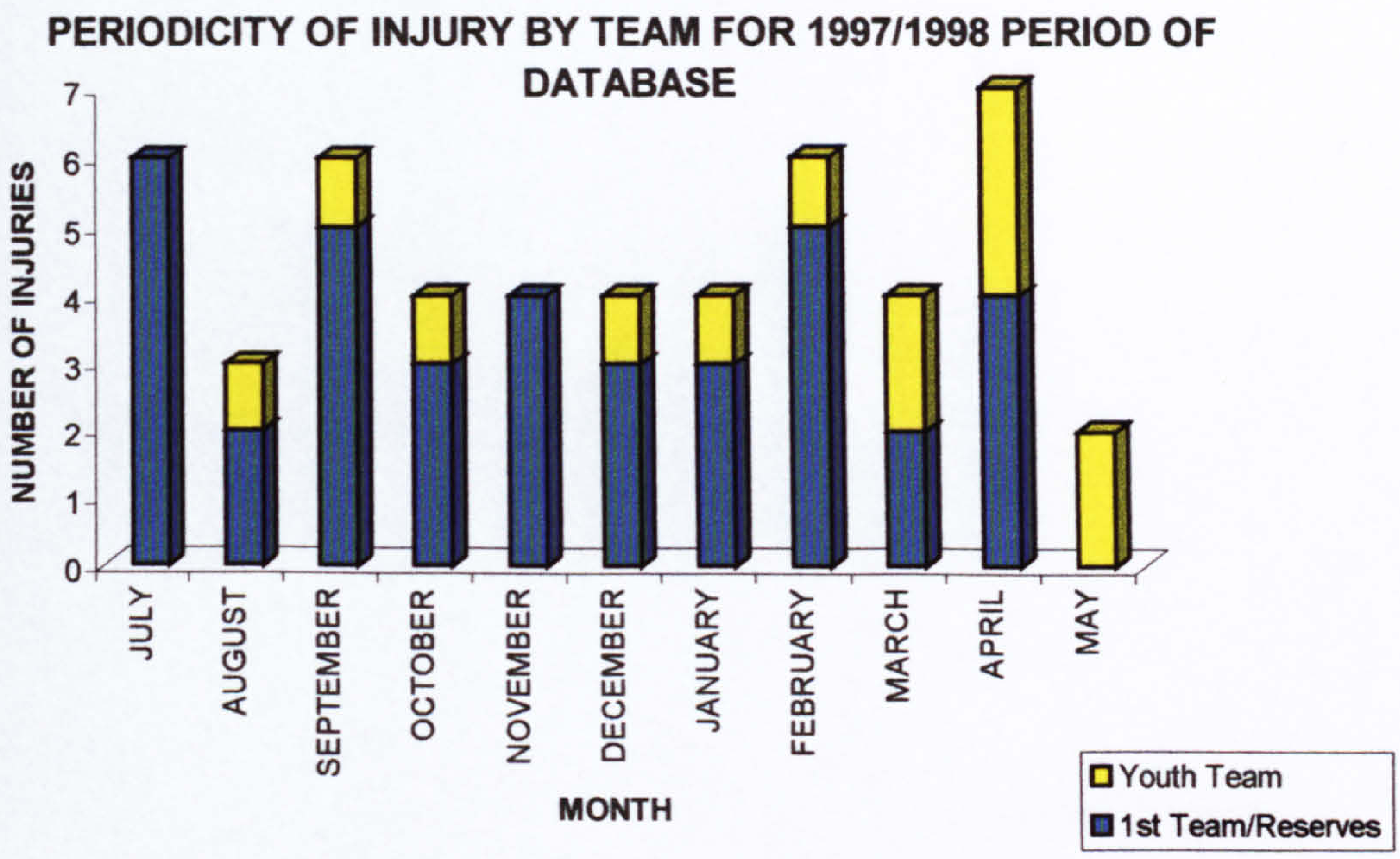
The periodicity of injury for this period is shown in *Figure n° 86*. This shows peaks of incidence at the start of pre-season training and the competitive season, then again in February and over the Easter period and end of season in April. For the Youth team, peaks are seen at the beginning and end of the competitive season and for the First/Reserve squad peaks of incidence are evident at the afore mentioned times. Team injury distribution over period 2 is depicted in *Figure n° 87*.

Figure n° 86 Periodicity of Injury for 1997/1998 Period of Database



The total number of injuries incurred by the First/Reserve team players was 37 (74%), with the youth team incurring the remaining 26% of injuries.

Figure n° 87 Periodicity of Injury by Team 1997/1998 Period



8.1.2.2 Type and Location of Injury

Of the 50 injuries, 62% were strains and sprains (*Table n° 8.16*) with injury most frequently to the knee (26%), ankle (18%) and hamstring (12%). The full details of injury location are in *Table n° 8.17.*

The side affected by injury was one and a half times more likely to be the right than the left, with 62.5% of injuries (that can be attributed to a side) incurred on the right side and 37.5% on the left (*Table n° 8.18*).

Table n° 8.16 Type of Injury Incurred over the 1997/1998 Period

Injury Type	*1997/1998 Period*	
	N° of Injuries	Percentage of Injuries
STRAIN	20	40%
SPRAIN	11	22%
CONTUSION	6	12%
ABRASION	1	2%
OVERUSE INJURY	-	-
FRACTURE	-	-
LACERATION	3	6%
UNKNOWN	-	-
DISLOCATION	-	-
OTHER	9	18%

Table nº 8.17 Injury Location over the 1997/1998 Period

Body Part Injured	*1997/1998 Period*	
	Nº of Injuries	Percentage of Injuries
LOWER LEG	3	6%
KNEE	13	26%
HAMSTRING	6	12%
ANKLE	9	18%
THIGH	3	6%
PELVIS/GROIN	3	6%
FOOT	2	4%
TOE	1	2%
VERTEBRAE	-	-
BACK	-	-
FINGER	-	-
HIP	2	4%
ABDOMEN	-	-
SHOULDER	1	2%
NECK	-	-
HAND	1	2%
UPPER ARM	1	2%
CHEST	1	2%
OTHER	4	8%

Table Nº 8.18 Distribution of Injury by Side Affected for the 1997/1998 Period

Period of Database	*1997/1998 Period*		
Injured Side	**LEFT**	**RIGHT**	**Not Applicable**
Nº of Injuries	15	25	10
Percentage of Injuries (corrected)	30% (37.5%)	50% (62.5%)	20%

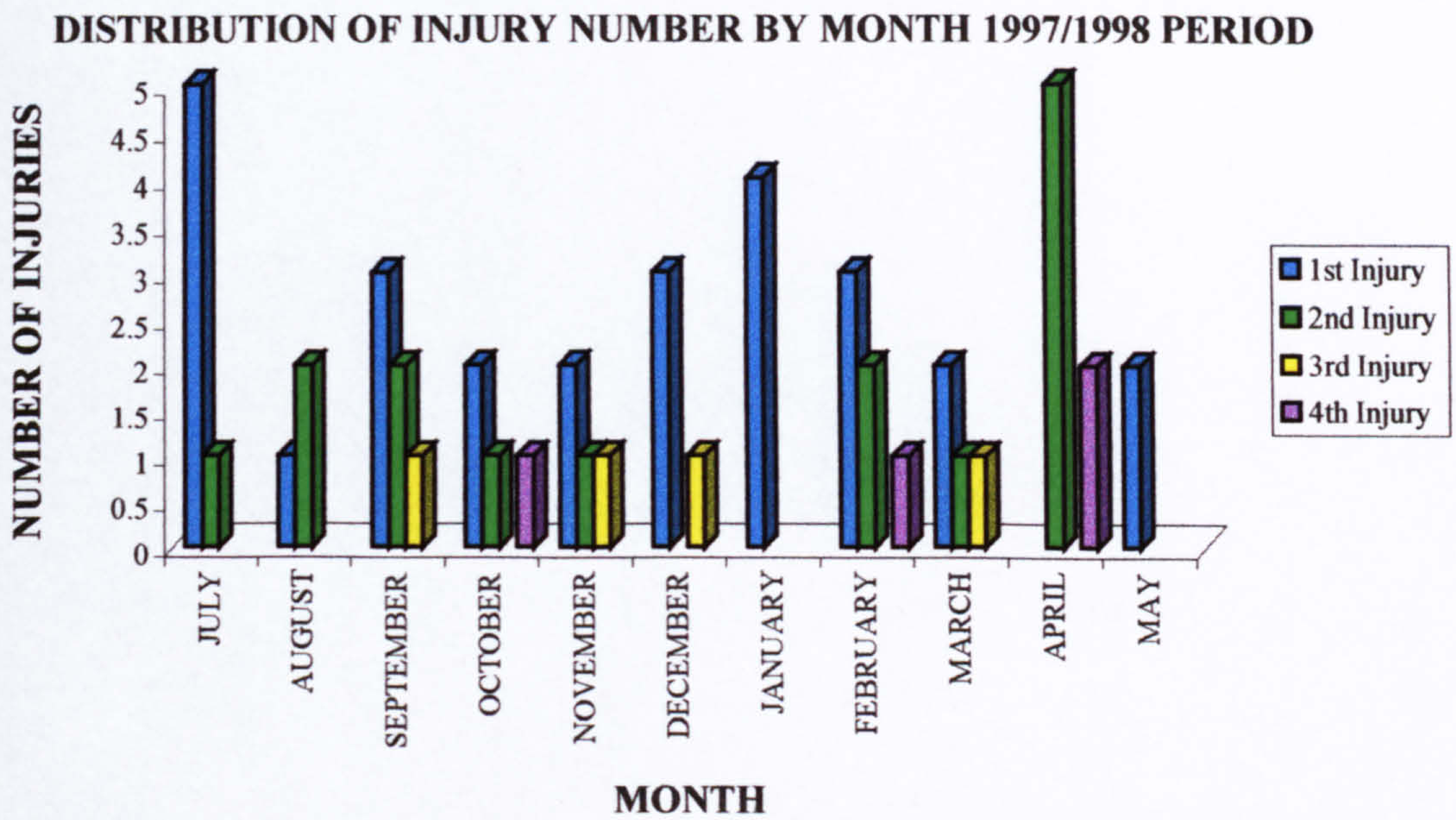
8.1.2.3 Incidence of Re-injury

Only one injury of the fifty was a re-injury. However 8% of players incurred up to four injuries in the course of the season as presented in *Table nº 8.19* and *Figure nº 88*.

Table nº 8.19 Number of Injuries and Incidence of Re-injury 1997/1998 Period

INJURY NUMBER	*Nº OF INJURIES*	*PERCENTAGE OF INJURIES*	*RE-INJURIES*
1st Injury	26	52%	-
2nd Injury	16	32%	1
3rd Injury	4	8%	-
4th Injury	4	8%	-

Figure n° 88 Distribution of Injuries (1997/1998) by Injury Number and Month



8.1.2.4 Time Lost due to Injury

Table n° 8.20 shows the amount of time lost due to injury; 36% of injuries requiring treatment for up to two months.

Table n° 8.20 Time Lost due to Injury 1997/1998 Period

Time Lost from Football	*Number of Incidences*	*Percentage of Incidences*
3 – 7 DAYS	6	12%
8 – 14 DAYS	10	20%
15 – 21 DAYS	8	16%
22 – 28 DAYS	5	10%
1 – 2 MONTHS	18	36%
2 MONTHS OR LONGER	3	6%

8.1.2.5 Training Vs Match Incidence

A total of 60% of injuries occurred during match situations, the remaining 40% during training sessions. The distribution by team is shown in *Table n° 8.21*.

Table n° 8.21 Distribution of Injury over Training and Match Situations

TEAM	*N° of Injuries Occurring During Training*	*N° of Injuries occurring in Matches*
Club	20 (40%)	30 (60%)
First/Reserve Team	15	22
Youth Team	5	8

8.1.2.6 Miscellaneous Injury Factors

Day and time of injury are presented in *Table n^os^ 8.22* and *8.23* respectively. Saturday was the most frequent day of injury (26%) and time of injury is evenly distributed between morning 9am and 12pm (46%) and afternoon/evening 3pm to 9pm (44%).

Table n° 8.22 Distribution of Injuries by Day of Week over 1997/1998 Period

Day	*Number of Injuries 1997/1998 Period*	*Percentage of Injuries 1997/1998 Period*
MONDAY	4	8%
TUESDAY	12	24%
WEDNESDAY	6	12%
THURSDAY	5	10%
FRIDAY	5	10%
SATURDAY	13	26%
SUNDAY	2	4%
NOT RECORDED	3	6%

Table n° 8.23 Distribution of Injuries by Time of Day over 1997/1998 Period

Time of Day	*Number of Injuries 1997/1998 Period*	*Percentage of Injuries 1997/1998 Period*
6am – 9am	-	-
9am – 12pm	23	46%
12pm – 3pm	1	2%
3pm – 6pm	11	22%
6pm – 9pm	11	22%
9pm – 12am	-	-
Unknown	4	8%

8.2 ATHLETIC PERFORMANCE RESULTS

Twenty subjects (*Table n^o^ 8.24*) were tested on four separate occasions:

1st Session: Untaped and Taped (before training)

2nd Session: Untaped and Taped (before training)

3rd Session: Untaped and Taped (before training)

4th Session: After proprioceptive training (untaped)

For each condition, the subject undertook two trials of each of the four athletic performance tests, the mean of the two trials giving a value for that session. The session values were then averaged, the mean results are presented in *Table nos 8.25* to *8.28*.

Table nº 8.24 Subject Information for Athletic Performance Tests

SUBJECT	AGE (years)	HEIGHT (in/cm)	WEIGHT (kg/lb)	POSITION PLAYED
1	17 years	5ft 6 in 167.74 cm	62 kg 9 st 8 lb	LEFT MIDFIELD
2	19 years	5 ft 11 in 180.34 cm	68 kg 10 st 10 lb	LEFT BACK
3	17 years	6 ft 182.88 cm	74 kg 11 st 7 lb	CENTRE BACK
4	16 years	5 ft 6 in 167.74 cm	60 kg 9 st 7 lb	LEFT BACK
5	17 years	5 ft 11 in 180.34 cm	79 kg 12 st 4 lb	MIDFIELD
6	20 years	5 ft 10 in 177.80 cm	75 kg 11 st 10 lb	CENTRE FORWARD
7	16 years	5 ft 11 in 180.34 cm	68 kg 10 st 10 lb	CENTRE MIDFIELD
8	17 years	5 ft 7 in 170.24 cm	64.9 kg 10 st 2 lb	CENTRE BACK
9	16 years	6 ft 182.88 cm	75.3 kg 11 st 12 lb	CENTRE BACK
10	16 years	6 ft 188.88 cm	74 kg 11 st 7 lb	GOALKEEPER
11	19 years	6 ft 182.88 cm	82.5 kg 13 st	LEFT MIDFIELD
12	18 years	6 ft 2 in 187.96 cm	83 kg 13 st 1 lb	GOALKEEPER
13	17 years	5 ft 11 in 180.34 cm	73 kg 11 st 5 lb	CENTRE HALF
14	17 years	5 ft 11 in 180.34 cm	70 kg 11 st	BACK
15	16 years	5 ft 11 in 180.34 cm	66 kg 10 st 6 lb	CENTRE HALF
16	18 years	5 ft 7 in 170.24 cm	72 kg 11 st 5 lb	MIDFIELD
17	18 years	5 ft 11 in 180.34 cm	68.9 kg 10 st 12 lb	MIDFIELD
18	17 years	6 ft 182.88 cm	72 kg 11 st 3 lb	RIGHT FORWARD
19	17 years	5 ft 11 in 180.34 cm	77 kg 12 st 1 lb	CENTRE FORWARD
20	17 years	5 ft 11 in 180.34 cm	71.6 kg 11 st 4 lb	CENTRE FORWARD
MEAN	17.25 years	179.26 cm	71.81 kg	

8.2.1 Descriptive Statistics on Performance Tests

The results of the four performance tests of vertical jump, broad jump, sprint run and shuttle run were analysed statistically in several ways to obtain the most useful information from the data.

Subject means, and overall mean and standard deviation values for the tests are presented in *Table n^{os} 8.25* to *8.28*.

*Table n° 8.25 Descriptive Statistics for **Vertical Jump** (all test conditions) in centimetres*

VERTICAL JUMP HEIGHT (CM)			
Subject Number	***Untaped Untrained***	***Taped***	***Proprioceptively Trained***
1	46.2	45.2	46.7
2	36.3	37	37.5
3	48.7	47.5	48.3
4	35.7	35.2	34.2
5	39.5	38.8	39.5
6	50.7	48.8	48.8
7	34.8	33.8	34.2
8	39.5	41	40.7
9	34.3	36	34.7
10	54.3	52.8	54.2
11	49.3	49.3	49.5
12	45.5	43.2	44.3
13	48.5	47.7	47.3
14	41.2	40.5	40.8
15	49.8	48	48.7
16	45	43	43.3
17	37	38.7	38
18	44.8	46.3	47.5
19	53.2	52.3	52.7
20	42.3	38.7	39.8
Overall Mean	43.83	43.19	43.54
Standard Deviation	6.30	5.77	6.14
Standard Error	1.41	1.29	1.37
Variance	39.74	33.35	37.69

*Table n° 8.26 Descriptive Statistics for **Broad Jump** (all test conditions) in centimetres*

BROAD JUMP DISTANCE (CM)			
Subject Number	***Untaped Untrained***	***Taped***	***Proprioceptively Trained***
1	220	215	214
2	196	196	197
3	210	210	210
4	214	211	213
5	199	200	200
6	213	209	212
7	206	207	201
8	184	187	193
9	199	199	199
10	199	198	203
11	200	204	189
12	182	184	202
13	211	211	200
14	195	194	213
15	225	221	209
16	205	196	198
17	200	196	206
18	212	208	216
19	218	217	195
20	184	183	183
Mean	203.6	202.3	202.65
Standard Deviation	12.05	10.77	8.95
Standard Error	2.70	2.41	2.00
Variance	145.31	116.01	80.13

*<u>Table n° 8.27 Descriptive Statistics for **Sprint Run**</u>*
<u>(all test conditions) in seconds</u>

SPRINT RUN TIME (Seconds)			
Subject Number	***Untaped Untrained***	***Taped***	***Proprioceptively Trained***
1	4.74	4.97	4.86
2	5.30	5.29	5.29
3	5.25	5.29	5.28
4	5.20	5.18	5.18
5	5.12	5.08	5.10
6	5.05	5.05	5.05
7	5.39	5.38	5.39
8	5.34	5.38	5.39
9	5.60	5.50	5.57
10	5.54	5.57	5.53
11	4.80	5.17	4.93
12	5.46	5.49	5.48
13	5.04	5.01	5.03
14	5.28	5.28	5.27
15	5.52	5.43	5.48
16	5.24	5.31	5.27
17	5.15	5.14	5.14
18	5.16	5.22	5.19
19	5.27	4.94	5.22
20	5.22	5.23	5.21
Mean	5.23	5.25	5.24
Standard Deviation	0.22	0.18	0.19
Standard Error	0.05	0.04	0.43
Variance	0.05	0.03	0.04

*<u>Table n° 8.28 Descriptive Statistics for **Shuttle Run**</u>*
<u>(all test conditions) in seconds</u>

SHUTTLE RUN TIME (Seconds)			
Subject Number	***Untaped Untrained***	***Taped***	***Proprioceptively Trained***
1	4.69	4.70	4.69
2	4.64	4.60	4.62
3	4.88	4.86	4.88
4	4.56	4.55	4.55
5	4.63	4.63	4.64
6	4.71	4.70	4.72
7	4.65	4.63	4.65
8	4.75	4.73	4.74
9	4.78	4.83	4.79
10	4.68	4.60	4.62
11	4.49	4.52	4.50
12	4.92	4.91	4.92
13	4.89	4.98	4.83
14	4.79	4.81	4.79
15	4.59	4.76	4.64
16	4.69	4.69	4.72
17	4.87	4.89	4.89
18	4.54	4.63	4.60
19	4.47	4.50	4.49
20	4.52	4.51	4.49
Mean	4.69	4.70	4.69
Standard Deviation	0.14	0.14	0.13
Standard Error	0.03	0.03	0.03
Variance	0.02	0.02	0.02

Boxplot graphs of the four performance tests illustrate the distribution of values across the three test conditions of Untaped or Untrained, Taped and Proprioceptively Trained. For each performance test, the boxplots show the results of the three test conditions separately, but plotted side by side for comparison. In the boxplot, the box itself represents that portion of the distribution falling between the 25th and 75th percentiles. The horizontal line across the interior of the box represents the median. The vertical lines outside the box (whiskers) connect the largest and smallest values that are not categorised as outliers or extreme values. A boxplot outlier (o) is defined as a value more than 1.5 box-lengths away from the box. The boxplots are displayed in *Figure nos 89 to 812*.

*Figure nº 89 Boxplot Representation of **Vertical Jump** Performance Test Results Comparing the three Testing Conditions of Untrained/Untaped, Taped and Trained.*

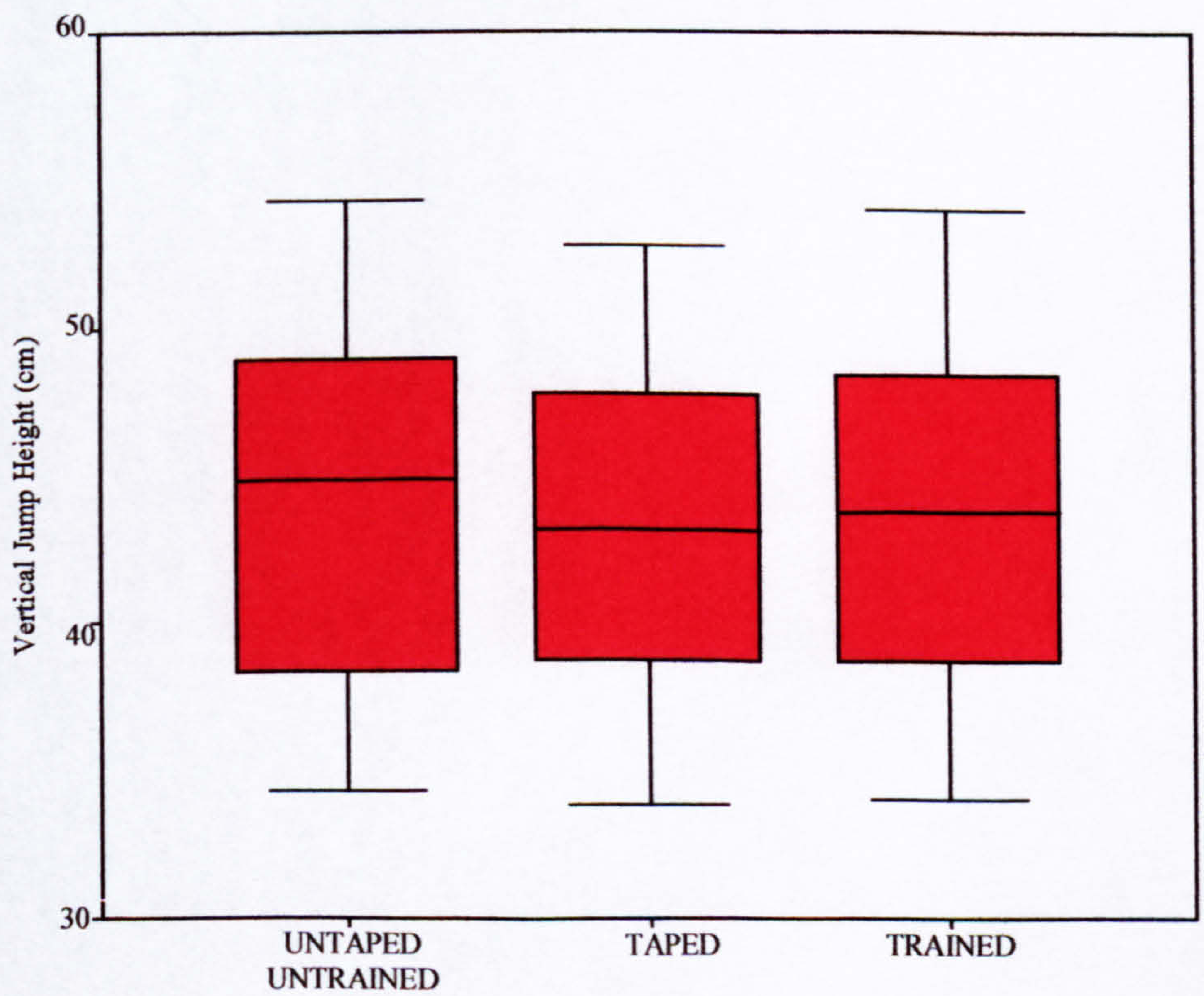


Figure nº 810 Boxplot Representation of ***Broad Jump*** *Performance Test Results Comparing the three Testing Conditions of Untrained/Untaped, Taped and Trained.*

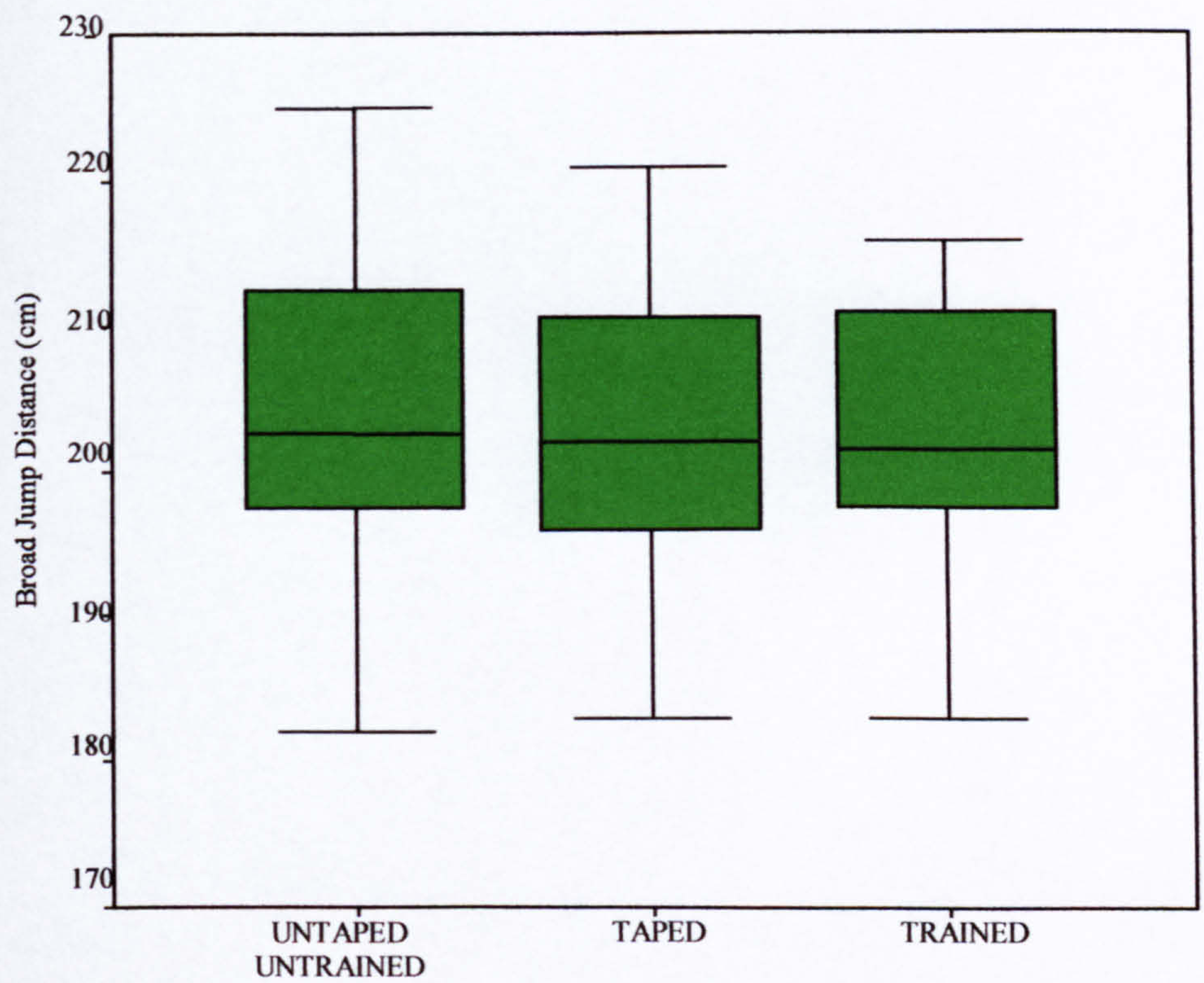


Figure nº 811 Boxplot Representation of ***Sprint Run*** *Performance Test Results Comparing the three Testing Conditions of Untrained/Untaped, Taped and Trained.*

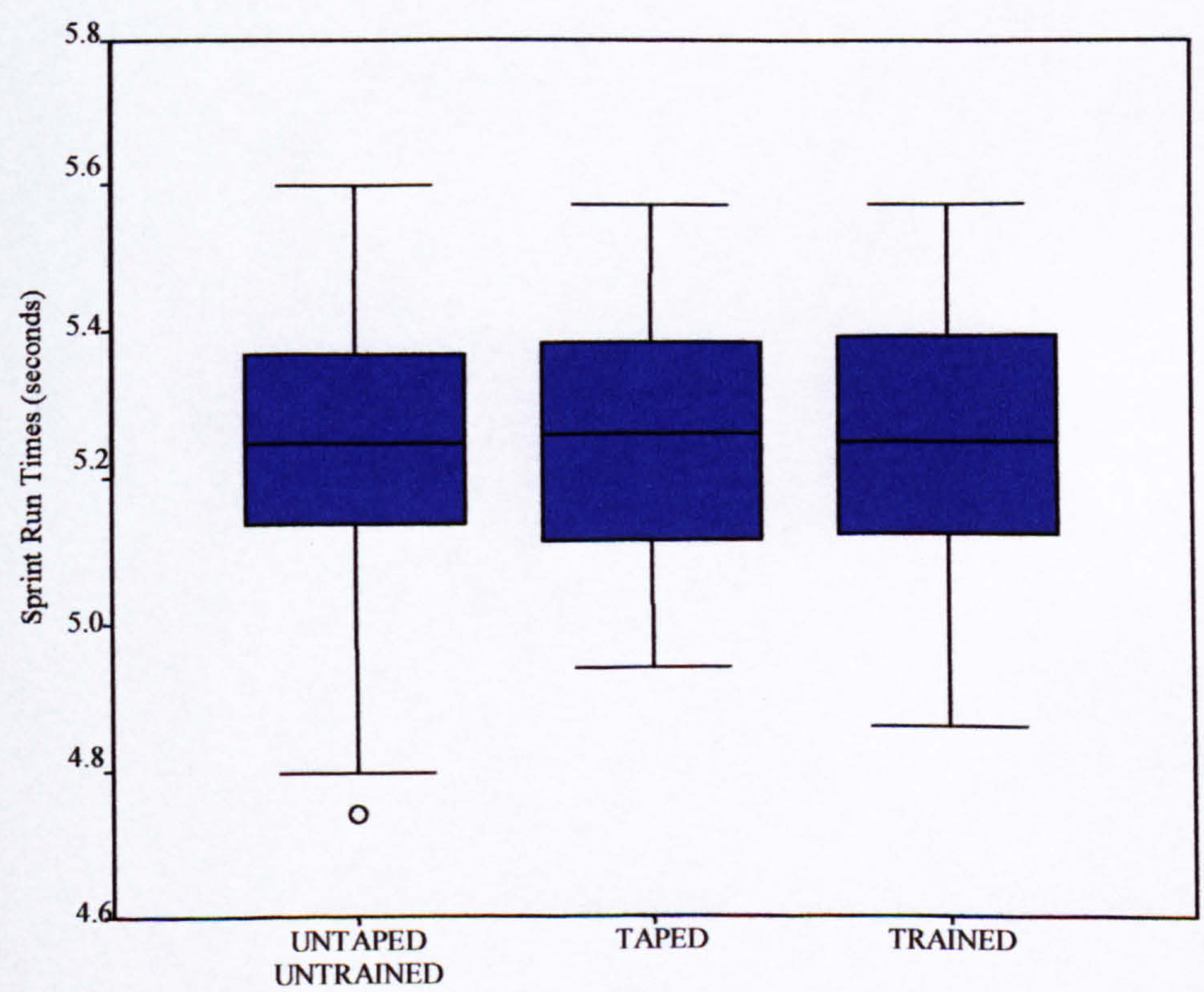
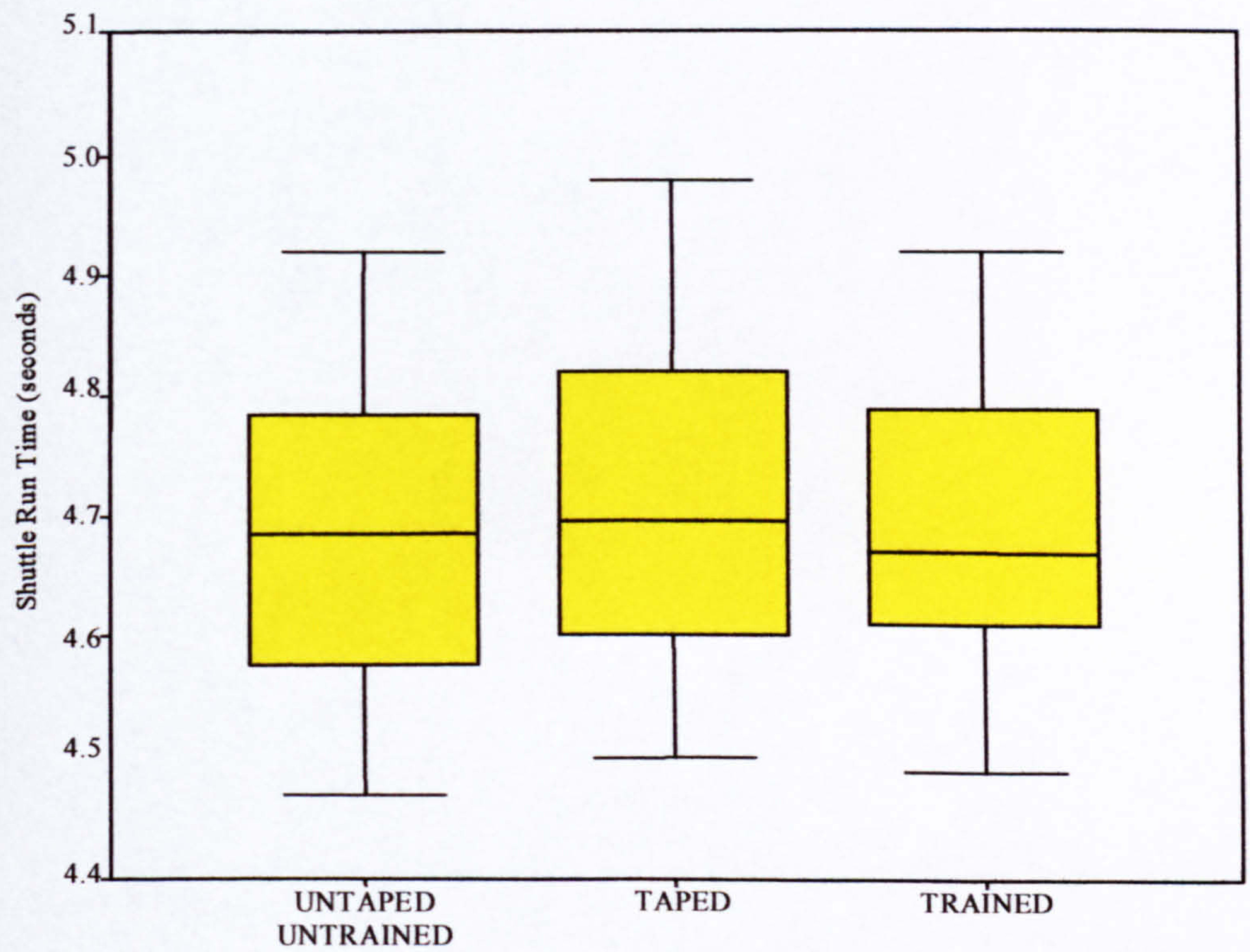


Figure n° 812 Boxplot Representation of ***Shuttle Run*** *Performance Test Results Comparing the three Testing Conditions of Untrained/Untaped, Taped and Trained.*



Analysis of the data by ANOVA (Analysis of Variance) with repeated measures on the independent variable of testing condition: Untaped/Untrained, Taped and Trained and t-tests for paired samples indicated that neither taping nor proprioceptive training of the ankle significantly affected performance of any of the four tests.

Vertical Jump	$F(2,38) = 3.53$	$p = 0.039$
	(Epsilon corrected Greenhouse-Geisser	*$p = 0.063$)*
Broad Jump	$F(2,38) = 0.25$	$p = 0.779$
	(Epsilon corrected Greenhouse-Geisser	*$p = 0.653$)*
Sprint Run	$F(2,38) = 0.17$	$p = 0.843$
	(Epsilon corrected Greenhouse-Geisser	*$p = 0.697$)*
Shuttle Run	$F(2,38) = 1.28$	$p = 0.289$
	(Epsilon corrected Greenhouse-Geisser	*$p = 0.289$)*

8.2.2 Confidence Intervals and Significance for Performance Tests

The 95% Confidence Intervals obtained from the paired samples t-tests are outlined in *Table n° 8.29 and 8.30.* These intervals represent, with 95% confidence, differences in performance caused by test day (Trials 1, 2 and 3 in the Untaped and Taping groups) and trials within the test day (for the Trained group) and taping or proprioceptive training.

Table n° 8.29 Ninety Five Percent Confidence Intervals Representing Changes in Performance Caused by Test Day on Test Condition

VERTICAL JUMP	*Untaped/Untrained*	*Taped*	*Proprioceptively Trained*
Trial 1 Vs Trial 2	-1.319 to 2.169 *p-value* = 0.616	-0.877 to 1.077 *p-value* = 0.833	-1.499 to –0.201 *p-value* = 0.013
Trial 1 Vs Trial 3	-3.237 to 1.855 *p-value* = 0.502	-3.237 to 0.687 *p-value* = 0.190	-0.899 to –0.699 *p-value* = 0.796
Trial 2 Vs Trial 3	-3.233 to 0.583 *p-value* = 0.162	-3.257 to 0.507 *p-value* = 0.143	-0.200 to 1.700 *p-value* = 0.115
BROAD JUMP	*Untaped/Untrained*	*Taped*	*Proprioceptively Trained*
Trial 1 Vs Trial 2	1.287 to 7.363 *p-value* = 0.008	-5.520 to 1.295 *p-value* = 0.210	-3.124 to 2.724 *p-value* = 0.888
Trial 1 Vs Trial 3	1.653 to 6.297 *p-value* = 0.002	-4.676 to 2.101 *p-value* = 0.436	-7.821 to 6.721 *p-value* = 0.876
Trial 2 Vs Trial 3	-3.523 to 2.823 *p-value* = 0.820	-3.059 to 4.709 *p-value* = 0.662	-8.136 to 7.436 *p-value* = 0.926
SPRINT RUN	*Untaped/Untrained*	*Taped*	*Proprioceptively Trained*
Trial 1 Vs Trial 2	-0.191 to 0.033 *p-value* = 0.158	-0.037 to 0.038 *p-value* = 0.978	-0.055 to 0.069 *p-value* = 0.816
Trial 1 Vs Trial 3	-0.084 to –0.017 *p-value* = 0.006	-0.168 to 0.041 *p-value* = 0.217	-0.070 to 0.067 *p-value* = 0.964
Trial 2 Vs Trial 3	-0.083 to 0.140 *p-value* = 0.6	-0.175 to 0.047 *p-value* = 0.244	-0.037 to 0.020 *p-value* = 0.536
SHUTTLE RUN	*Untaped/Untrained*	*Taped*	*Proprioceptively Trained*
Trial 1 Vs Trial 2	-0.026 to 0.067 *p-value* = 0.363	-0.029 to 0.036 *p-value* = 0.822	-0.070 to 0.019 *p-value* = 0.249
Trial 1 Vs Trial 3	-0.131 to 0.079 *p-value* = 0.610	-0.148 to 0.054 *p-value* = 0.343	-0.046 to 0.024 *p-value* = 0.524
Trial 2 Vs Trial 3	-0.151 to 0.058 *p-value* = 0.362	-0.154 to 0.053 *p-value* = 0.320	-0.011 to 0.040 *p-value* = 0.246

From *Table n° 8.29*, significance ($p < 0.05$) can be seen between trials for;

Vertical Jump Trained $p = 0.013$(Trial 1&2)

Broad Jump Untaped/Untrained $p = 0.08$ (Days 1&2)

$p = 0.002$ (Days 1&3)

Sprint Run Untaped/Untrained $p = 0.006$ (Days 1&3)

Table nº 8.30 Ninety Five Percent Confidence Intervals Representing Changes in Performance Caused by Testing Condition

	VERTICAL JUMP (centimetres)	*BROAD JUMP (centimetres)*	*SPRINT RUN (seconds)*	*SHUTTLE RUN (seconds)*
Untaped Vs Taped	-0.040 to 1.320 *p-value* = 0.063	-0.142 to 2.742 *p-value* = 0.074	-0.074 to 0.050 *p-value* = 0.689	-0.040 to 0.011 *p-value* = 0.246
Untrained Vs Trained	-0.028 to 0.958 *p-value* = 0.063	-3.849 to 5.749 *p-value* = 0.683	-0.031 to 0.012 *p-value* = 0.375	-0.015 to 0.012 *p-value* = 0.824
Taped Vs Trained	-0.506 to 0.156 *p-value* = 0.282	-5.076 to 4.376 *p-value* = 0.878	-0.041 to 0.046 *p-value* = 0.905	-0.009 to 0.035 *p-value* = 0.224

From *Table 8.30*, it can be seen that no test condition significantly affected performance ($p < 0.05$). However, values for **Vertical Jump**, Taped and Trained show a significance ($p < 0.1$) of $p = 0.063$. **Broad Jump** performance Taped also shows a significance ($p < 0.1$) of $p = 0.074$, thus the results have a confidence of approximately 92.5% that they are not due to chance.

8.2.3 Correlation and Reliability for Performance Tests

Test-retest reliability was performed on the data for all of the performance tests using Pearson's correlation coefficient to check for repeatability of results within trials. Correlation was also examined between test conditions to investigate for significant differences.

For **Vertical Jump** performance, correlation between test conditions and between trials was high *Table nº 8.31*.

Table nº 8.31 Pearson Correlation Coefficients for Between Condition and Between Trials on ***Vertical Jump*** *Performance*

BETWEEN CONDITION	*Pearson's Correlation*		
UNTAPED Vs TAPED	0.97		
UNTRAINED Vs TRAINED	0.98		
TAPED Vs TRAINED	0.99		
BETWEEN TRIAL	***UNTAPED/ UNTRAINED***	***TAPED***	***PROPRIOCEPTIVELY TRAINED***
TRIAL 1 Vs TRIAL 2	0.84	0.94	0.98
TRIAL 1 Vs TRIAL 3	0.66, $p = 0.002$	0.76	0.96
TRIAL 2 Vs TRIAL 3	0.87	0.79	0.95

Correlations between test conditions for **Broad Jump** were variable from high correlation between Untaped and Taped r = 0.97 to moderate between Untaped/Untrained and Trained and Taped and Trained r = 0.56, *p = 0.011* and r = 0.49, *p = 0.03* respectively. The between trial correlations were high, with the exception of Trial 1 Vs Trial 3 and Trial 2 Vs Trial 3 after proprioceptive training with r = 0.07, *p = 0.758* and r = 0.103, *p = 0.67* respectively (*Table n^o 8.32*).

*Table n^o 8.32 Pearson Correlation Coefficients for Between Condition and Between Trials on **Broad Jump** Performance*

BETWEEN CONDITION	Pearson's Correlation		
UNTAPED Vs TAPED	0.97		
UNTRAINED Vs TRAINED	0.56, *p = 0.011*		
TAPED Vs TRAINED	0.49, *p = 0.03*		
BETWEEN TRIAL	UNTAPED/ UNTRAINED	TAPED	PROPRIOCEPTIVELY TRAINED
TRIAL 1 Vs TRIAL 2	0.87	0.80	0.87
TRIAL 1 Vs TRIAL 3	0.94	0.84	0.07, *p = 0.758*
TRIAL 2 Vs TRIAL 3	0.87	0.78	0.10, *p = 0.67*

Sprint Run correlations were high between test conditions, but showed some moderate to low correlations between trials as depicted in *Table n^o 8.33*.

*Table n^o 8.33 Pearson Correlation Coefficients for Between Condition and Between Trials on **Sprint Run** Performance*

BETWEEN CONDITION	Pearson's Correlation		
UNTAPED Vs TAPED	0.80		
UNTRAINED Vs TRAINED	0.98		
TAPED Vs TRAINED	0.99		
BETWEEN TRIAL	UNTAPED/ UNTRAINED	TAPED	PROPRIOCEPTIVELY TRAINED
TRIAL 1 Vs TRIAL 2	0.58, *p = 0.008*	0.93	0.81
TRIAL 1 Vs TRIAL 3	0.95	0.48, *p = 0.03*	0.73
TRIAL 2 Vs TRIAL 3	0.56, *p = 0.009*	0.43, *p = 0.06*	0.96

Shuttle Run correlations were also high between conditions and again showed variable correlations between trials (*Table n^o 8.34*).

*Table nº 8.34 Pearson Correlation Coefficients for Between Condition and Between Trials on **Shuttle Run** Performance*

BETWEEN CONDITION	Pearson's Correlation		
UNTAPED Vs TAPED	0.93		
UNTRAINED Vs TRAINED	0.98		
TAPED Vs TRAINED	0.95		
BETWEEN TRIAL	UNTAPED/ UNTRAINED	TAPED	PROPRIOCEPTIVELY TRAINED
TRIAL 1 Vs TRIAL 2	0.77	0.89	0.77
TRIAL 1 Vs TRIAL 3	0.36, $p = 0.125$	0.48, $p = 0.03$	0.85
TRIAL 2 Vs TRIAL 3	0.34, $p = 0.138$	0.46, $p = 0.04$	0.93

Figure nºs 813 to *816* illustrate the correlations between the tests by means of scatterplots depicting the close correlations in performance tests of vertical jump, sprint run and shuttle run, with low correlations between conditions for broad jump performance.

Figure nº 813 Scatterplot for Vertical Jump Performance

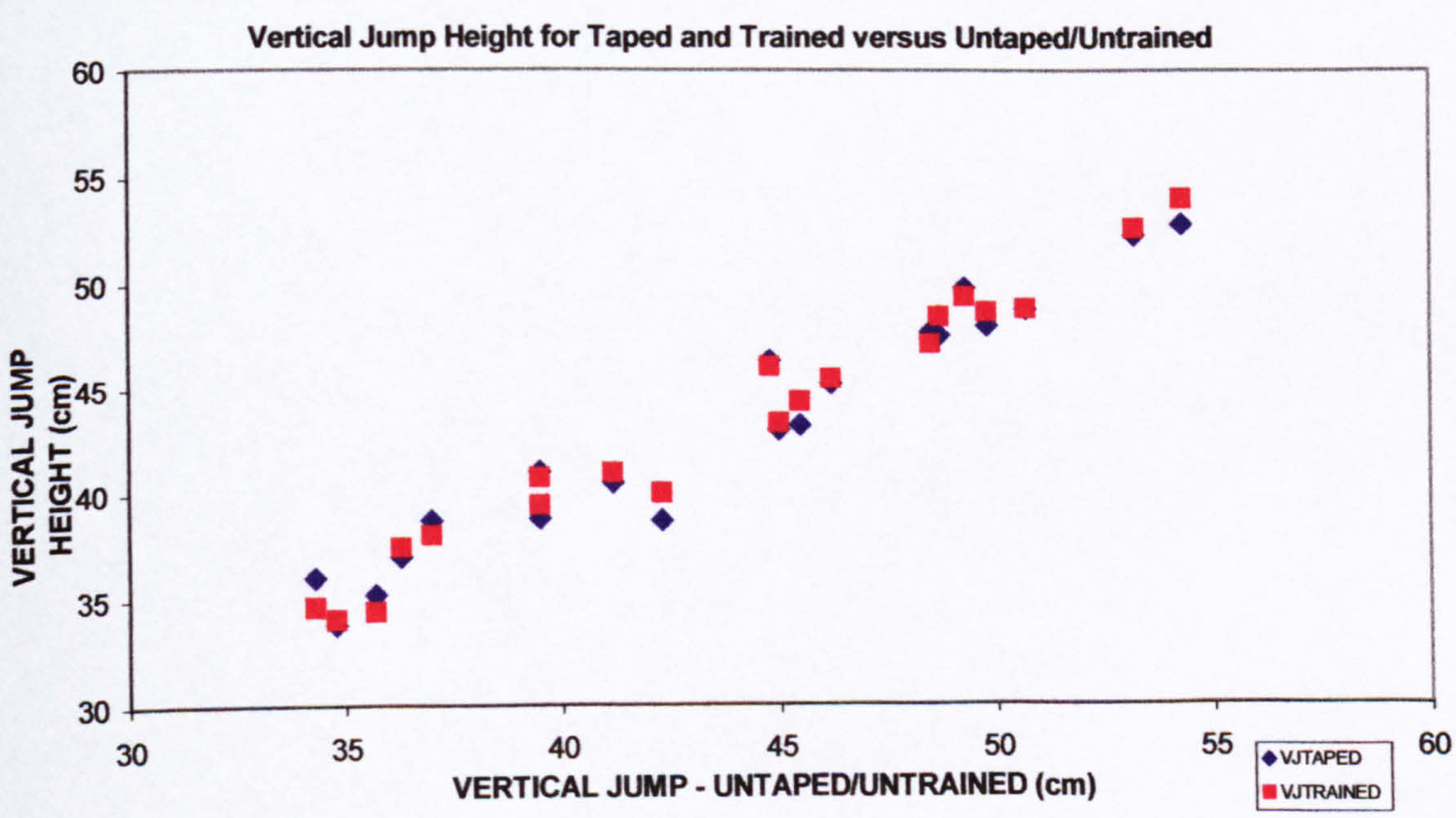


Figure n° 814 Scatterplot for Broad Jump Performance

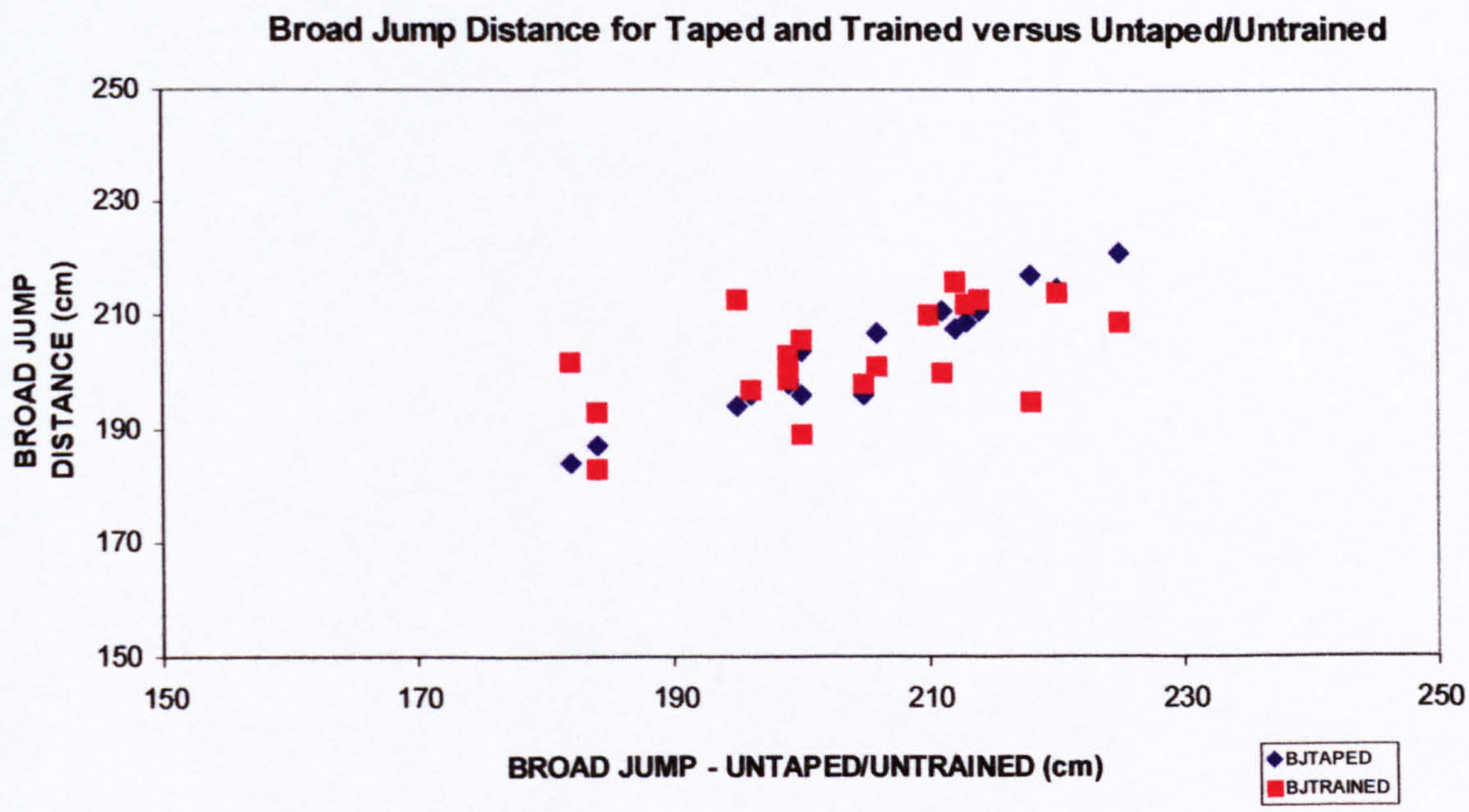


Figure n° 815 Scatterplot for Sprint Run Performance

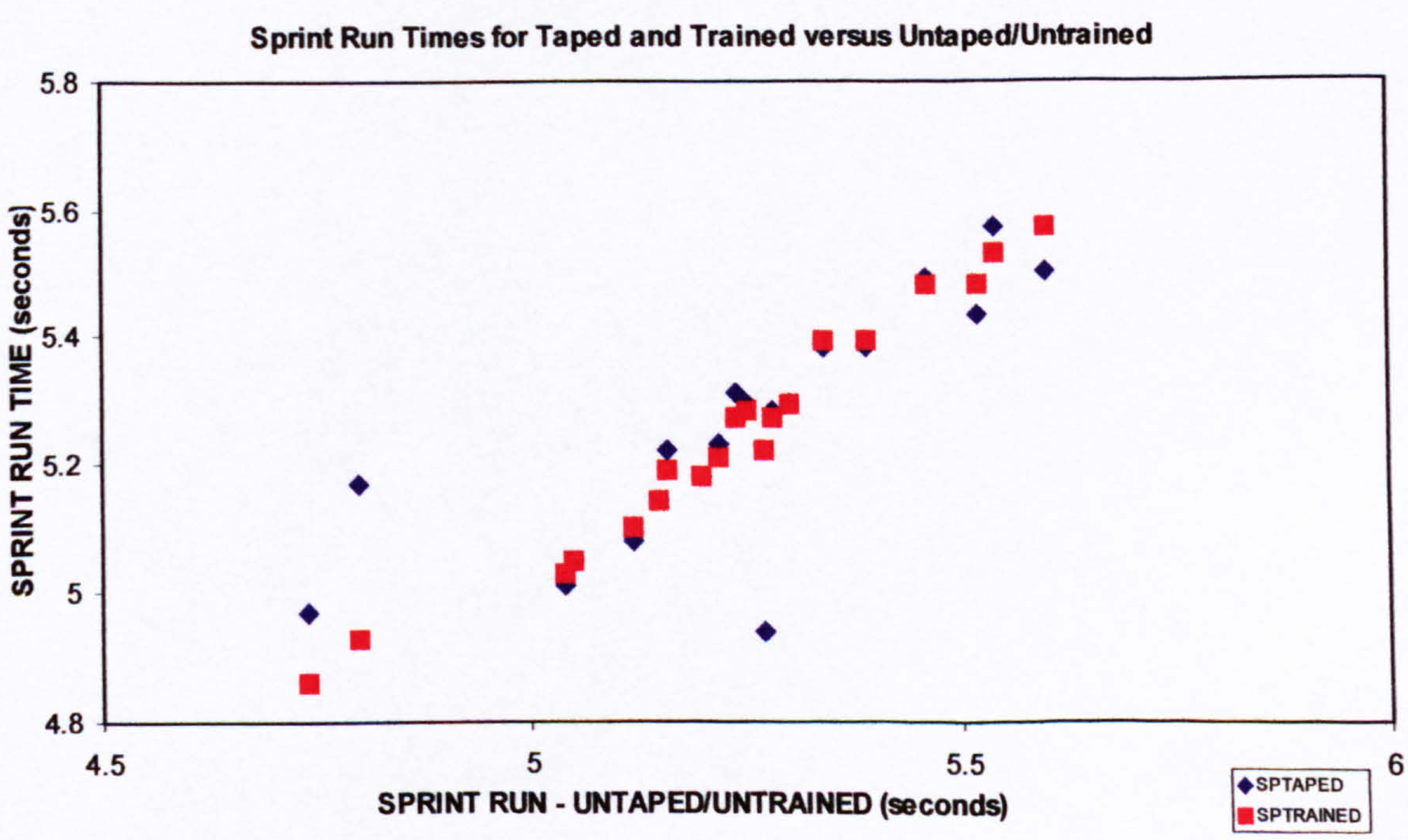
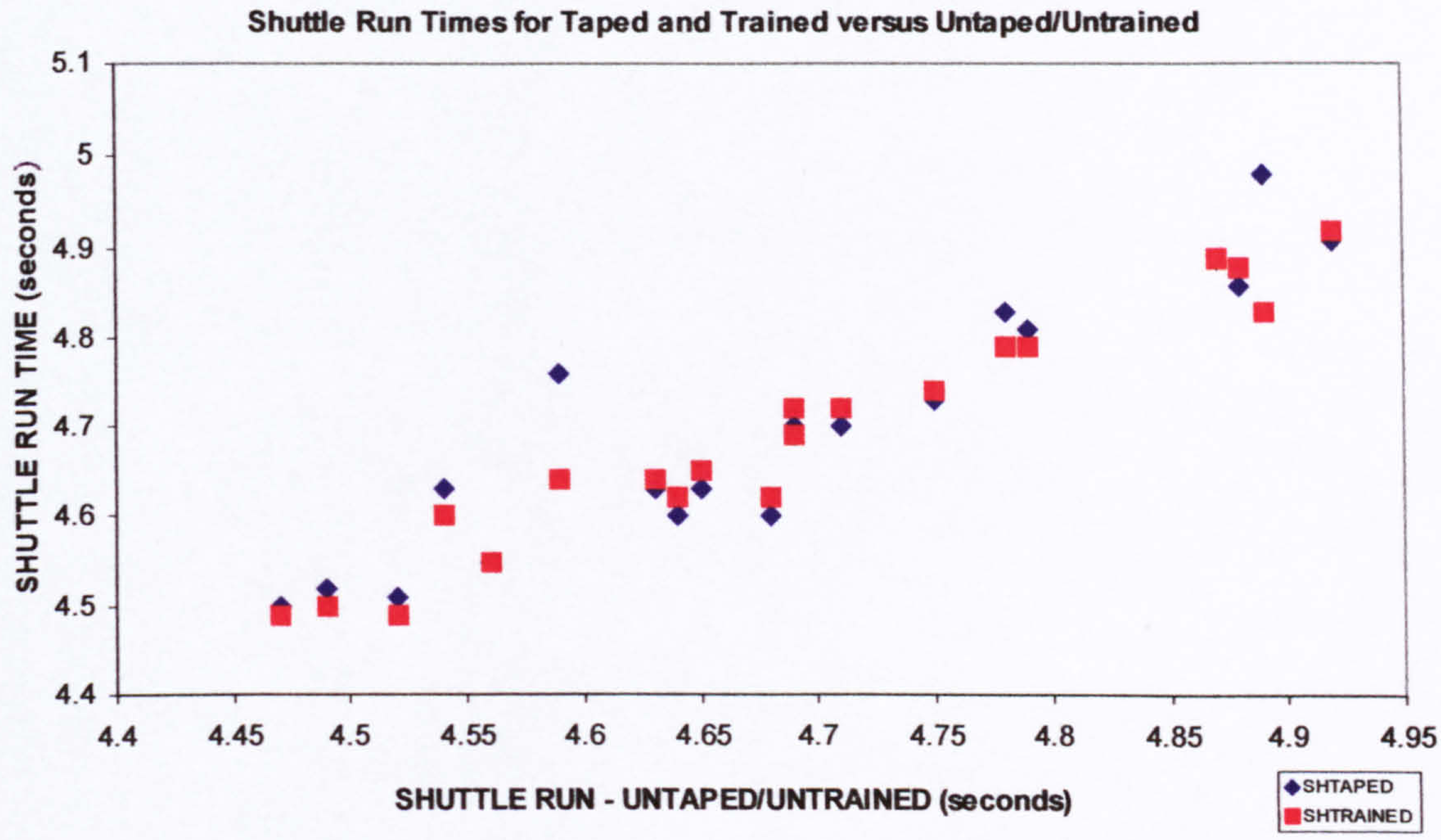


Figure nº 816 Scatterplot for Shuttle Run Performance



8.2.4 Percentage Difference in Performance for Performance Tests

Evaluating the percentage difference in performance for the test conditions shows an overall decrease in performance (*Table nº 8.35*). Range 0.19% [**Sprint Run** (Untrained Vs Trained)] to 1.46% [**Vertical Jump** (Untrained Vs Taped)]. By contrast, a slight increase in performance is seen comparing taping to proprioceptive training. This ranges from 0.17% (**Broad Jump**) to 0.8% (**Vertical Jump**).

Table nº 8.35 Percentage Difference in Athletic Performance for Performance Tests with Changing Testing Condition

PERFORMANCE TEST	UNTAPED Vs TAPED	UNTRAINED Vs TRAINED	TAPED Vs TRAINED
VERTICAL JUMP	1.46 % Decrease	0.66 % Decrease	0.8 % Increase
BROAD JUMP	0.64 % Decrease	0.47 % Decrease	0.17 % Increase
SPRINT RUN	0.38 % Decrease	0.19 % Decrease	0.19 % Increase
SHUTTLE RUN	0.21 % Decrease	0 % Difference	0.21 % Increase

8.2.5 Statistical Effect of Position on Athletic Performance

Results from the subjects were separated into their relevant playing positions as stated in *Table nº 8.24* and the data was analysed by paired samples t-test with groups of forward, midfield and back positions.

The analysis revealed statistical significance (*$p < 0.05$*) in the **Broad Jump** test data between forward and midfield positions in the taped condition; $p = 0.041$ for a 95% confidence interval of 0.032 to 1.011.

Within the positions there was statistical significance (*$p < 0.05$*) for midfield players in the **Vertical Jump** test and for forward players in the **Shuttle Run** test. These are presented in *Table n° 8.36.*

Table n° 8.36 Statistically Significant Within Position Performance Values

Position	*Performance Test*	*Testing Condition*	*p-value*	*95% Confidence Interval*
MIDFIELD	Vertical Jump	Untaped Vs Taped	*P = 0.009*	0.272 to 1.185
MIDFIELD	Vertical Jump	Untrained Vs Trained	*P = 0.041*	0.032 to 1.011
FORWARD	Shuttle Run	Taped Vs Trained	*P = 0.046*	-0.027 to 0.000

8.2.6 Subjective Questionnaire Results on Taping

Subjective questionnaires (*Appendix n° A4*) were supplied to the subjects for feedback on how the taping 'felt' while performing the athletic performance tests. Of the twenty subjects, 36.8% did not think that the tape affected performance. However, 10.5% thought that the tape enhanced their performance. With respect to restriction of movement 47.4% 'felt' that the taping restricted the natural movement of the ankle.

The tape had an average comfort rating of 5.6 on a scale of increasing comfort from 1 to 10 with 1 being very uncomfortable and 10, very comfortable. The level of support had an average rating of 7.9 increasing from no support (1) to maximal support (10). Confidence of the subject while wearing the tape had an average rating of 7.8 again on a scale from no confidence (1) to very confident (10) whilst performing while taped.

Only one subject from the 20 subjects tested, described skin irritation while wearing the tape.

8.3 POSTURAL STABILITY RESULTS

All subjects completed the study protocol. During testing, several subjects lost their balance; at this point the trial was stopped and re-testing was conducted for that particular trial.

The descriptive statistics of sway index, left/right sway, anterior/posterior sway, centre of balance $_{x\text{-axis}}$ and centre of balance $_{y\text{-axis}}$ are presented in *Table n^{os} 8.37 to 8.41.*

To recapitulate the definitions of these descriptors;

The *Sway Index* reflects the degree of scatter of data about the subject's centre of balance. The data from the force transducer measurements are interfaced with software that filters and samples the data at approximately 15 cycles per second, and the sway index is calculated by determining the distance from the subject's centre of balance for each of the data points. Overall, the sway index is a numeric value of the standard deviation of time and distance that a subject spends away from their centre of balance for the period of the trial.

Left/Right and *Anterior/Posterior Sway* are the maximum movements in centimetres that the subject moves away from their centre of balance in the left/right and anterior/posterior directions respectively.

COB $_{X\ and\ Y}$ are the average x and y co-ordinates plotted using 'normal' COB as a reference point, where 'normal' COB is the point between the feet where the ball and heel of each foot has 25% of the body weight in double-leg stance and the point in single-leg stance where the ball and heel of the foot has 50% of the body weight.

Table nº 8.37 Sway Index (cm) Measurements across Groups and Testing Conditions

Test Condition	*UNTAPED*		*UNTRAINED*		*TAPED*		*TRAINED*	
Eye Condition	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
SINGLE LEG: LEFT								
Range	0.710 1.080	1.260 2.360	0.640 1.550	1.490 2.710	0.780 1.320	1.210 2.360	0.570 1.540	1.760 2.520
Mean	0.938	1.695	0.908	1.809	0.991	1.830	1.013	2.103
StD	0.115	0.323	0.238	0.337	0.207	0.368	0.340	0.233
SE	0.036	0.102	0.069	0.097	0.066	0.116	0.098	0.067
95% CI	0.856 1.020	1.464 1.926	0.756 1.059	1.595 2.024	0.843 1.139	1.567 2.093	0.798 1.229	1.956 2.251
SINGLE LEG: RIGHT								
Range	0.540 1.220	1.390 2.670	0.690 1.040	1.460 2.330	0.600 1.990	1.390 2.720	0.530 1.310	1.700 2.840
Mean	0.935	1.736	0.843	1.909	0.985	2.174	0.872	2.150
StD	0.234	0.382	0.118	0.297	0.443	0.434	0.189	0.337
SE	0.074	0.121	0.034	0.086	0.140	0.137	0.055	0.096
95% CI	0.767 1.103	1.463 2.009	0.768 0.918	1.720 2.098	0.669 1.302	1.864 2.484	0.751 0.991	1.940 2.360
DOUBLE LEG: NARROW								
Range	0.360 0.730	0.640 1.780	0.380 0.610	0.380 0.910	0.370 0.830	0.550 1.990	0.420 1.050	0.630 1.120
Mean	0.522	0.899	0.470	0.702	0.568	0.980	0.618	0.891
StD	0.128	0.361	0.076	0.124	0.175	0.451	0.168	0.149
SE	0.040	0.114	0.022	0.036	0.055	0.143	0.049	0.043
95% CI	0.431 0.613	0.641 1.157	0.422 0.518	0.623 0.781	0.443 0.693	0.658 1.302	0.511 0.725	0.796 0.986
DOUBLE LEG: WIDE								
Range	0.280 0.740	0.400 1.190	0.340 0.900	0.420 0.660	0.330 0.820	0.300 1.320	0.330 1.080	0.300 0.950
Mean	0.498	0.635	0.513	0.548	0.517	0.732	0.572	0.650
StD	0.138	0.257	0.192	0.086	0.176	0.227	0.228	0.222
SE	0.044	0.081	0.056	0.025	0.056	0.088	0.066	0.064
95% CI	0.399 0.597	0.451 0.819	0.390 0.635	0.494 0.603	0.391 0.643	0.534 0.930	0.427 0.716	0.509 0.791

StD = Standard Deviation, SE = Standard Error, 95% CI = Ninety-five percent Confidence Interval

Table nº 8.38 Left/Right Sway (cm) Measurements across Groups and Testing Conditions

Test Condition	*UNTAPED*		*UNTRAINED*		*TAPED*		*TRAINED*	
Eye Condition	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
SINGLE LEG: LEFT								
Range	1.810 2.710	3.130 5.370	2.060 3.240	4.460 5.790	1.880 2.990	3.060 5.700	1.560 3.260	4.130 5.760
Mean	2.184	4.159	2.534	4.832	2.497	4.620	2.546	5.066
StD	0.283	0.639	0.397	0.379	0.360	0.807	0.552	0.481
SE	0.089	0.202	0.115	0.110	0.114	0.255	0.159	0.139
95% CI	1.982 2.386	3.702 4.616	2.282 2.787	4.591 5.073	2.240 2.752	4.043 5.198	2.195 2.897	4.760 5.372
SINGLE LEG: RIGHT								
Range	1.530 3.480	3.260 6.130	1.940 3.700	3.960 6.440	1.940 4.050	4.310 6.630	1.750 2.990	4.170 6.330
Mean	2.236	4.291	2.493	4.877	2.631	5.453	2.374	5.058
StD	0.608	0.819	0.492	0.651	0.573	0.742	0.379	0.596
SE	0.192	0.259	0.142	0.188	0.181	0.235	0.110	0.172
95% CI	1.801 2.671	3.706 4.877	2.181 2.806	4.463 5.290	2.221 3.041	4.922 5.984	2.133 2.615	4.679 5.437
DOUBLE LEG: NARROW								
Range	0.560 1.290	0.950 2.770	0.690 2.440	0.940 3.500	0.820 1.810	1.050 3.150	1.000 2.430	1.380 3.210
Mean	0.923	1.710	1.368	2.138	1.202	2.125	1.519	2.079
StD	0.204	0.590	0.545	0.698	0.317	0.708	0.383	0.561
SE	0.065	0.187	0.157	0.202	0.100	0.224	0.111	0.162
95% CI	0.777 1.069	1.288 2.132	1.022 1.715	1.695 2.582	0.975 1.429	1.618 2.632	1.276 1.763	1.723 2.436
DOUBLE LEG: WIDE								
Range	0.620 1.921	0.420 1.570	0.670 2.190	0.560 2.110	0.460 9.000	0.450 2.560	0.630 1.800	0.630 1.640
Mean	1.130	0.849	1.156	1.300	1.702	1.375	1.087	1.110
StD	0.436	0.364	0.397	0.509	2.575	0.655	0.395	0.296
SE	0.138	0.115	0.115	0.147	0.814	0.207	0.114	0.086
95% CI	0.819 1.442	0.589 1.109	0.904 1.408	0.977 1.623	-0.140 3.544	0.907 1.843	0.836 1.338	0.922 1.298

StD = Standard Deviation
SE = Standard Error
95% CI = Ninety-five percent Confidence Interval

Table nº 8.39 Anterior/Posterior Sway (cm) Measurements across Groups and Testing Conditions

Test Condition	*UNTAPED*		*UNTRAINED*		*TAPED*		*TRAINED*	
Eye Condition	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
SINGLE LEG: LEFT								
Range	2.460 5.310	4.060 11.910	2.360 7.590	4.700 10.060	2.250 5.380	3.950 10.180	1.940 5.750	5.980 9.900
Mean	3.751	7.004	3.503	6.411	3.829	6.651	3.777	7.609
StD	0.833	2.467	1.367	1.814	1.004	1.711	1.411	1.162
SE	0.263	0.780	0.395	0.524	0.317	0.541	0.407	0.336
95% CI	3.155 4.347	5.239 8.769	2.635 4.372	5.259 7.563	3.111 4.547	5.427 7.875	2.880 4.673	6.871 8.348
SINGLE LEG: RIGHT								
Range	1.870 5.330	4.970 11.510	2.440 4.460	4.800 10.190	1.940 6.090	3.750 11.080	1.630 4.870	5.380 9.590
Mean	3.696	6.688	3.203	6.952	3.433	8.015	3.108	7.741
StD	1.073	2.047	0.722	1.752	1.347	2.142	0.741	1.377
SE	0.339	0.647	0.208	0.506	0.426	0.677	0.214	0.397
95% CI	2.928 4.464	5.224 8.153	2.744 3.661	5.839 8.065	2.470 4.396	6.483 9.547	2.637 3.578	6.866 8.616
DOUBLE LEG: NARROW								
Range	1.320 3.380	2.150 7.150	1.060 2.050	1.310 3.190	1.230 3.090	1.960 6.950	1.500 3.810	2.100 5.330
Mean	2.224	3.380	1.675	2.453	2.117	3.668	2.204	3.538
StD	0.715	1.575	0.290	0.566	0.717	1.544	0.662	0.963
SE	0.226	0.498	0.084	0.163	0.227	0.488	0.191	0.278
95% CI	1.713 2.735	2.253 4.507	1.491 1.859	2.093 2.812	1.604 2.630	2.563 4.773	1.784 2.625	2.926 4.150
DOUBLE LEG: WIDE								
Range	1.080 3.000	1.590 4.180	1.200 3.560	1.630 3.130	1.180 3.050	1.500 4.520	1.270 3.750	1.060 4.330
Mean	2.071	2.632	1.842	2.213	1.962	3.028	2.152	2.688
StD	0.632	0.994	0.678	0.457	0.607	0.907	0.752	0.975
SE	0.200	0.314	0.196	0.132	0.192	0.287	0.217	0.281
95% CI	1.619 2.523	1.921 3.343	1.411 2.273	1.923 2.504	1.528 2.396	2.379 3.677	1.674 2.630	2.068 3.307

StD = Standard Deviation
SE = Standard Error
95% CI = Ninety-five percent Confidence Interval

Table n° 8.40 Centre of Balance $_{x\text{-}axis}$ (cm) Measurements across Groups and Testing Conditions

Test Condition	*UNTAPED*		*UNTRAINED*		*TAPED*		*TRAINED*	
Eye Condition	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
SINGLE LEG: LEFT								
Range	-1.200 0.700	-0.930 0.400	-1.900 0.300	-1.400 -0.050	-1.500 -0.300	-1.900 0.200	-0.870 0.500	-0.800 0.600
Mean	-0.003	-0.296	-0.799	-0.702	-0.874	-0.648	-0.381	-0.325
StD	0.596	0.434	0.709	0.373	0.358	0.573	0.350	0.436
SE	0.188	0.137	0.205	-0.108	0.113	0.118	0.101	0.126
95% CI	-0.429 0.423	-0.606 0.014	-1.250 -0.349	-0.939 -0.465	-1.130 -0.618	-1.058 -0.238	-0.603 -0.159	-0.602 -0.048
SINGLE LEG: RIGHT								
Range	0.100 1.170	0.000 1.530	-1.100 0.830	-0.600 0.930	-0.100 0.700	-0.900 0.630	-0.500 0.900	-0.100 0.700
Mean	0.564	0.722	-0.011	0.155	0.256	0.269	0.178	0.366
StD	0.365	0.533	0.516	0.495	0.251	0.454	0.395	0.227
SE	0.116	0.168	0.149	0.143	0.079	0.144	0.114	0.080
95% CI	0.303 0.825	0.341 1.103	-0.339 0.317	-0.159 0.469	0.077 0.435	-0.056 0.594	-0.073 0.428	0.190 0.542
DOUBLE LEG: NARROW								
Range	-0.330 0.700	-0.800 0.800	-0.500 0.300	-0.600 0.500	-0.500 -0.130	-1.070 0.600	-0.930 0.000	-1.000 0.500
Mean	0.034	0.007	-0.117	-0.131	-0.309	-0.174	-0.392	-0.336
StD	0.335	0.433	0.277	0.296	0.114	0.471	0.310	0.393
SE	0.106	0.137	0.080	0.086	0.036	0.149	0.089	0.114
95% CI	-0.205 0.273	-0.303 0.317	-0.293 0.059	-0.319 0.057	-0.390 -0.228	-0.516 0.163	-0.588 -0.195	-0.586 -0.086
DOUBLE LEG: WIDE								
Range	-0.800 0.400	-0.370 0.500	-0.900 0.630	-0.970 0.200	-1.270 -0.500	-1.400 -0.430	-1.000 0.370	-2.000 0.300
Mean	-0.201	-0.014	-0.336	-0.423	-0.900	-0.873	-0.242	-0.835
StD	0.392	0.292	0.428	0.427	0.255	0.313	0.377	0.660
SE	0.124	0.092	0.124	0.123	0.081	0.099	0.110	0.191
95% CI	-0.481 0.079	-0.223 0.195	-0.608 -0.064	-0.694 -0.151	-1.082 -0.718	-1.097 -0.649	-0.483 -0.001	-1.254 -0.416

StD = Standard Deviation
SE = Standard Error
95% CI = Ninety-five percent Confidence Interval

Table n° 8.41 Centre of Balance $_{y\text{-}axis}$ (cm) Measurements across Groups and Testing Conditions

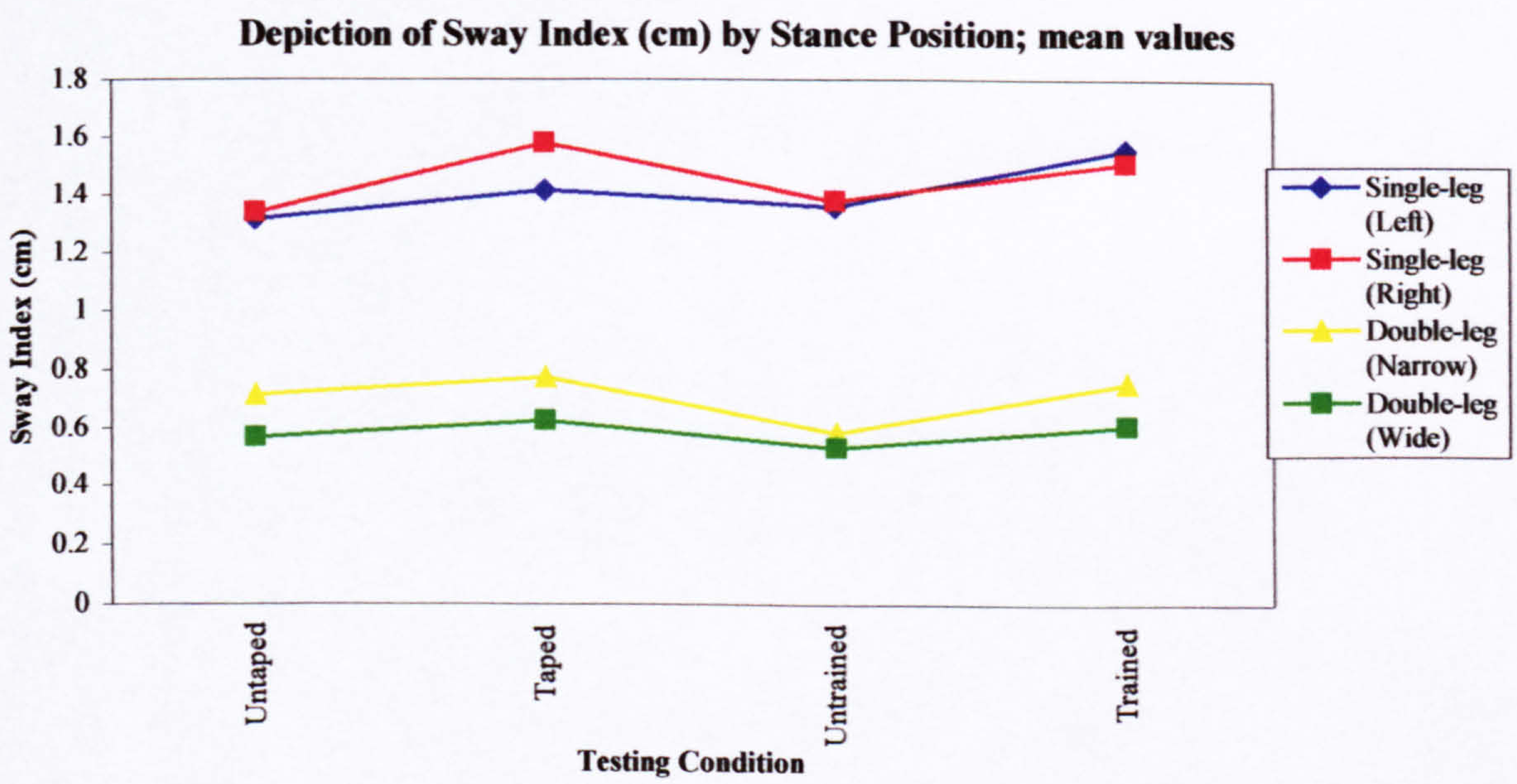
Test Condition	*UNTAPED*		*UNTRAINED*		*TAPED*		*TRAINED*	
Eye Condition	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed	Eyes Open	Eyes Closed
SINGLE LEG: LEFT								
Range	-3.000 3.070	-0.300 4.000	0.730 3.200	0.870 2.800	-1.230 3.000	-0.800 3.100	0.200 2.800	1.030 3.700
Mean	-0.067	1.595	1.911	1.993	0.816	1.310	1.609	2.013
StD	2.164	1.497	0.805	0.677	1.598	1.330	0.784	0.853
SE	0.684	0.473	0.232	0.196	0.505	0.421	0.226	0.246
95% CI	-1.615 1.481	0.524 2.666	1.400 2.422	1.563 2.424	-0.327 1.959	0.359 2.261	1.111 2.107	1.471 2.555
SINGLE LEG: RIGHT								
Range	-1.030 3.670	-0.530 1.900	0.500 2.400	-0.100 3.030	-1.000 3.570	0.000 2.700	0.070 2.330	0.300 3.830
Mean	1.224	1.274	1.595	1.598	1.451	1.277	1.394	1.971
StD	1.430	0.767	0.619	0.995	1.621	0.908	0.797	1.315
SE	0.452	0.243	0.179	0.287	0.513	0.287	0.230	0.380
95% CI	0.201 2.247	0.725 1.823	1.202 1.988	0.966 2.230	0.292 2.610	0.627 1.927	0.888 1.900	1.135 2.807
DOUBLE LEG: NARROW								
Range	-0.830 4.100	-1.000 3.530	-0.900 3.130	0.300 2.830	-0.700 3.200	-0.800 2.100	-1.100 3.100	-1.500 2.130
Mean	1.060	0.623	0.919	1.222	0.983	0.537	1.303	0.773
StD	1.737	1.379	1.436	0.802	1.339	0.839	1.212	1.185
SE	0.549	0.436	0.415	0.232	0.424	0.265	0.350	0.342
95% CI	-0.183 2.303	-0.363 1.609	0.007 1.832	0.712 1.731	0.025 1.941	-0.063 1.137	0.534 2.073	0.020 1.525
DOUBLE LEG: WIDE								
Range	-1.730 6.340	-0.700 4.670	-0.830 3.000	-0.900 3.030	-2.170 3.800	-1.200 3.900	-2.270 3.400	-1.600 3.070
Mean	0.947	1.107	0.689	0.964	0.953	0.857	1.070	1.162
StD	3.023	1.937	1.352	1.399	2.036	1.696	1.418	1.455
SE	0.956	0.612	0.390	0.404	0.644	0.536	0.409	0.420
95% CI	-1.216 3.110	-0.279 2.493	-0.170 1.548	0.075 1.853	-0.503 2.409	-0.356 2.070	0.169 1.971	0.237 2.086

StD = Standard Deviation
SE = Standard Error
95% CI = Ninety-five percent Confidence Interval

8.3.1 Sway Index (cm) Measurement Results

The values of postural sway as measured by the Sway Index (SI) ranged from 0.53 to 2.84 cm and from 0.28 to 1.99 cm for single and double-leg stance respectively. The mean values are illustrated in *Figure n° 817*.

Figure n° 817 Mean Sway Index Values (cm) for all Test Conditions by Stance Position



8.3.1.1 Mixed ANOVA Results for Sway Index

The mixed analysis of variance revealed no overall significance between groups for SI. The ANOVA table for the analysis is presented in *Table n° 8.42*.

Table nº 8.42 Analysis of Variance for Repeated Measures Mixed Model of Three Within and One Between Subject Variables for ***Sway Index*** *(cm)*

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean of Squares*	*F-value*	*p-value*
Between Subject Effects					
Within Cells	4.04	20	0.20		
Group	0.00	1	0.00	0.00	0.963
Within Subject Effects					
Within Cells	1.68	20	0.08		
EYE	1.63	1	1.63	19.45	0.000*
Group x Eye	0.01	1	0.01	0.09	0.768
Within Cells	2.59	20	0.13		
TEST	31.30	1	31.30	241.82	0.000*
Group x Test	0.04	1	0.04	0.28	0.601
Within Cells	4.59	60	0.08		
STANCE	53.77	3	17.92	234.21	0.000*
Group x Stance	0.33	3	0.11	1.42	0.247
Within Cells	0.66	20	0.03		
Eye x Test	0.46	1	0.46	13.97	0.001*
Group x Eye x Test	0.01	1	0.01	0.41	0.532
Within Cells	3.89	60	0.06		
Eye x Stance	0.24	3	0.08	1.24	0.302
Group x Eye x Stance	0.26	3	0.09	1.31	0.281
Within Cells	3.61	60	0.06		
Test x Stance	13.28	3	4.43	73.67	0.000*
Group x Test x Stance	0.65	3	0.22	3.58	0.019*
Within Cells	2.47	60	0.04		
Eye x Test x Stance	0.33	3	0.11	2.69	0.54
Group x Eye x Test x Stance	0.11	3	0.04	0.87	0.463

*denotes $p<0.05$, therefore significant.

Significant differences were seen within the eye, test and stance conditions and significant interaction was also seen in the Eye by Test, Test by Stance and Group by Test by Stance conditions.

8.3.1.2 One-way Repeated Measure Analysis of Variance for Sway Index

One-way analysis of variance between groups only revealed a significance between the two groups of taping and training in the condition of Taped versus Trained, single-leg stance (Left), eyes closed where $F(1,20) = 4.4918$ $p = 0.0468$.

8.3.1.3 Paired Samples t-test Analysis of Sway Index

Paired t-test analysis for within subject factors revealed significance in the taping group comparing Untaped and Taped conditions only in;

Single-leg stance (Right), eyes closed;

t = -3.16 df = 9 p=0.012 95% CI (-0.751 to –0.125).

By comparison in the training group, comparing Untrained and Trained conditions revealed significance in both single-leg stance positions, eyes closed;

Left leg	t = -3.98	df = 11	p = 0.002	95% CI (-0.457 to –0.132)
Right leg	t = -2.49	df = 11	p = 0.030	95% CI (-0.454 to –0.028)

and in double-leg stance, narrow position, eyes open and closed;

Eyes open	t = -3.28	df = 11	p = 0.007	95% CI (-0.248 to –0.049)
Eyes closed	t = -3.31	df = 11	p = 0.007	95% CI (-0.315 to –0.063)

8.3.1.4 Independent Samples t-test Analysis of Sway Index

Independent t-tests for between subject significance (taping group versus training group), reveals significance only in the Taped Vs Trained condition, single-leg (Left), eyes closed;

Levene's test for equality of variances F = 2.173 p = 0.156 variances equal:

t = -2.12 df = 20 p = 0.047 SE = 0.129 95% CI (-0.542 to –0.004).

8.3.1.5 Analysis of Dependent Variables for Sway Index

For the dependent variable of visual condition (eyes open versus eyes closed), in both groups significance in sway index was seen between the two conditions in all stance positions except for double-leg stance (Wide). This is illustrated in *Figure* n^{os} *818* and *819*.

Figure n° 818 Comparison of Visual Condition Effect on Postural Stability as Measured by Sway Index (cm) for Taping Group Conditions

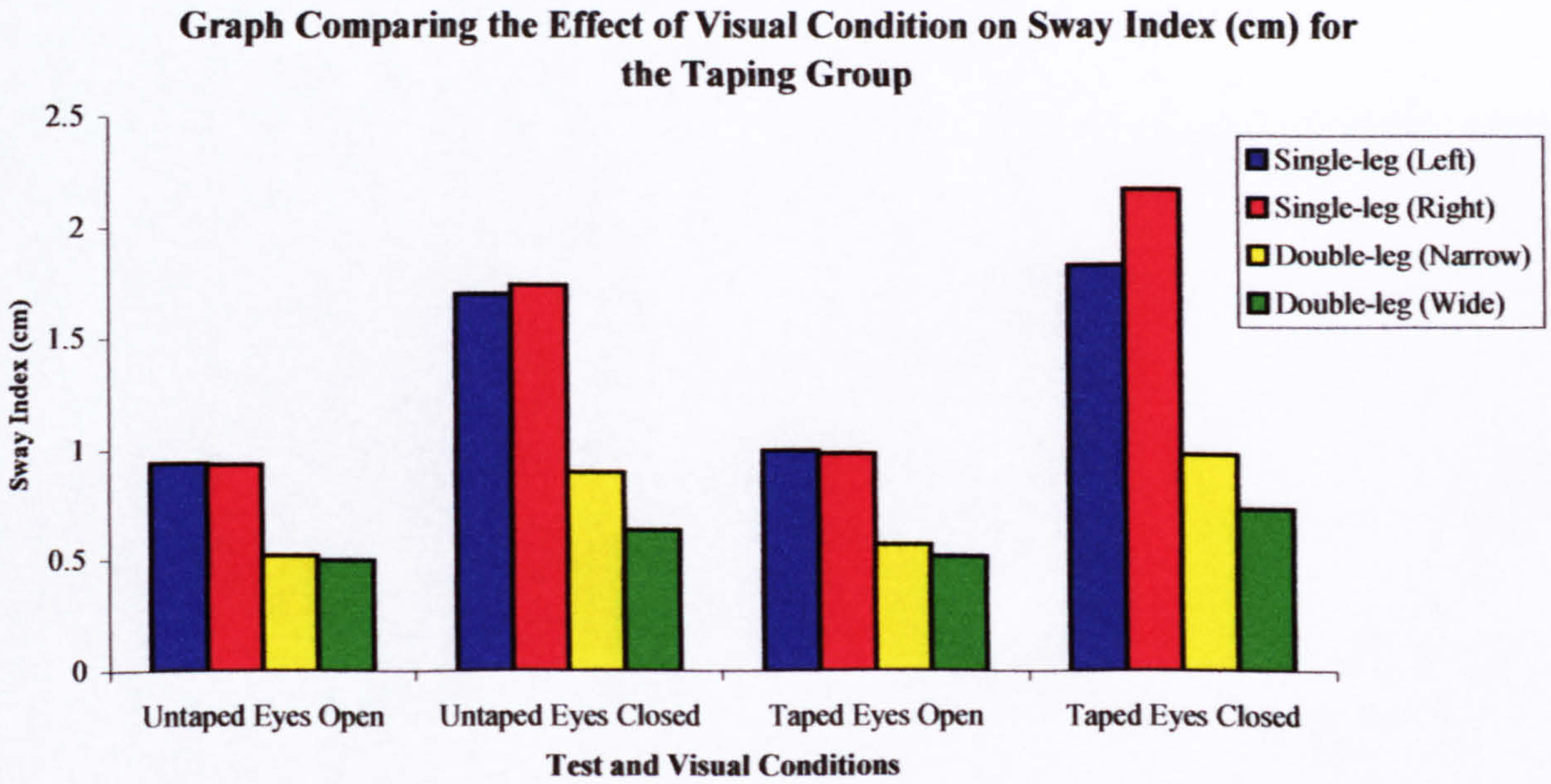
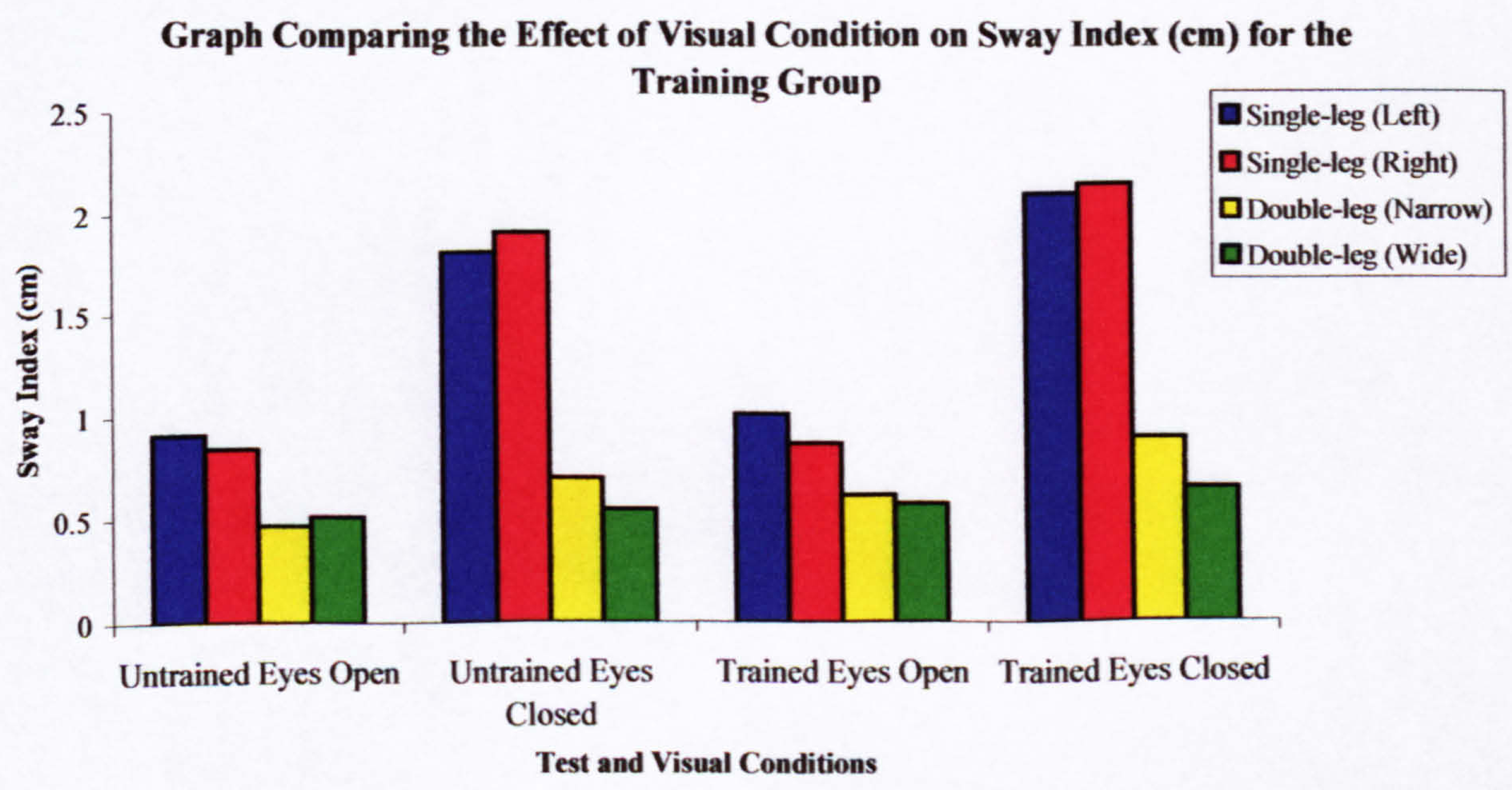


Figure n° 819 Comparison of Visual Condition Effect on Postural Sway as Measured by Sway Index (cm) for Training Group Conditions



If the difference in sway between the eyes open and eyes closed visual condition is considered (calculated by subtracting the sway index (cm) measurement eyes open from that of eyes closed condition) t-test analysis shows significance only within subjects, right leg

Untaped Vs Taped	t = -2.6	df = 9	$p = 0.028$	95% CI (-0.724 to –0.052)
Untrained Vs Trained	t = -2.20	df = 11	$p = 0.050$	95% CI (-0.425 to 0.000).

No significant differences were found for SI between groups. *Figure n^os 820* and *821* illustrate the change (or difference between visual conditions) in postural sway as measured by the sway index with tape and after proprioceptive training. This is a measure of the effect of removing visual input on the proprioceptive system.

Figure n° 820 Comparison of Postural Sway as Measured by Sway Index (cm) for Taping Group Conditions

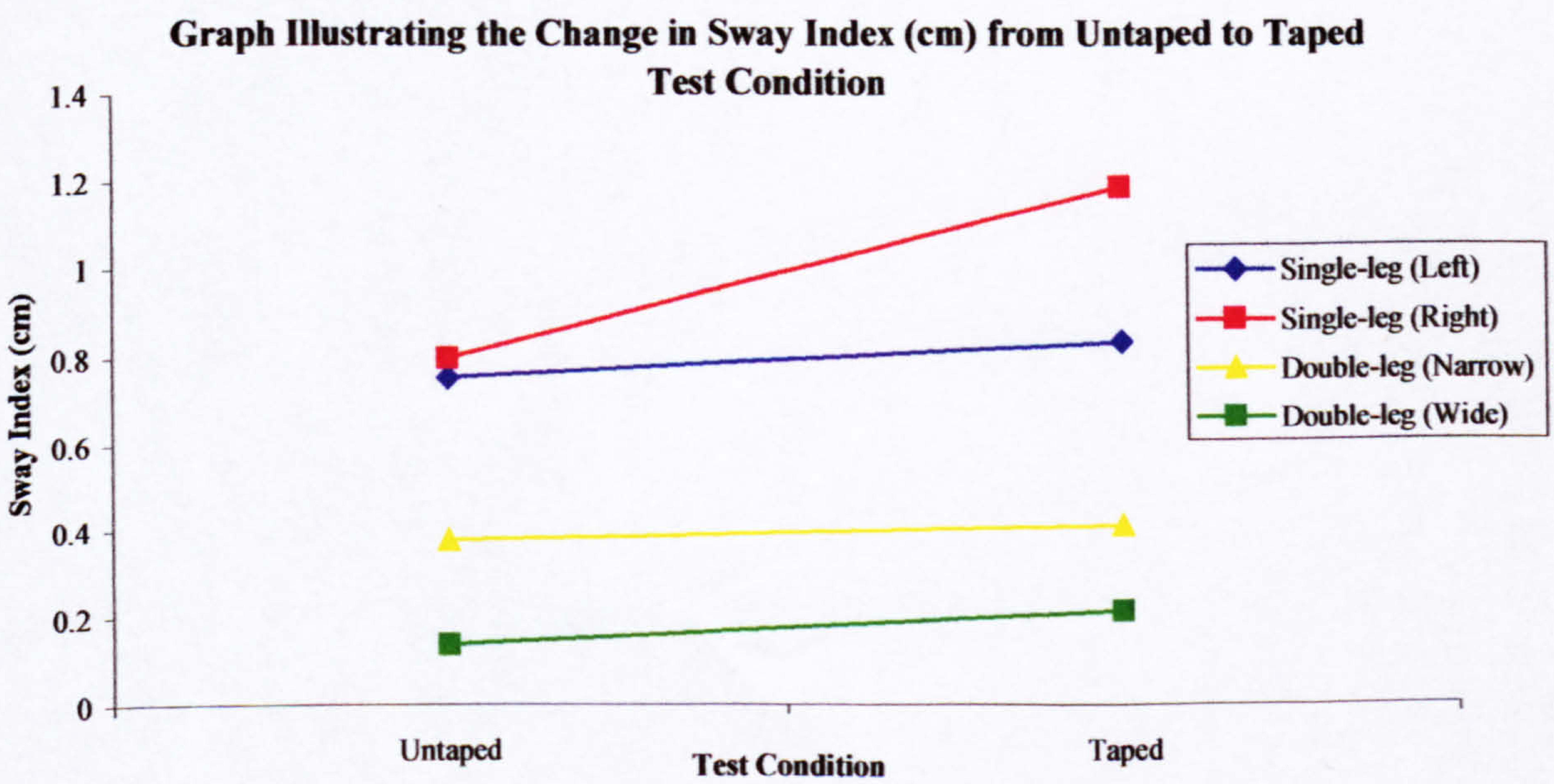
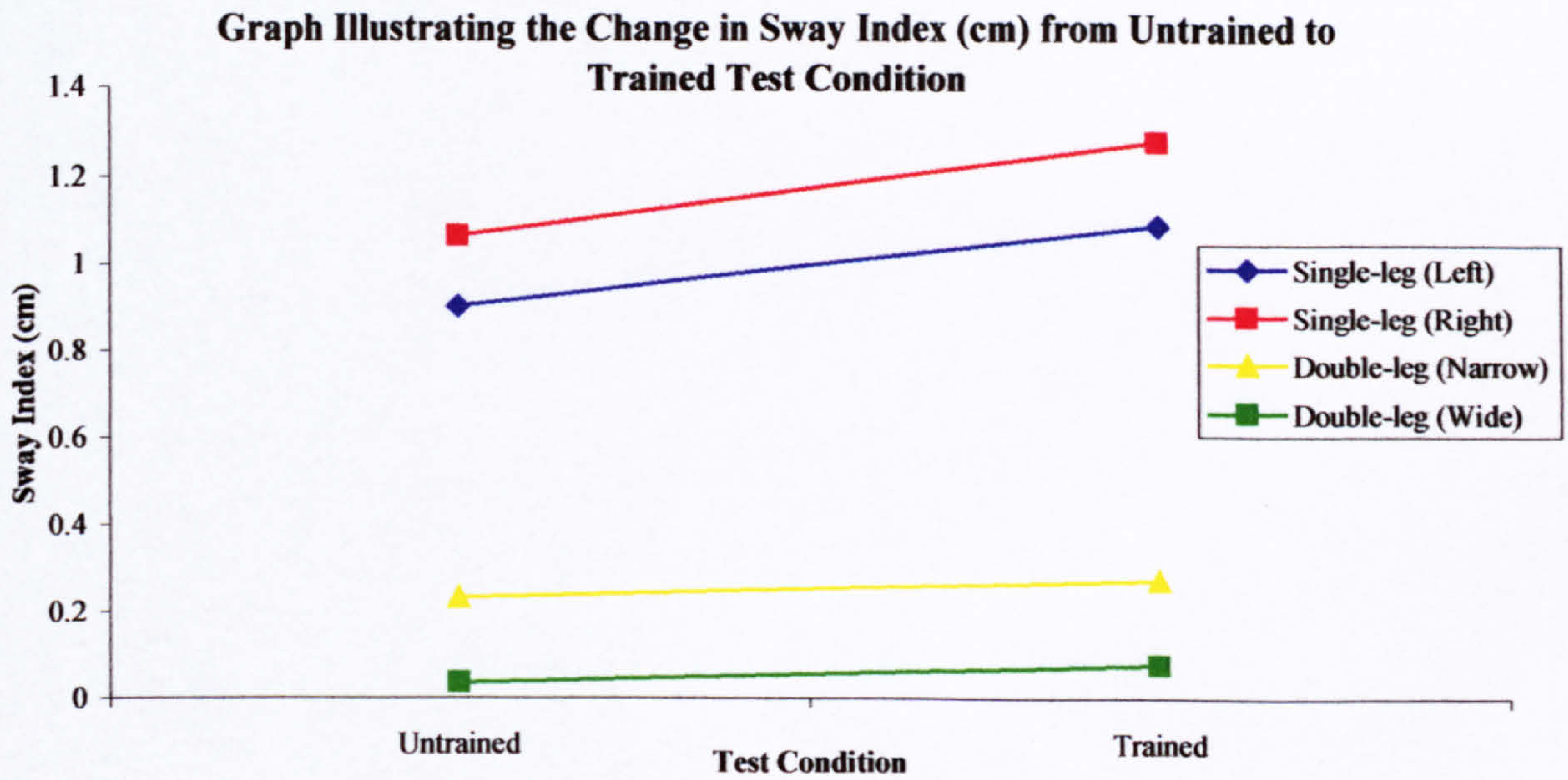


Figure n° 821 Comparison of Postural Sway as Measured by Sway Index (cm) for Training Group Conditions



For the dependent variable of stance, significant differences between SI of left and right legs occur only when Taped, eyes closed;

SI (cm) $t = -2.57$ $df = 9$ $p = 0.03$ 95 % CI (-0.647 to –0.041).

For double-leg stance positions of narrow and wide, significant difference is seen in the training group both before and after training, eyes closed;

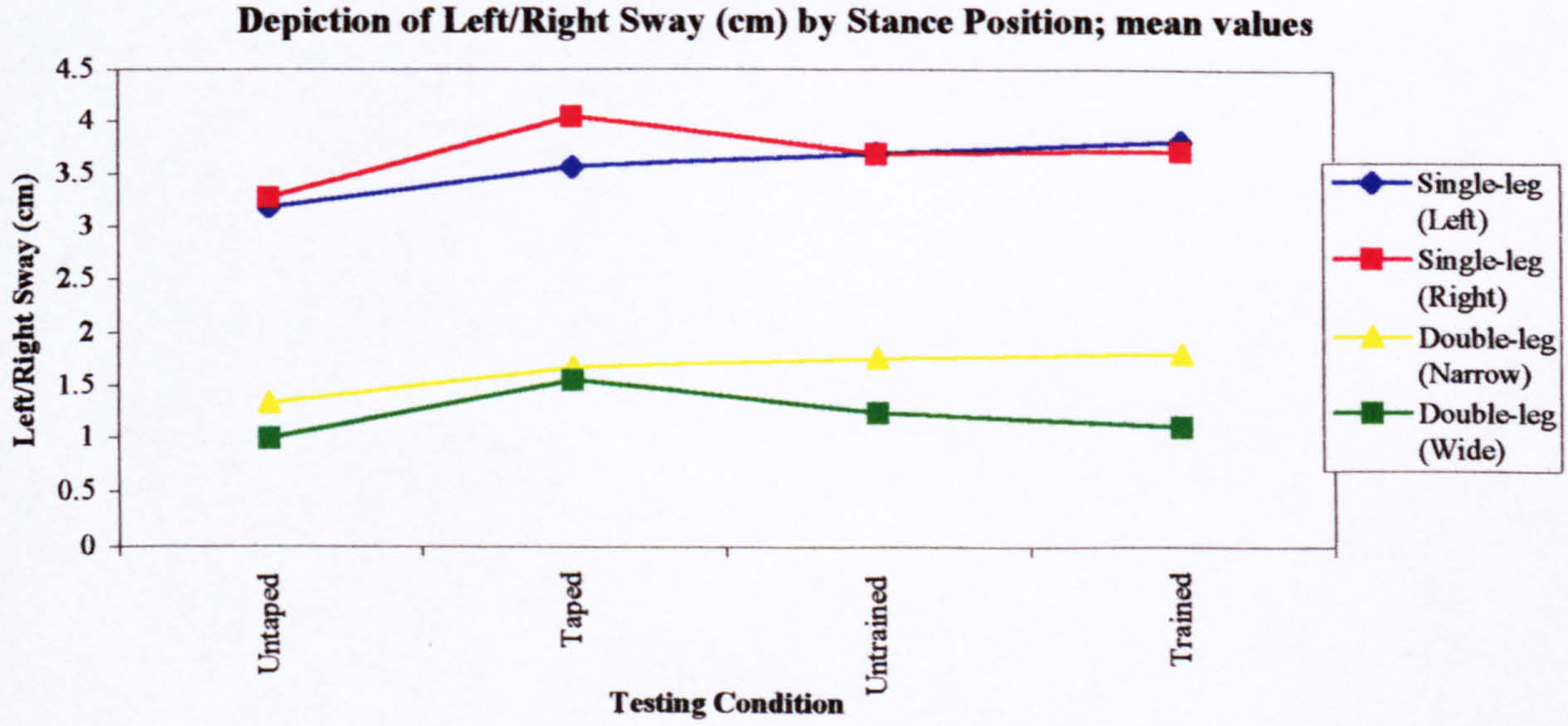
Untrained	$t = 3.21$	$df = 11$	$p = 0.008$	95% CI (0.048 to 0.295)
Trained	$t = 3.15$	$df = 11$	$p = 0.009$	95% CI (0.072 to 0.409)

When comparing single-leg stance to double-leg stance, significance is seen for all tests of sway index (cm).

8.3.2 Left/Right Sway (cm) Measurement Results

The mean values of left/right (L/R) sway ranged from 1.53 to 6.63 cm and from 0.42 to 9.00 cm for single and double-leg stance respectively. The mean values are illustrated in *Figure nº 822*.

Figure nº 822 Mean Left/Right Sway Values (cm) for all Test Conditions by Stance Position



8.3.2.1 Mixed ANOVA Results for L/R Sway

The analysis of variance revealed significance between groups for L/R sway. The ANOVA table for the analysis is presented in *Table nº 8.43*.

*Table n° 8.43 Analysis of Variance for Repeated Measures Mixed Model of Three Within and One Between Subject Variables for **Left/Right Sway** (cm)*

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean of Squares*	*F-value*	*p-value*
Between Subject Effects					
Within Cells	14.75	20	0.74		
Group	3.63	1	3.63	4.92	0.038*
Within Subject Effects					
Within Cells	8.05	20	0.40		
EYE	4.07	1	4.07	10.11	0.005*
Group x Eye	3.43	1	3.43	8.53	0.008*
Within Cells	5.58	20	0.28		
TEST	169.10	1	169.10	605.82	0.000*
Group x Test	0.08	1	0.08	0.30	0.592
Within Cells	13.40	60	0.22		
STANCE	451.50	3	150.50	674.06	0.000*
Group x Stance	1.58	3	0.53	2.36	0.080
Within Cells	3.45	20	0.17		
Eye x Test	1.37	1	1.37	7.95	0.011*
Group x Eye x Test	0.90	1	0.90	5.19	0.034*
Within Cells	14.79	60	0.25		
Eye x Stance	1.77	3	0.59	2.40	0.077
Group x Eye x Stance	0.90	3	0.30	1.21	0.313
Within Cells	13.85	60	0.23		
Test x Stance	86.98	3	28.99	125.63	0.000*
Group x Test x Stance	0.87	3	0.29	1.25	0.299
Within Cells	13.36	60	0.22		
Eye x Test x Stance	0.94	3	0.31	1.41	0.249
Group x Eye x Test x Stance	0.64	3	0.21	0.96	0.418

*denotes $p<0.05$, therefore significant.

Significant differences were seen within Eye, Test and Stance conditions as well as significant interactions in; Group by Eye, Group by Eye by Test and Test by Stance conditions.

8.3.2.2 One-way Repeated Measures ANOVA for L/R Sway

One-way analysis of variance between groups for L/R sway showed significant difference between Untaped and Untrained conditions as follows;

Eyes open, left leg	$F(1,20) = 5.4832$	$p = 0.0297$
Eyes open, narrow position	$F(1,20) = 5.9317$	$p = 0.0244$
Eyes closed, left leg	$F(1,20) = 9.3946$	$p = 0.0061$
Eyes closed, wide position	$F(1,20) = 5.4985$	$p = 0.0295$

and between Taped and Trained conditions;

Eyes open, narrow position F(1,20) = 4.3543 $p = 0.0499$

8.3.2.3 Paired Samples t-test Analysis for L/R Sway

Paired t-test analysis for within subject factors revealed significance in the taping group comparing Untaped and Taped conditions of;

Single-leg (Left), eyes open
t = -2.60 df = 9 $p = 0.029$ 95% CI (-0.585 to –0.041)

Single-leg (Right), eyes closed
t = -4.78 df = 9 $p = 0.001$ 95% CI (-1.712 to –0.612)

Double-leg (Wide), eyes closed
t = -2.40 df = 9 $p = 0.040$ 95% CI (-1.021 to –0.031)

The training group, comparing Untrained and Trained conditions showed no significance between conditions.

8.3.2.4 Independent Samples t-test Analysis of L/R Sway

Independent t-tests for between subject significance revealed significance between groups as follows;

Untaped Vs Untrained, eyes open, single-leg (Left)
Levene's test for equality of variance F = 1.169 $p = 0.293$ variances equal;
t = -2.33 df = 20 $p = 0.03$ SE = 0.150 95% CI (-0.663 to –0.037)

Untaped Vs Untrained, eyes closed, single-leg (Left)
Levene's test for equality of variance F = 1.861 $p = 0.188$ variances equal;
t = -3.07 df = 20 $p = 0.006$ SE = 0.219 95% CI (-1.131 to –0.215)

Untaped Vs Untrained, eyes open, double-leg (Narrow)
Levene's test for equality of variance F = 4.145 $p = 0.055$ variances equal;
t = -2.62 df = 14.52 $p = 0.020$ SE = -0.170 95% CI (-0.808 to –0.083)

Untaped Vs Untrained, eyes closed, double-leg (Wide)
Levene's test for equality of variance F = 1.733 $p = 0.203$ variances equal;
t = -2.34 df = 20 $p = 0.029$ SE = 0.192 95% CI (-0.852 to –0.050)

Taped Vs Trained, eyes open, double-leg (Narrow)

Levene's test for equality of variance $F = 0.230$ $p = 0.636$ variances equal;

$t = -2.09$ $df = 20$ $p = 0.050$ $SE = 0.152$ 95% CI (-0.634 to 0.000).

8.3.2.5 Analysis of Dependent Variables for L/R Sway

For the dependent variable of visual condition; eyes open versus eyes closed, in both groups significant differences in L/R sway were seen in all stance positions, with the exception of double-leg stance (Wide) as illustrated by *Figure n^{os} 823* and *824*.

Figure n° 823 Comparison of Visual Condition Effect on Postural Stability as Measured by Left/Right Sway (cm) for Taping Group Conditions

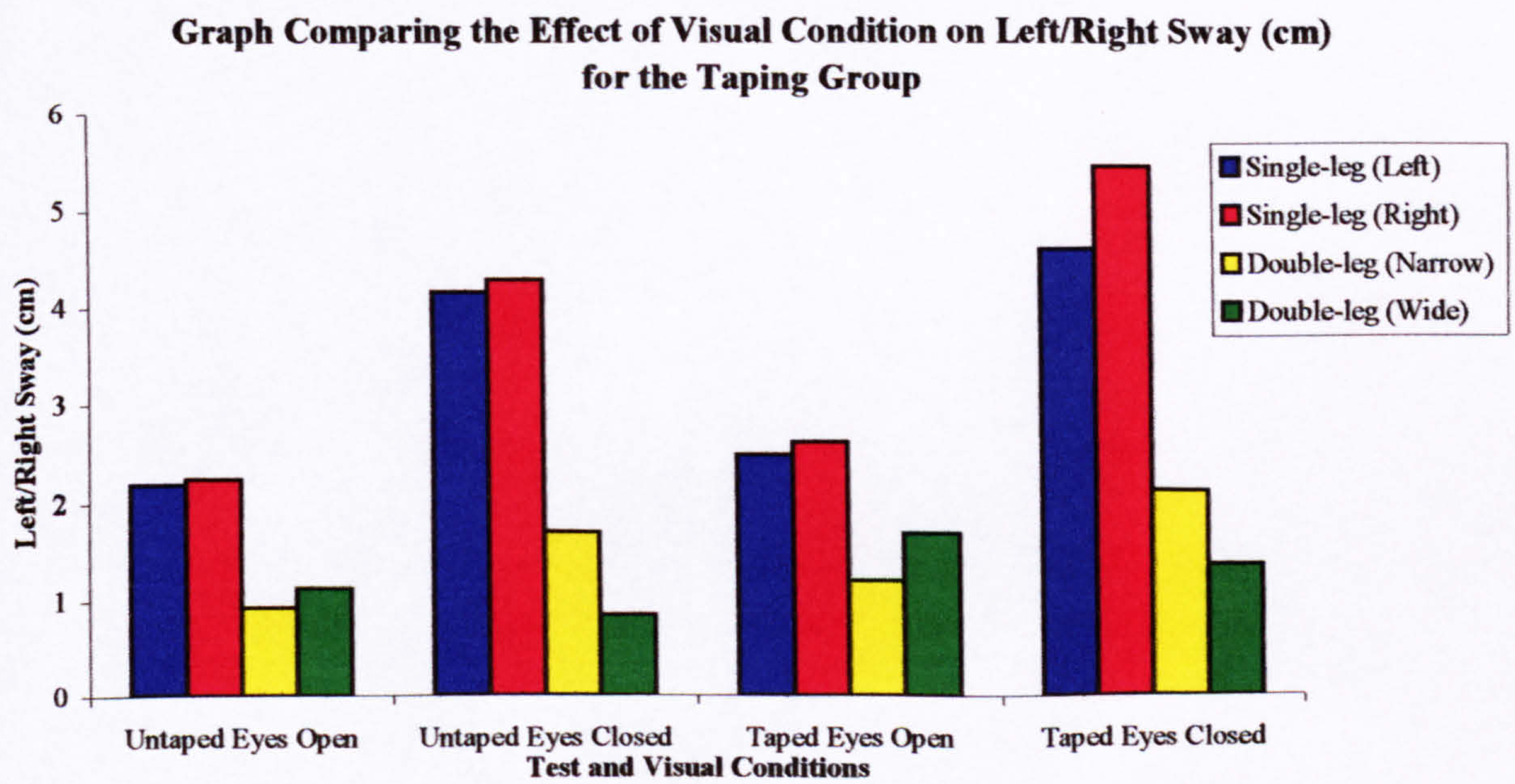
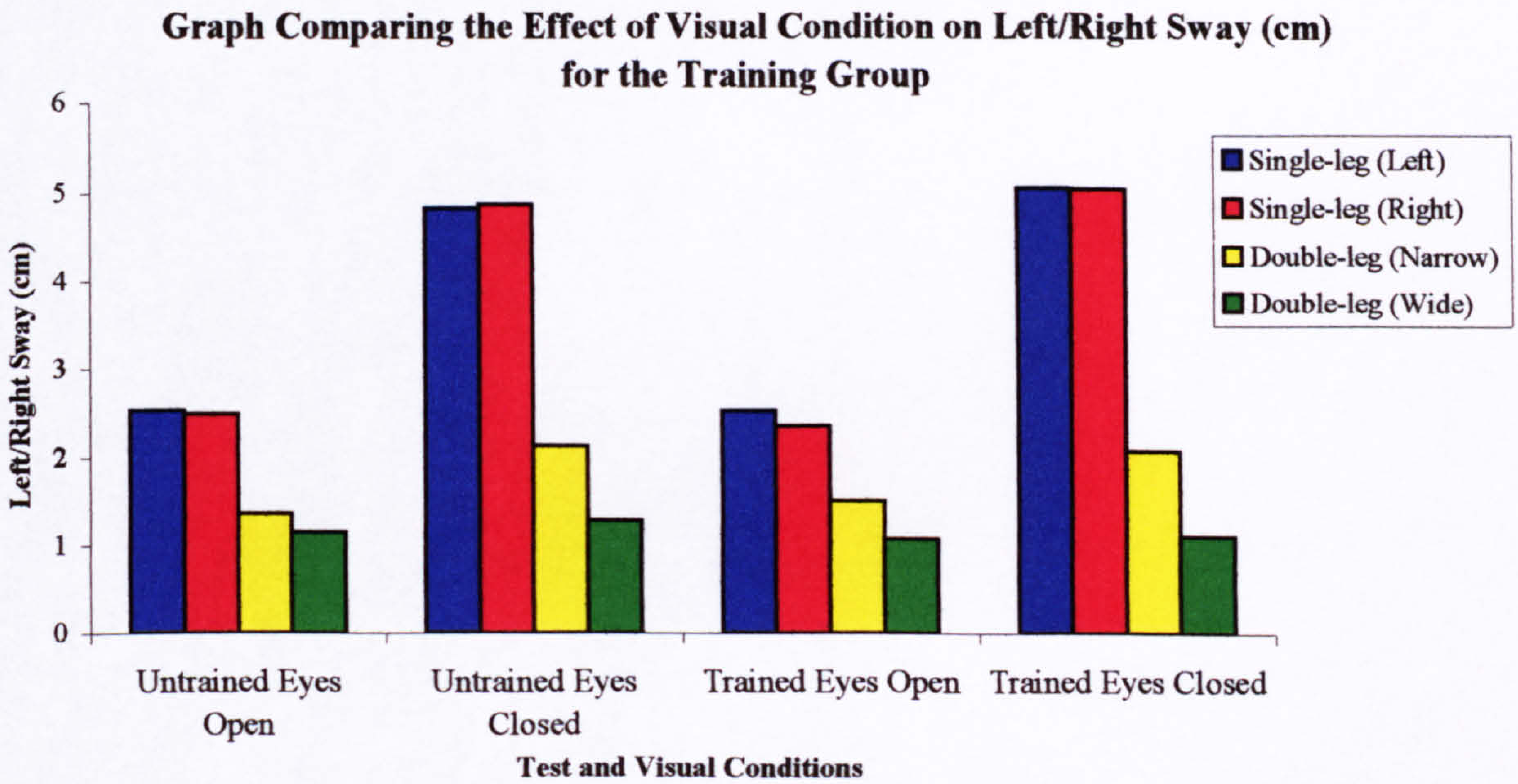


Figure n° 824 Comparison of Visual Condition Effect on Postural Sway as Measured by Left/Right Sway (cm) for Training Group Conditions



If the difference in sway between the eyes open and eyes closed visual conditions is considered, t-test analysis shows significance only within-subjects, double-leg (Wide):

Taped Vs Untaped t = -2.95 df = 9 $p = 0.016$ 95% CI (-1.350 to –0.178)

Figure n^os 825 and *826* illustrate the change (or difference between visual conditions) in L/R sway taped and after proprioceptive training for all stance positions.

Figure n° 825 Comparison of Postural Sway as Measured by Left/Right Sway (cm) for Taping Group Conditions

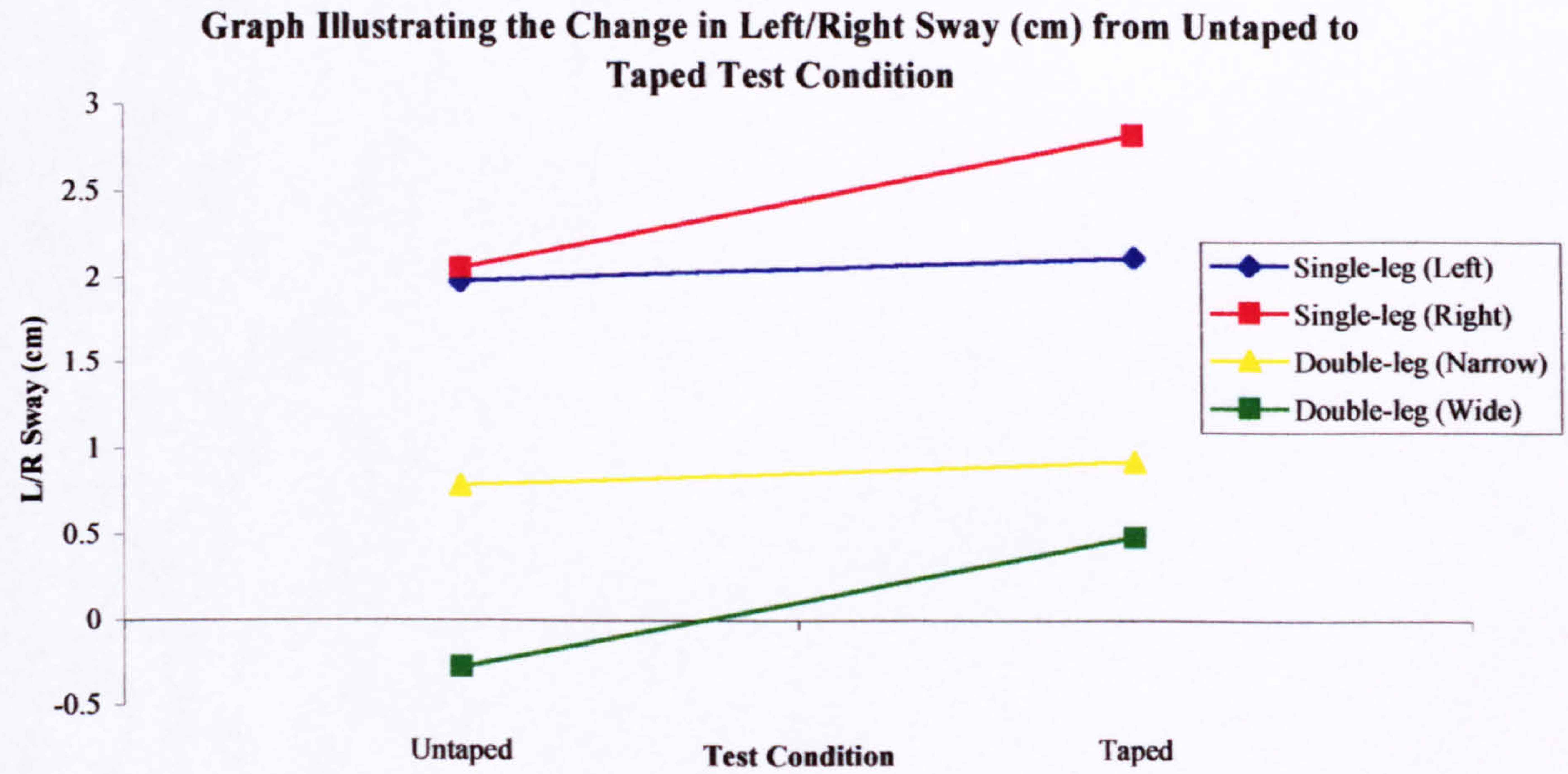
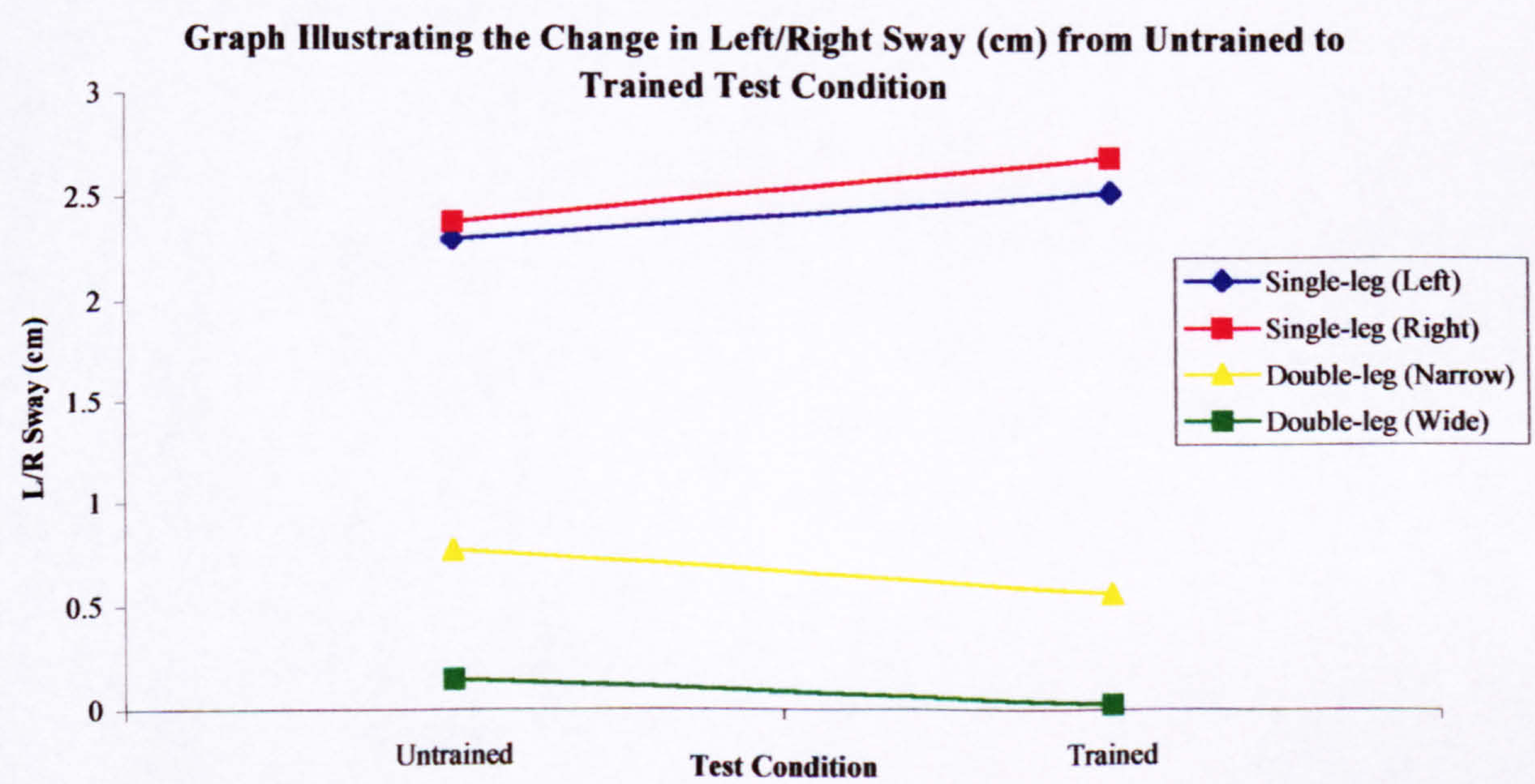


Figure n° 826 Comparison of Postural Sway as Measured by Left/Right Sway (cm) for Training Group Conditions



For the dependent variable of stance, significant differences in L/R sway between left and right legs are only seen in the taping group when Taped, eyes closed;
L/R (cm) t = -2/64 df = 9 $p = 0.027$ 95% CI (-1.548 to –0.118)

For double-leg stance positions of small versus wide, significant difference is seen in the training group, both before and after training, eyes closed and after training eyes open;

Untrained, eyes closed
t = 5.56 df = 11 $p = 0.000$ 95% CI (0.506 to 1.170)

Trained, eyes closed
t = -8.77 df = 11 $p = 0.000$ 95% CI (0.726 to 1.212)

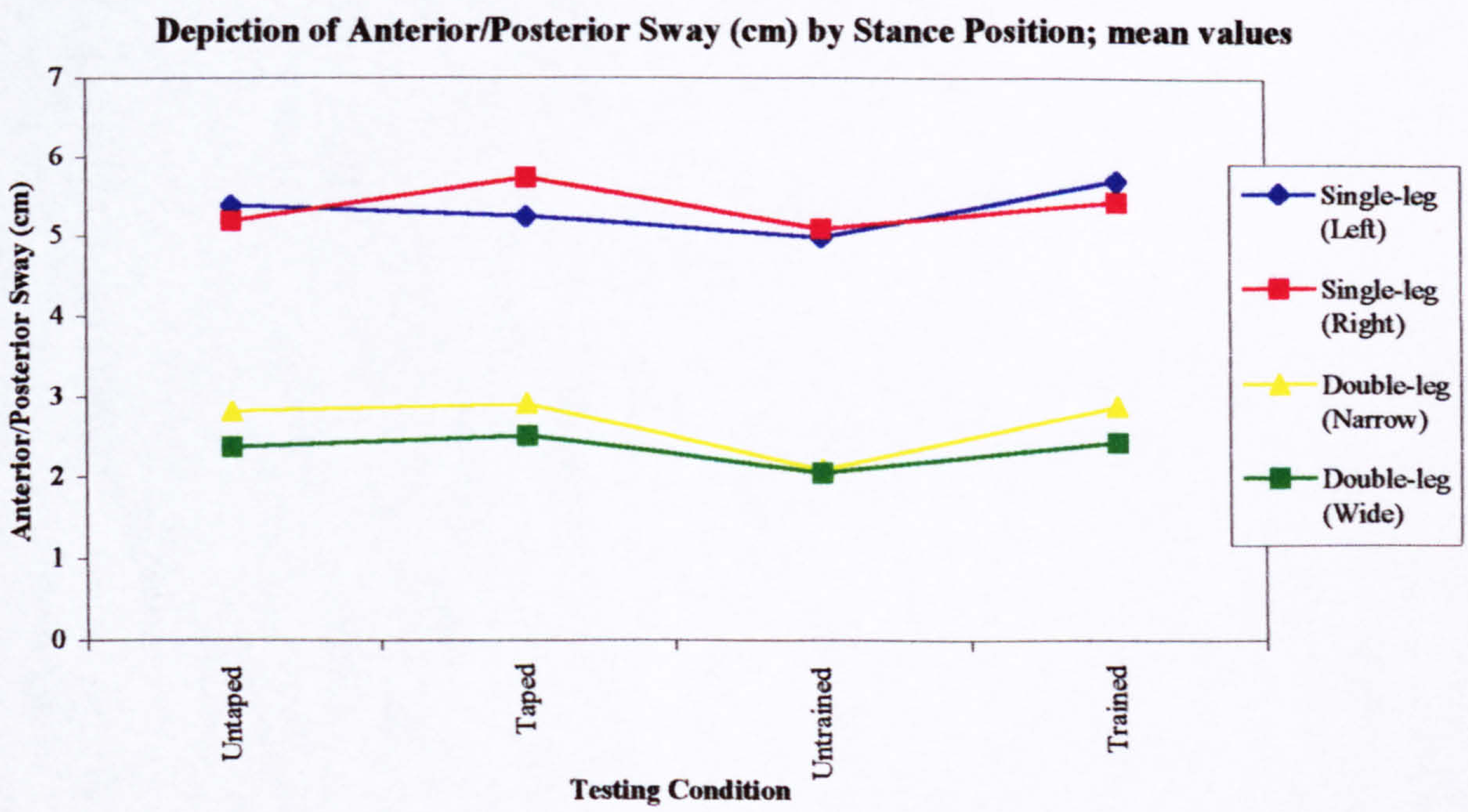
Trained, eyes open
t = 3.19 df = 11 $p = 0.009$ 95% CI (0.134 to 0.731)

When comparing single-leg stance to double-leg stance, significance is seen for all tests of L/R sway with the exception of single-leg to double-leg (Wide), eyes open, Taped.

8.3.3 Anterior/Posterior Sway (cm) Results

The values of anterior/posterior (A/P) sway ranged from 1.63 to 11.91 cm and 1.06 to 7.15 cm for single and double-leg stance respectively. The mean values are illustrated in *Figure n° 827*.

Figure n° 827 Mean Anterior/Posterior Sway Values (cm) for all Test Conditions by Stance Position



8.3.3.1 Mixed ANOVA Results for A/P Sway

The analysis of variance revealed no significance between groups for A/P sway. The ANOVA table for the analysis is presented in *Table n° 8.44*.

Table n° 8.44 Analysis of Variance for Repeated Measures Mixed Model of Three Within and One Between Subject Variables for ***Anterior/Posterior Sway (cm)***

Source of Variation	*Sum of Squares*	*Degrees of Freedom*	*Mean of Squares*	*F-value*	*p-value*
Between Subject Effects					
Within Cells	82.69	20	4.13		
Group	3.22	1	3.22	0.78	0.388
Within Subject Effects					
Within Cells	33.20	20	1.66		
EYE	11.59	1	11.59	6.98	0.016*
Group x Eye	3.75	1	3.75	2.26	0.149
Within Cells	34.32	20	1.72		
TEST	445.09	1	445.09	259.34	0.000*
Group x Test	0.01	1	0.01	0.01	0.941
Within Cells	102.42	60	1.71		
STANCE	711.68	3	237.23	138.97	0.000*
Group x Stance	1.72	3	0.57	0.34	0.799
Within Cells	13.74	20	0.69		
Eye x Test	7.21	1	7.21	10.49	0.004*
Group x Eye x Test	0.08	1	0.08	0.11	0.739
Within Cells	90.28	60	1.50		
Eye x Stance	0.58	3	0.19	0.13	0.942
Group x Eye x Stance	3.73	3	1.24	0.83	0.485
Within Cells	62.38	60	1.04		
Test x Stance	166.83	3	55.61	53.49	0.000*
Group x Test x Stance	2.69	3	0.90	0.86	0.465
Within Cells	62.99	60	1.05		
Eye x Test x Stance	3.38	3	1.13	1.07	0.368
Group x Eye x Test x Stance	3.29	3	1.10	1.04	0.367

*denotes $p < 0.05$, therefore significant.

Significant differences were seen within Eye, Test and Stance conditions as expected. Also significant were;

Eye by Test interaction $F(1,20) = 10.49$ $p = 0.004$

and Test by Stance interaction $F(3,60) = 53.49$ $p = 0.000$.

8.3.3.2 One-way Repeated Measures ANOVA for A/P Sway

One-way analysis of variance between groups for A/P sway showed significance in the Untaped Vs Untrained comparison for double-leg (Narrow), eyes open condition only; $F(1,20) = 5.9504$ $p = 0.0242$

8.3.3.3 Paired Samples t-test analysis of A/P Sway

Paired t-test analysis for within subject factors revealed no significance between conditions for the taping group. However, for the training group A/P sway significance was seen for conditions of;

Single-leg stance (Left), eyes closed
t = -2.52 df = 11 $p = 0.028$ 95% CI (-2.245 to –0.152)

Double-leg stance (Narrow), eyes open
t = -2.71 df = 11 $p = 0.020$ 95% CI (-0.959 to –0.099)

Double-leg stance (Narrow), eyes closed
t = -3.14 df = 11 $p = 0.009$ 95% CI (-1.846 to –0.325).

8.3.3.4 Independent Samples t-test Analysis of A/P Sway

Independent t-tests for between subjects only revealed significance in the Untaped Vs Untrained condition for double-leg stance (Narrow), eyes open;
Levene's test for equality of variance F = 19.123 $p = 0.000$ Variances unequal;
t = 2.28 df = 11.46 $p = 0.043$ SE = 0.241 95% CI (0.018 to 1.080).

8.3.3.5 Analysis of Dependent Variables for A/P Sway

For the dependent variable of visual condition; eyes open versus eyes closed, in both groups significant differences in A/P sway were seen between the two visual conditions in all stance positions with the exception of double-leg stance (Wide) in Untaped, Untrained and Trained conditions. *Figure n^os 828* and *829* compare conditions of eyes open and eyes closed for the four stance positions in the taping and training groups.

Figure n° 828 Comparison of Visual Condition Effect on Postural Stability as Measured by Anterior/Posterior Sway (cm) for Taping Group Conditions

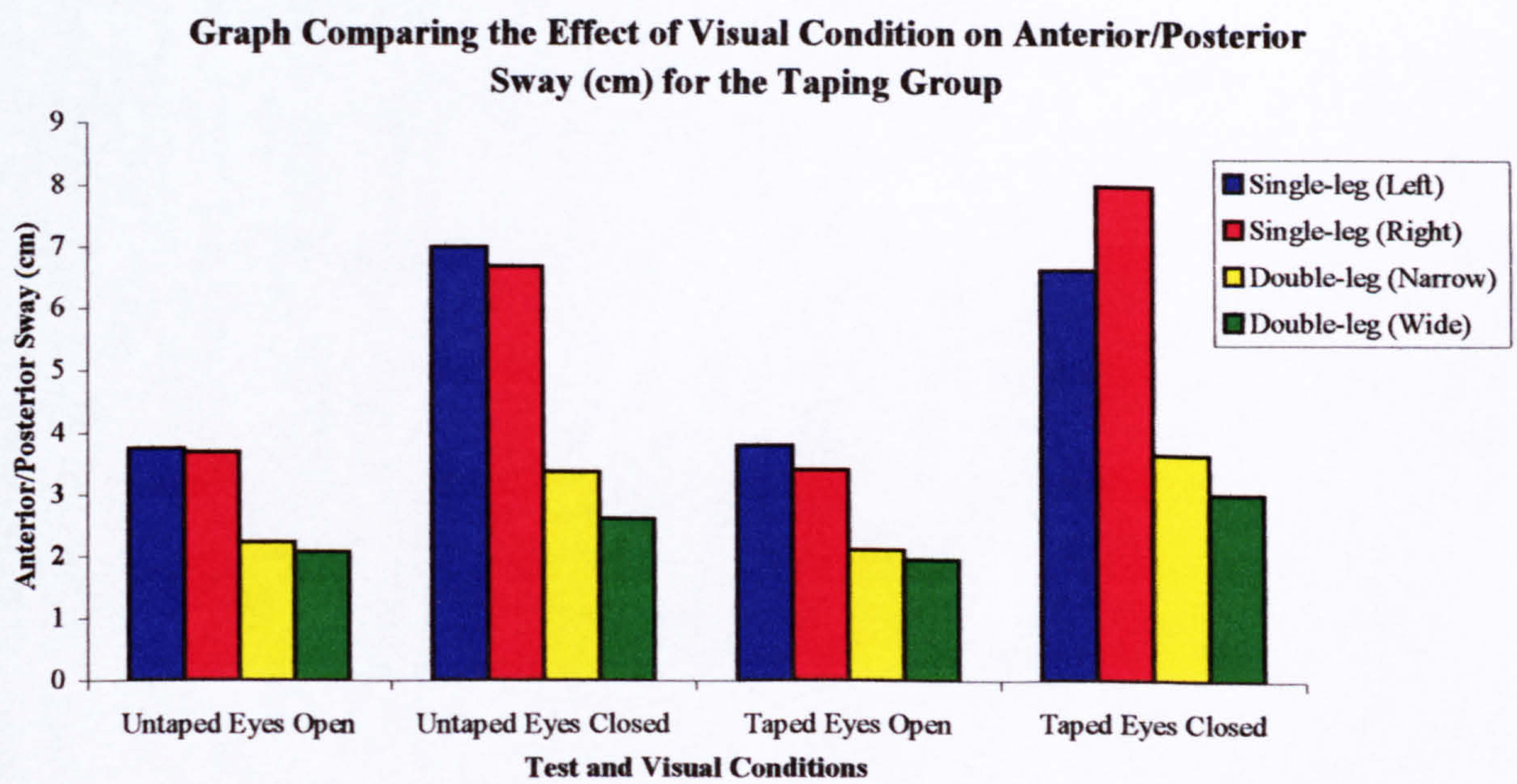
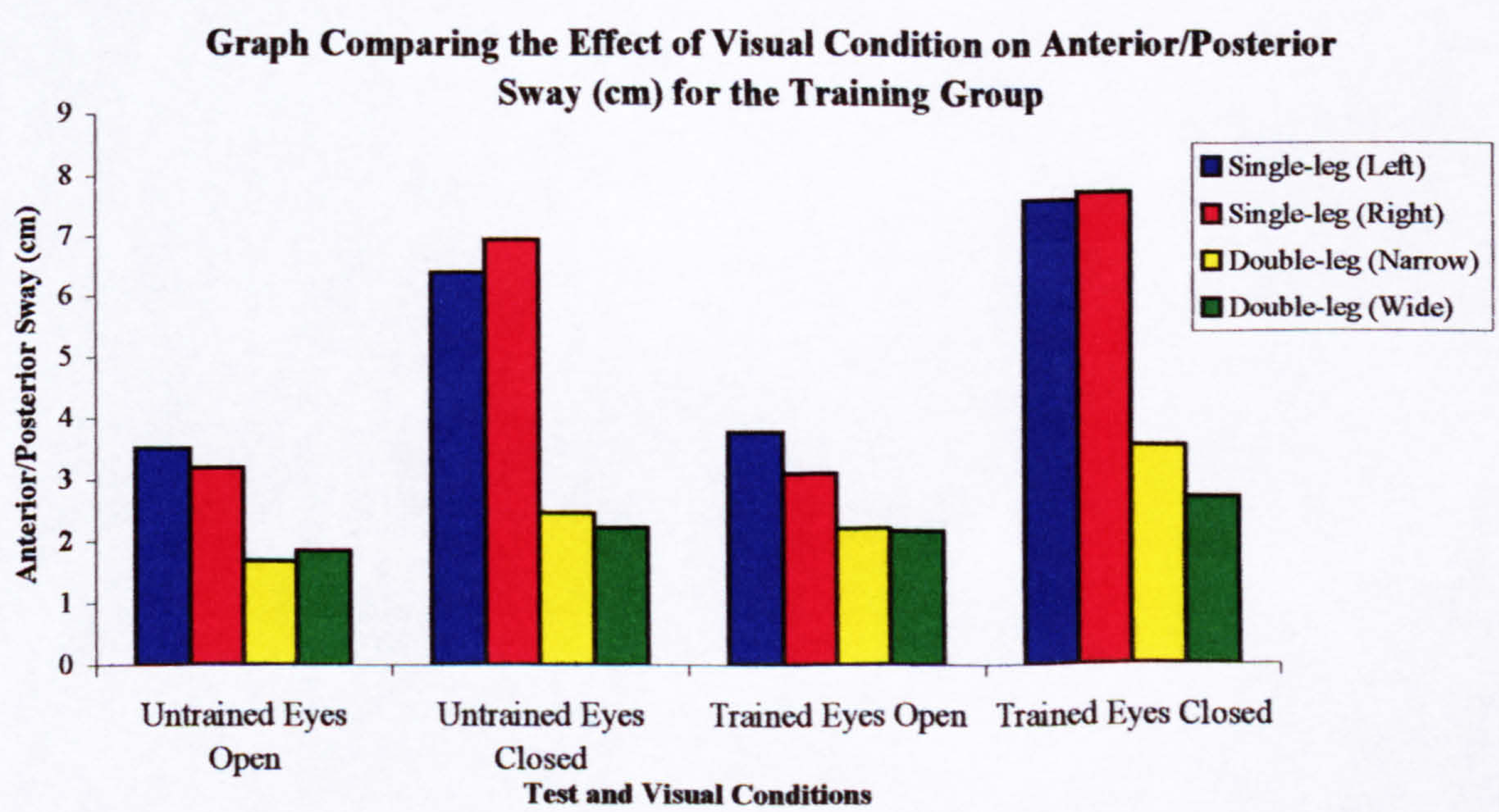


Figure n° 829 Comparison of Visual Condition Effect on Postural Stability as Measured by Anterior/Posterior Sway (cm) for Training Group Conditions



If the difference in sway between the eyes open and eyes closed visual conditions is considered, t-test analysis reveals significance only within subjects, single-leg (Right) comparing Untaped and Taped conditions;

t = -2.33 df = 9 $p = 0.045$ 95% CI (-3.137 to –0.043)

Figure n^os^ 830 and *831* illustrates the change (or difference between visual conditions) in A/P sway Taped and Trained.

Figure n° 830 Comparison of Postural Sway as Measured by Anterior/Posterior Sway (cm) for Taping Group Conditions

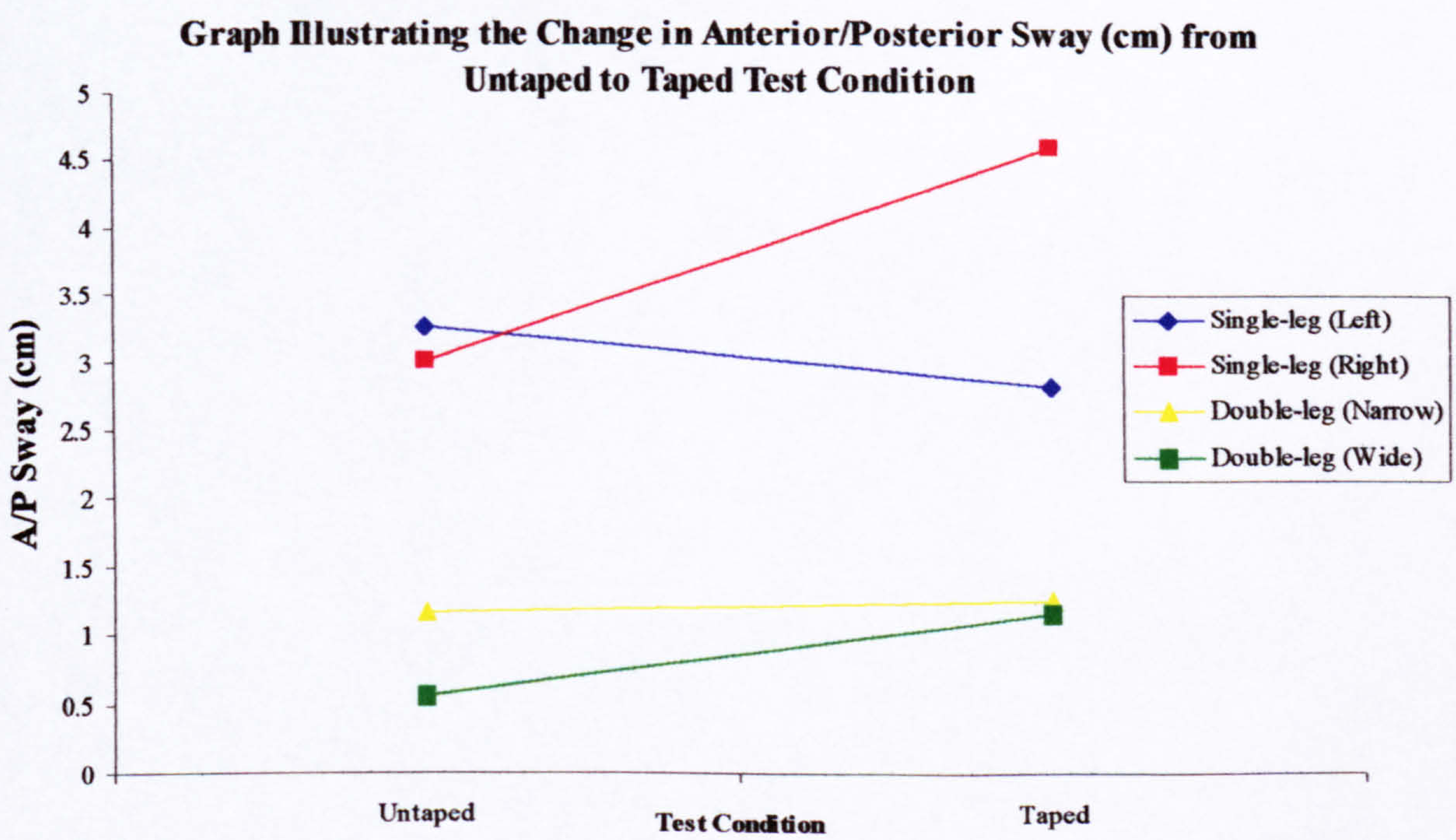
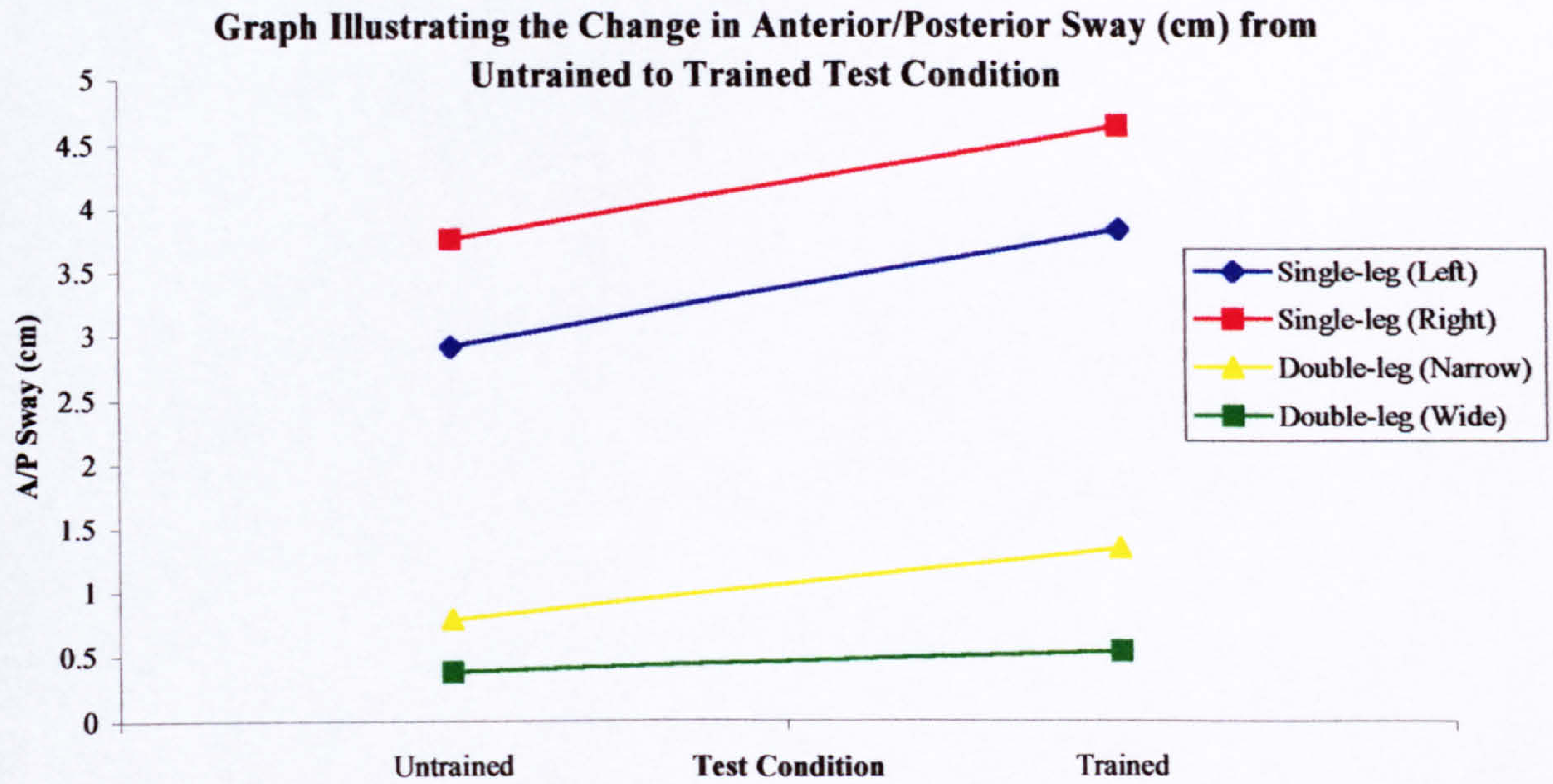


Figure n° 831 Comparison of Postural Sway as Measured by Anterior/Posterior Sway (cm) for Training Group Conditions

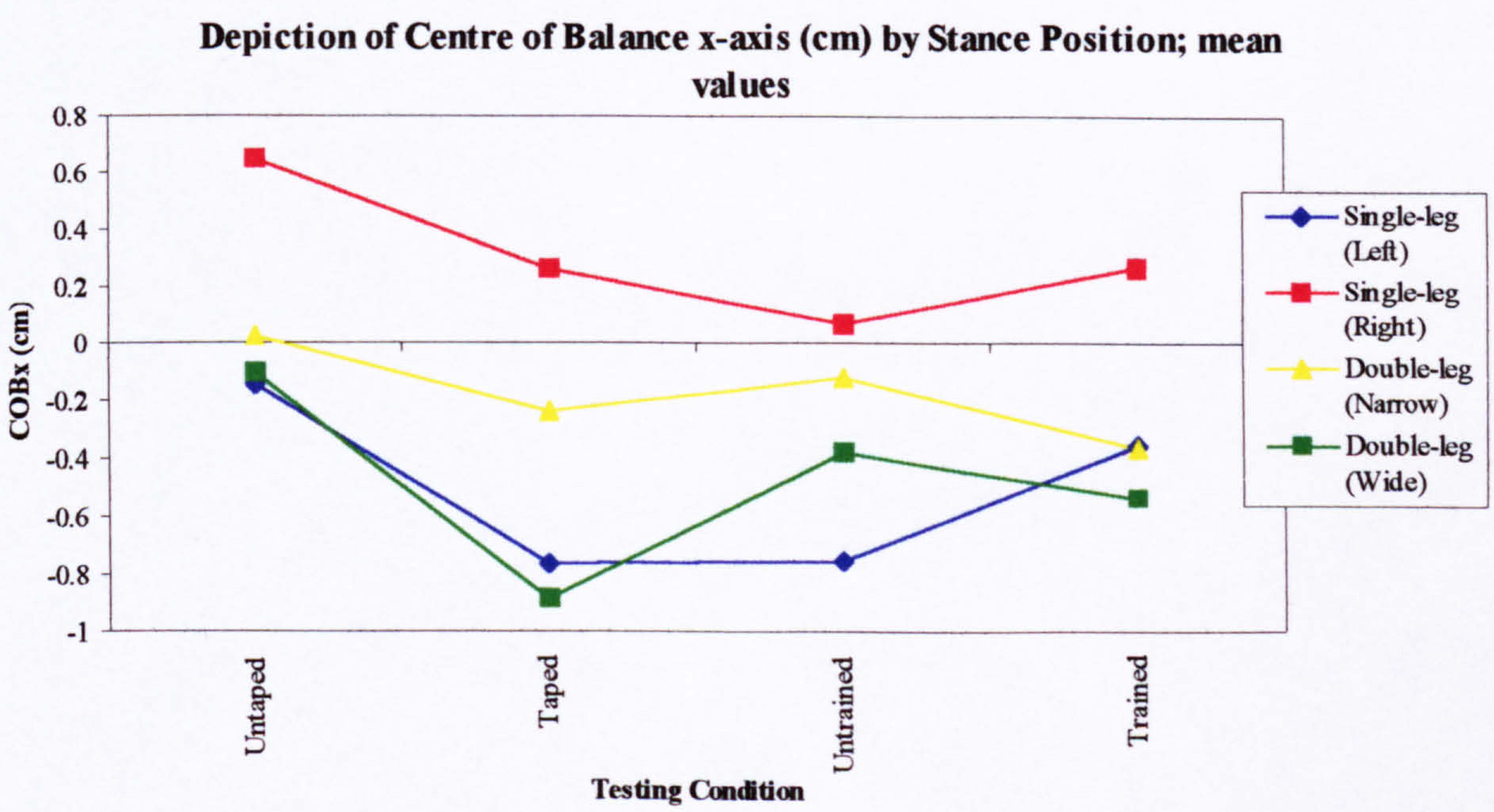


For the dependent variable of stance, no significant differences are seen in A/P sway between left and right legs or when comparing double-leg stance positions. When comparing single-leg stance to double-leg stance significance is seen for all tests of A/P sway.

8.3.4 Centre of Balance $_{X\text{-axis}}$ (cm) Results

The values of Centre of Balance $_{X\text{-axis}}$ (COB_X), ranged from –1.9 to 1.53 cm and –1.4 to 0.8 cm for single and double-leg stance respectively. The mean values are illustrated by *Figure n° 832*.

Figure n° 832 Mean COB_X Position Values (cm) for all Test Conditions by Stance Position



8.3.4.1 Mixed ANOVA Results for COB_X

The analysis of variance revealed significant difference between groups for COB_X. The ANOVA table for the analysis is presented in *Table n° 8.45*.

Table n° 8.45 Analysis of Variance for Repeated Measures Mixed Model of Three Within and One Between Subject Variables for ***COB_X*** *Positioning*

Source of Variation	Sum of Squares	Degrees of Freedom	Mean of Squares	F-value	p-value
Between Subject Effects					
Within Cells	4.66	20	0.23		
Group	1.34	1	1.34	5.76	0.026*
Within Subject Effects					
Within Cells	3.90	20	0.19		
EYE	4.58	1	4.58	23.51	0.000*
Group x Eye	6.80	1	6.80	34.91	0.000*
Within Cells	1.39	20	0.07		
TEST	0.05	1	0.05	0.74	0.398
Group x Test	0.07	1	0.07	1.04	0.319
Within Cells	17.21	60	0.29		
STANCE	38.29	3	12.76	44.51	0.000*
Group x Stance	1.11	3	0.37	1.29	0.285
Within Cells	1.69	20	0.08		
Eye x Test	0.00	1	0.00	0.03	0.867
Group x Eye x Test	0.24	1	0.24	2.82	0.109
Within Cells	12.96	60	0.22		
Eye x Stance	2.02	3	0.67	3.12	0.033*
Group x Eye x Stance	2.71	3	0.90	4.19	0.009*
Within Cells	7.14	60	0.12		
Test x Stance	0.70	3	0.23	1.95	0.132
Group x Test x Stance	1.20	3	0.40	3.37	0.024*
Within Cells	7.19	60	0.12		
Eye x Test x Stance	1.00	3	0.33	2.79	0.048*
Group x Eye x Test x Stance	0.41	3	0.14	1.14	0.339

*denotes $p < 0.05$, therefore significant.

Significant differences were seen within Eye and Stance conditions, but not Test. Other significant interactions included;

Group by Eye	$F(1,20) = 34.91$	$p = 0.000$
Eye by Stance	$F(3,60) = 3.12$	$p = 0.033$
Group by Eye by Stance	$F(3,60) = 4.19$	$p = 0.009$
Group by Test by Stance	$F(3,60) = 3.37$	$p = 0.024$
Eye by Test by Stance	$F(3,60) = 2.79$	$p = 0.048$.

8.3.4.2 One-way Repeated Measures ANOVA for COB_X

One-way analysis of variance between groups for COB_X showed significance in the Untaped Vs Untrained comparison for;

Eyes open, left	$F(1,20) = 10.1024$	$p = 0.047$
Eyes open, right	$F(1,20) = 8.7283$	$p = 0.0078$
Eyes closed, left	$F(1,20) = 5.5670$	$p = 0.0286$
Eyes closed, right	$F(1,20) = 6.6861$	$p = 0.0177$
Eyes closed, wide	$F(1,20) = 6.5623$	$p = 0.0186$.

In the Taped Vs Trained condition, significant difference between the groups was seen for;

Eyes open, left	$F(1,20) = 9.0485$	$p = 0.0069$
Eyes open, wide	$F(1,20) = 21.8046$	$p = 0.0001$.

8.3.4.3 Paired Samples t-test Analysis for COB_X

Paired t-test analysis for within subject factors revealed significance between Untaped and Taped conditions in all eyes open visual conditions for stance;

Left	$t = 3.44$	$df = 9$	$p = 0.007$	95% CI (0.209 to 1.444)
Right	$t = 2.43$	$df = 9$	$p = 0.038$	95% CI (0.032 to 0.874)
Narrow	$t = 2.99$	$df = 9$	$p = 0.015$	95% CI (0.083 to o.603)
Wide	$t = 8.28$	$df = 9$	$p = 0.000$	95% CI (-1.021 to –0.031)

and for single-leg (Right), eyes closed;

$t = 2.43$ $df = 9$ $p = 0.038$ 95% CI (0.032 to 0.874)

and double-leg (Wide), eyes closed;

$t = 8.28$ $df = 9$ $p = 0.000$ 95% CI (0.524 to 1.094)

For the training group, significant differences were only seen between Untrained and Trained conditions for;

Eyes open; narrow	$t = -2.44$	$df = 11$	$p = 0.033$	95% CI (-0.717 to –0.036)
Eyes closed; left	$t = 4.82$	$df = 11$	$p = 0.001$	95% CI (0.149 to 0.401).

8.3.4.4 Independent Samples t-test analysis of COB_X

Independent t-tests for between subject significance revealed significance in the Untaped Vs Untrained condition, eyes open and eyes closed for single-leg stance;

Eyes open, left
Levene's test for equality of variance F = 0.767 p = 0.391 variances equal;
t = 2.82 df = 20 p = 0.011 SE = 0.283 95% CI (0.206 to 1.386)

Eyes open, right
Levene's test for equality of variance F = 0.341 p = 0.566 variances equal;
t = 2.95 df = 20 p = 0.008 SE = 0.195 95% CI (0.169 to 0.981)

Eyes closed, left
Levene's test for equality of variance F = 0.671 p = 0.422 variances equal;
t = 2.36 df = 20 p = 0.029 SE = 0.172 95% CI (0.047 to 0.764)

Eyes closed, right
Levene's test for equality of variance F = 0.205 p = 0.656 variances equal;
t = 2.59 df = 20 p = 0.018 SE = 0.219 95% CI (0.109 to 1.025)

and eyes closed double-leg stance (Wide)
Levene's test for equality of variance F = 2.941 p = 0.102 variances equal;
t = 2.56 df = 20 p = 0.029 SE = 0.192 95% CI (-0.852 to –0.050)

For the Taped Vs Trained condition, significance was found for eyes open single-leg (Left)
Levene's test for equality of variance F = 0.076 p = 0.786 variances equal;
t = -3.26 df = 20 p = 0.004 SE = 0.181 95% CI (-0.809 to –0.177)

and eyes open double-leg stance (Wide)
Levene's test for equality of variance F = 1.000 p = 0.329 variances equal;
t = -4.67 df = 20 p = 0.000 SE = 0.141 95% CI (-0.952 to –0.364).

8.3.4.5 Analysis of Dependent Variables for COB_X

For the dependent variable of visual condition; eyes open versus eyes closed, there were no significant differences in COB_X except for Trained, double-leg stance (Wide) condition;

t = 2.90 df = 11 p = 0.014 95% CI (0.143 to 1.044)

Figure n° 833 and *834* illustrates the comparison of eyes open and eyes closed visual conditions for all stance positions in the taping and training groups.

Figure n° 833 Comparison of Visual Condition Effect on Centre of Balance $_{X\_axis}$ for Taping Group

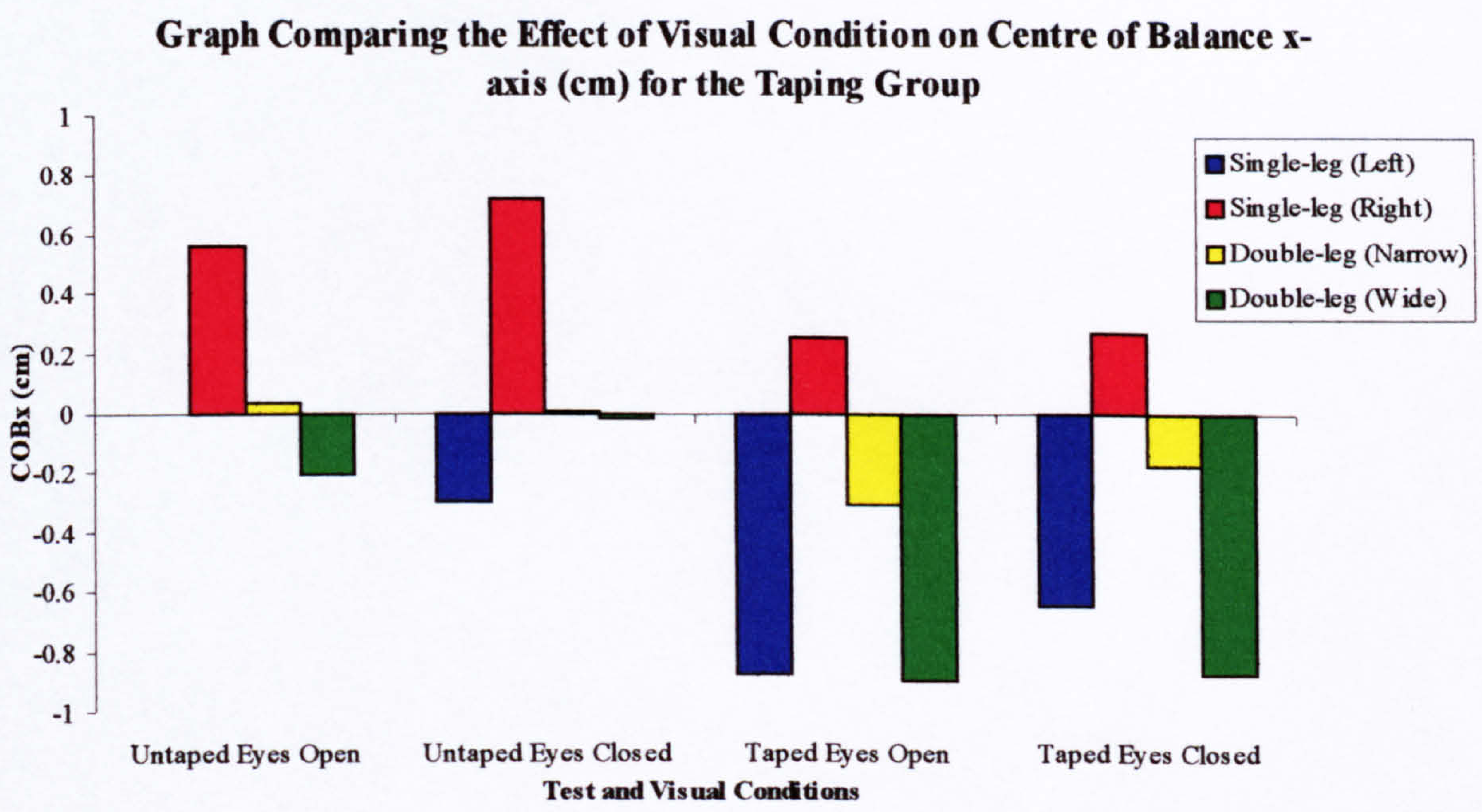
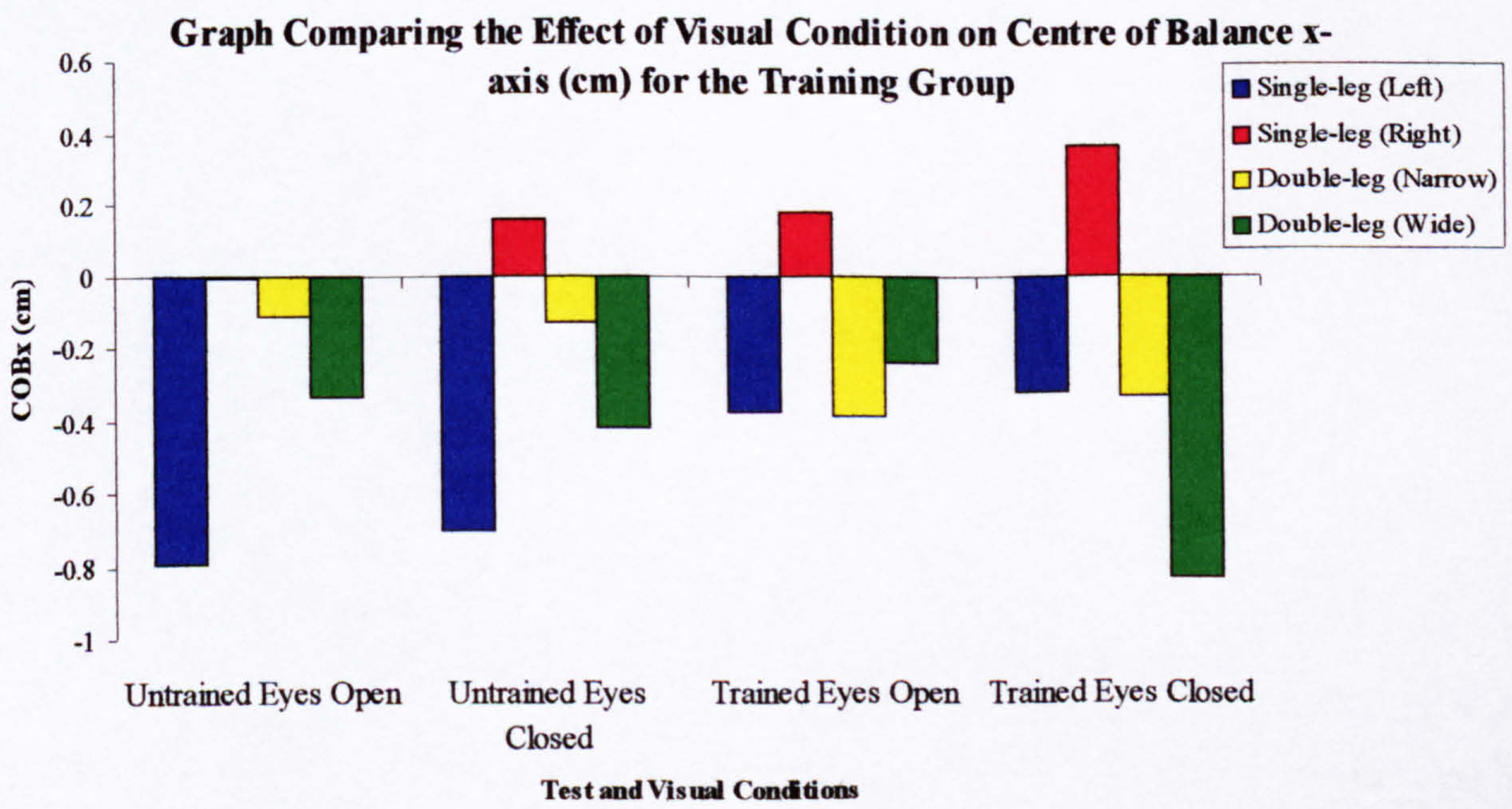


Figure n° 834 Comparison of Visual Condition Effect on Centre of Balance $_{X\text{-}axis}$ for Training Group



If a comparison is made of the change in COB_X position by averaging the means of COB_X for eyes open and eyes closed visual conditions and comparing this value in Untaped and Taped conditions and Untrained and Trained conditions, the change in overall centre of balance position can be seen, as illustrated in *Figure n^{os} 835* and *836*.

Figure n° 835 Comparison of Centre of Balance $_{X\text{-axis}}$ (cm) for Taping Group Conditions

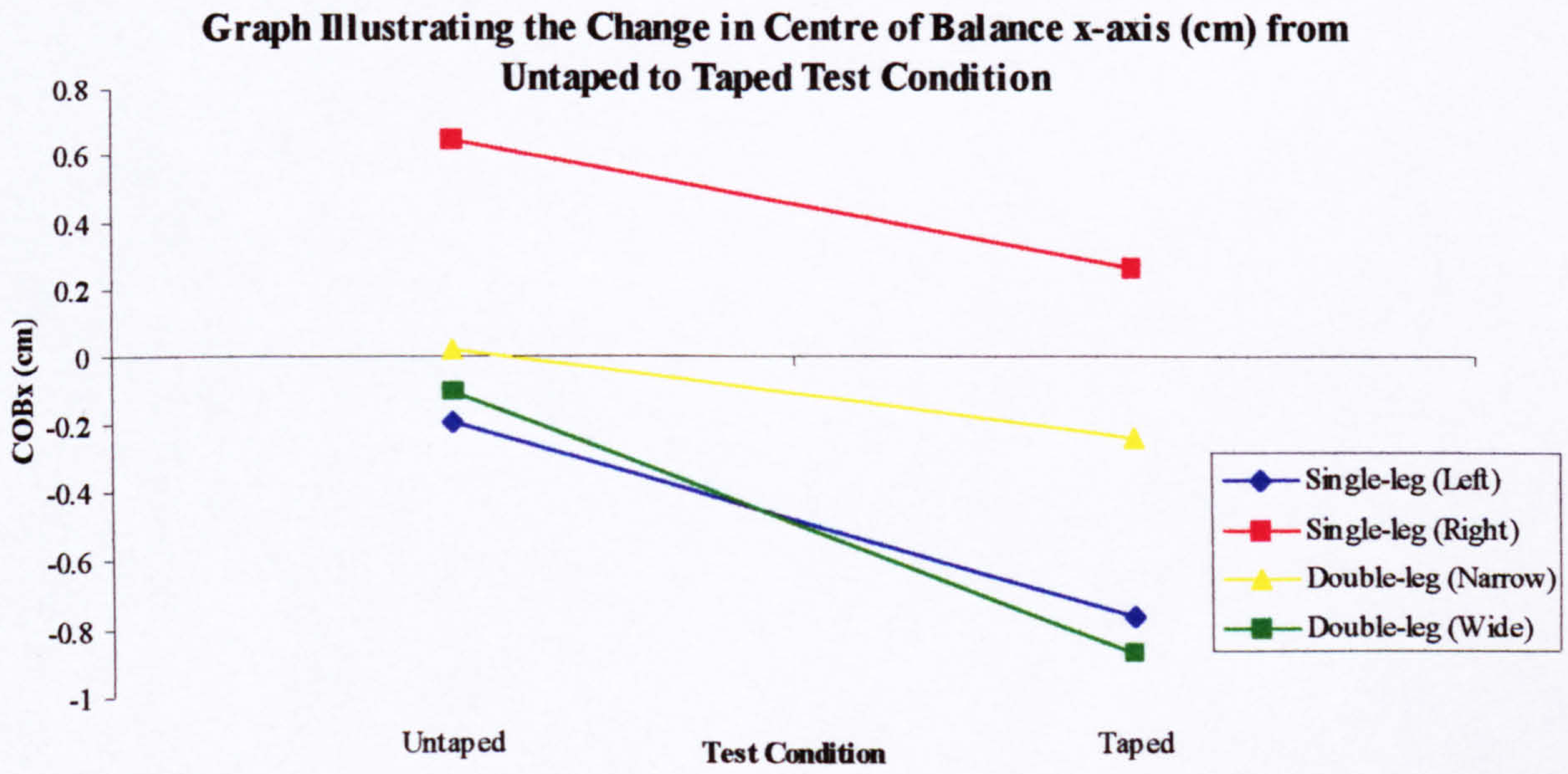
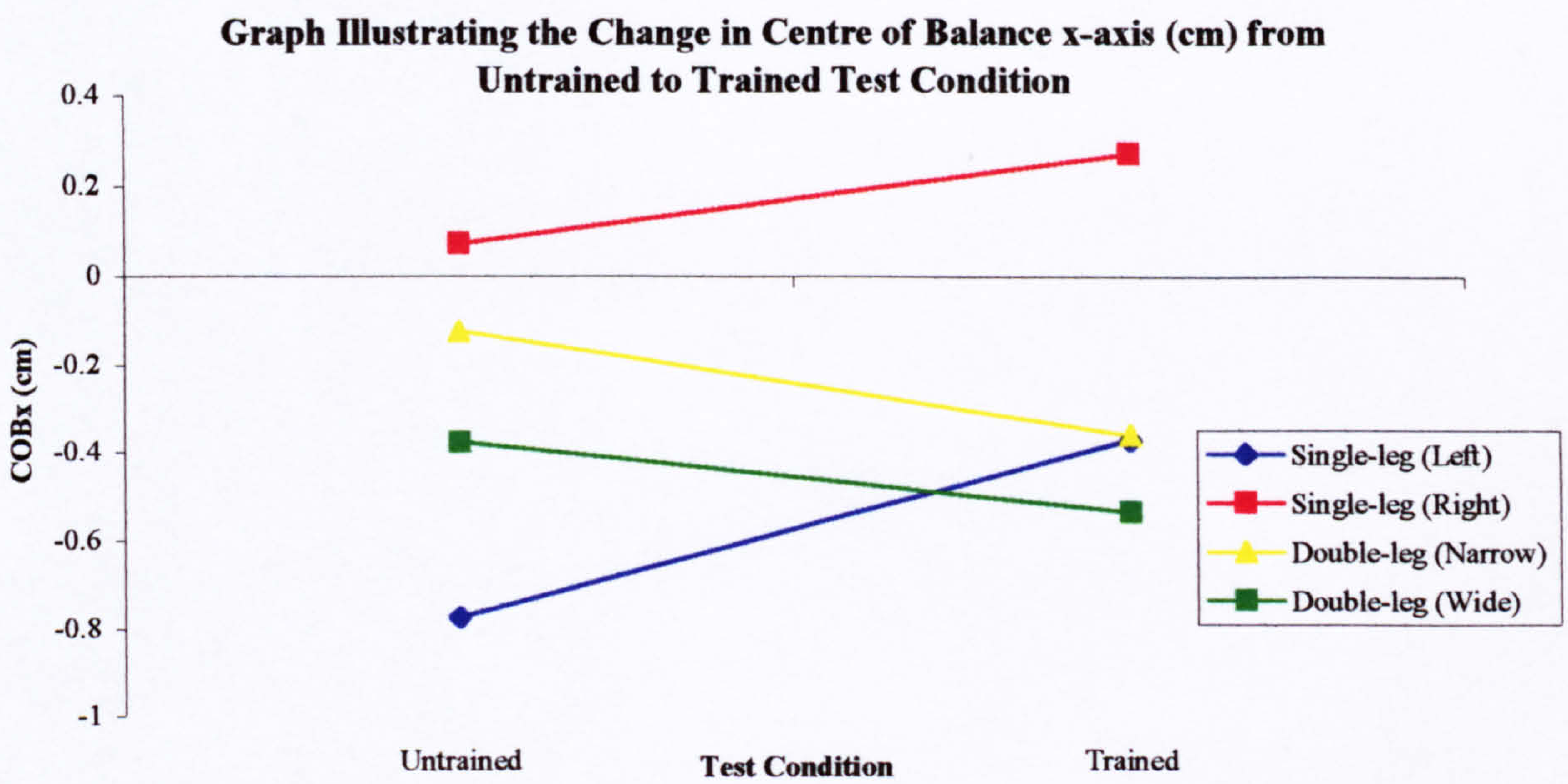


Figure n° 836 Comparison of Centre of Balance $_{X\text{-axis}}$ (cm) for Training Group Conditions



By paired samples t-test analysis, significance is found for all stance conditions within both taping and training groups for overall COB_X position, with the exception of double-leg stance (Wide). The significant values are;

Single-leg (Left),	Taping	t = 3.29	df = 19	$p = 0.004$
	Training	t = -5.80	df = 23	$p = 0.000$
Single-leg (Right)	Taping	t = 3.38	df = 19	$p = 0.003$
	Training	t = -1.79	df = 23	$p = 0.086$**
Double-leg (Narrow)	Taping	t = 2.24	df = 19	$p = 0.037$
	Training	t = 3.11	df = 23	$p = 0.005$

** denotes significance at the $p < 0.1$ level, all other significant values are at the $p < 0.05$ level.

For the dependent variable of stance, significant differences are seen in COB_X positioning between left and right legs for single-leg stance Taped and Trained eyes open;

Taped	t = -7.00	df = 9	$p = 0.000$	95% CI (-1.495 to –0.765)

Trained	t = -3.14	df = 11	$p = 0.009$	95% CI (-9.50 to -0.501)

and Untaped, Taped, Untrained and Trained for eyes closed;

Untaped	t = -3.74	df = 9	$p = 0.005$	95% CI (-1.634 to –0.402)
Taped	t = -6.39	df = 9	$p = 0.000$	95% CI (-1.242 to –0.592)
Untrained	t = 5.31	df = 11	$p = 0.009$	95% CI (-0.950 to –0.167)
Trained	t = -3.79	df = 11	$p = 0.003$	95% CI (-1.092 to –0.289)

When comparing double-leg stance, significant differences are seen in eyes open Taped and Untrained;

Taped	t = 7.00	df = 9	$p = 0.000$	95% CI (0.400 to 0.782)
Untrained	t = 2.45	df = 11	$p = 0.032$	95% CI (0.022 to 0.416)

and in eyes closed for Taped, Untrained and Trained;

Taped	t = 3.75	df = 9	$p = 0.005$	95% CI (0.277 to 1.121)
Untrained	t = 2.56	df = 11	$p = 0.027$	95% CI (0.041 to 0.543)
Trained	t = 2.81	df = 11	$p = 0.017$	95% CI (0.108 to 0.891)

Comparing single-leg stance to double-leg stance, significant differences in COB_X positioning is seen between single-leg (Left) and double-leg (Narrow) as follows;

Taped, eyes open	t = -4.91	df = 9	$p = 0.001$	95% CI (-0.825 to –0.305)
Untrained, eyes open	t = -2.76	df = 11	$p = 0.018$	95% CI (-1.226 to –0.139)
Untrained, eyes closed	t = -3.90	df = 11	$p = 0.002$	95% CI (-0.893 to –0.249)

between single-leg (Right) and double-leg (Narrow);

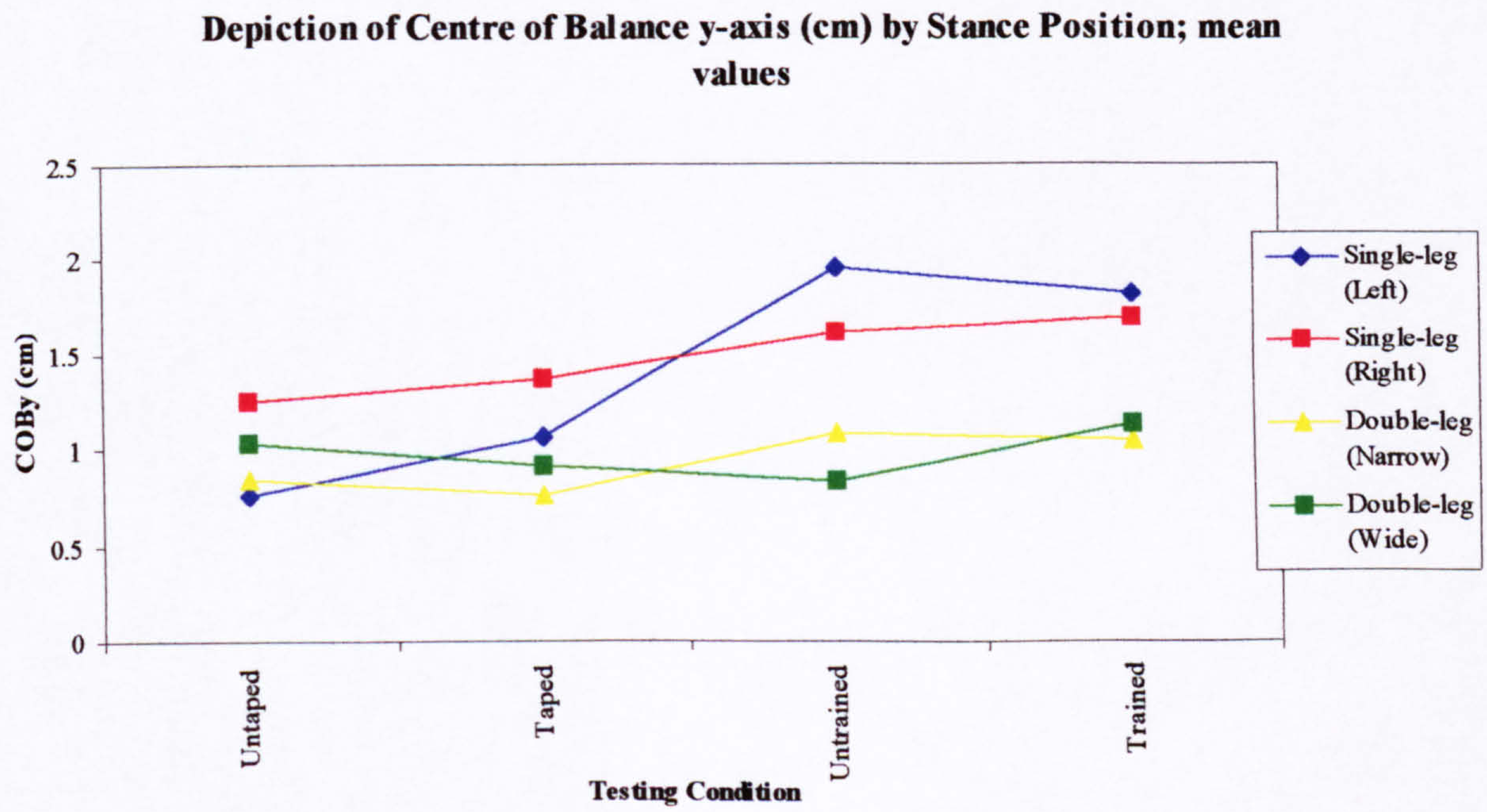
Untaped, eyes open	t = 3.15	df = 9	$p = 0.012$	95% CI (0.150 o 0.910)
Taped, eyes open	t = 6.47	df = 9	$p = 0.000$	95% CI (0.367 to 0.763)
Untaped, eyes closed	t = 2.85	df = 9	$p = 0.019$	95% CI (0.148 to 1.282)
Trained, eyes open	t = 4.43	df = 11	$p = 0.001$	95% CI (0.287 to 0.832)
Trained, eyes closed	t = 6.23	df = 11	$p = 0.000$	95% CI (0.454 to 0.950)

No difference is seen between single-leg (Left) and double-leg (Wide), but significance is seen between single-leg (Right) and double-leg (Wide) for all conditions.

8.3.5 Centre of Balance $_{Y\text{-axis}}$ (cm) Results

The values of Centre of Balance $_{Y\text{-axis}}$ (COB_Y) ranged from –1.23 to 4.00 cm and –2.27 to 6.34 cm for single and double-leg stance respectively. The mean values are illustrated in *Figure n° 837*.

Figure n° 837 Mean COB_Y Position Values (cm) for all Test Conditions by Stance Position



8.3.5.1 Mixed ANOVA Results for COB_Y

The analysis of variance revealed no significant difference between groups for COB_Y positioning. The ANOVA table for the analysis is presented in *Table n° 8.46*.

Table n° 8.46 Analysis of Variance for Repeated Measures Mixed Model of Three Within and One Between Subject Variables for ***COB_Y*** *Positioning*

Source of Variation	Sum of Squares	Degrees of Freedom	Mean of Squares	F-value	p-value
Between Subject Effects					
Within Cells	257.03	20	12.85		
Group	13.30	1	13.30	1,04	0.321
Within Subject Effects					
Within Cells	72.98	20	3.65		
EYE	0.23	1	0.23	0.06	0.805
Group x Eye	0.00	1	0.00	0.00	0.994
Within Cells	25.52	20	1.28		
TEST	1.98	1	1.98	1.55	0.227
Group x Test	0.00	1	0.00	0.00	0.993
Within Cells	127.44	60	2.12		
STANCE	21.09	3	7.03	3.31	0.026*
Group x Stance	11.00	3	3.67	1.73	0.171
Within Cells	7.73	20	0.39		
Eye x Test	1.07	1	1.07	2.76	0.112
Group x Eye x Test	0.81	1	0.81	2.10	0.162
Within Cells	52.94	60	0.88		
Eye x Stance	0.34	3	0.11	0.13	0.942
Group x Eye x Stance	2.00	3	0.67	0.75	0.524
Within Cells	37.40	60	0.62		
Test x Stance	9.75	3	3.25	5.22	0.003*
Group x Test x Stance	5.17	3	1.72	2.76	0.050*
Within Cells	37.48	60	0.62		
Eye x Test x Stance	1.32	3	0.44	0.70	0.555
Group x Eye x Test x Stance	4.03	3	1.34	2.15	0.130

*denotes $p < 0.05$, therefore significant.

Significant differences were only seen within the stance condition for;

Stance	$F(3,60) = 3.31$	$p = 0.026$
Test by Stance	$F(3,60) = 5.22$	$p = 0.003$
Group by Test by Stance	$F(3,60) = 2.76$	$p = 0.050$.

8.3.5.2 One-way Repeated Measures ANOVA for COB_Y

One-way analysis of variance between groups for COB_Y showed significance only in the Untaped versus Untrained comparison for single-leg (Left), eyes open; $F(1,20) = 8.6584$ $p = 0.0081$.

No significance is seen in the Taped versus Trained condition.

8.3.5.3 Paired Samples t-test Analysis for COB_Y

Paired t-test analysis for within subject factors revealed no significance between Untaped and Taped or Untrained and Trained conditions.

8.3.5.4 Independent Samples t-test Analysis for COB_Y

Independent t-tests for between subject significance revealed no significance for any condition tested.

8.3.5.5 Analysis of Dependent Variables for COB_Y

For the dependent variable of visual condition; eyes open versus eyes closed, significance was seen only the Untaped, single-leg (Left) condition;

$t = -3.98$ $df = 9$ $p = 0.003$ 95% CI (-2.607 to –0.717)

Figure n^{os} 838 and *839* illustrates the comparison of eyes open and eyes closed visual conditions for all stance positions in the taping and training groups.

Figure n^{o} 838 Comparison of Visual Condition Effect on Centre of Balance $_{Y\_axis}$ for Taping Group

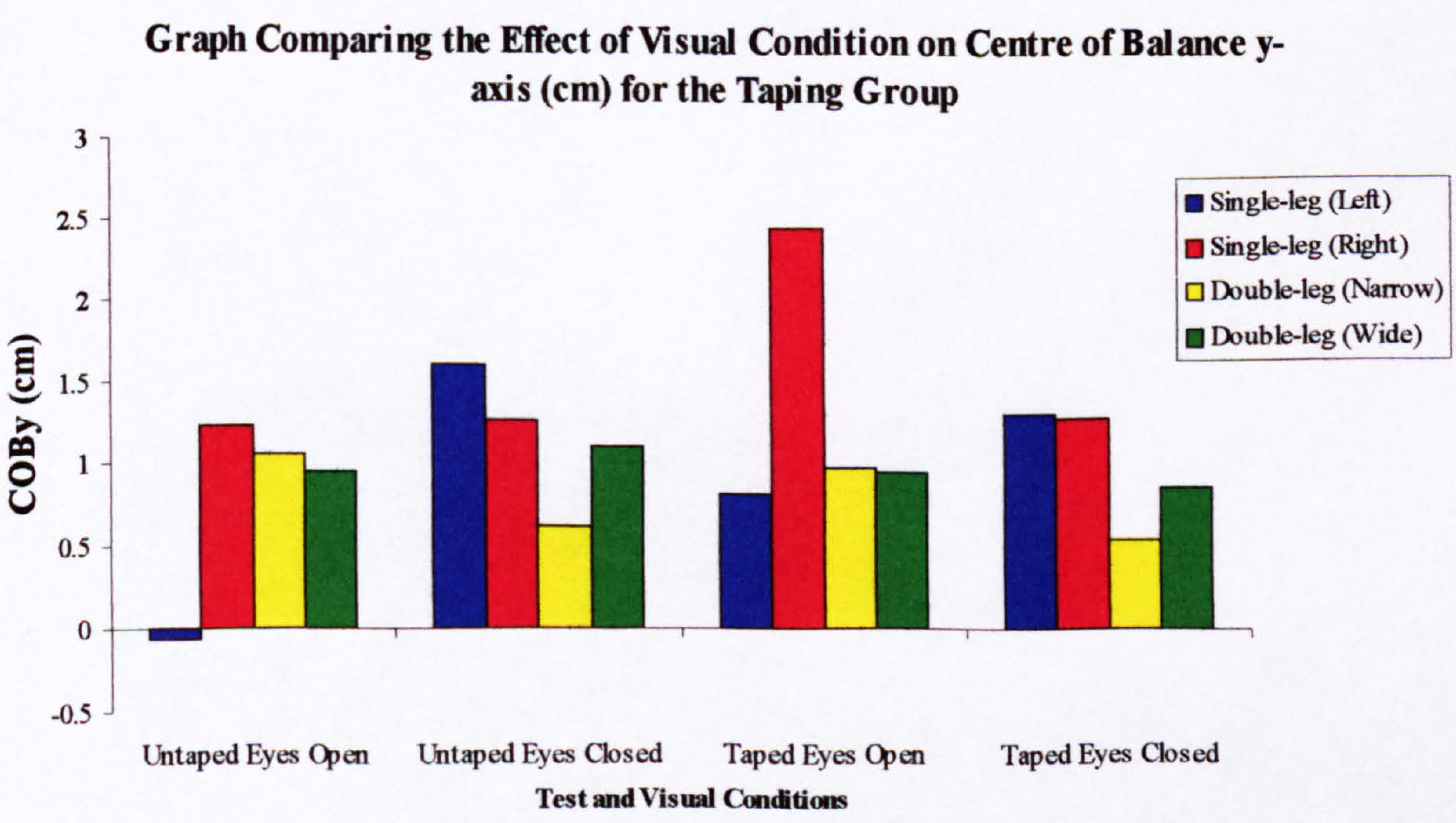
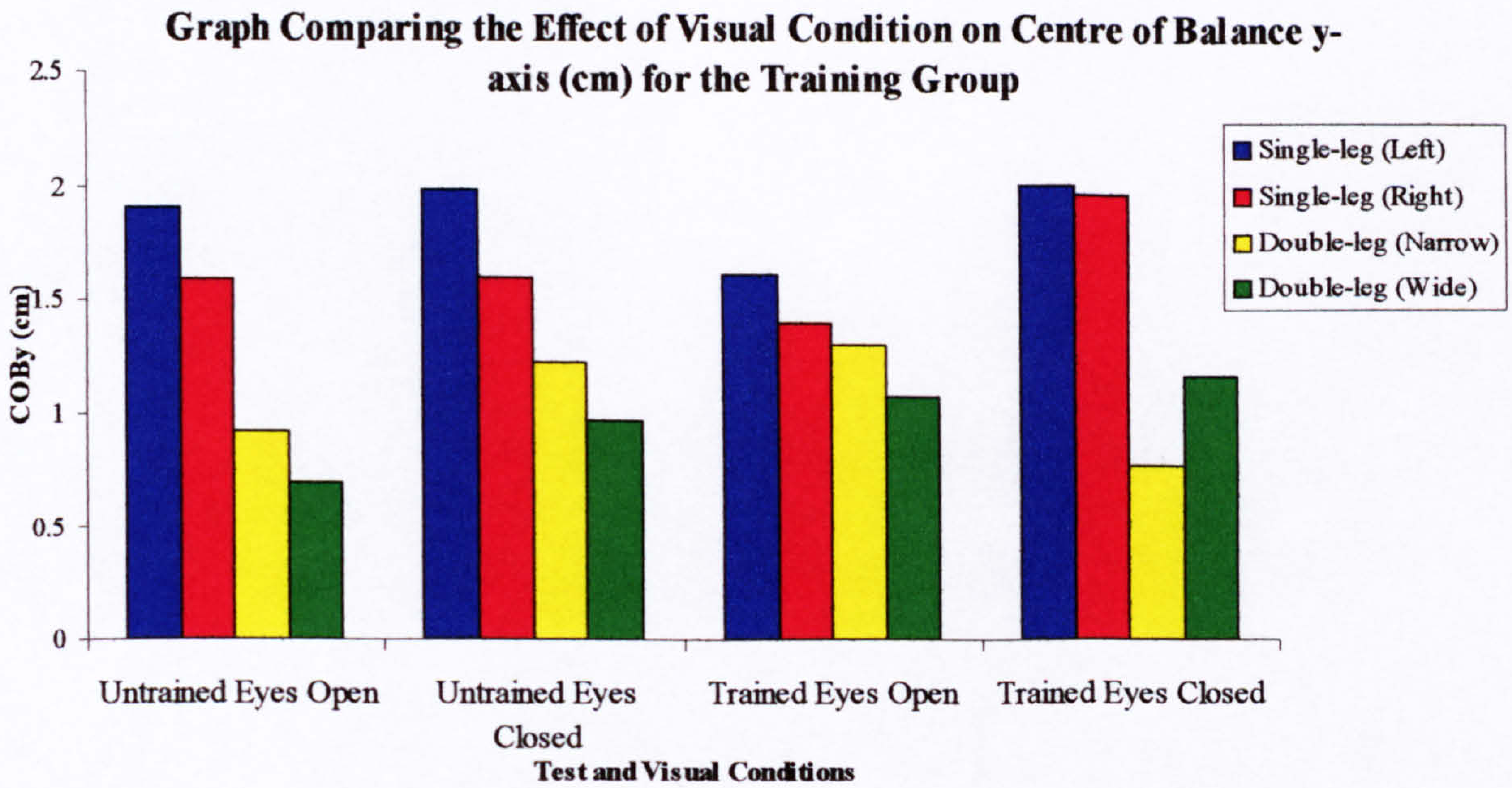


Figure 839 Comparison of Visual Condition Effect on Centre of Balance $_{Y\_axis}$ for Training Group



If a comparison is made of the change in COB_Y position by averaging the means of COB_Y for eyes open and eyes closed visual conditions and comparing this value in Untaped and Taped conditions and Untrained and Trained conditions, the change in overall centre of balance position can be seen, as illustrated in *Figure n^{os} 840* and *841*.

Figure n° 840 Comparison of Centre of Balance $_{Y\text{-}axis}$ (cm) for Taping Group Conditions

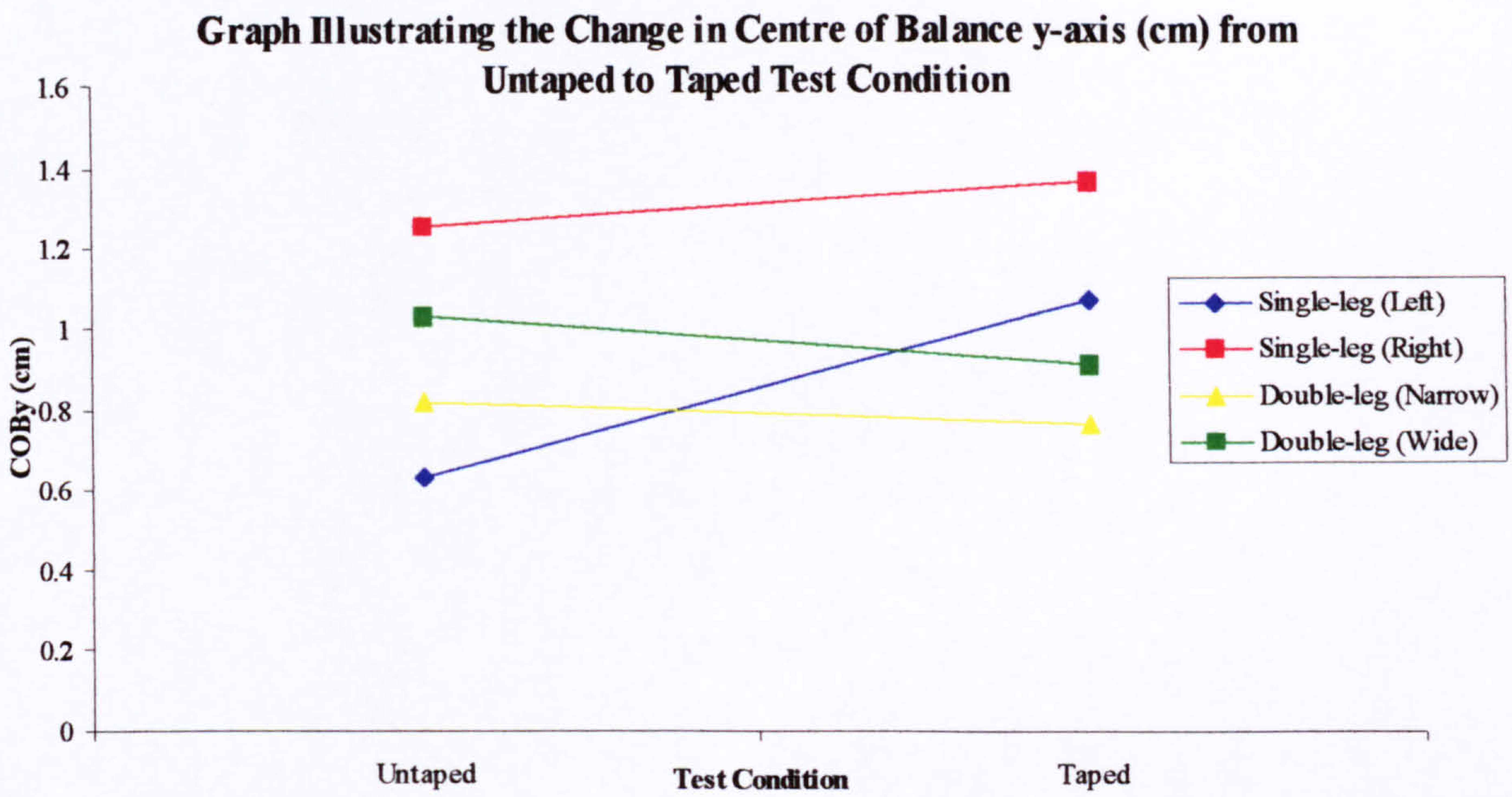
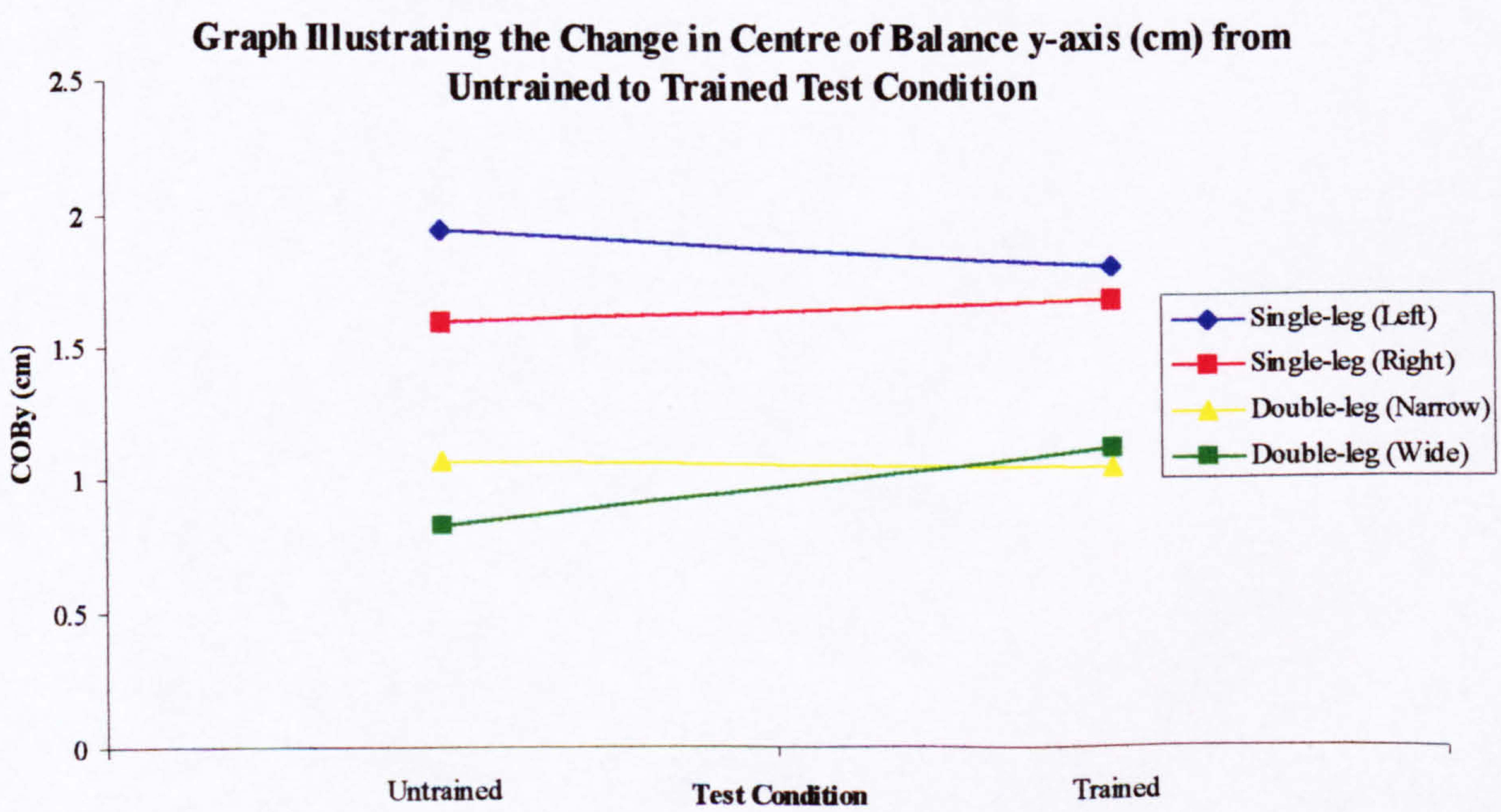


Figure n° 841 Comparison of Centre of Balance $_{Y\text{-}axis}$ (cm) for Training Group Conditions



By paired samples t-test analysis, no significance is found within the taping or training groups for overall COB_Y position.

For the dependent variable of stance, no significant differences are seen in COB_Y positioning between left and right legs for single-leg stance, or narrow and wide positioning for double-leg stance.

Comparing single-leg stance with double-leg stance positions, significant differences are seen between single-leg (Left) and double-leg (Narrow);

Untaped, eyes closed t = 2.71 df = 9 $p = 0.024$ 95% CI (0.160 to 1.784)
Taped, eyes closed t = 5.61 df = 9 $p = 0.000$ 95% CI (1.490 to 3.500)
Untrained, eyes open t = 2.85 df = 11 $p = 0.016$ 95% CI (0.225 to 1.758)
Untrained, eyes closed t = 4.67 df = 11 $p = 0.001$ 95% CI (0.408 to1.135)
Trained, eyes closed t = 3.96 df = 11 $p = 0.002$ 95% CI (0.551 to 1.931)

and single-leg (Right) with double-leg (Narrow)

Trained, eyes closed t = 3.73 df = 11 $p = 0.003$ 95% CI (0.491 to 1.905)

For comparison with double-leg (Wide) with single-leg (Left);

Untrained, eyes open t = 3.45 df = 11 $p = 0.005$ 95% CI (0.443 to 2.000)
Untrained, eyes closed t = 3.93 df = 11 $p = 0.002$ 95% CI (0.453 to 1.605)
Trained, eyes closed t = 2.60 df = 11 $p = 0.025$ 95% CI (0.130 to 1.754)

and single-leg (Right);

Untrained, eyes open t = 2.37 df = 11 $p = 0.037$ 95% CI (0.063 to 1.749).

8.3.6 Postural Stability Results Summary

Postural sway is seen to increase on closing the eyes for all test conditions. In the Untaped/Untrained conditions, sway during double-leg balance is approximately half that of single-leg balance.

Changes is sway due to taping and training become more marked in the eyes closed condition, though only significant for single-leg (Right) $p = 0.012$.

Overall there is more sway in single-leg (Right) than single-leg (Left), though only significant with taping, eyes closed (p = 0.03). For double-leg stance positions, there is more sway in double-leg (Wide) than double-leg (Narrow), both

Untrained and Trained (p = 0.008 and p = 0.009 respectively). There is significance between single-leg and double-leg stance positions.

If the Sway Index is separated into its two component parts of Left/Right and Anterior/Posterior sway, the effect of changes of these components on overall sway can be seen.

A greater increase in L/R sway is seen with taping, eyes closed. Taping causes a greater increase in L/R sway single-leg (Right) and double-leg (Wide) than either single-leg (Left) or double-leg (Narrow). For the training group, an increase in L/R sway is seen in single-leg stance and a decrease in L/R sway in double-leg stance. These changes are not significant.

Considering the A/P component reveals a marked increase in A/P sway for single-leg (Right) with taping (p = 0.045) and a decrease in A/P sway for single-leg (Left), though insignificant. Training results in an increase in A/P sway in all stance positions, though this increase is not significant.

A/P sway is greater for single-leg stance positions than double-leg positions both with tape and after proprioceptive training.

Also investigated were the loci for centre of balance. Results indicate movement of COB $_X$ to the Left with taping (laterally away from the CBOS for left and double-leg stance positions and medially towards the CBOS for single-leg (Right)). For the training group, COB $_X$ moved right for single-leg positions and left for double-leg stance positions. Here, in contrast to findings in the taping group, single-leg (Left) COB $_X$ moves medially towards the CBOS and single-leg (Right), along with double-leg positions, laterally away from the CBOS.

COB $_Y$ moves anteriorly with taping for the single-leg positions and posteriorly with taping for the double-leg positions. Training results in an anterior shift in single-leg stance positions and double-leg (Wide). Double-leg (Narrow) COB $_Y$ shifts posteriorly with training.

8.4 ELECTROMYOGRAPHY RESULTS

EMG traces for gastrocnemius, peroneus longus, tibialis anterior and soleus muscles were recorded for the second of the three balance trials conducted for each test condition, for each subject. [EMG recording of all three trials for each test condition was not possible due to the large amount of data per trial, along with equipment and time constraints]. The data was then analysed firstly by statistical analysis of minimum and maximum peak values and secondly, by calculation of a mean EMG trace over a ten second trial for each test condition derived from the subject data. The mean EMG traces were then compared graphically.

The minimum and maximum EMG results are presented first, followed by the results for the mean ten second balance trials.

8.4.1 EMG – Minimum and Maximum Results

For each EMG trace, the maximum and minimum peak values of muscle activity (mV) for each muscle over the ten second period of testing was noted. Statistical analysis was performed on this data using t-test analysis (SPSS Version 6.0).

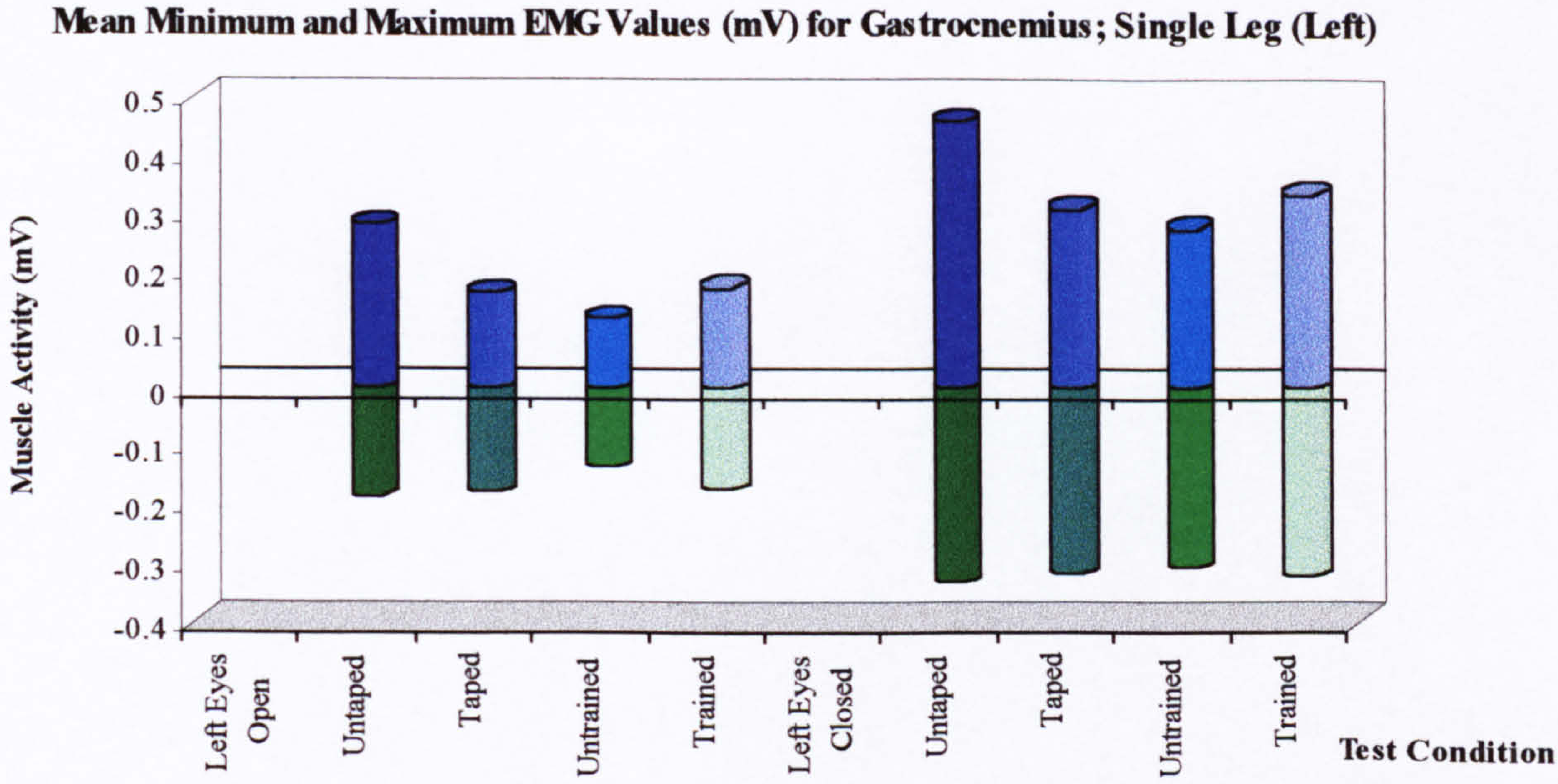
The results for each muscle are presented separately, in the order; gastrocnemius, peroneus longus, tibialis anterior and then soleus, and within each of these, single-leg (Left), single-leg (Right), double-leg (Narrow) and then double-leg (Wide). A graphical representation of the mean minimum and maximum results for each condition is displayed first, followed by the statistical analysis of visual condition by paired samples t-test for each stance condition. Following this, the results for the within subject analyses of test condition and stance position are presented. Finally, a statement of the independent t-test analysis between groups is made.

8.4.1.1 Gastrocnemius EMG – Minimum and Maximum Results

Separate paired-samples t-tests were conducted to analyse within-subject factors of the taping and training groups. Statistical significance was set at the 0.05 level.

Figure n° 842 illustrates the overall mean minimum and maximum peak values for the left leg in each test condition.

Figure n° 842 Overall Mean Minimum and Maximum Peak Values for Single-leg (Left) by Test Condition; Gastrocnemius Muscle



For the within-subject factor of visual condition, comparing gastrocnemius muscle activity in eyes open and eyes closed conditions, significance was found for the single-leg (Left) stance position as displayed in *Table n° 8.47*.

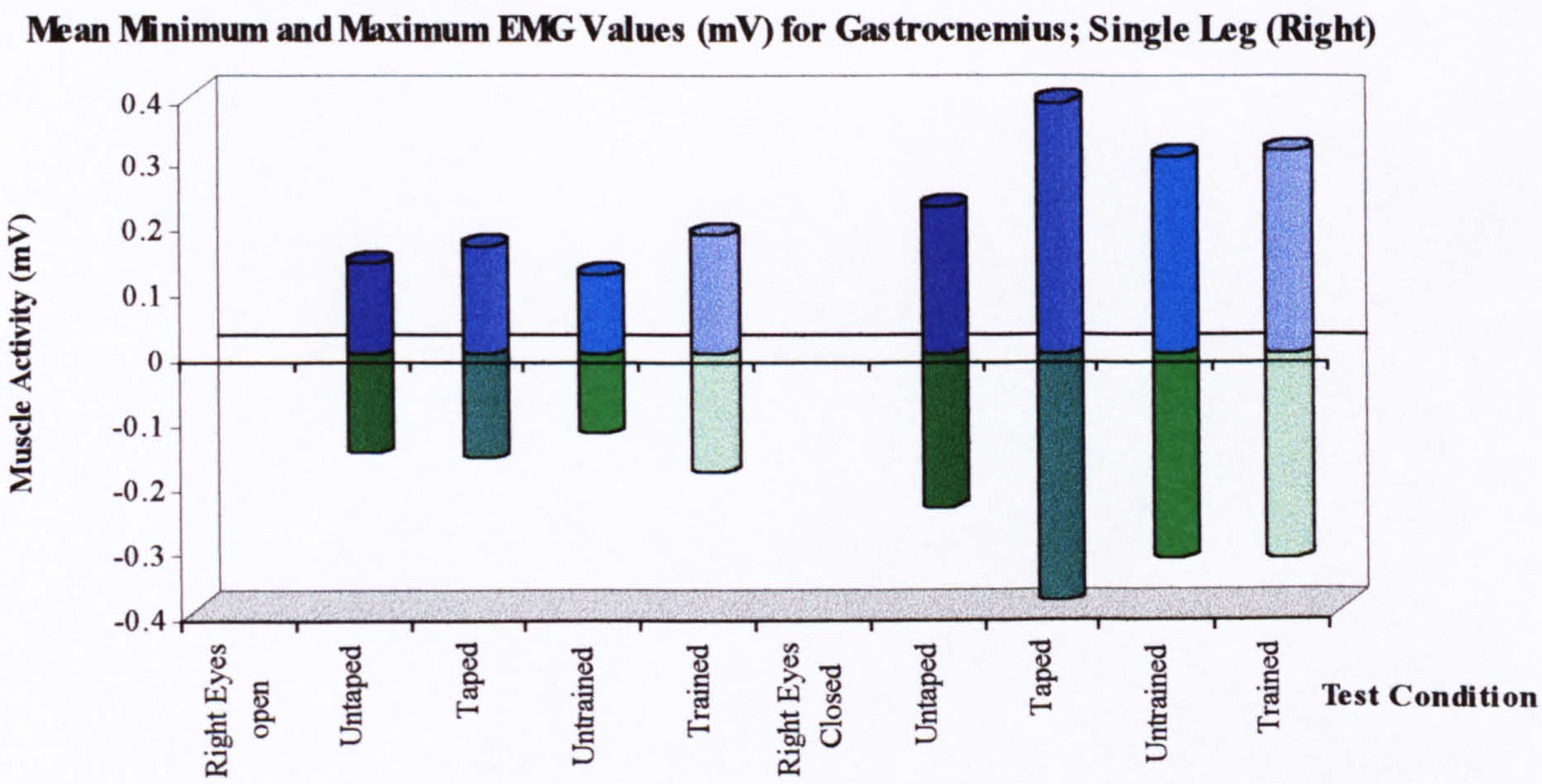
Table n° 8.47 Significant Results of Paired t-test Analysis on Single-leg (Left) for Visual Condition; Gastrocnemius Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Left)	EO Vs EC	Untaped	MIN	3.00	6	0.024	0.027 to 0.267
Single-leg (Left)	EO Vs EC	Untaped	MAX	-4.20	6	0.006	-0.283 to -0.074
Single-leg (Left)	EO Vs EC	Taped	MAX	-2.33	13	0.036	-0.133 to -0.005
Single-leg (Left)	EO Vs EC	Trained	MIN	5.43	13	0.000	0.090 to 0.210
Single-leg (Left)	EO Vs EC	Trained	MAX	-4.67	13	0.000	-0.233 to -0.085

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

The overall minimum and maximum peak values for each test condition in single-leg (Right) are displayed in *Figure n° 843*.

Figure n° 843 Overall Mean Minimum and Maximum Peak Values for Single-leg (Right) by Test Condition; Gastrocnemius Muscle



For single-leg (Right) stance, significance was found in conditions as displayed in *Table n° 8.48* comparing visual condition.

Table n° 8.48 Significant Results of Paired t-test Analysis on Single-leg (Right) for Visual Condition; Gastrocnemius Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Right)	EO Vs EC	Taped	MIN	4.32	14	0.001	0.115 to 0.343
Single-leg (Right)	EO Vs EC	Taped	MAX	-4.25	14	0.001	-0.355 to –0.117
Single-leg (Right)	EO Vs EC	Untrained	MIN	2.88	6	0.028	0.024 to 0.293
Single-leg (Right)	EO Vs EC	Untrained	MAX	-3.15	6	0.020	-0.279 to -0.035
Single-leg (Right)	EO Vs EC	Trained	MIN	2.18	13	0.048	0.001 to 0.277
Single-leg (Right)	EO Vs EC	Trained	MAX	-2.36	13	0.034	-0.244 to –0.011

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Paired-samples t-test analysis was also conducted on the data for double-leg stance positions of narrow and wide. For the gastrocnemius muscle, no statistical significance was found for minimum or maximum peak values of muscle activity (mV) in either group of taping or training for the within-subject factor of visual condition comparing eyes open and eyes closed conditions. *Figure n^{os} 844* and *845* illustrate the overall minimum and maximum peak values for double-leg stance, narrow and wide respectively for each test condition.

Figure n^o 844 Overall Mean Minimum and Maximum Peak Values for Double-leg (Narrow) by Test Condition; Gastrocnemius Muscle

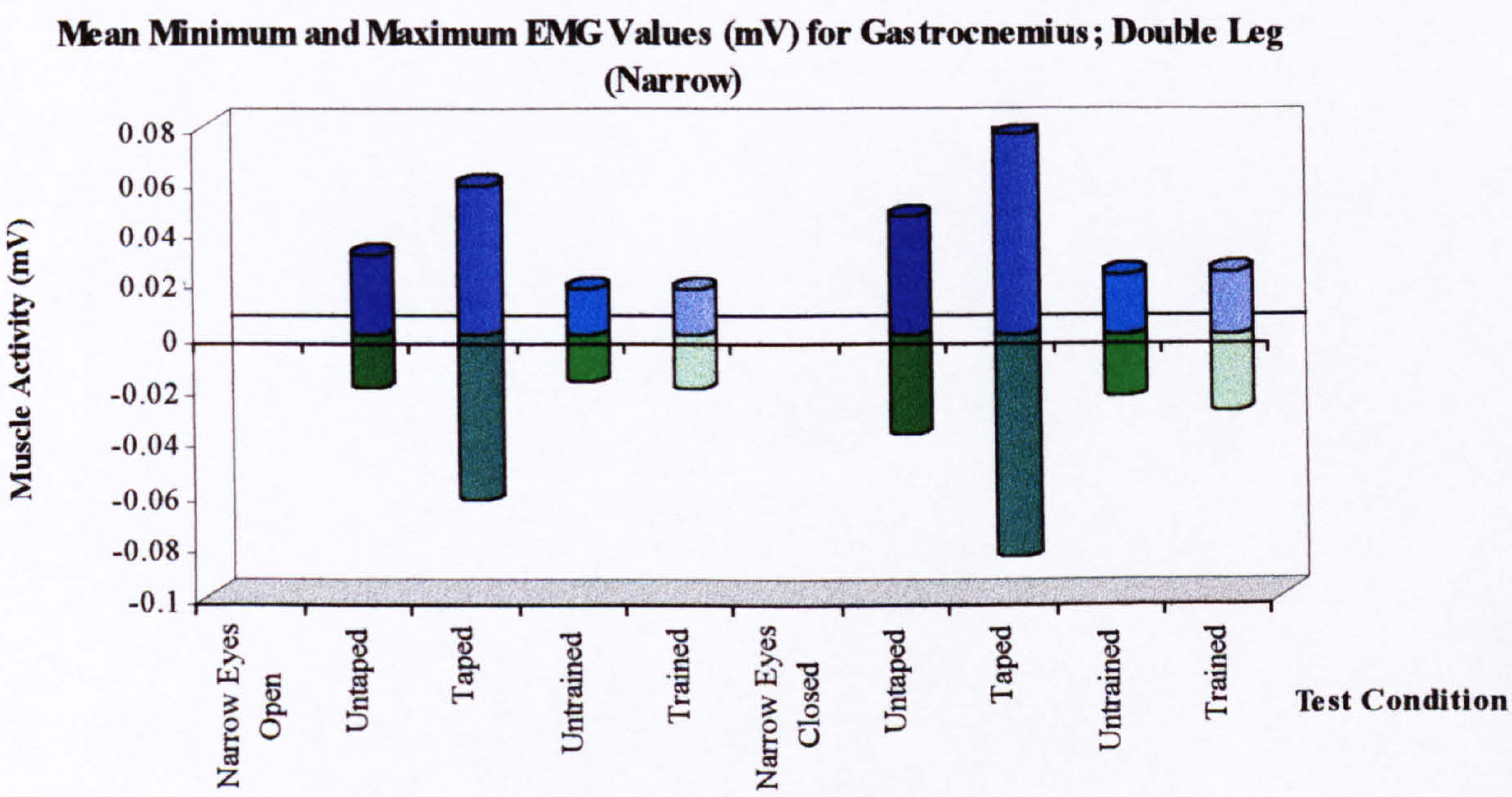
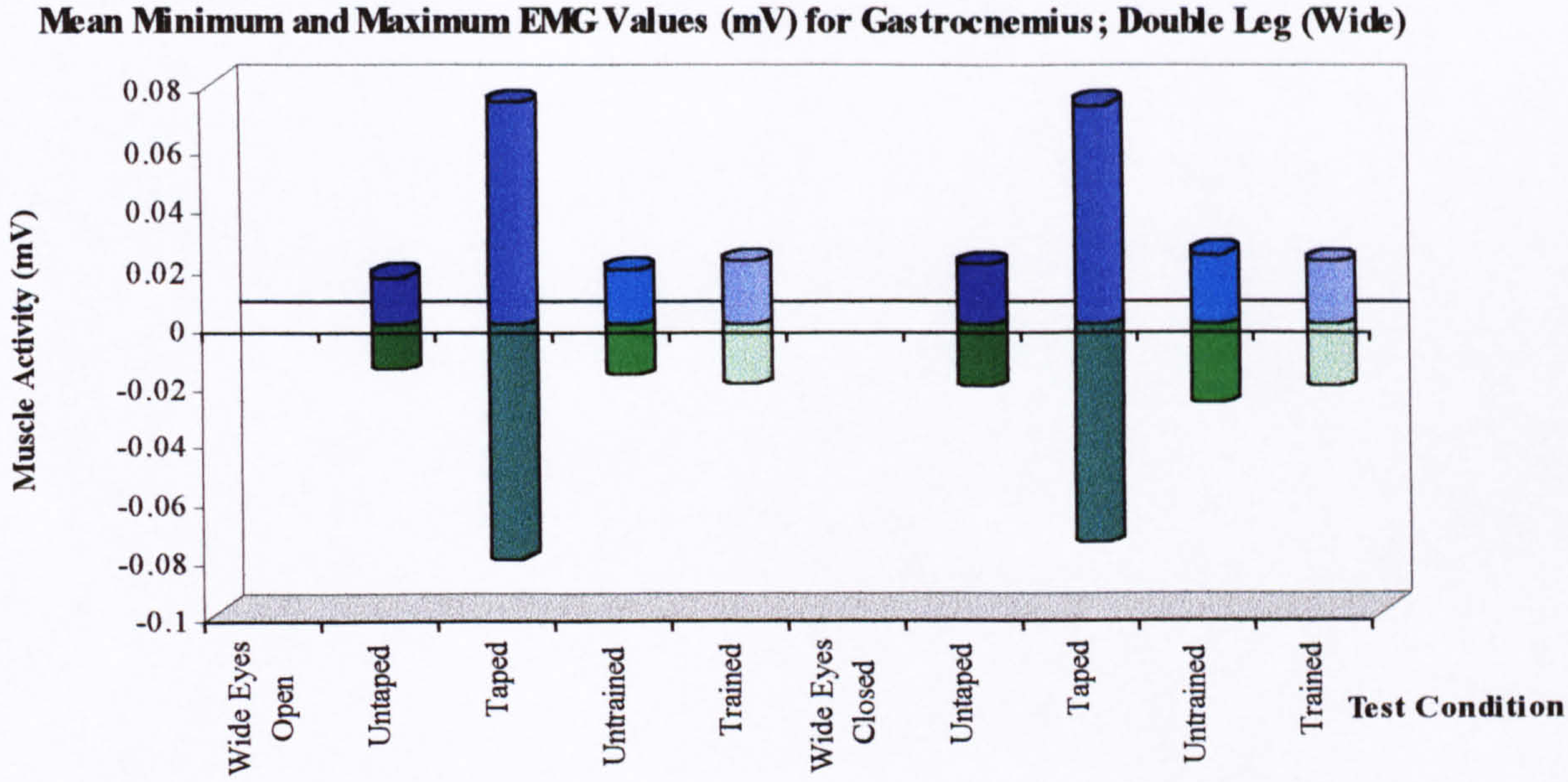


Figure n° 845 Overall Mean Minimum and Maximum Peak Values for Double-leg (Wide) by Test Condition; Gastrocnemius Muscle



For paired-samples t-test analysis of within-subject factors of Untaped versus Taped and Untrained versus Trained, with statistical significance again set at the 0.05 level, for single-leg stance positions of left and right legs, significance was found only in the left leg. The significant results are displayed in *Table n° 8.49*

Table n° 8.49 Significant Results of Paired t-test Analysis on Single-leg (Left) for Test Condition; Gastrocnemius Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Left)	EC	Untaped Vs Taped	MIN	-2.76	6	0.033	-0.217 to –0.013
Single-leg (Left)	EO	Untrained Vs Trained	MIN	2.67	6	0.037	0.005 to 0.117
Single-leg (Left)	EO	Untrained Vs Trained	MAX	-2.52	6	0.045	-0.118 to –0.002

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

No statistical significance was found in double-leg stance positions for within-subject analysis of test conditions.

Paired t-test analysis was also conducted on the data to compare the within-subject stance conditions of single-leg left versus right and double-leg narrow versus wide. Significance was found for the gastrocnemius muscle only in single-leg (Left) versus single-leg (Right) positions as shown in *Table n° 8.50*. No significance was found between the two double-leg stance positions.

Table n° 8.50 Significant Results of Paired t-test Analysis on Within-subject Factor of Stance Condition; Gastrocnemius Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Right	EC	Untaped	MIN	-3.22	6	0.018	-0.165 to -0.022

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

If single-leg stance positions are compared with double-leg stance positions, paired t-test analysis reveals significant differences between stance positions in all cases for the gastrocnemius muscle with the exception of those reported in *Table n° 8.51*. The non-significant results are depicted here because they are divergent to the expected results.

Table n° 8.51 Non-Significant Results of Paired t-test Analysis on Within-subject Comparison of Single-leg and Double-leg Stance Conditions; Gastrocnemius Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Small	EO	Untaped	MAX	2.14	6	0.076	-0.038 to 0.565
Left Vs Small	EC	Untaped	MAX	2.21	5	0.078	-0.067 to 0.885
Left Vs Small	EO	Taped	MIN	-1.25	9	0.244	-0.146 to 0.042
Left Vs Small	EO	Taped	MAX	1.83	9	0.100	-0.015 to 0.145
Left Vs Wide	EO	Untaped	MAX	2.19	6	0.071	-0.031 to 0.565
Left Vs Wide	EO	Taped	MIN	-0.66	8	0.530	-0.165 to 0.092
Left Vs Wide	EO	Taped	MAX	0.95	8	0.371	-0.064 to 0.152
Right Vs Small	EC	Untaped	MIN	-2.40	5	0.062	-0.336 to 0.012
Right Vs Small	EC	Untaped	MAX	2.02	5	0.099	-0.041 to 0.0339
Right Vs Small	EO	Taped	MIN	-1.37	9	0.203	-0.180 to 0.044
Right Vs Small	EO	Taped	MAX	1.67	9	0.129	-0.030 to 0.200
Right Vs Wide	EO	Taped	MIN	-0.81	8	0.439	-0.148 to 0.071
Right Vs Wide	EO	Taped	MAX	1.19	8	0.268	-0.048 to 0.149

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

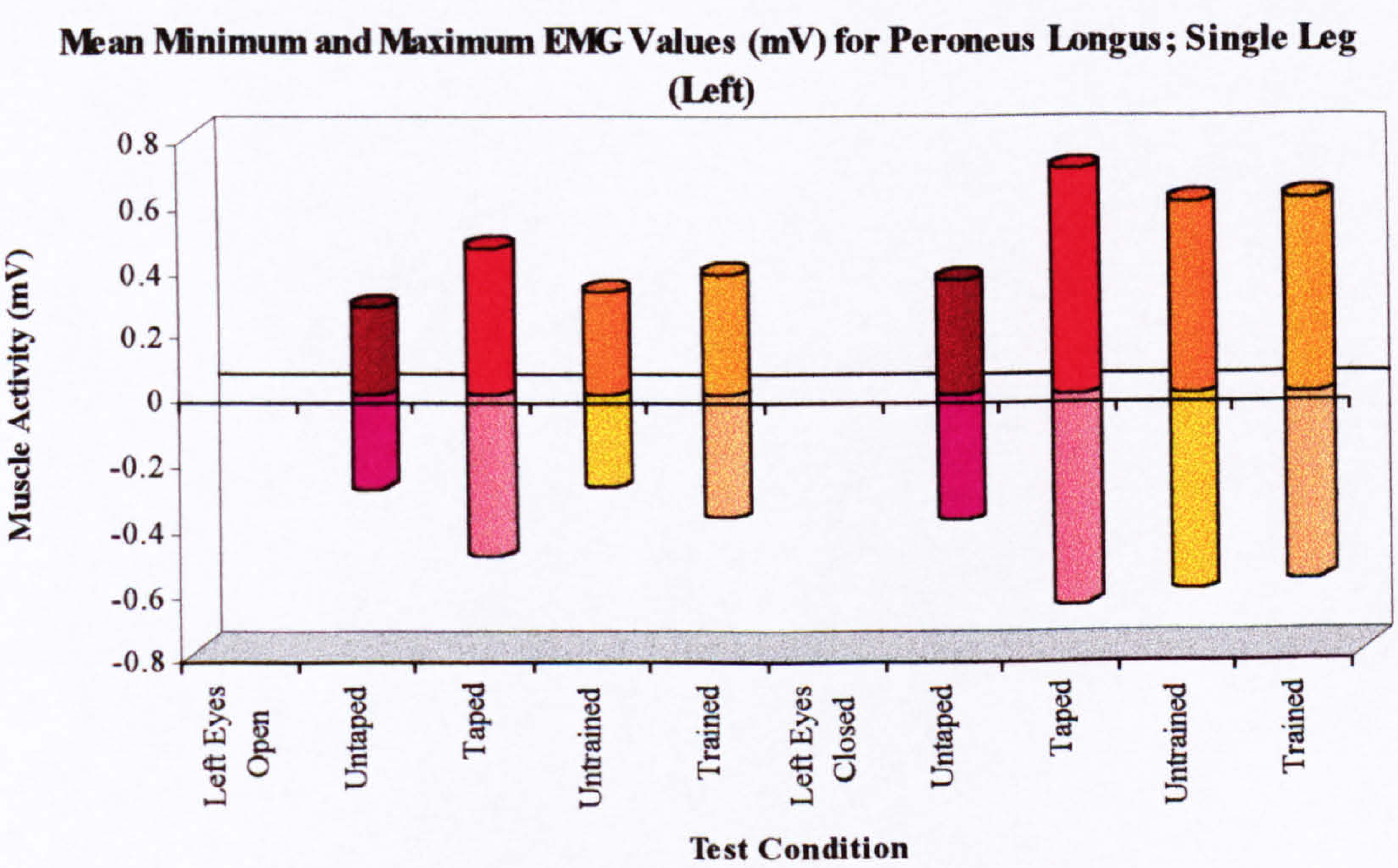
Independent t-test analysis was conducted to compare conditions between groups of Untaped versus Untrained and Taped versus Trained. No statistical significance was found for the gastrocnemius muscle with significance set at the 0.05 level.

8.4.1.2 Peroneus Longus EMG – Minimum and Maximum Results

Separate paired-samples t-tests were conducted to analyse within-subject conditions of the taping and training groups.

Figure n° 846 illustrates the overall mean minimum and maximum peak values of the peroneus longus muscle for the left leg in each test condition.

Figure n° 846 Overall Mean Minimum and Maximum Peak Values for Single-leg (Left) by Test Condition; Peroneus Longus Muscle



For the within-subject factor of visual condition comparing eyes open and eyes closed conditions within the groups, significance by t-test analysis was found for single-leg (Left) as displayed in *Table n° 8.52*.

Table nº 8.52 Significant Results of Paired t-test Analysis on Single-leg (Left) for Visual Condition; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Left)	EO Vs EC	Taped	MAX	-2.86	13	0.013	-0.546 to -0.076
Single-leg (Left)	EO Vs EC	Untrained	MIN	2.61	5	0.048	0.005 to 0.686
Single-leg (Left)	EO Vs EC	Trained	MIN	5.49	13	0.000	0.119 to 0.274
Single-leg (Left)	EO Vs EC	Trained	MAX	-4.40	13	0.001	-0.343 to –0.117

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Figure nº 847 illustrates the overall minimum and maximum peak values for the right leg in each test condition.

Figure nº 847 Overall Mean Minimum and Maximum Peak Values for Single-leg (Right) by Test Condition; Peroneus Longus Muscle

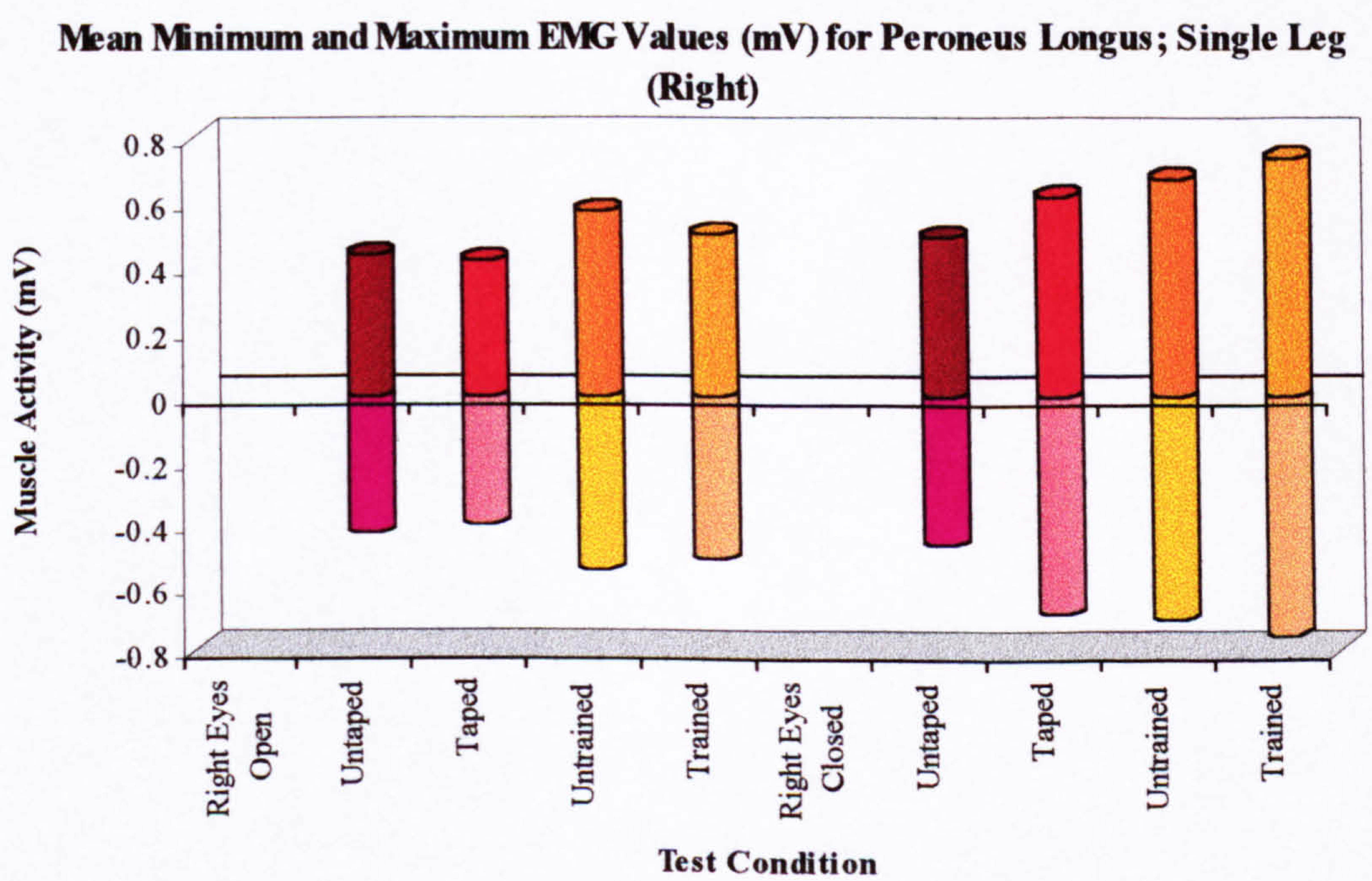


Table nº 8.53 displays the significant results from paired t-test analysis of single-leg stance (Right) comparing the within-subject factor of visual condition.

Table n° 8.53 Significant Results of Paired t-test Analysis on Single-leg (Right) for Visual Condition; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Right)	EO Vs EC	Taped	MIN	3.87	14	0.002	0.112 to 3.93
Single-leg (Right)	EO Vs EC	Taped	MAX	-3.14	14	0.007	-0.274 to –0.051
Single-leg (Right)	EO Vs EC	Trained	MIN	5.58	13	0.000	0.153 to 0.348
Single-leg (Right)	EO Vs EC	Trained	MAX	-6.78	13	0.000	-0.325 to -0.168

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Figure n[os] 848 and *849* illustrate the overall minimum and maximum peak values for double-leg stance, narrow and wide respectively for each test condition of the peroneus longus muscle.

Figure n° 848 Overall Mean Minimum and Maximum Peak Values for Double-leg (Narrow) by Test Condition; Peroneus Longus Muscle

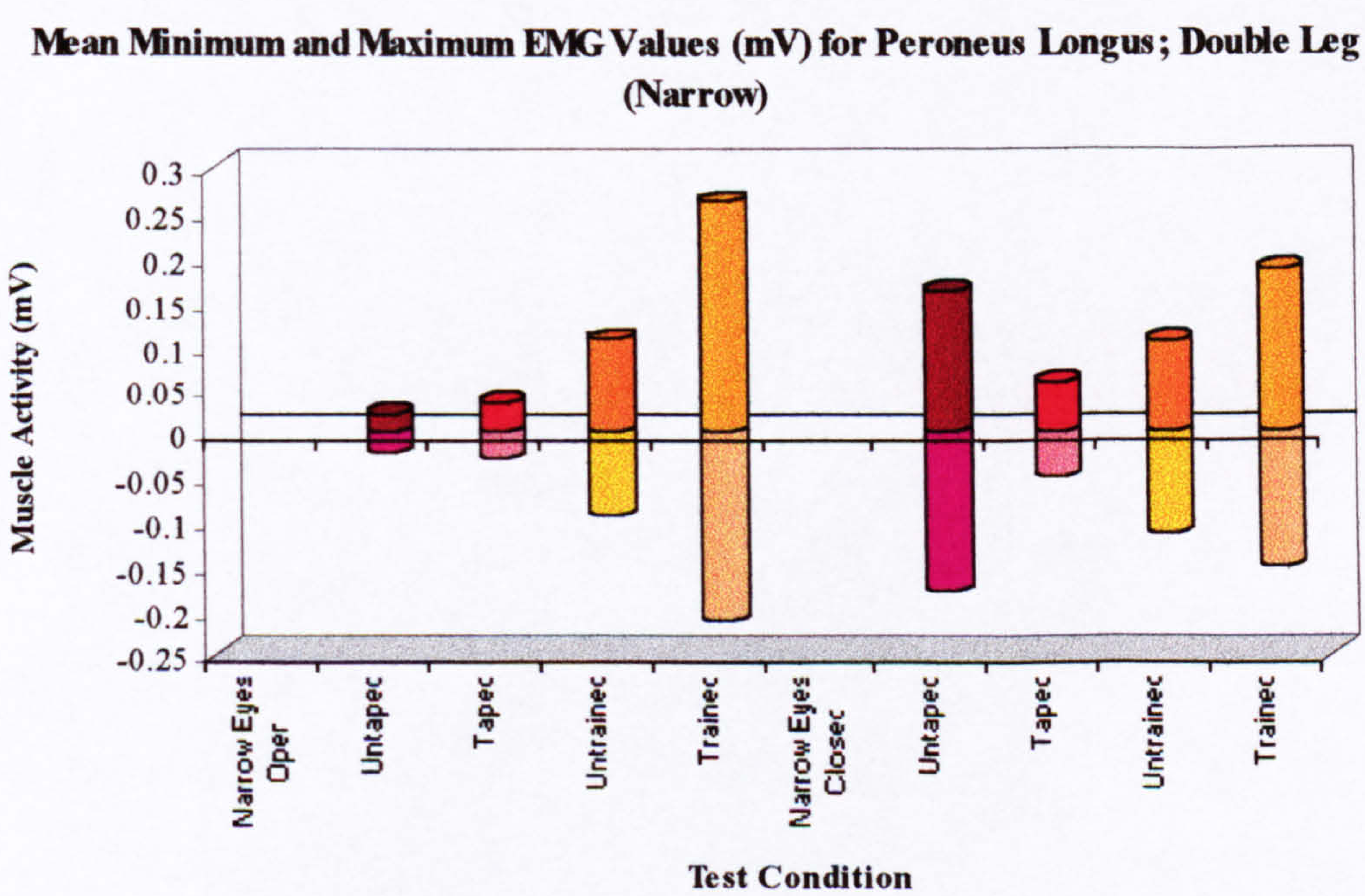
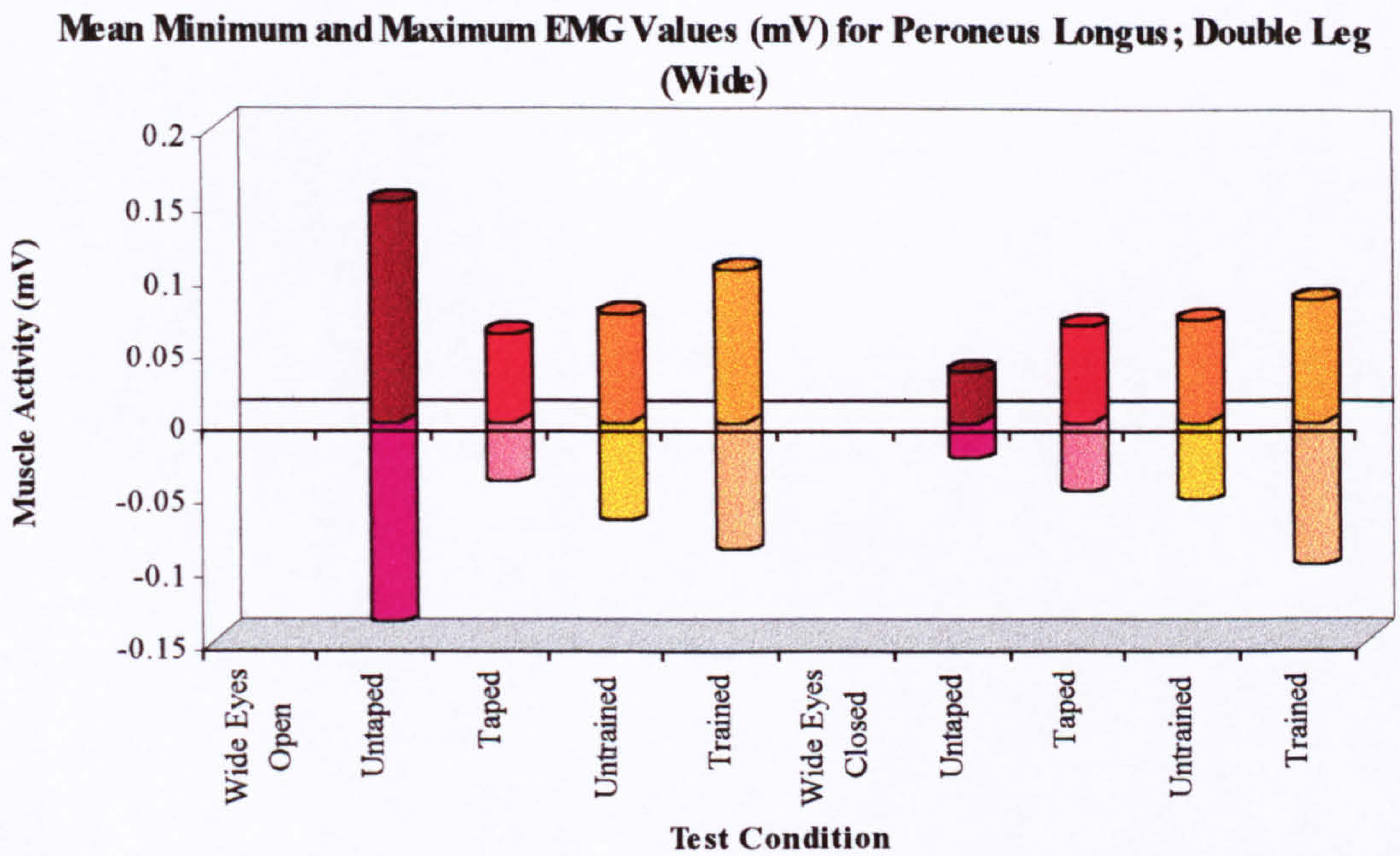


Figure n° 849 Overall Mean Minimum and Maximum Peak Values for Double-leg (Wide) by Test Condition; Peroneus Longus Muscle



Paired samples t-test analysis was also conducted on the data for double-leg stance positions of narrow and wide for the within-subject factor of visual condition. For the peroneus longus muscle significance was found in double-leg (Narrow) as reported in *Table n° 8.54*, but not in the wide position.

Table n° 8.54 Significant Results of Paired t-test Analysis on Double-leg (Narrow) for Visual Condition; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Double-leg (Narrow)	EO Vs EC	Taped	MIN	2.32	9	0.046	0.001 to 0.047
Double-leg (Narrow)	EO Vs EC	Taped	MAX	-2.32	9	0.045	-0.083 to –0.001

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

For paired samples t-test analysis of within-subject test conditions of Untaped versus Taped and Untrained versus Trained with statistical significance set at the 0.05 level, no significance was found in either single-leg or double-leg stance positions for either group.

Paired t-test analysis was also conducted on the peroneus longus data to compare the within-subject stance conditions of single-leg, left versus right and double-leg, narrow versus wide. The significant results are shown in *Table n° 8.55*.

Table n° 8.55 Significant Results of Paired t-test Analysis on Within-subject Factor of Stance Condition; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Right	EO	Untrained	MIN	2.79	6	0.032	0.032 to 0.491
Narrow Vs Wide	EO	Trained	MIN	-2.22	11	0.048	-0.245 to -0.001

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

If single-leg stance positions are compared with double-leg stance positions, paired sample t-test analysis reveals significance in all cases for the peroneus longus muscle with the exception of those reported in *Table n°s 8.56* and *8.57*. As for the gastrocnemius muscle, the non-significant results are presented as these results are opposite to those expected.

Table n° 8.56 Non-Significant Results of Paired t-test Analysis on Within-subject Comparison of Single-leg (Left) and Double-leg Stance Conditions; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Narrow	EC	Untaped	MIN	-1.18	5	0.291	-0.859 to 0.318
Left Vs Narrow	EC	Untaped	MAX	1.26	5	0.263	-0.264 to 0.771
Left Vs Narrow	EO	Untrained	MIN	-1.63	6	0.155	-0.482 to 0.097
Left Vs Narrow	EO	Untrained	MAX	1.49	6	0.186	-0.137 to 0.566
Left Vs Narrow	EC	Untrained	MAX	2.25	5	0.074	-0.068 to 1.028
Left Vs Narrow	EO	Trained	MAX	1.68	11	0.120	-0.036 to 0.272
Left Vs Narrow	EO	Untaped	MIN	-0.96	6	0.373	-0.539 to 0.232
Left Vs Wide	EO	Untaped	MAX	0.77	6	0.472	-0.271 to 0.518
Left Vs Wide	EO	Untrained	MIN	-1.89	6	0.108	-0.502 to 0.065
Left Vs Wide	EO	Untrained	MAX	1.87	6	0.111	-0.076 to 0.571
Left Vs Wide	EC	Untrained	MAX	2.49	5	0.055	-0.017 to 1.056

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Table n° 8.57 Non-Significant Results of Paired t-test Analysis on Within-subject Comparison of Single-leg (Right) and Double-leg Stance Conditions; Peroneus Longus Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Right Vs Narrow	EC	Untaped	MIN	-1.69	5	0.151	-0.652 to 0.134
Right Vs Narrow	EC	Untaped	MAX	2.14	5	0.086	-0.060 to 0.648
Right Vs Narrow	EO	Trained	MIN	-2.09	11	0.060	-0.622 to 0.016
Right Vs Narrow	EO	Trained	MAX	1.47	11	0.169	-0.115 to 0.580

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

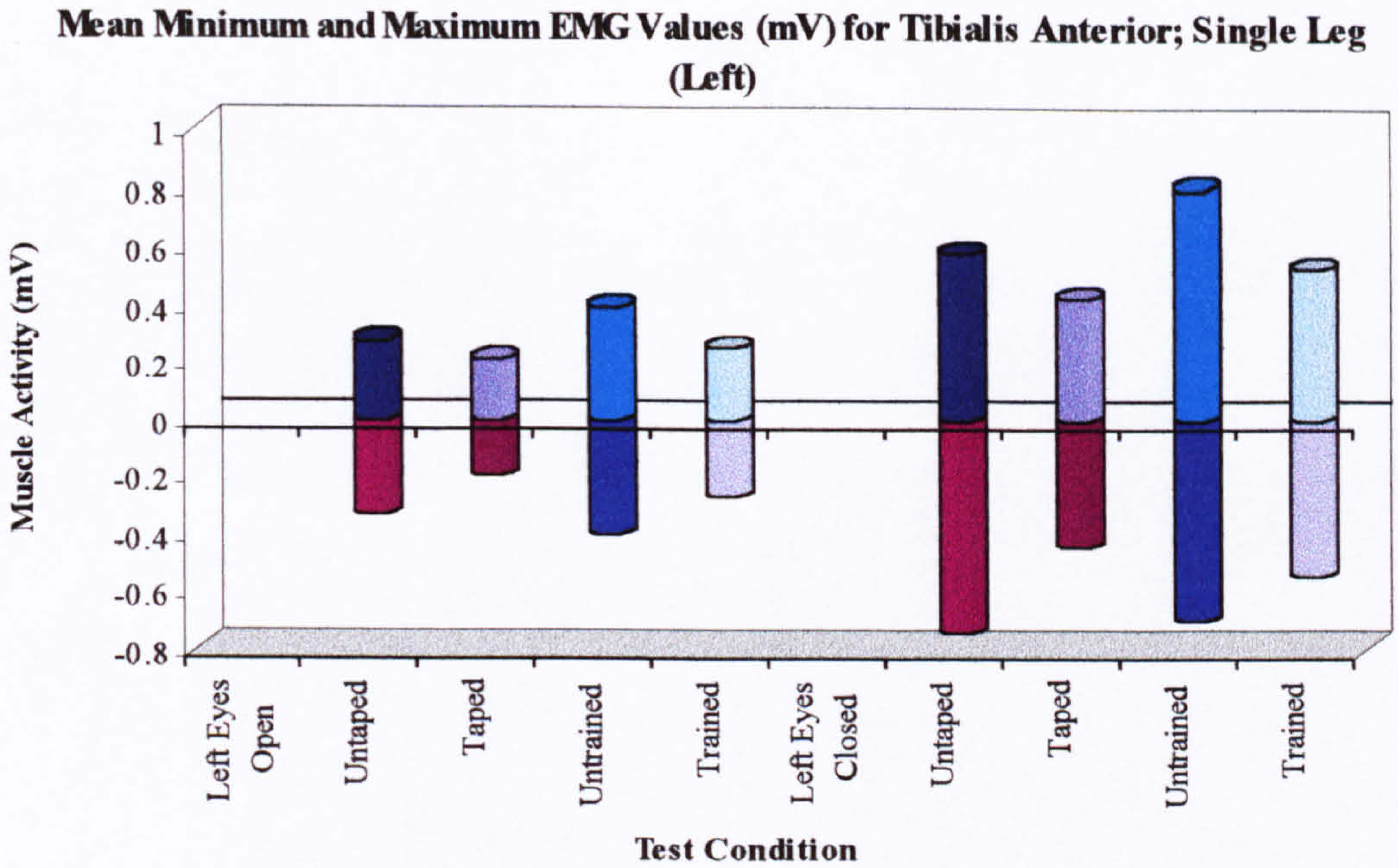
Independent t-test analysis was conducted to compare conditions between groups of Untaped versus Untrained and Taped versus Trained. No statistical significance was found for the peroneus longus muscle (significance set at 0.05 level).

8.4.1.3 Tibialis Anterior EMG – Minimum and Maximum Results

Separate paired sample t-tests were conducted to analyse within-subject factors of the taping and training groups for the tibialis anterior muscle. Statistical significance was set at the 0.05 level.

Figure n° 850 illustrates the overall mean minimum and maximum peak values for muscle activity in the tibialis anterior muscle of the left leg in each test condition.

Figure nº 850 Overall Mean Minimum and Maximum Peak Values for Single-leg (Left) by Test Condition; Tibialis Anterior Muscle



For the within-subject factor of visual condition, comparing muscle activity in eyes open and eyes closed conditions, significance was found for the single-leg (Left) stance position as displayed in *Table nº 8.58*.

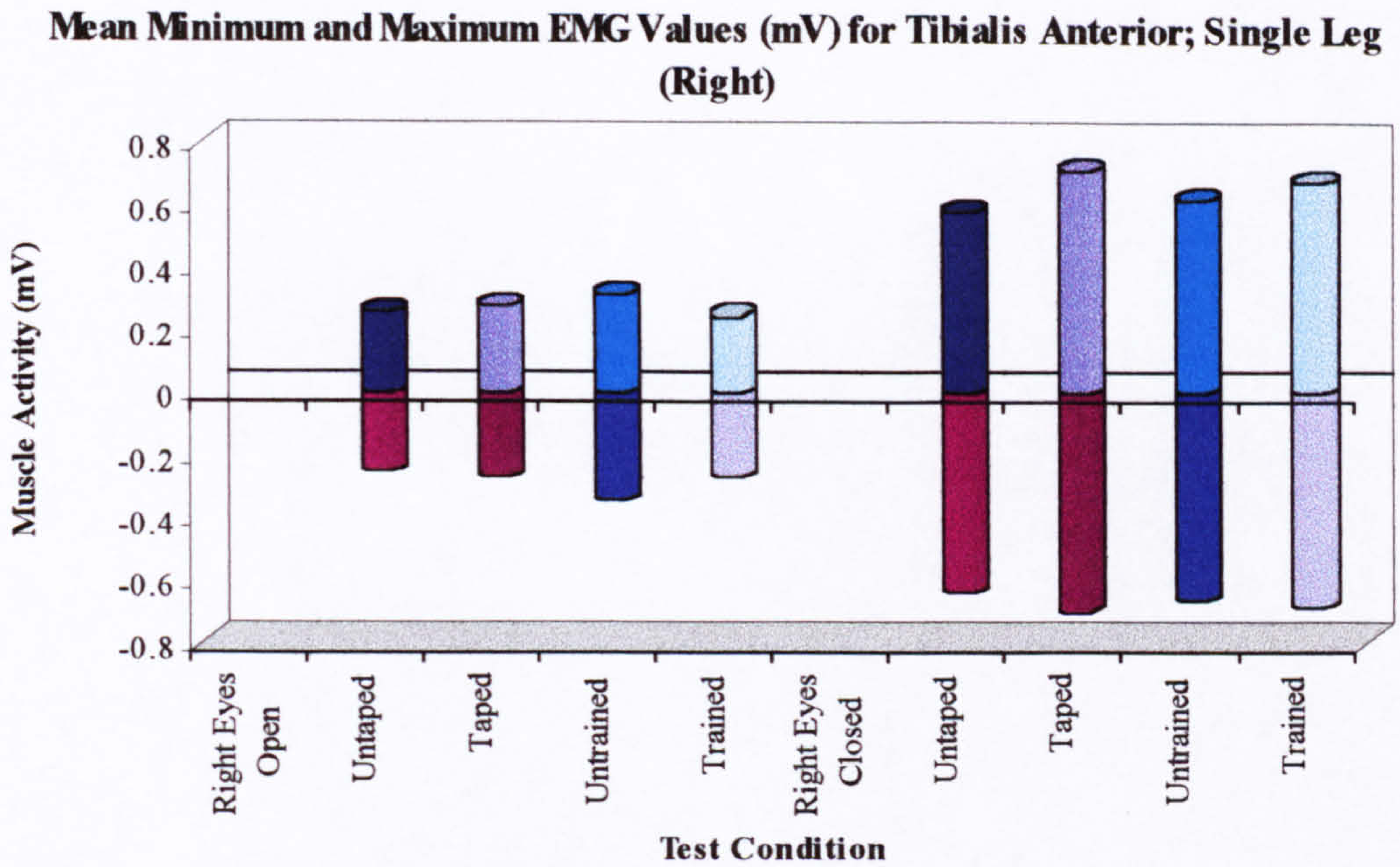
Table nº 8.58 Significant Results of Paired t-test Analysis on Single-leg (Left) for Visual Condition; Tibialis Anterior Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Left)	EO Vs EC	Untaped	MIN	3.63	6	0.011	0.133 to 0.685
Single-leg (Left)	EO Vs EC	Untaped	MAX	-2.63	6	0.039	-0.590 to –0.021
Single-leg (Left)	EO Vs EC	Taped	MIN	7.97	13	0.000	0.177 to 0.309
Single-leg (Left)	EO Vs EC	Taped	MAX	-7.61	13	0.000	-0.275 to -0.153
Single-leg (Left)	EO Vs EC	Untrained	MAX	-2.96	5	0.032	-0.702 to -0.049
Single-leg (Left)	EO Vs EC	Trained	MIN	5.77	13	0.000	0.172 to 0.377
Single-leg (Left)	EO Vs EC	Trained	MAX	-5.28	13	0.000	-0.384 to –0.161

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Figure nº 851 illustrates the overall minimum and maximum peak values for the right leg in each test condition.

Figure n° 851 Overall Mean Minimum and Maximum Peak Values for Single-leg (Right) by Test Condition; Tibialis Anterior Muscle



The significant results from paired t-test analysis of single-leg stance (Right) comparing the within-subject factor of visual condition are displayed in *Table n° 8.59*.

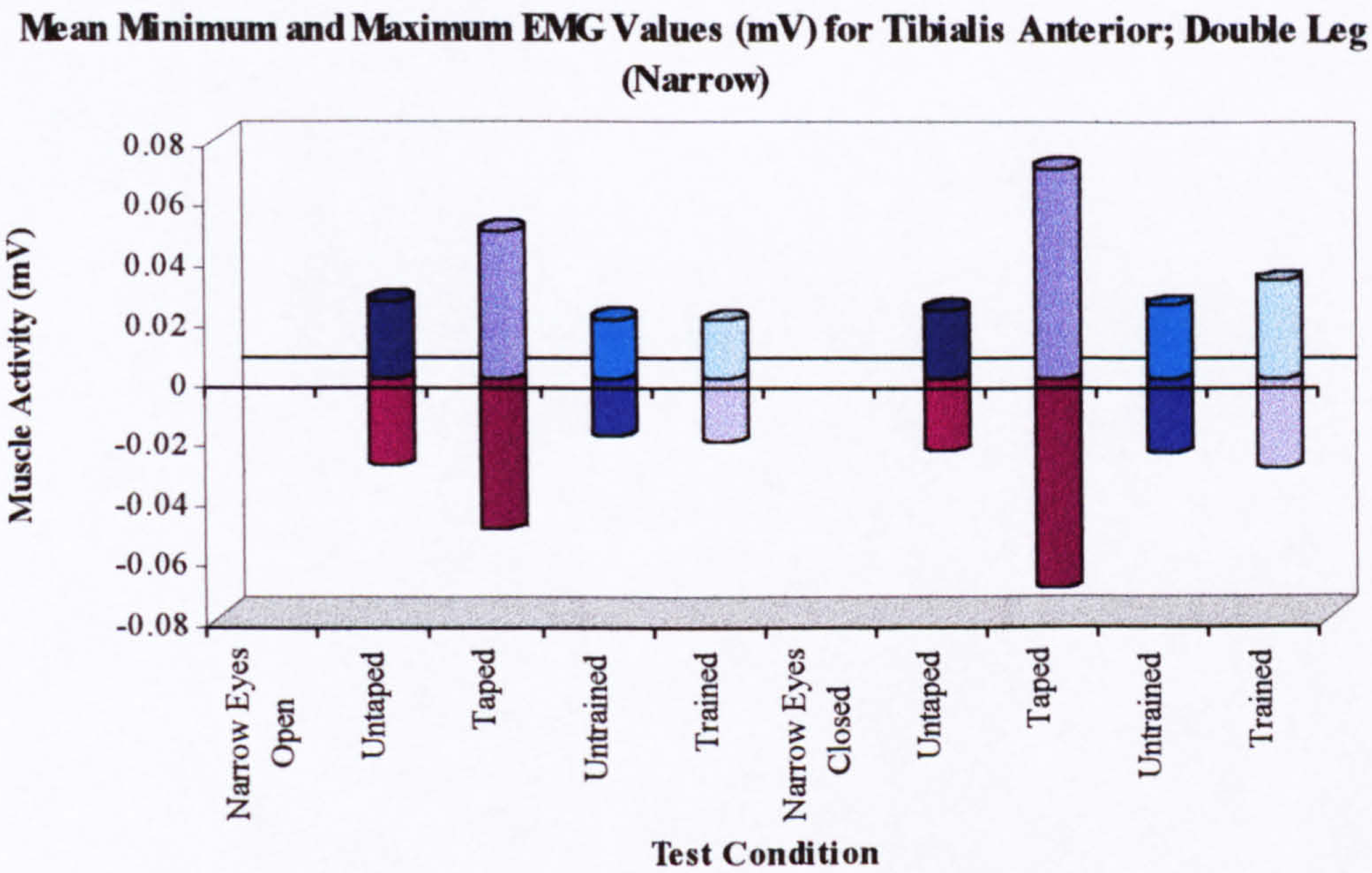
Table n° 8.59 Significant Results of Paired t-test Analysis on Single-leg (Right) for Visual Condition; Tibialis Anterior Muscle ($p < 0.05$ *for significance*)

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Right)	EO Vs EC	Untaped	MIN	7.32	6	0.000	0.261 to 5.23
Single-leg (Right)	EO Vs EC	Untaped	MAX	-5.14	6	0.002	-0.476 to –0.169
Single-leg (Right)	EO Vs EC	Taped	MIN	6.75	14	0.000	0.287 to 0.555
Single-leg (Right)	EO Vs EC	Taped	MAX	-5.96	14	0.000	-0.591 to -0.278
Single-leg (Right)	EO Vs EC	Untrained	MIN	5.64	6	0.001	0.206 to 0.521
Single-leg (Right)	EO Vs EC	Untrained	MAX	-5.44	6	0.002	-0.495 to -0.188
Single-leg (Right)	EO Vs EC	Trained	MIN	8.61	13	0.000	0.335 to 0.560
Single-leg (Right)	EO Vs EC	Trained	MAX	-10.34	13	0.000	-0.564 to -0.369

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

The overall minimum and maximum peak values for double-leg stance (Narrow) for each test condition of the tibialis anterior are presented in *Figure n° 852*.

Figure n° 852 Overall Mean Minimum and Maximum Peak Values for Double-leg (Narrow) by Test Condition; Tibialis Anterior Muscle



Paired samples t-test analysis was conducted on the tibialis anterior muscle data for double-leg stance positions of narrow and wide for the within-subject factor of visual condition. Significance at the 0.05 level was found in the narrow position as reported in *Table n° 8.60*.

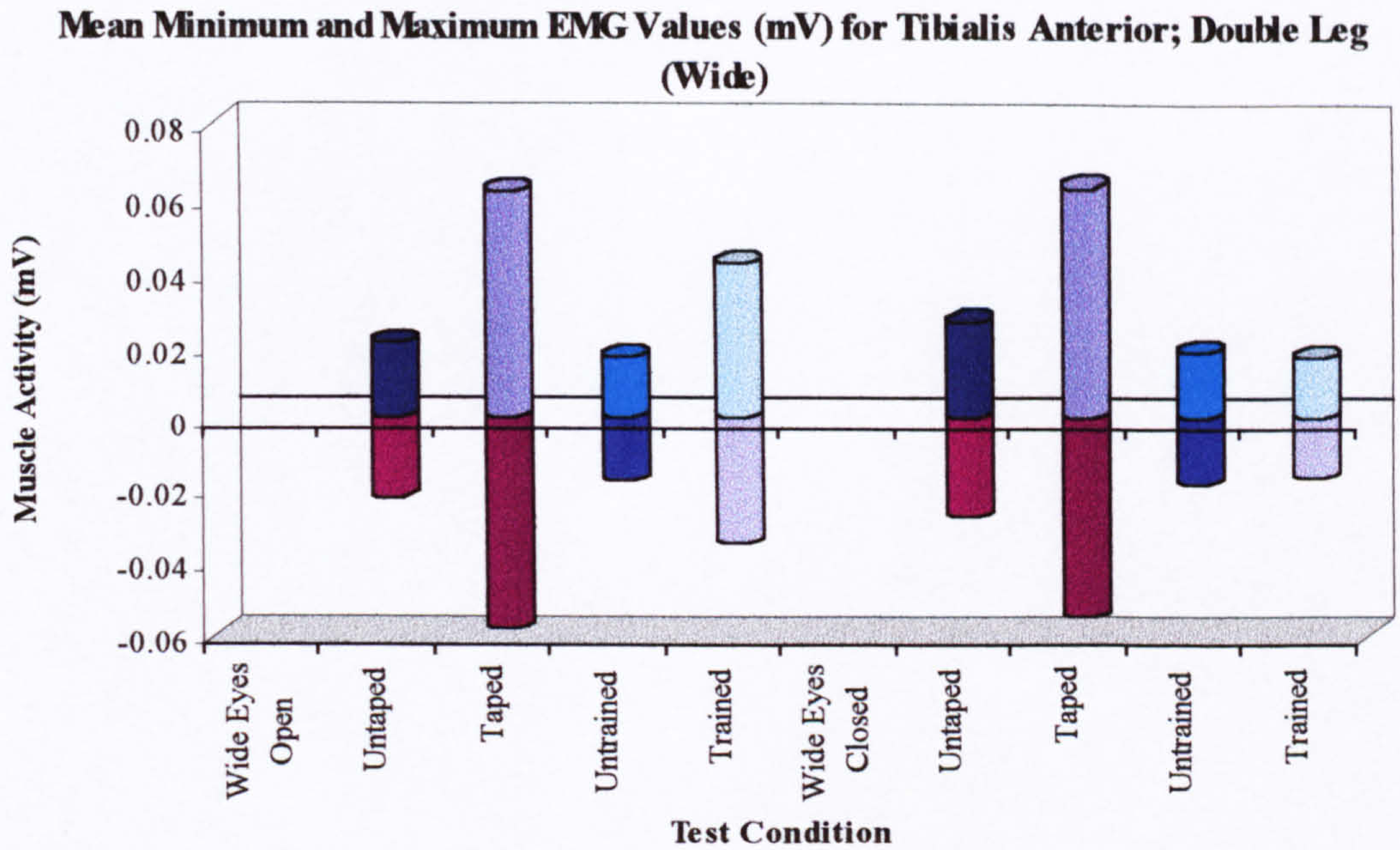
Table n° 8.60 Significant Results of Paired t-test Analysis on Double-leg (Narrow) for Visual Condition; Tibialis Anterior Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Double-leg (Narrow)	EO Vs EC	Untrained	MIN	2.58	6	0.042	0.000 to 0.011
Double-leg (Narrow)	EO Vs EC	Untrained	MAX	-2.69	6	0.036	-0.009 to 0.000

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Figure n° 853 illustrates the overall minimum and maximum peak values for double-leg stance (Wide) for each test condition of the tibialis anterior muscle.

Figure n° 853 Overall Mean Minimum and Maximum Peak Values for Double-leg (Wide) by Test Condition; Tibialis Anterior Muscle



Significant results for the minimum and maximum peak values of muscle activity in the tibialis anterior for the wide position are displayed in *Table n° 8.61*.

Table n° 8.61 Significant Results of Paired t-test Analysis on Double-leg (Wide) for Visual Condition; Tibialis Anterior Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Double-leg (Wide)	EO Vs EC	Untrained	MAX	-2.46	6	0.049	-0.004 to 0.000

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

For paired samples t-test analysis of within-subject test conditions of Untaped versus Taped and Untrained versus Trained with statistical significance again set at the 0.05 level, for single-leg stance positions of left and right legs, significance was found only in the left leg. The significant results are displayed in *Table n° 8.62*.

Table n° 8.62 Significant Results of Paired t-test Analysis on Single-leg (Left) for Test Condition; Tibialis Anterior Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Left)	EO	Untaped Vs Taped	MAX	2.72	6	0.034	0.009 to 0.160
Single-leg (Left)	EC	Untaped Vs Taped	MIN	-2.60	6	0.041	-0.533 to- 0.016

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

No statistical significance was found in double-leg stance positions for within-subject analysis of test conditions factor.

Paired t-test analysis was also conducted on the tibialis anterior muscle data to compare the within-subject factor of stance conditions comparing single-leg positions, left and right and double-leg positions, narrow and wide. Significance was found only in the comparison of single-leg stance positions as presented in *Table n° 8.63*.

Table n° 8.63 Significant Results of Paired t-test Analysis on Within-subject Factor of Stance Condition; Tibialis Anterior Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Left Vs Right	EC	Taped	MIN	4.08	15	0.001	0.125 to 0.398
Left Vs Right	EC	Taped	MAX	-3.64	15	0.002	-0.458 to 0.398
Left Vs Right	EC	Trained	MIN	3.91	13	0.002	0.075 to 0.262
Left Vs Right	EC	Trained	MAX	-4.02	13	0.001	-0.278 to -0.083

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

If single-leg stance positions are compared with double-leg stance positions, paired sample t-test analysis reveals significance in all cases for the tibialis anterior muscle.

Independent t-test analysis was also conducted to compare conditions between groups of Untaped versus Untrained and Taped versus Trained. With the significance level set at 0.05, for the tibialis anterior muscle significance was found between groups for the condition of single-leg (Left), eyes closed Taping versus Training as follows;

Minimum peak value : Levene's test for equality of variance F = 4.308 $p = 0.047$ therefore variances unequal;

t-value = 2.32 df = 17.29 $p = 0.033$ SE = 0.047 95%CI = 0.010 to 0.204

Maximum peak value : Levene's test for equality of variance F = 2.796 $p = 0.000$ therefore variances unequal;

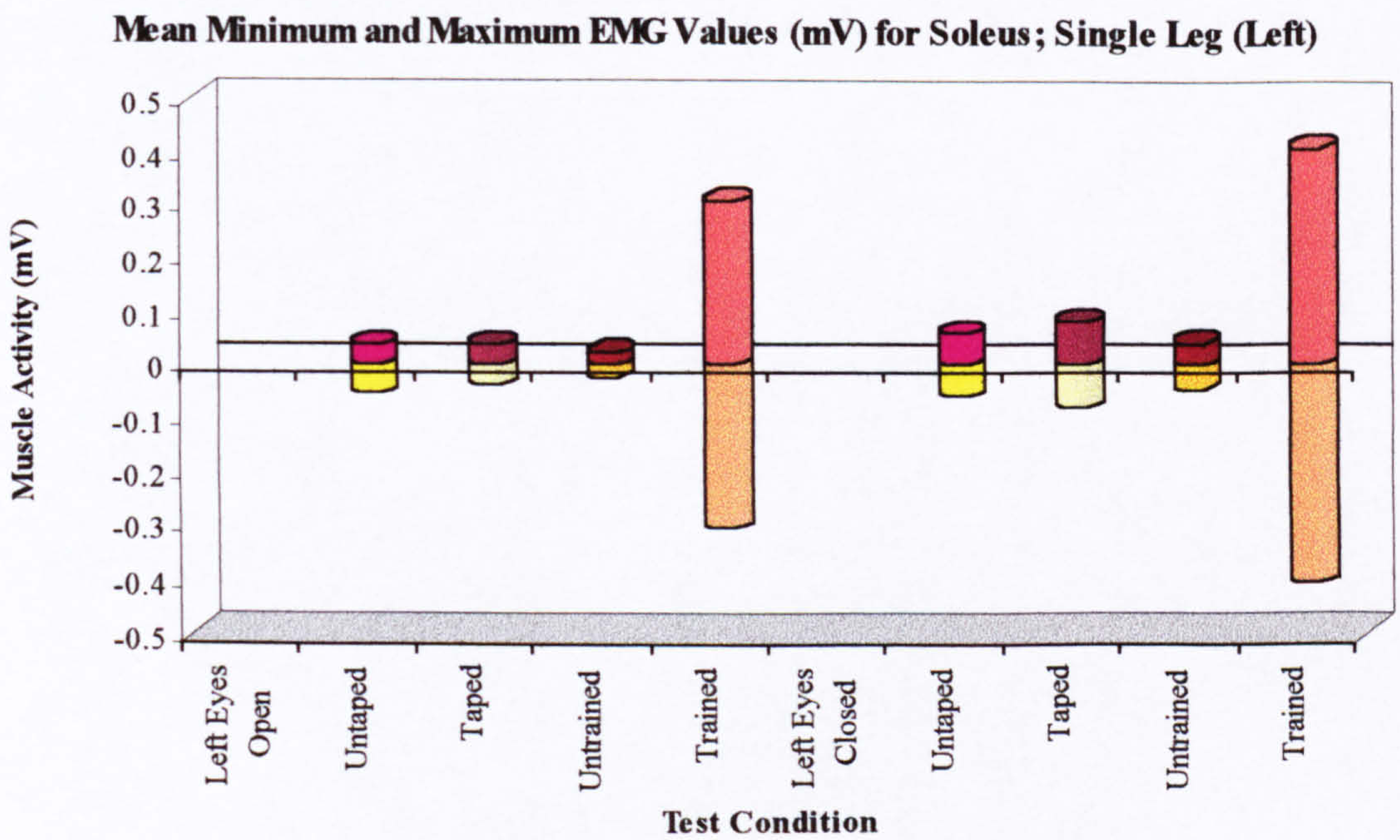
t-value = -2.67 df = 29 $p = 0.012$ SE = 0.039 95%CI = -0.185 to –0.024

8.4.1.4 Soleus EMG – Minimum and Maximum Results

Separate paired-samples t-tests were conducted to analyse within-subject conditions of the taping and training groups.

Figure n° 854 illustrates the overall mean minimum and maximum peak values for the left leg in each test condition.

Figure n° 854 Overall Mean Minimum and Maximum Peak Values for Single-leg (Left) by Test Condition; Soleus Muscle



For the within-subject factor of visual condition comparing eyes open and eyes closed conditions within the groups, significance by t-test analysis was found for single-leg (Left) as displayed in *Table n° 8.64*.

Table n° 8.64 Significant Results of Paired t-test Analysis on Single-leg (Left) for Visual Condition; Soleus Muscle *(p < 0.05 for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Left)	EO Vs EC	Untaped	MIN	3.73	6	0.010	0.008 to 0.037
Single-leg (Left)	EO Vs EC	Untaped	MAX	-3.39	6	0.015	-0.042 to -0.007
Single-leg (Left)	EO Vs EC	Taped	MIN	3.99	13	0.002	0.027 to 0.089
Single-leg (Left)	EO Vs EC	Taped	MAX	-4.10	13	0.001	-0.086 to –0.027
Single-leg (Left)	EO Vs EC	Trained	MAX	-2.28	13	0.040	-0.200 to –0.006

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

The overall minimum and maximum peak values for muscle activity in each test condition in the right leg soleus are presented in *Figure n° 855*.

Figure n° 855 Overall Mean Minimum and Maximum Peak Values for Single-leg (Right) by Test Condition; Soleus Muscle

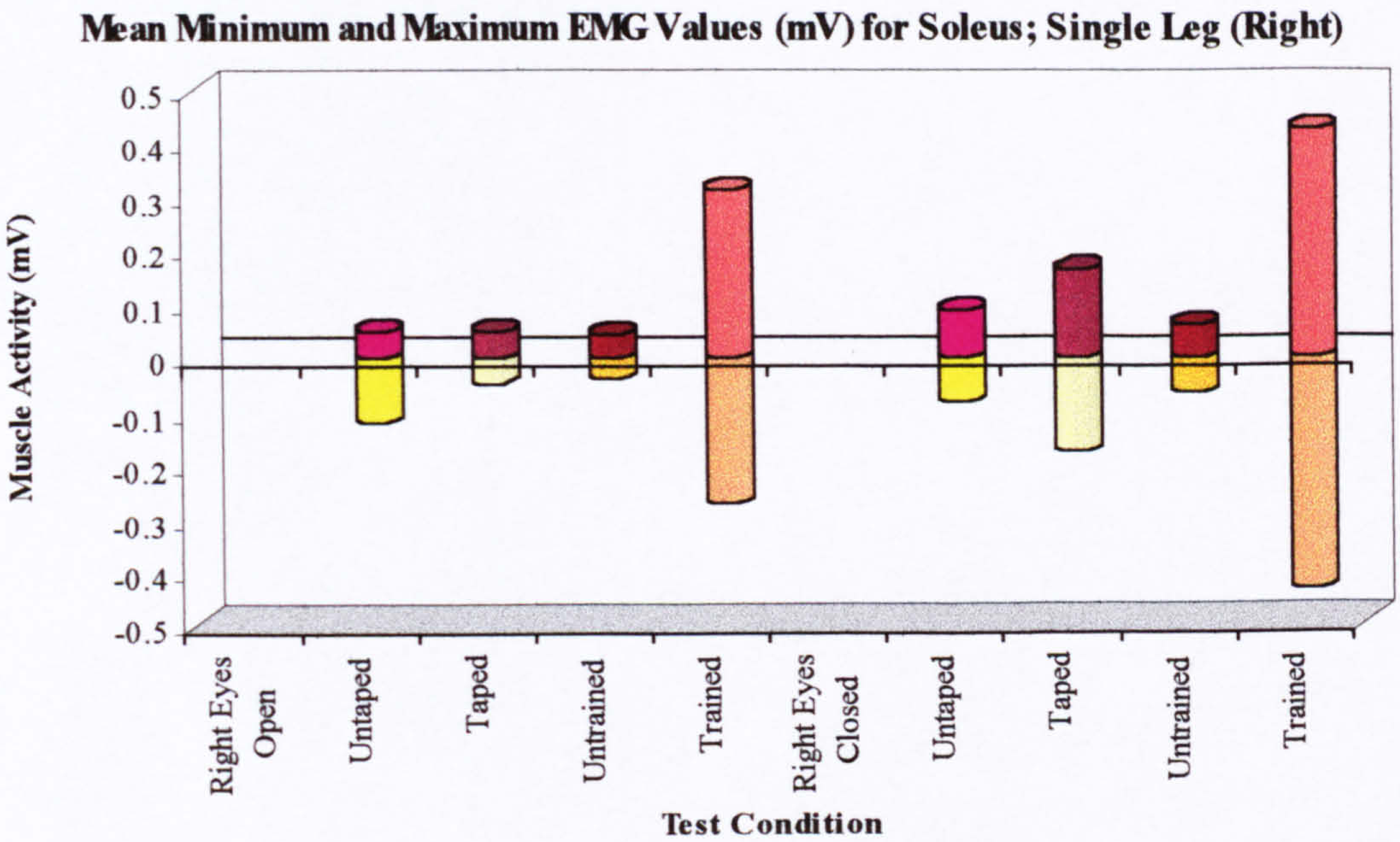


Table n° 8.65 displays the significant results from paired t-test analysis of single-leg stance (Right) comparing the within-subject factor of visual condition.

Table n° 8.65 Significant Results of Paired t-test Analysis on Single-leg (Right) for Visual Condition; Soleus Muscle *($p < 0.05$ for significance)*

Stance Condition	*Visual Condition*	*Test condition*	*Peak Value*	*t-value*	*DF*	*p-value*	*95% Confidence Interval*
Single-leg (Right)	EO Vs EC	Untaped	MAX	-3.60	6	0.011	-0.059 to –0.011
Single-leg (Right)	EO Vs EC	Taped	MIN	3.44	14	0.004	0.051 to 0.221
Single-leg (Right)	EO Vs EC	Taped	MAX	-2.91	14	0.012	-0.221 to -0.033
Single-leg (Right)	EO Vs EC	Trained	MIN	2.25	13	0.043	0.007 to 0.367

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Paired sample t-test analysis was also conducted on soleus minimum and maximum peak values of muscle activity for double-leg stance positions of narrow and wide. No statistical significance was found for either the taping or training group for the within-subject factor of visual condition comparing eyes open with eyes closed.

Figure n^{os} 856 and *857* illustrate the overall minimum and maximum peak values for double-leg stance, narrow and wide respectively for each test condition.

Figure n^{o} 856 Overall Mean Minimum and Maximum Peak Values for Double-leg (Narrow) by Test Condition; Soleus Muscle

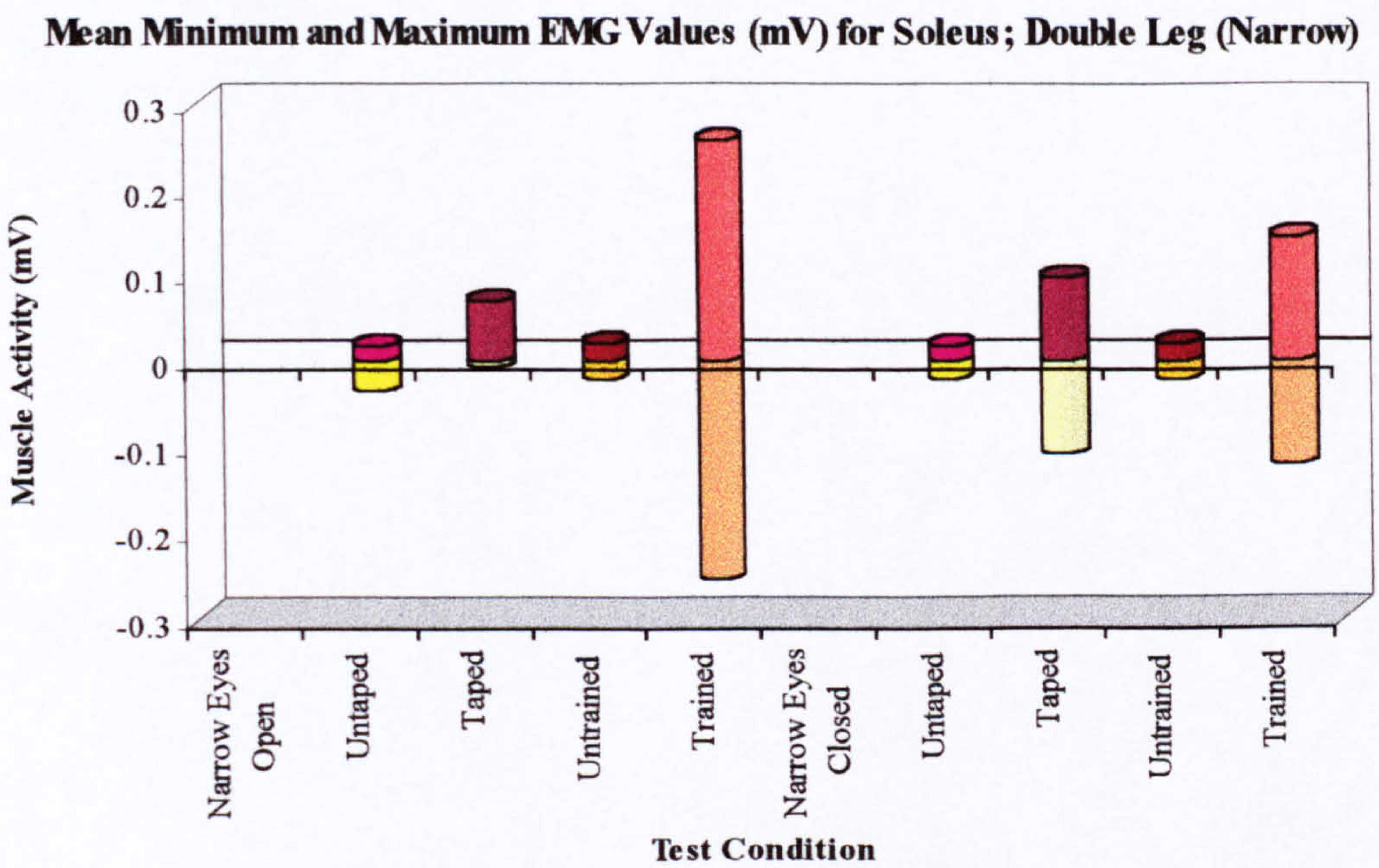
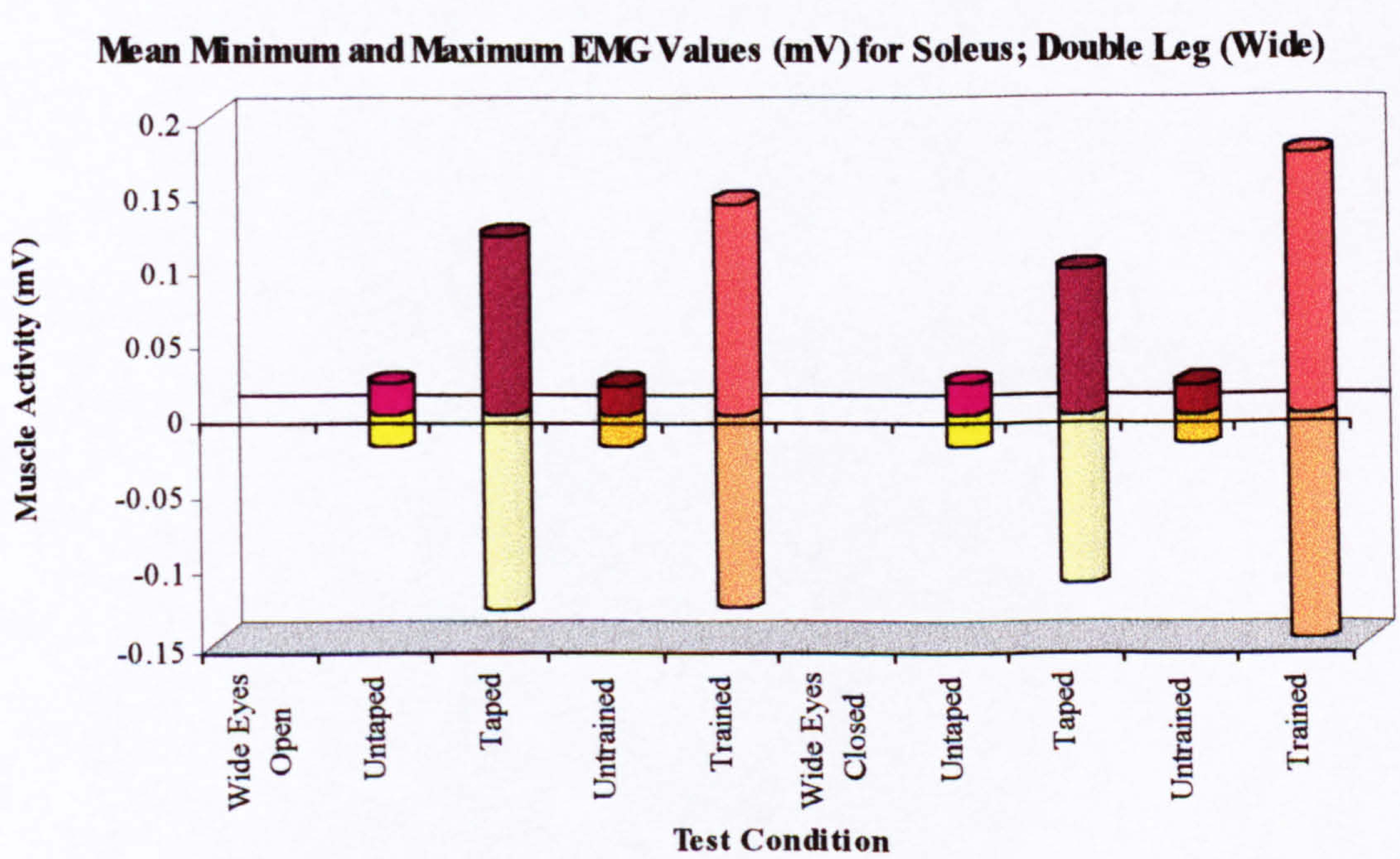


Figure n^{o} 857 Overall Mean Minimum and Maximum Peak Values for Double-leg (Wide) by Test Condition; Soleus Muscle



For paired-samples t-test analysis of within-subject factors of Untaped versus Taped and Untrained versus Trained, with statistical significance again set at the

0.05 level, for single-leg stance positions of left and right legs, significance was found in the single-leg (Left) stance position as presented in *Table n° 8.66*.

Table n° 8.66 Significant Results of Paired t-test Analysis on Single-leg (Left) for Test Condition; Soleus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Left)	EC	Untaped Vs Taped	MIN	2.71	6	0.035	0.004 to 0.075
Single-leg (Left)	EO	Untrained Vs Trained	MIN	3.11	6	0.021	0.114 to 0.950
Single-leg (Left)	EO	Untrained Vs Trained	MAX	-3.19	6	0.019	-0.962 to -0.126
Single-leg (Left)	EC	Untrained Vs Trained	MIN	3.25	5	0.023	0.156 to 1.330
Single-leg (Left)	EC	Untrained Vs Trained	MAX	-3.65	5	0.015	-1.317 to -0.229

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

With significance also found in single-leg (Right) as presented in *Table n° 8.67*.

Table n° 8.67 Significant Results of Paired t-test Analysis on Single-leg (Right) for Test Condition; Soleus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Single-leg (Right)	EC	Untaped Vs Taped	MIN	2.52	6	0.046	0.005 to 0.379
Single-leg (Right)	EO	Untrained Vs Trained	MAX	-4.02	6	0.007	-0.874 to -0.212
Single-leg (Right)	EO	Untrained Vs Trained	MIN	2.61	7	0.035	0.059 to 1.214
Single-leg (Right)	EC	Untrained Vs Trained	MAX	-2.89	7	0.023	-1.135 to -0.113
Single-leg (Right)	EO	Untrained Vs Trained	MIN	3.84	6	0.009	0.171 to 0.768

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

For the same analysis on double-leg stance, no statistical significance was found with significance set at the 0.05 level.

Paired t-test analysis was also conducted on the soleus muscle data to compare the within-subject factor of stance condition. Within the single-leg and double-leg conditions, significance was found only in single-leg (Left) versus single-leg (Right) stance positions as shown in *Table n° 8.68*.

Table nº 8.68 Significant Results of Paired t-test Analysis on Within-subject Factor of Stance Condition; Soleus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Right	EC	Taped	MIN	2.51	15	0.024	0.013 to 0.161

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

If single-leg stance positions are compared with double-leg stance positions, paired sample t-test analysis reveals significance as presented in *Table nº 8.69*.

Table nº 8.69 Significant Results of Paired t-test Analysis on Within-subject Comparison of Single-leg and Double-leg Stance; Soleus Muscle *($p < 0.05$ for significance)*

Stance Condition	Visual Condition	Test condition	Peak Value	t-value	DF	p-value	95% Confidence Interval
Left Vs Narrow	EC	Untaped	MIN	-2.99	5	0.030	-0.086 to –0.007
Left Vs Narrow	EC	Untaped	MAX	2.78	5	0.039	0.004 to 0.094
Left Vs Narrow	EC	Trained	MIN	-2.64	11	0.023	-0.608 to -0.055
Left Vs Narrow	EC	Trained	MAX	2.63	11	0.024	0.051 to 0.584
Left Vs Wide	EC	Untaped	MIN	-2.59	6	0.041	-0.074 to –0.002
Left Vs Wide	EO	Trained	MIN	-2.69	11	0.021	-0.397 to –0.040
Left Vs Wide	EO	Trained	MAX	2.59	11	0.025	0.031 to 0.384
Left Vs Wide	EC	Trained	MIN	-2.42	11	0.034	-0.583 to –0.027
Left Vs Wide	EC	Trained	MAX	2.44	11	0.033	0.028 to 0.544
Right Vs Narrow	EC	Untaped	MIN	-3.47	5	0.018	-0.127 to –0.019
Right Vs Narrow	EC	Untaped	MAX	3.34	5	0.020	0.018 to 0.140
Right Vs Narrow	EC	Taped	MIN	-2.36	10	0.040	-0.221to –0.006
Right Vs Narrow	EC	Trained	MAX	2.24	11	0.047	0.005 to 0716
Right Vs Wide	EC	Untaped	MIN	-2.93	6	0.026	-0.111 to –0.010
Right Vs Wide	EC	Untaped	MAX	2.78	6	0.032	0.008 to 0.123

EO = Eyes open EC = Eyes Closed DF = Degrees of Freedom

Independent t-test analysis was conducted to compare conditions between groups of Untaped versus Untrained and Taped versus Trained for soleus peak values of muscle activity. With statistical significance set at 0.05 and Levene's test for equality of variances in place, significance was found between groups and the significant results are presented in *Table n° 8.70*.

Table n° 8.70 Significant Results for Independent t-test Analysis Between Groups; Soleus Muscle *($p < 0.05$ for significance)*

Peak Value	F –Value	p-Value	Variance Equal	t-Value	df	p-Value	SE	95 % CI
Left Leg: Taped Vs Trained Eyes Open								
MIN	32.056	0.000	Unequal	2.47	13.12	0.028	0.107	0.034 to 0.498
MAX	37.598	0.000	Unequal	-2.47	13.11	0.028	0.109	-0.505 to –0.034
Left Leg: Taped Vs Trained Eyes Closed								
MIN	20.951	0.000	Unequal	2.54	13.19	0.024	0.129	0.049 to 0.607
MAX	29.625	0.000	Unequal	-2.58	13.18	0.013	0.129	-0.610 to –0.054
Right Leg: Taped Vs Trained Eyes Open								
MIN	96.863	0.000	Unequal	2.56	13.23	0.023	0.088	0.035 to 0.417
MAX	117.402	0.000	Unequal	-2.61	13.16	0.021	0.101	-0.483 to –0.045

df = Degrees of Freedom
SE = Standard Error
95% CI = Ninety-five percent Confidence Interval.

8.4.2 EMG – Mean Results of Ten Second Balance Trials

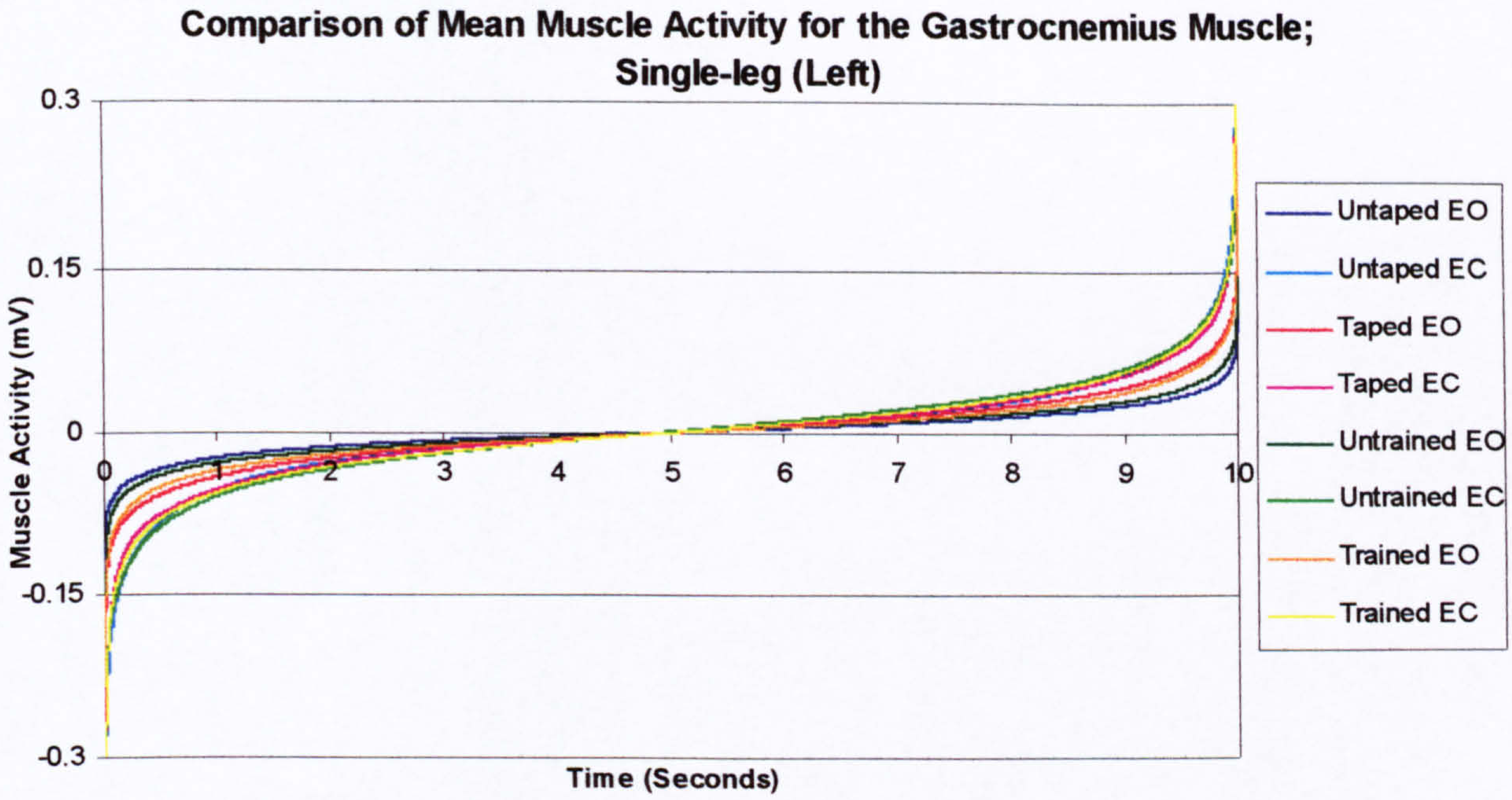
For all subjects in each test condition, four EMG traces were obtained; one for each of the muscles tested. In each instance this trace consisted of 10 000 data points. For comparison between test conditions, the data points for every subject were sorted into ascending order and then within the test condition, each data point was averaged across subjects to give a mean ten second EMG trace consisting of 10 000 data point for the individual muscle. These mean traces were then represented graphically and statistically analysed to investigate any significance between test conditions and groups.

The results for each muscle are again presented separately in the order; gastrocnemius, peroneal longus, tibialis anterior and soleus. Within each of these, stance position results are presented, single-leg (Left), single-leg (Right), double-leg (Narrow) and finally, double-leg (Wide). In each of the stance sections, presentation of the mean EMG traces for the eight test conditions is made. The test conditions are then disassociated for clarity into the taping and training groups. This is followed by the statistical analysis by paired and independent t-tests investigating the within and between group significances. Each stance section concludes with a statement of the means, standard deviations and Pearson correlation coefficients for all test conditions.

8.4.2.1 Gastrocnemius – Mean Ten Second Balance Results

Comparison of the eight test conditions for Single-leg (Left) is displayed in *Figure n° 858* from which it can be seen that muscle activity for the gastrocnemius muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition.

Figure n° 858 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Left)



Separation into the taping (*Figure n° 859*) and training (*Figure n° 860*) groups reveals very little change in activity with tape and after training in the eyes closed condition, but a slight increase with both in the eyes open condition.

Figure n° 859 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Left) in the Taping Group

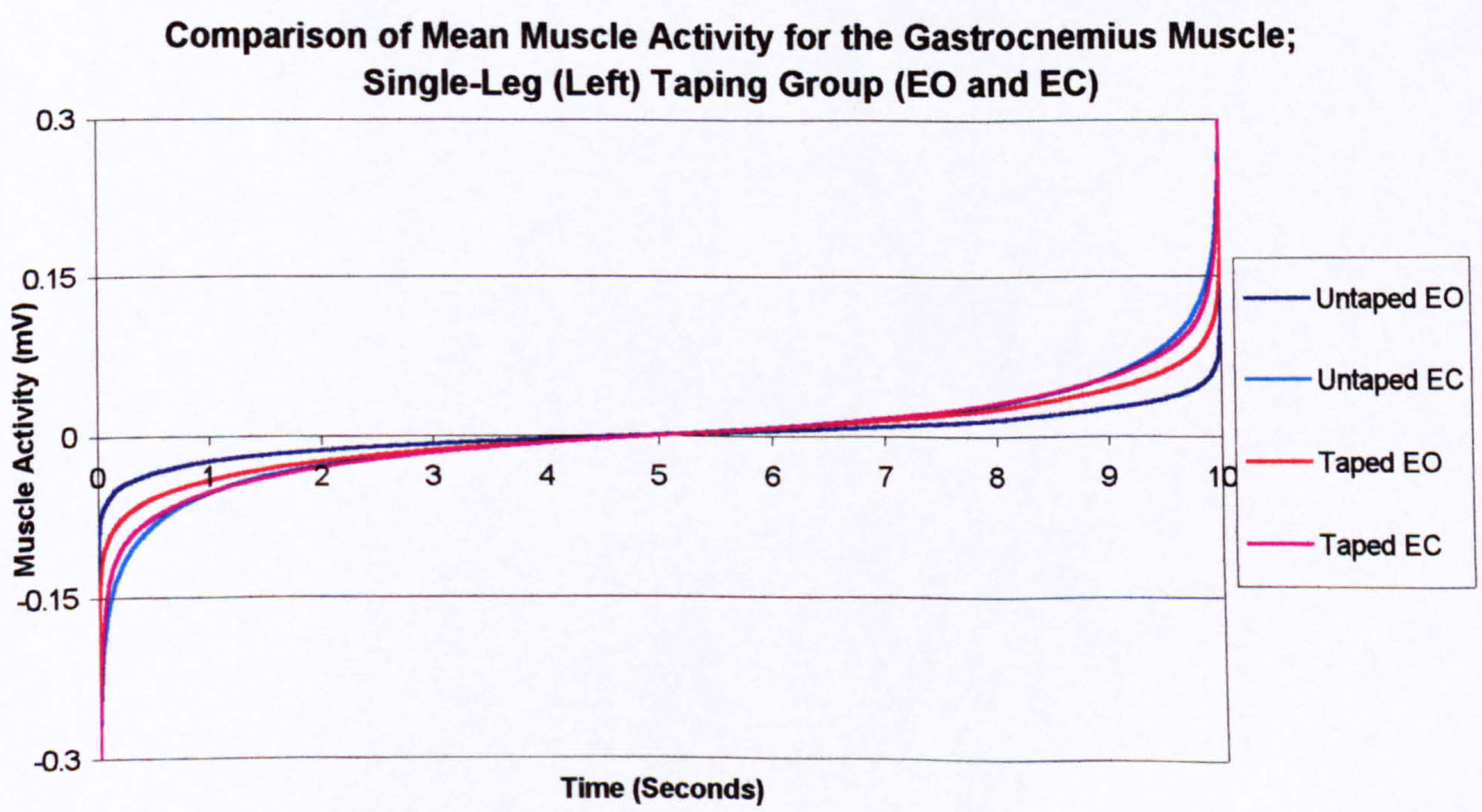
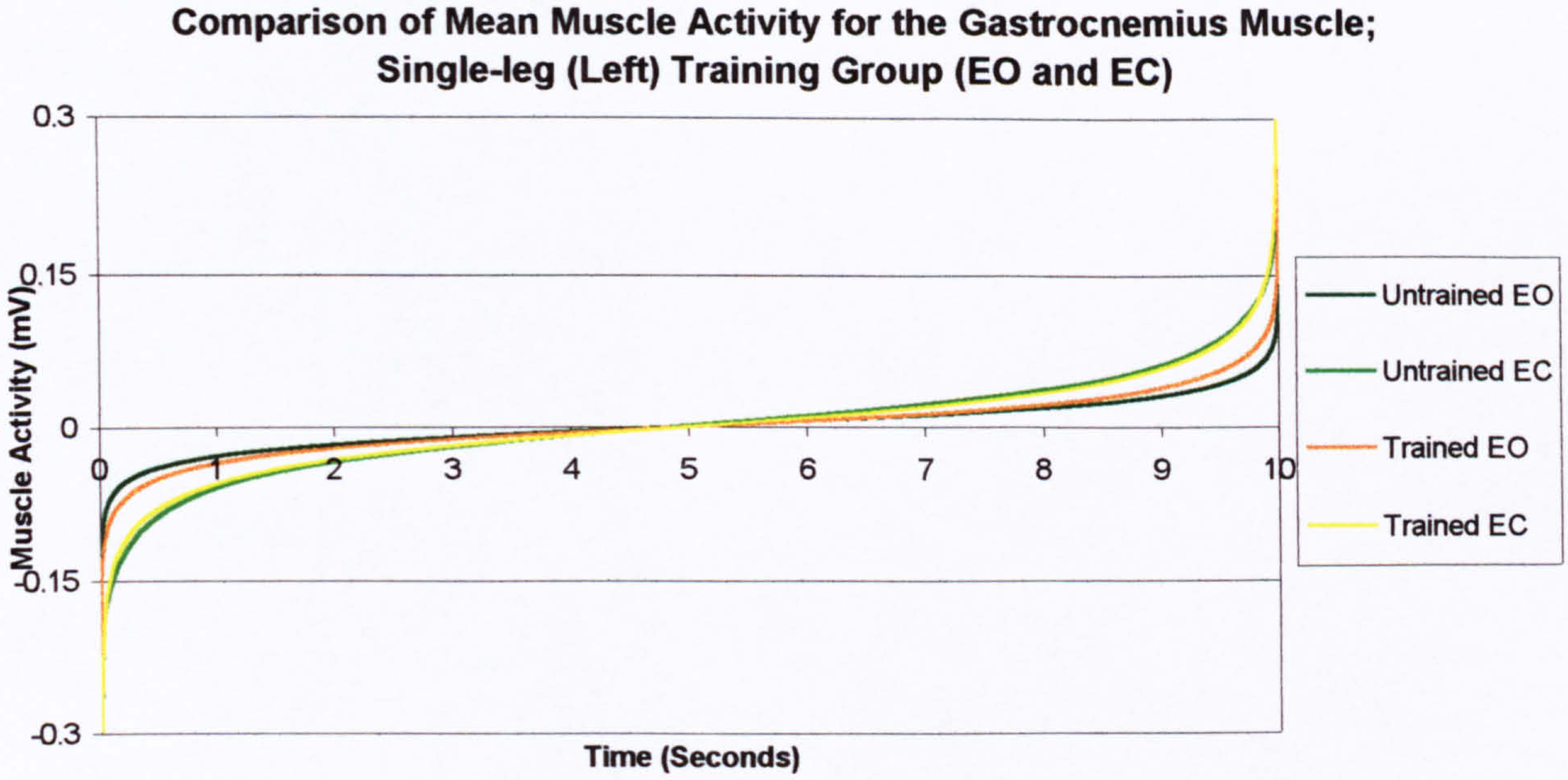


Figure n° 860 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Left) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.71* or between the groups as analysed by independent t-tests *Table n° 8.72*. All test conditions also have a high degree of correlation as presented in *Table n° 8.73*.

Table n° 8.71 Paired t-test Analysis on Single-leg (Left) Within Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.126	-0.010	0.068	-0.017
p-Value	0.900	0.992	0.946	0.987
TEST CONDITION	EO UNTAPED Vs EO TAPED	EC UNTAPED Vs EC TAPED	EO UNTRAINED Vs EO TRAINED	EC UNTRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.084	0.574	-0.168	-0.947
p-Value	0.933	0.566	0.866	0.344

EO = Eyes Open EC = Eyes Closed

Table n° 8.72 Independent t-test Analysis on Single-leg (Left) Between Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.018	0.085	0.013	0.006
p-Value	0.986	0.932	0.990	0.995

EO = Eyes Open EC = Eyes Closed

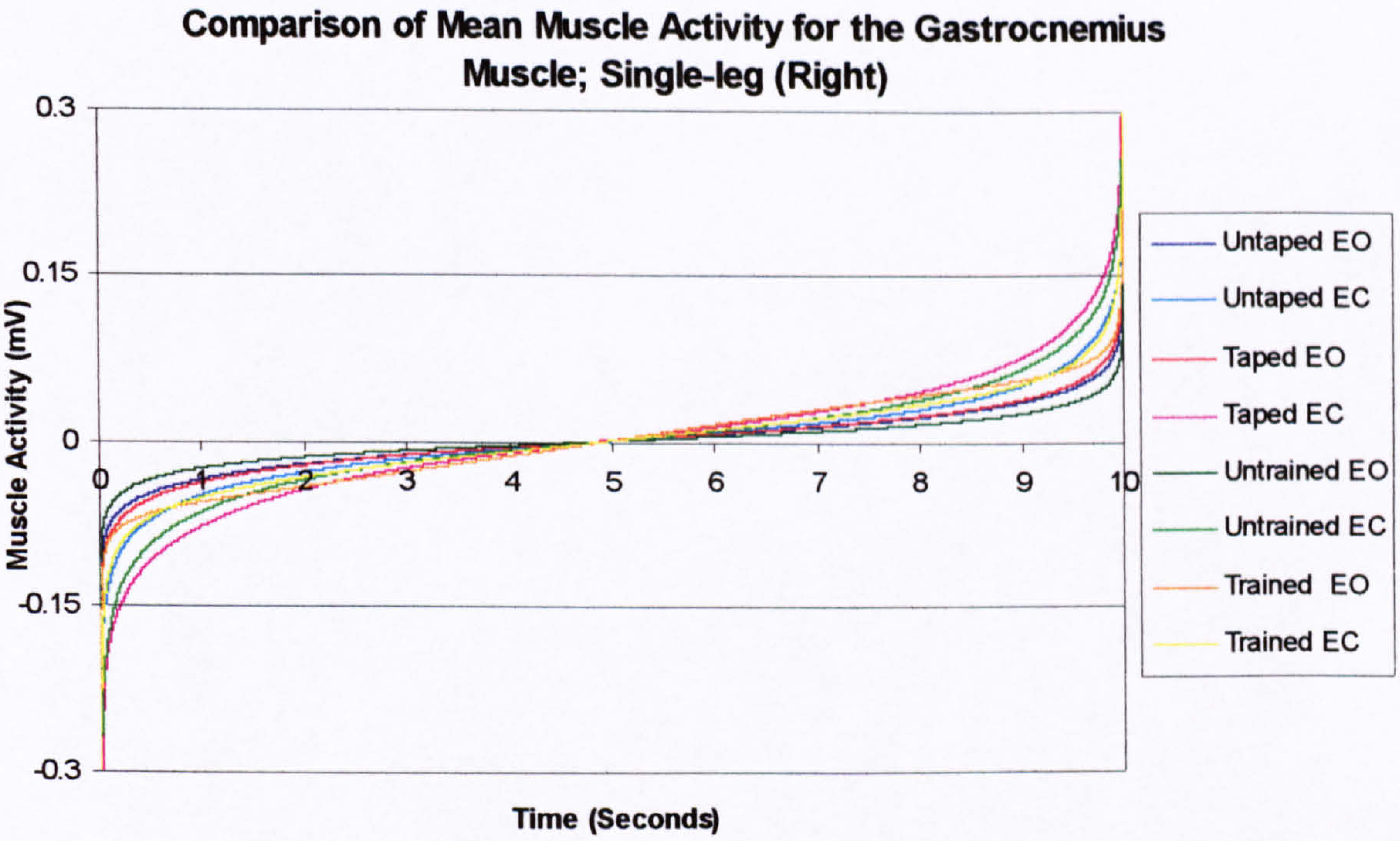
Table n° 8.73 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Left); Gastrocnemius Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean (E-05)	-6.02	-2.08	-4.79	-4.66	-6.64	-8.53	-5.42	-5.11
StD	0.022	0.053	0.036	0.049	0.026	0.054	0.033	0.052
EO Untaped	1							
EC Untaped	0.982	1						
EO Taped	0.992	0.991	1					
EC Taped	0.987	0.998	0.994	1				
EO Untrained	0.997	0.988	0.998	0.992	1			
EC Untrained	0.988	0.994	0.998	0.996	0.995	1		
EO Trained	0.991	0.995	0.999	0.997	0.997	0.998	1	
EC Trained	0.987	0.997	0.997	0.999	0.994	0.998	0.999	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Single-leg (Right) is displayed in *Figure n° 861* from which it can be seen that muscle activity for the gastrocnemius muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition for the majority of test conditions.

Figure n° 861 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Right)



Separation into the taping (*Figure n° 862*) and training (*Figure n° 863*) groups reveals virtually no change in muscle activity between Untaped and Taped eyes open conditions, but a slight increase in muscle activity with taping in the eyes closed condition. By comparison, in the training group there is a decrease in muscle activity with training in the eyes closed test condition and noticeably, a higher level of muscle activity in the eyes open trained condition by comparison to the other three test conditions within the group.

Figure n° 862 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Right) in the Taping Group

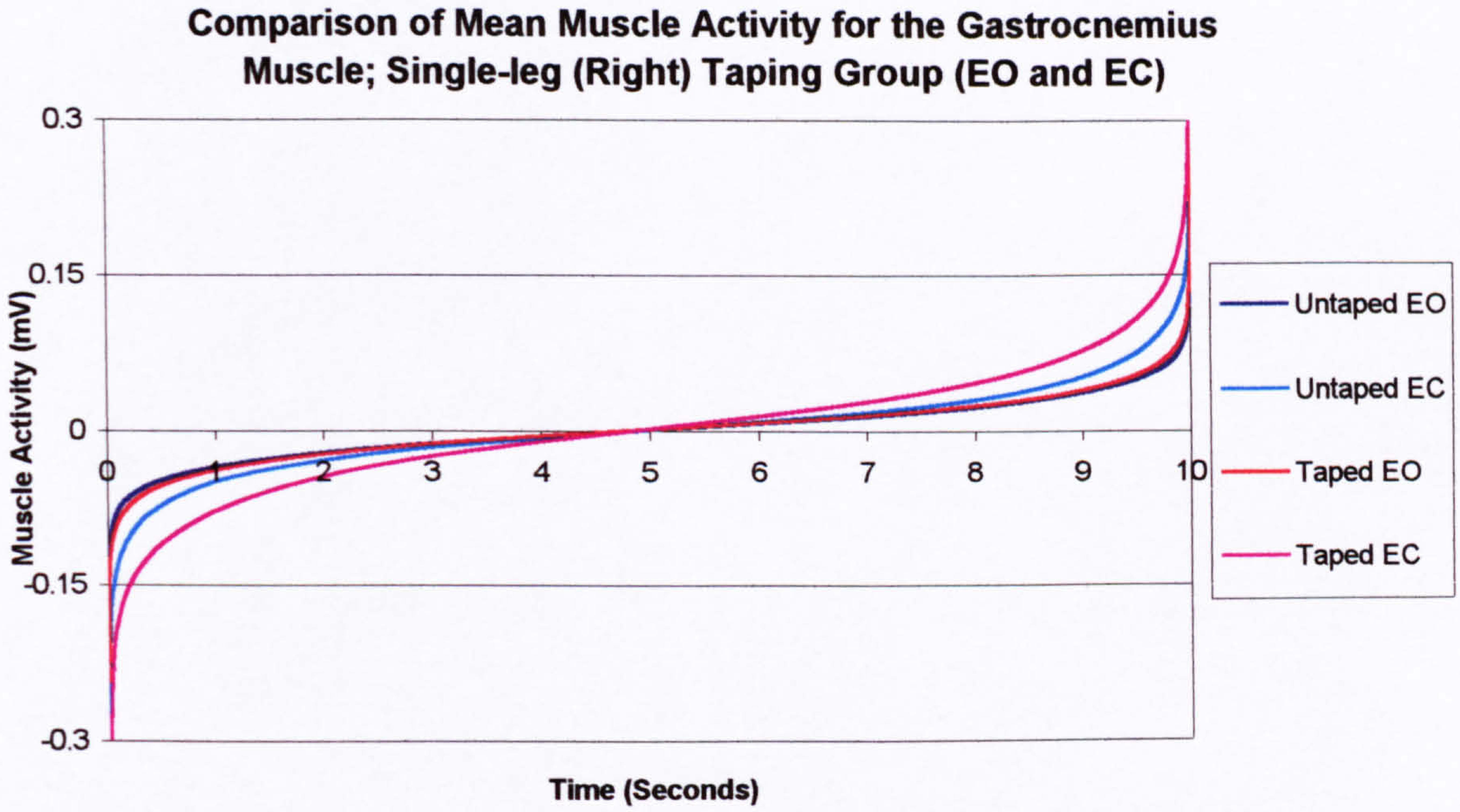
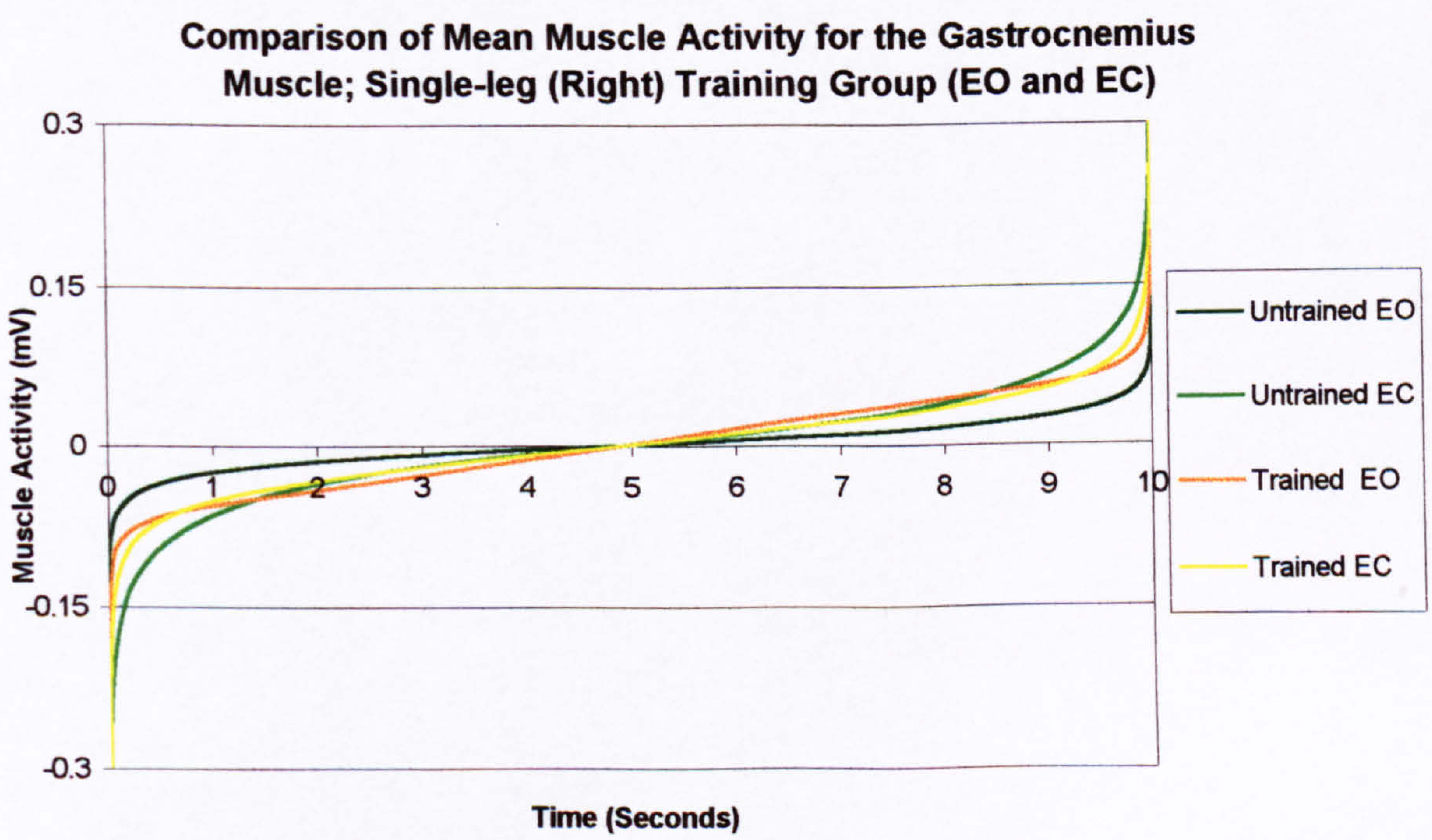


Figure n° 863 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Single-leg (Right) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.74* or between the groups as analysed by independent t-tests *Table n° 8.75*. All test conditions also have a high degree of correlation as presented in *Table n° 8.76*.

Table nº 8.74 Paired t-test Analysis on Single-leg (Right) Within Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.127	0.069	-0.037	-0.233
p-Value	0.899	0.945	0.971	0.816
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.632	0.114	0.009	-0.050
p-Value	0.528	0.909	0.993	0.960

EO = Eyes Open EC = Eyes Closed

Table nº 8.75 Independent t-test Analysis on Single-leg (Right) Between Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.009	0.004	0.030	-0.035
p-Value	0.993	0.997	0.976	0.972

EO = Eyes Open EC = Eyes Closed

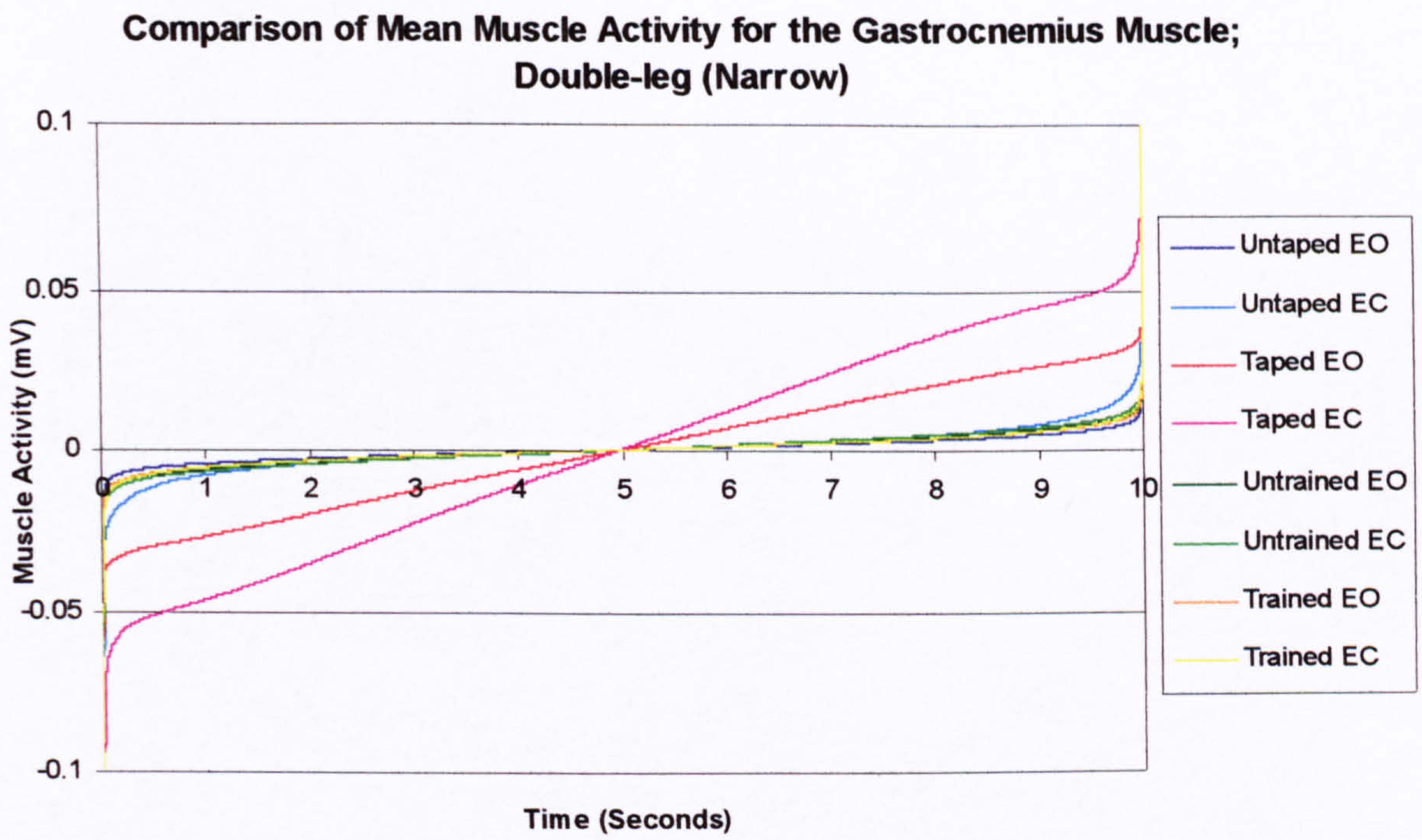
Table n° 8.76 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Right); Gastrocnemius Muscle

Test Condition	*EO Untaped*	*EC Untaped*	*EO Taped*	*EC Taped*	*EO Untrained*	*EC Untrained*	*EO Trained*	*EC Trained*
Mean (E-05)	-7.30	-5.30	-5.50	-7.80	-7.00	-5.70	-7.20	-5.00
StD	0.031	0.046	0.033	0.067	0.023	0.058	0.045	0.046
EO Untaped	1							
EC Untaped	0.996	1						
EO Taped	0.999	0.998	1					
EC Taped	0.994	0.998	0.997	1				
EO Untrained	0.994	0.988	0.992	0.982	1			
EC Untrained	0.993	0.999	0.997	0.999	0.983	1		
EO Trained	0.981	0.965	0.977	0.969	0.967	0.961	1	
EC Trained	0.998	0.997	0.998	0.997	0.990	0.995	0.979	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Narrow) is displayed in *Figure n° 864* from which it can be seen that muscle activity for the gastrocnemius muscle in Double-leg balance is virtually the same for all test conditions with the exception of Taped, both eyes open and eyes closed conditions.

Figure n° 864 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Narrow)



Separation into the taping (*Figure n° 865*) and training (*Figure n° 866*) groups shows this difference more clearly with an increase in muscle activity being evident in the Taped, eyes open condition compared to the Untaped condition and, a further increase in activity when the eyes are closed. By contrast, the training group reveals no change in muscle activity in any of the test conditions.

Figure n° 865 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Narrow) in the Taping Group

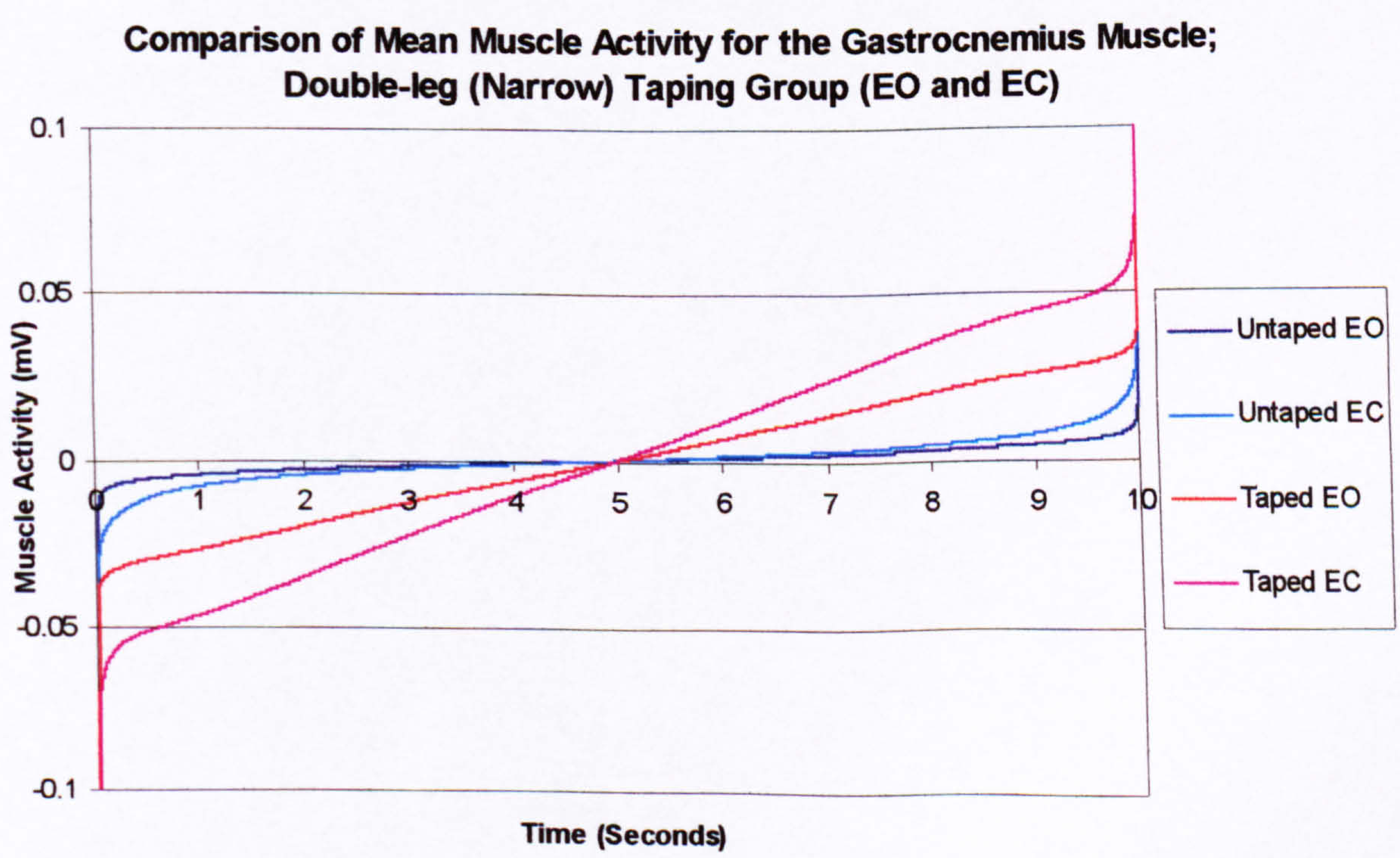
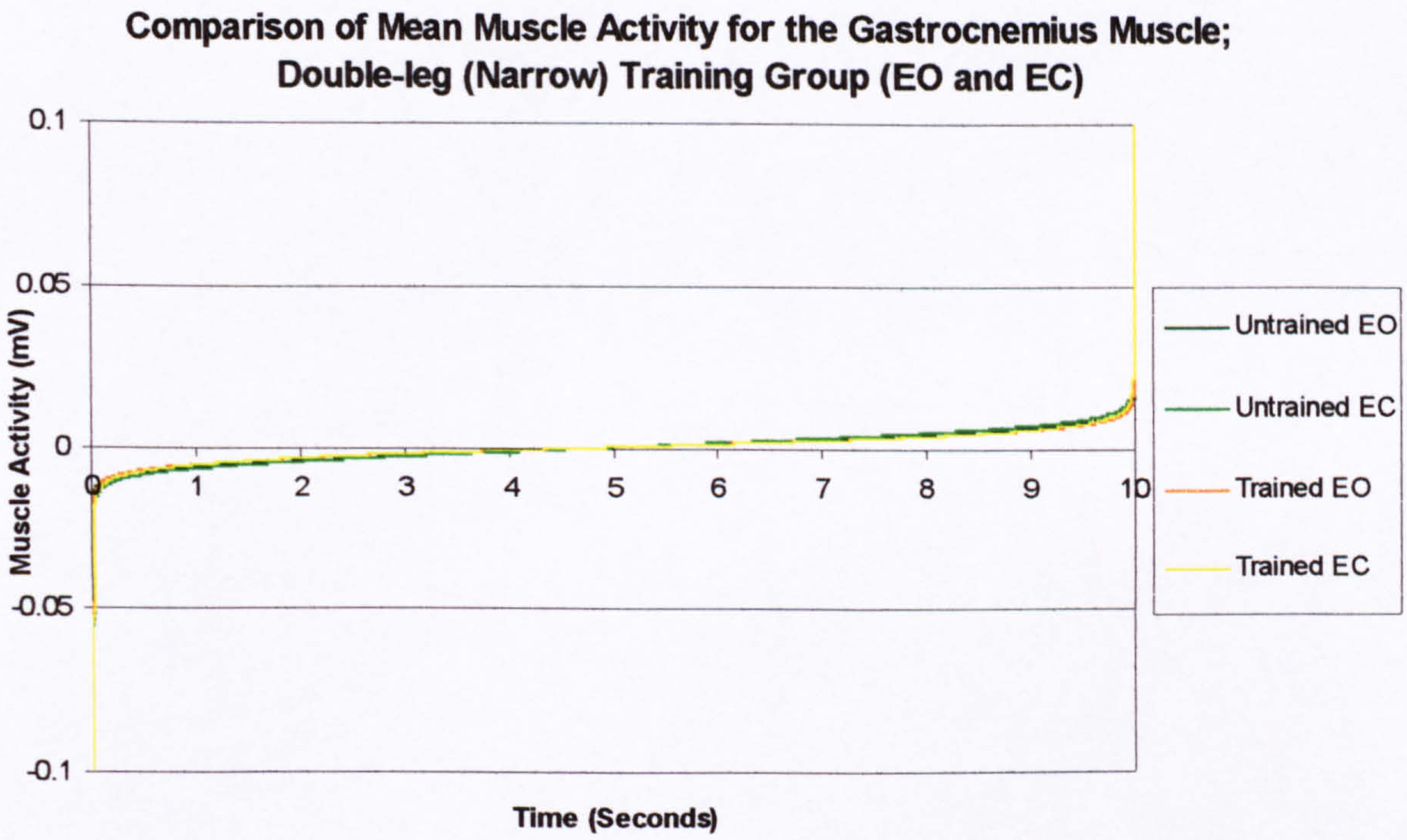


Figure n° 866 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Narrow) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.77* or between the groups as analysed by independent t-tests *Table n° 8.78.*

Table n° 8.77 Paired t-test Analysis on Double-leg (Narrow) Within Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.048	0.055	-0.320	-0.210
p-Value	0.962	0.956	0.749	0.834
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.044	0.008	0.024	0.068
p-Value	0.965	0.993	0.981	0.946

EO = Eyes Open EC = Eyes Closed

Table n° 8.78 Independent t-test Analysis on Double-leg (Narrow) Between Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle *(p < 0.05 for Significance)*

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.005	0.001	0.035	-0.003
p-Value	0.996	0.999	0.972	0.998

EO = Eyes Open EC = Eyes Closed

In the case of Double-leg (Narrow), not all test conditions have a high degree of correlation. This is due to the fact that there is a higher level of muscle activity in the Taped test conditions than the others, resulting in a low correlation of this test condition with the rest of between 0.519 and 0.756 as presented in *Table n° 8.79*.

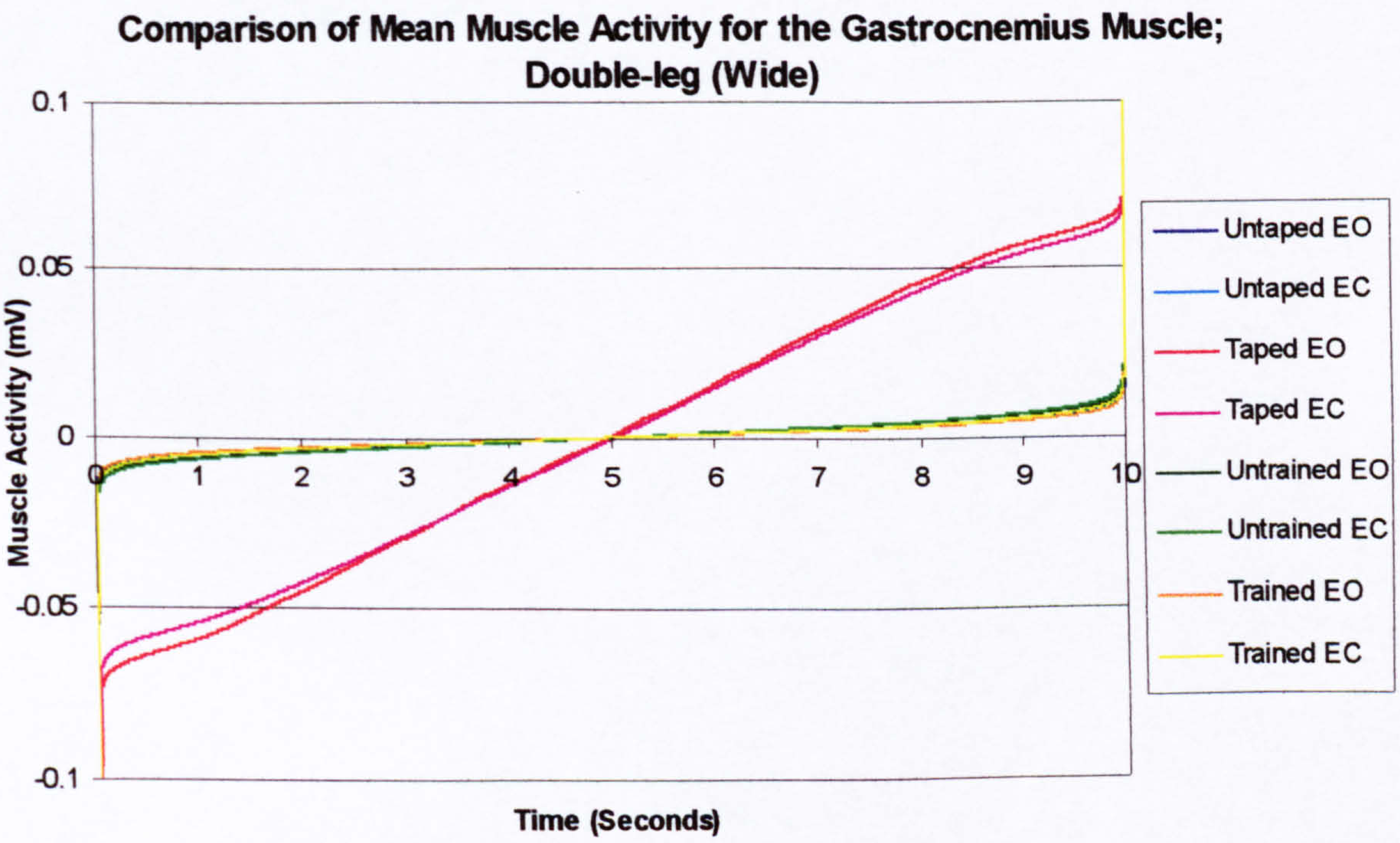
Table n° 8.79 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Narrow); Gastrocnemius Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean (E-07)	3.27	2E-06	7.57 E-06	-2.90	-5.70	1.71 E-06	-9.30	7.18
StD	0.013	0.015	0.021	0.035	0.014	0.014	0.012	0.013
EO Untaped	1							
EC Untaped	0.973	1						
EO Taped	0.624*	0.756*	1					
EC Taped	0.519*	0.669*	0.991	1				
EO Untrained	0.996	0.986	0.691*	0.592*	1			
EC Untrained	0.994	0.990	0.703*	0.606*	1.000	1		
EO Trained	0.996	0.988	0.688*	0.590*	1.000	1.000	1	
EC Trained	0.996	0.990	0.684*	0.586*	0.999	0.999	1.000	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed
* = Low Correlation

Comparison of the eight test conditions for Double-leg (Wide) is displayed in *Figure n° 867* from which it can be seen that muscle activity for the gastrocnemius muscle in Double-leg balance is virtually the same for all test conditions, again with the exception of Taped, both eyes open and eyes closed conditions.

Figure n° 867 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Wide)



Separation into the taping (*Figure n° 868*) and training (*Figure n° 869*) groups shows this difference more clearly with an increase in muscle activity being evident in the Taped condition compared to the Untaped but no difference within the Taped condition between eyes open and eyes closed visual conditions. Again, by contrast the training group reveals no change in muscle activity in any of the test conditions.

Figure n° 868 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Wide) in the Taping Group

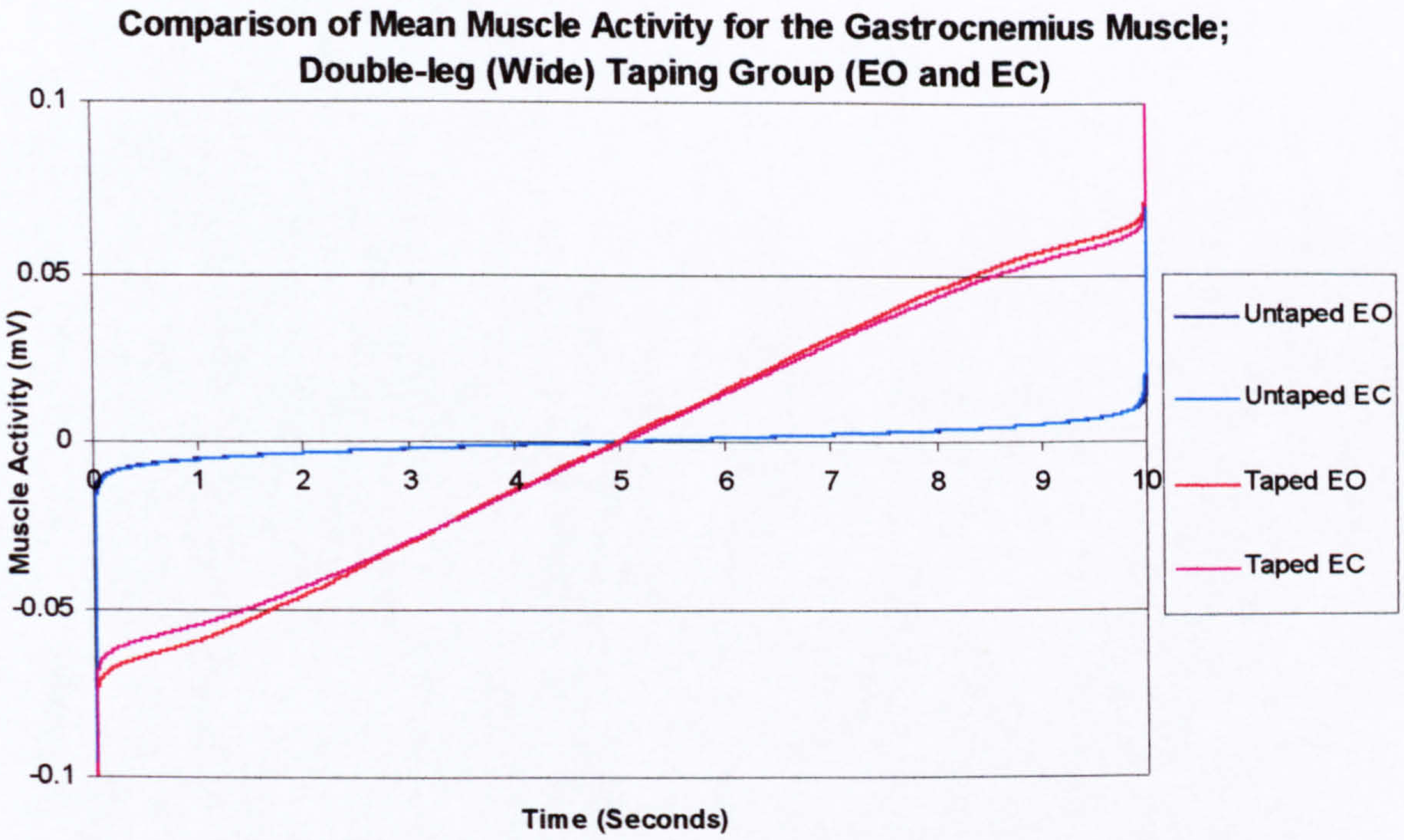
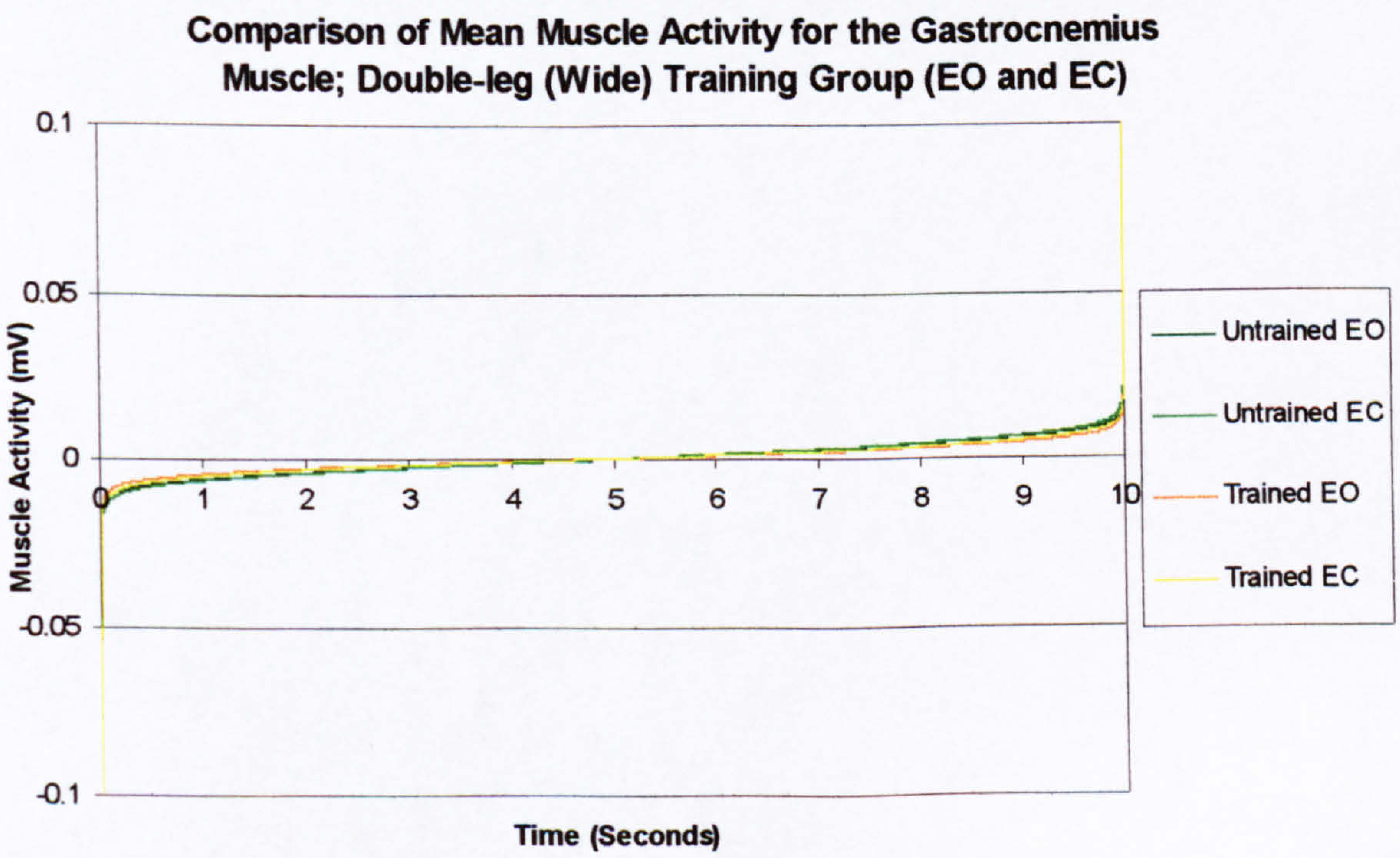


Figure n° 869 Mean Muscle Activity (mV) for the Gastrocnemius Muscle Double-leg (Wide) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.80* or between the groups as analysed by independent t-tests *Table n° 8.81*.

Table n° 8.80 Paired t-test Analysis on Double-leg (Wide) Within Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.114	-0.143	0.476	-0.302
p-Value	0.909	0.887	0.634	0.762
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.018	0.009	0.157	-0.201
p-Value	0.986	0.993	0.751	0.840

EO = Eyes Open EC = Eyes Closed

Table n° 8.81 Independent t-test Analysis on Double-leg (Wide) Between Groups for Mean EMG Results of Ten Second Balance Trials; Gastrocnemius Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.005	0.011	-0.013	-0.007
p-Value	0.996	0.991	0.990	0.994

EO = Eyes Open EC = Eyes Closed

In the case of Double-leg (Wide), not all test conditions have a high degree of correlation. This is due to the fact that there is a higher level of muscle activity in the Taped test conditions than the others, resulting in a low correlation of this test condition with the rest of between 0.481 and 0.589 as presented in *Table n° 8.82*.

Table n° 8.82 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Wide); Gastrocnemius Muscle

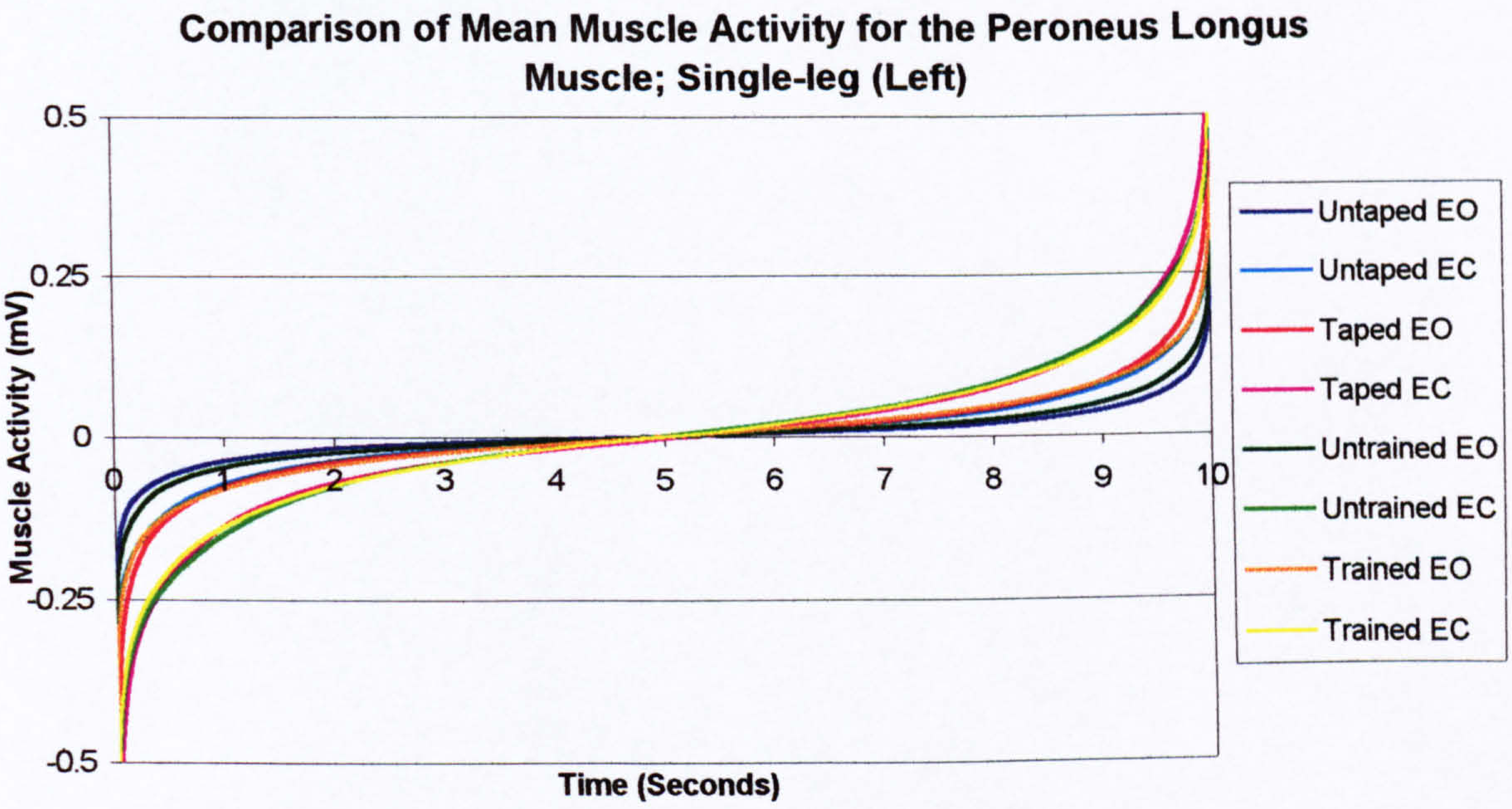
Test Condition	*EO Untaped*	*EC Untaped*	*EO Taped*	*EC Taped*	*EO Untrained*	*EC Untrained*	*EO Trained*	*EC Trained*
Mean (E-07)	3.29	1.09 E-06	-6.40 E-06	-2.20 E-06	1.28 E-06	-1.00 E-06	-5.50	9.65
StD	0.013	0.013	0.043	0.041	0.014	0.014	0.014	0.014
EO Untaped	1							
EC Untaped	1.000	1						
EO Taped	0.538*	0.534*	1					
EC Taped	0.516*	0.512*	0.999	1				
EO Untrained	0.999	0.999	0.572*	0.551*	1			
EC Untrained	0.998	0.998	0.589*	0.568*	0.999	1		
EO Trained	0.999	0.999	0.503*	0.481*	0.996	0.995	1	
EC Trained	1.000	1.000	0.531*	0.510*	0.999	0.997	0.999	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed
* = Low Correlation

8.4.2.2 Peroneus Longus – Mean Ten Second Balance Results

Comparison of the eight test conditions for Single-leg (Left) is displayed in *Figure n° 870* from which it can be seen that muscle activity for the peroneus longus muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition.

Figure n° 870 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Left)



Separation into the taping (*Figure n° 871*) and training (*Figure n° 872*) groups reveals an increase in muscle activity on closing the eyes in both groups. For the taping group the muscle activity in the Taped condition is higher for both visual conditions than in the eyes closed condition Untaped, thus there is an overall increase in muscle activity in the peroneus longus with tape as compared to the Untaped condition.

Although the training group shows an increase in muscle activity with the eyes closed, this level of activity is the same for the Untrained and Trained conditions; eyes closed, in comparison with a slight increase in activity in the eyes open Trained condition compared to the Untrained condition.

Figure n° 871 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Left) in the Taping Group

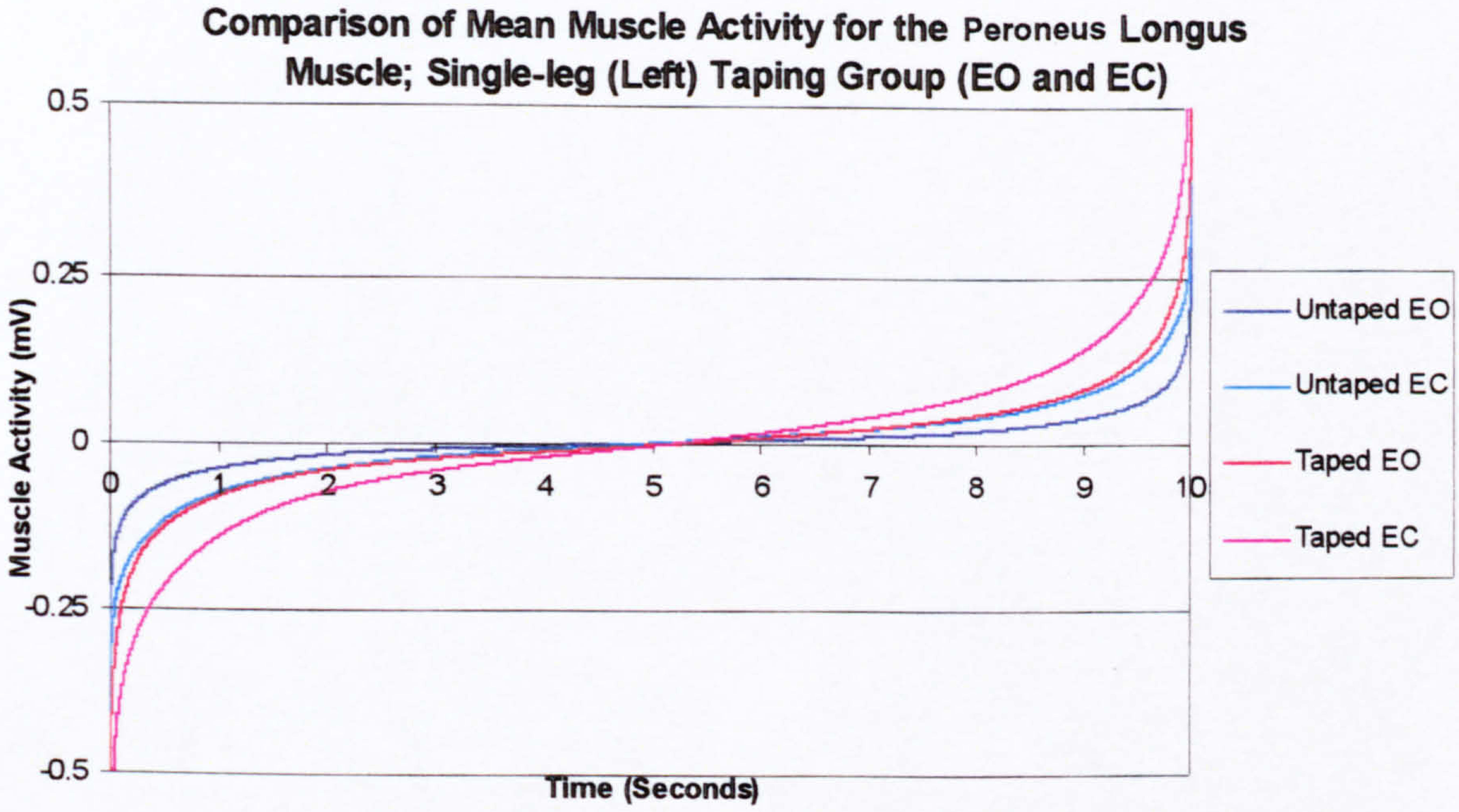
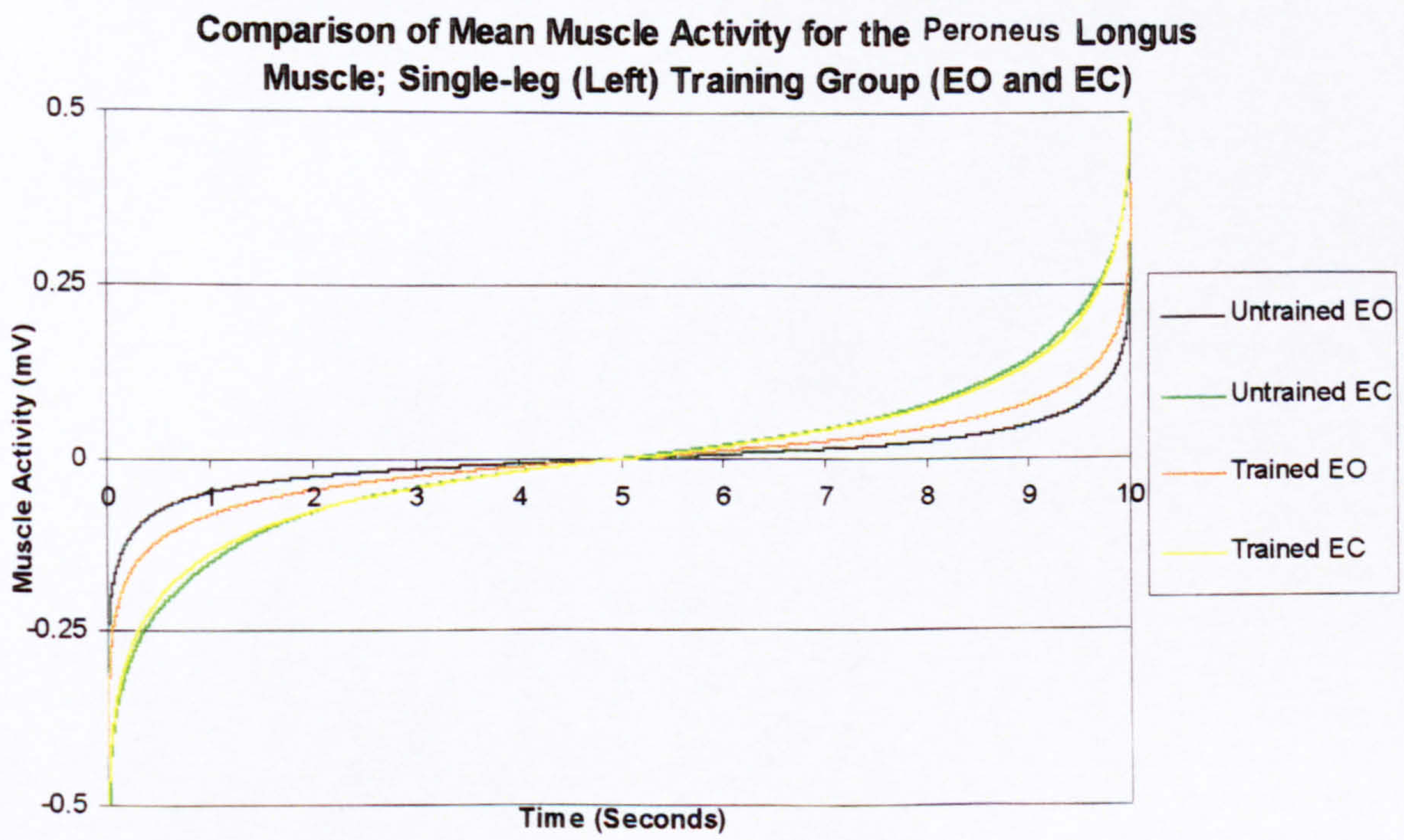


Figure n° 872 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Left) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.83* or between the groups as analysed by independent t-tests *Table n° 8.84*. All test conditions also have a high degree of correlation as presented in *Table n° 8.85*.

Table n° 8.83 Paired t-test Analysis on Single-leg (Left) Within Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.063	0.077	0.000	0.003
p-Value	0.950	0.938	1.000	0.997
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.021	0.016	0.047	0.203
p-Value	0.983	0.987	0.962	0.839

EO = Eyes Open EC = Eyes Closed

Table n° 8.84 Independent t-test Analysis on Single-leg (Left) Between Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.016	-0.006	0.028	-0.003
p-Value	0.987	0.995	0.978	0.998

EO = Eyes Open EC = Eyes Closed

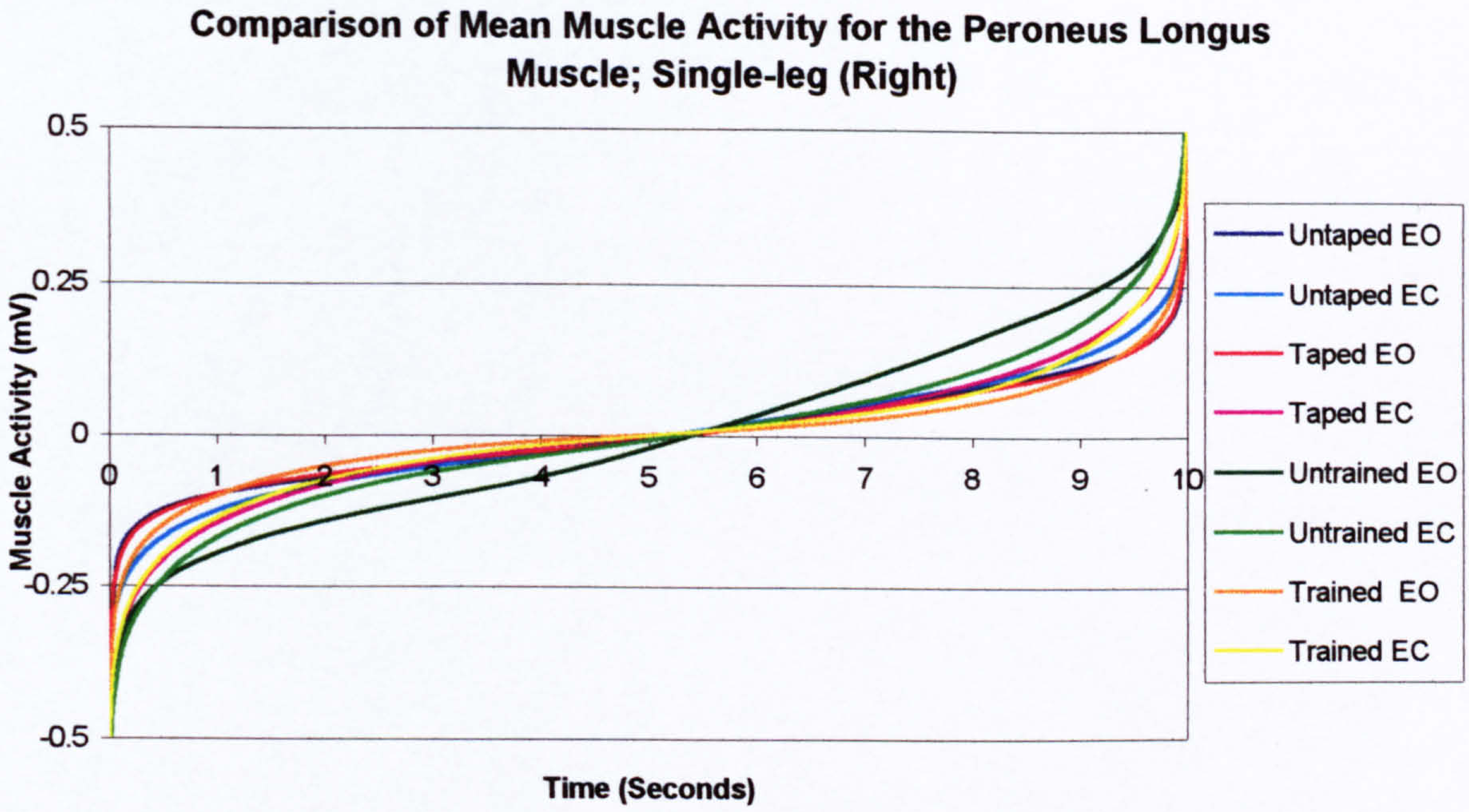
Table n° 8.85 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Left); Peroneus Longus Muscle

Test Condition	*EO Untaped*	*EC Untaped*	*EO Taped*	*EC Taped*	*EO Untrained*	*EC Untrained*	*EO Trained*	*EC Trained*
Mean (E-05)	6.25 E-06	-1.27	1.53	-2.27	-4.03 E-06	-4.18 E-06	-1.57	-1.73
StD	0.039	0.069	0.082	0.130	0.049	0.126	0.073	0.121
EO Untaped	1							
EC Untaped	0.994	1						
EO Taped	0.999	0.994	1					
EC Taped	0.995	0.999	0.996	1				
EO Untrained	0.998	0.998	0.999	0.998	1			
EC Untrained	0.984	0.997	0.985	0.996	0.990	1		
EO Trained	0.990	0.999	0.991	0.998	0.995	0.999	1	
EC Trained	0.986	0.998	0.988	0.997	0.992	0.999	0.999	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Single-leg (Right) is displayed in *Figure n° 873* from which it can be seen that muscle activity for the peroneus longus muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition for the majority of test conditions.

Figure n° 873 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Right)



Separation into the taping (*Figure n° 874*) and training (*Figure n° 875*) groups reveals virtually no change in muscle activity between Untaped and Taped eyes open conditions, but a slight increase in muscle activity with taping in the eyes closed condition. By comparison, in the training group there is a decrease in muscle activity with training and noticeably, a higher level of muscle activity in the eyes open Untrained condition by comparison to the other three test conditions within the group.

Figure n° 874 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Right) in the Taping Group

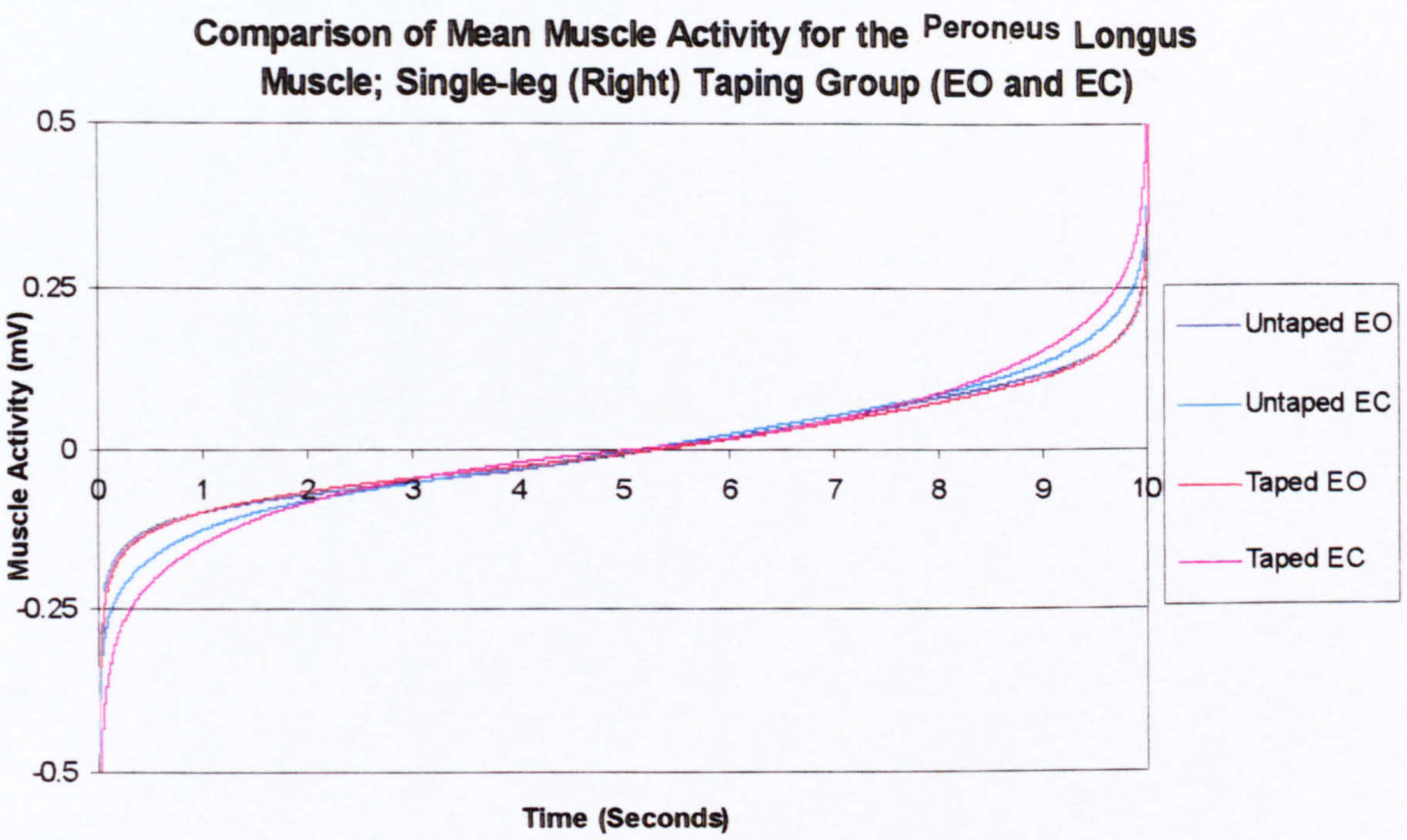
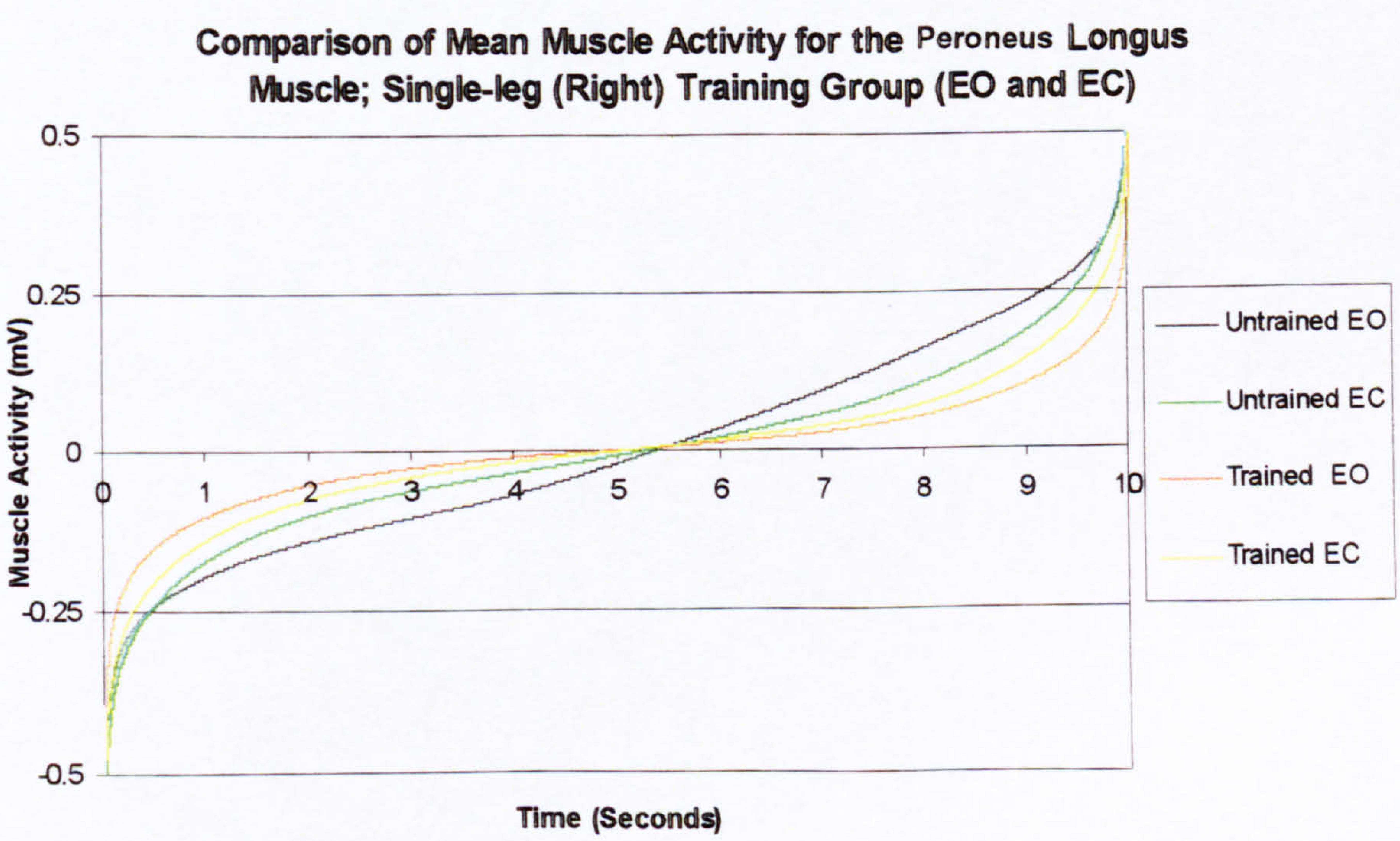


Figure n° 875 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Single-leg (Right) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.86* or between the groups as analysed by independent t-tests *Table n° 8.87*. All test conditions also have a high degree of correlation as presented in *Table n° 8.88*.

Table nº 8.86 Paired t-test Analysis on Single-leg (Right) Within Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.046	0.038	-0.004	0.151
p-Value	0.964	0.969	0.997	0.880
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.848	0.208	-0.014	0.125
p-Value	0.396	0.835	0.989	0.900

EO = Eyes Open EC = Eyes Closed

Table nº 8.87 Independent t-test Analysis on Single-leg (Right) Between Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.013	0.008	-0.024	-3E-05
p-Value	0.990	0.994	0.980	1.000

EO = Eyes Open EC = Eyes Closed

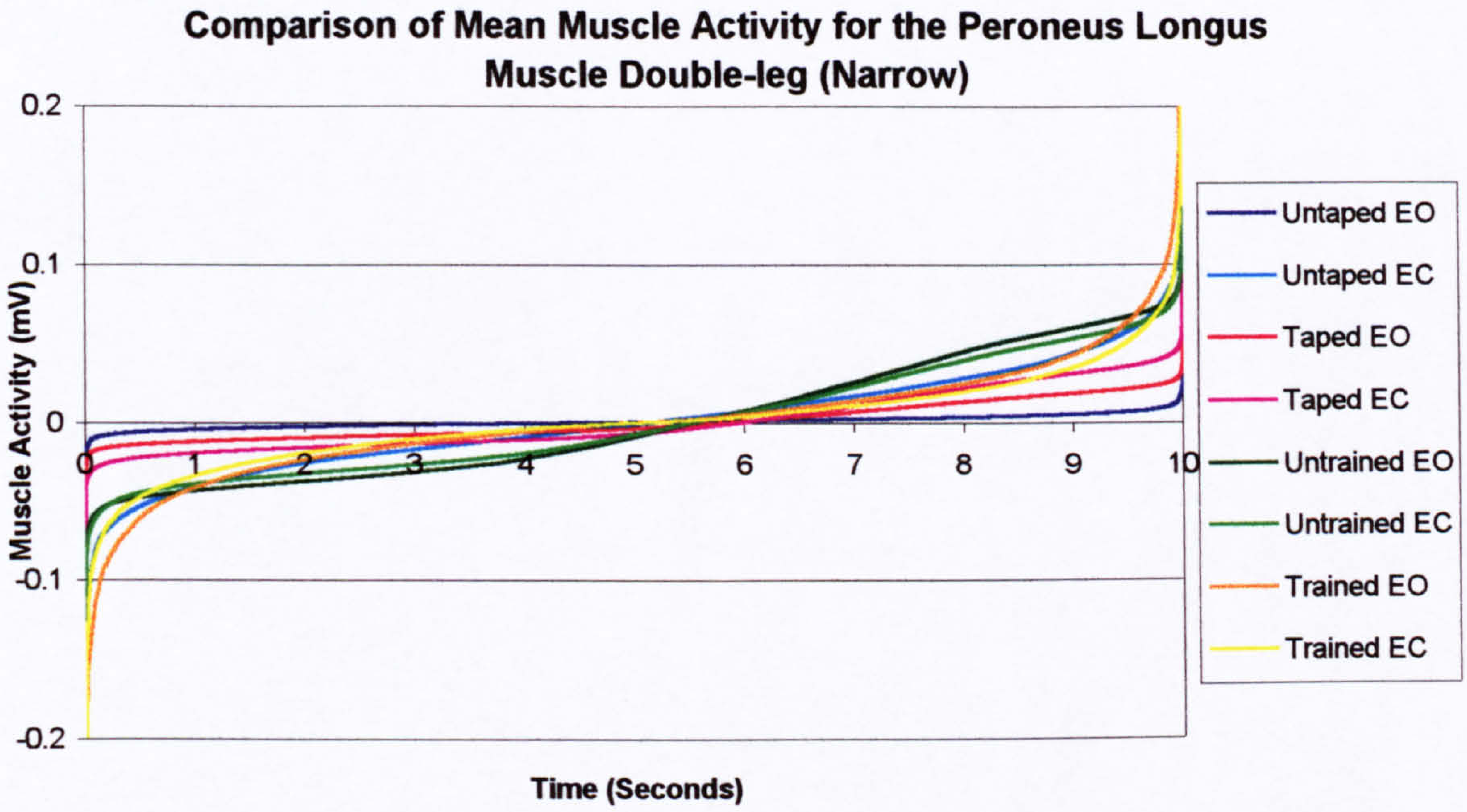
Table n° 8.88 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Right); Peroneus Longus Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean (E-05)	1.99	1.08	-2.40	-4.00	-4.80 E-06	-3.40 E-06	6.97 E-06	-4.00
StD	0.031	0.046	0.033	0.067	0.023	0.058	0.045	0.046
EO Untaped	1							
EC Untaped	0.995	1						
EO Taped	0.999	0.998	1					
EC Taped	0.986	0.993	0.992	1				
EO Untrained	0.994	0.991	0.992	0.971	1			
EC Untrained	0.990	0.998	0.996	0.997	0.983	1		
EO Trained	0.973	0.984	0.982	0.998	0.954	0.992	1	
EC Trained	0.978	0.970	0.987	0.998	0.964	0.996	0.999	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Narrow) is displayed in *Figure n° 876* from which it can be seen that muscle activity for the peroneus longus muscle in Double-leg balance is slightly different for all test conditions.

Figure n° 876 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Narrow)



Separation into the taping (*Figure n° 877*) and training (*Figure n° 878*) groups shows this difference more clearly. For the taping group, there is an increase in muscle activity Taped for the eyes open condition compared to Untaped, but a decrease in activity in the eyes closed condition.

For the training group, there is little difference between eyes open and eyes closed conditions, but muscle activity decreases with training for both visual conditions.

Figure nº 877 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Narrow) in the Taping Group

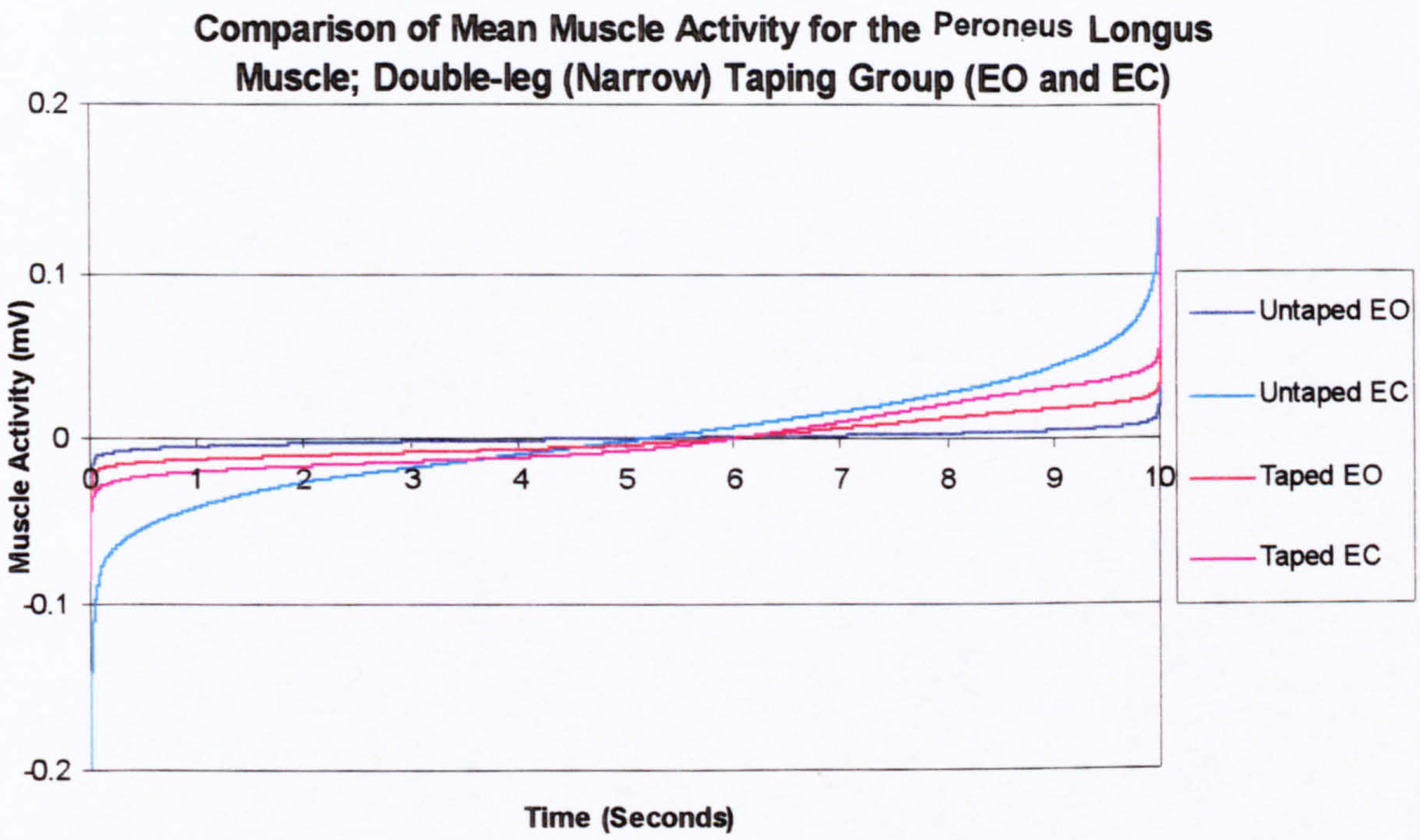
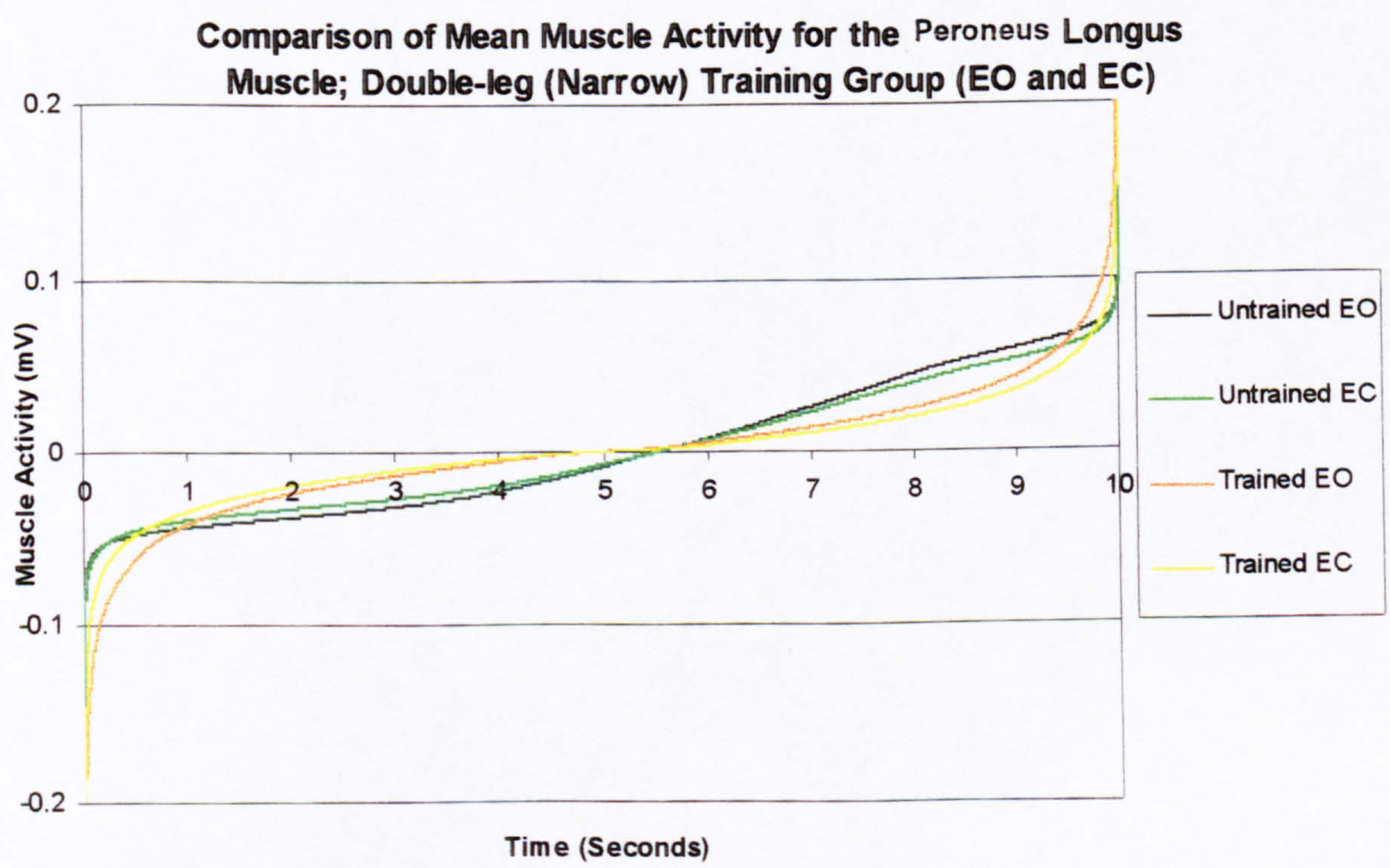


Figure nº 878 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Narrow) in the Training Group



Statistical analysis of the mean results reveal no significant differences within the groups of taping and training as analysed by paired t-tests *Table nº 8.89* or between the groups as analysed by independent t-tests *Table nº 8.90*. In the case of Double-leg (Narrow) for the peroneus longus muscle, all test conditions have a high degree of correlation as presented in *Table nº 8.91*.

Table n° 8.89 Paired t-test Analysis on Double-leg (Narrow) Within Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle *($p < 0.05$ for Significance)*

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.009	-0.009	-0.213	0.276
p-Value	0.992	0.993	0.832	0.783
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.055	0.005	-0.156	0.056
p-Value	0.956	0.996	0.876	0.955

EO = Eyes Open EC = Eyes Closed

Table n° 8.90 Independent t-test Analysis on Double-leg (Narrow) Between Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle *($p < 0.05$ for Significance)*

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.030	0.000	-0.054	0.021
p-Value	0.976	1.000	0.957	0.983

EO = Eyes Open EC = Eyes Closed

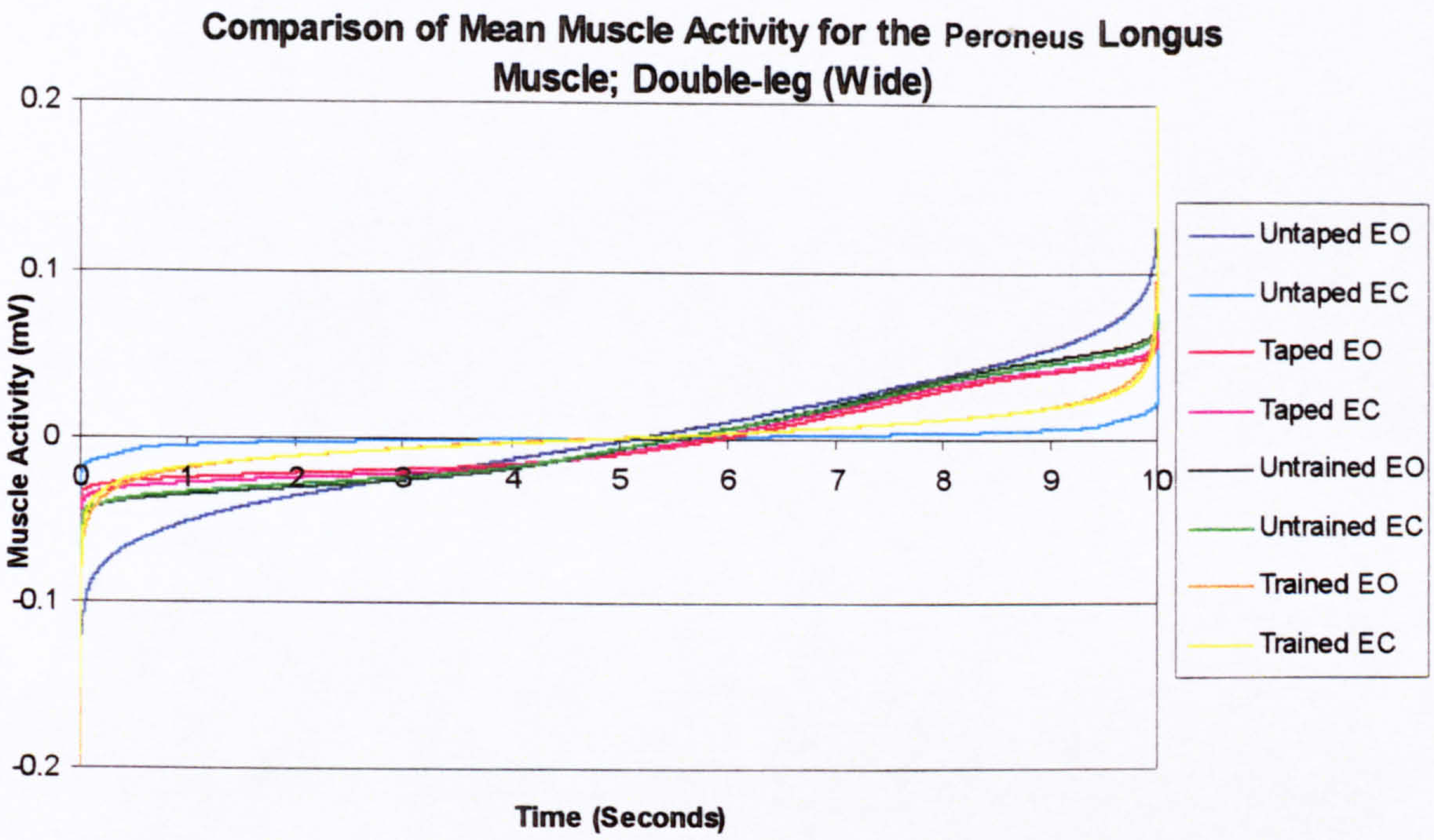
Table nº 8.91 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Narrow); Peroneus Longus Muscle

Test Condition	***EO Untaped***	***EC Untaped***	***EO Taped***	***EC Taped***	***EO Untrained***	***EC Untrained***	***EO Trained***	***EC Trained***
Mean	8.05 E-07	-2.10 E-06	-3.70 E-06	-3.00 E-06	-1.10 E-05	-2.30 E-06	1.93 E-05	1.10 E-05
StD	0.004	0.035	0.012	0.019	0.040	0.036	0.041	0.032
EO Untaped	1							
EC Untaped	0.976	1						
EO Taped	0.945	0.953	1					
EC Taped	0.916	0.956	0.989	1				
EO Untrained	0.908	0.954	0.981	0.993	1			
EC Untrained	0.923	0.967	0.981	0.994	0.999	1		
EO Trained	0.982	0.975	0.908	0.895	0.881	0.900	1	
EC Trained	0.993	0.961	0.928	0.896	0.879	0.896	0.979	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Wide) is displayed in *Figure nº 879* from which it can be seen that muscle activity for the peroneus longus muscle in Double-leg balance not the same for all test conditions.

Figure n° 879 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Wide)



Separation into the taping (*Figure n° 880*) and training (*Figure n° 881*) groups shows the difference more clearly. A decrease in muscle activity is evident Taped compared to Untaped in the eyes open condition, but an increase in muscle activity is seen in the eyes closed condition. No difference is apparent within the Taped condition between eyes open and eyes closed visual conditions.

In the training group there is a decrease in muscle activity for the peroneus longus after training, but no difference is seen between visual conditions for Untrained and Trained conditions.

Figure n° 880 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Wide) in the Taping Group

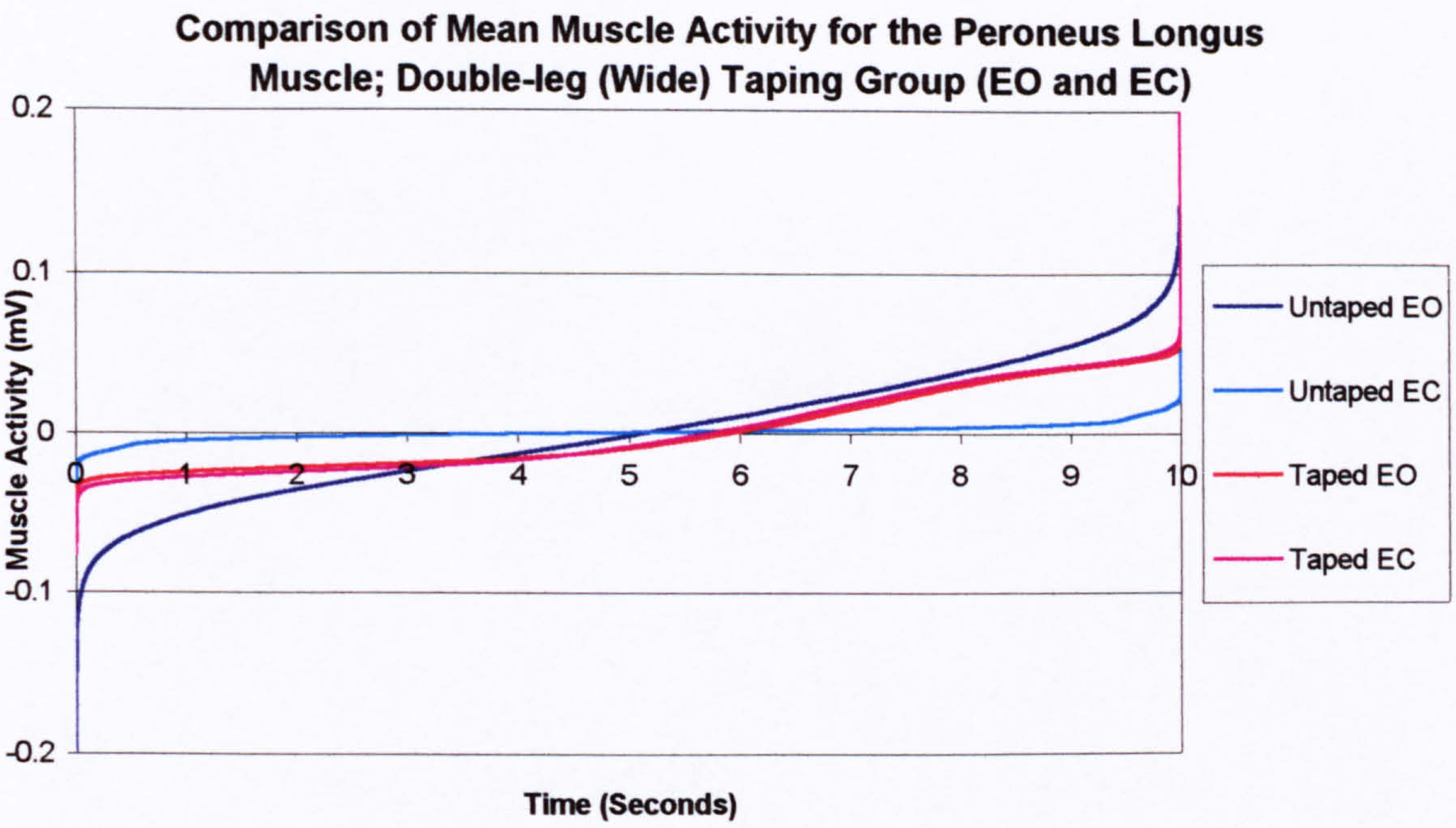
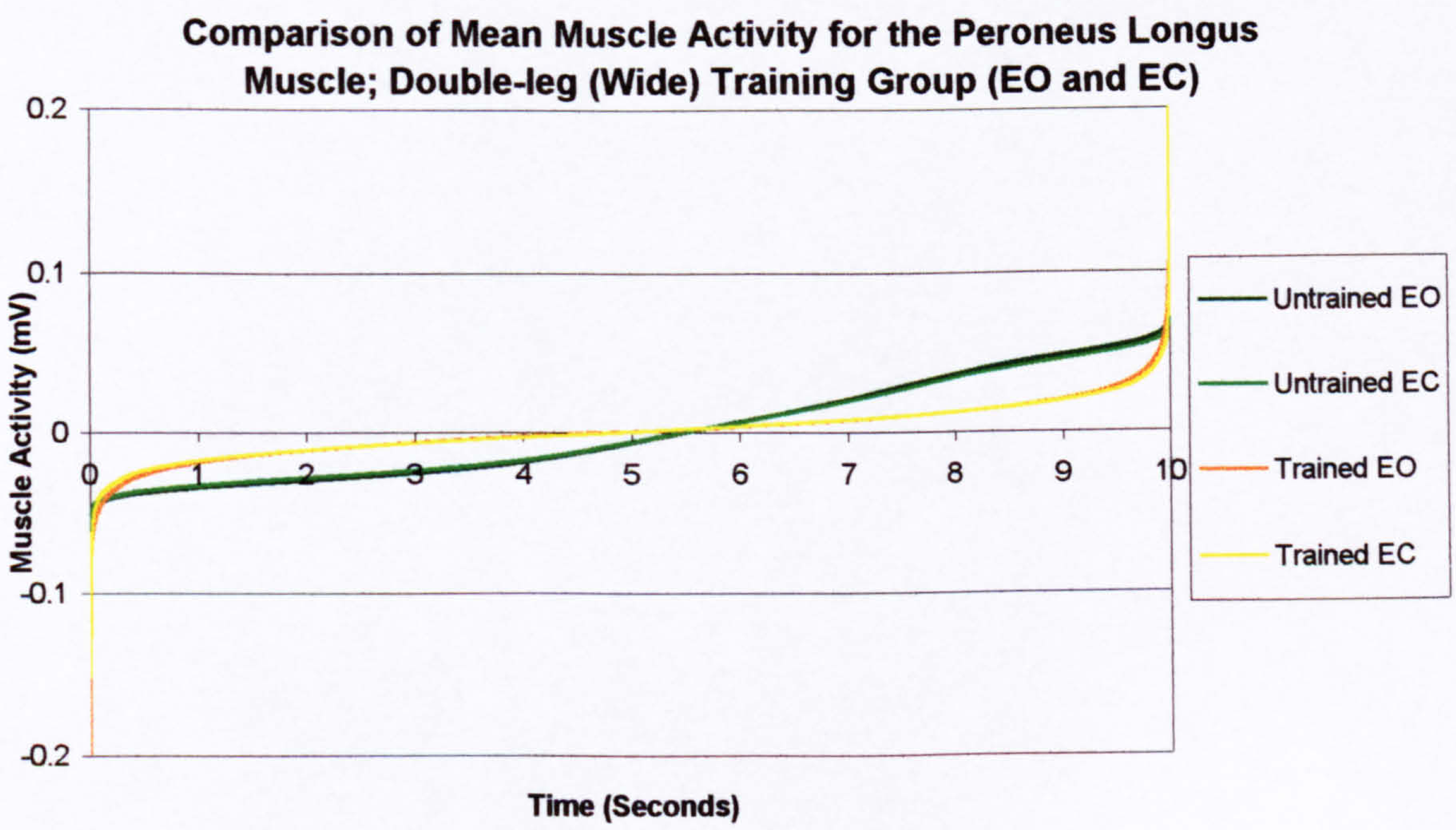


Figure n° 881 Mean Muscle Activity (mV) for the Peroneus Longus Muscle Double-leg (Wide) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.92* or between the groups as analysed by independent t-tests *Table n° 8.93*. In the case of Double-leg (Wide) all test conditions have a high degree of correlation as presented in *Table n° 8.94*.

Table nº 8.92 Paired t-test Analysis on Double-leg (Wide) Within Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.008	-0.382	0.088	0.163
p-Value	0.993	0.703	0.930	0.870
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.006	-0.054	0.043	0.063
p-Value	0.996	0.956	0.966	0.950

EO = Eyes Open EC = Eyes Closed

Table nº 8.93 Independent t-test Analysis on Double-leg (Wide) Between Groups for Mean EMG Results of Ten Second Balance Trials; Peroneus Longus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.010	-0.021	0.004	0.051
p-Value	0.992	0.983	0.997	0.960

EO = Eyes Open EC = Eyes Closed

Table n° 8.94 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Wide); Peroneus Longus Muscle

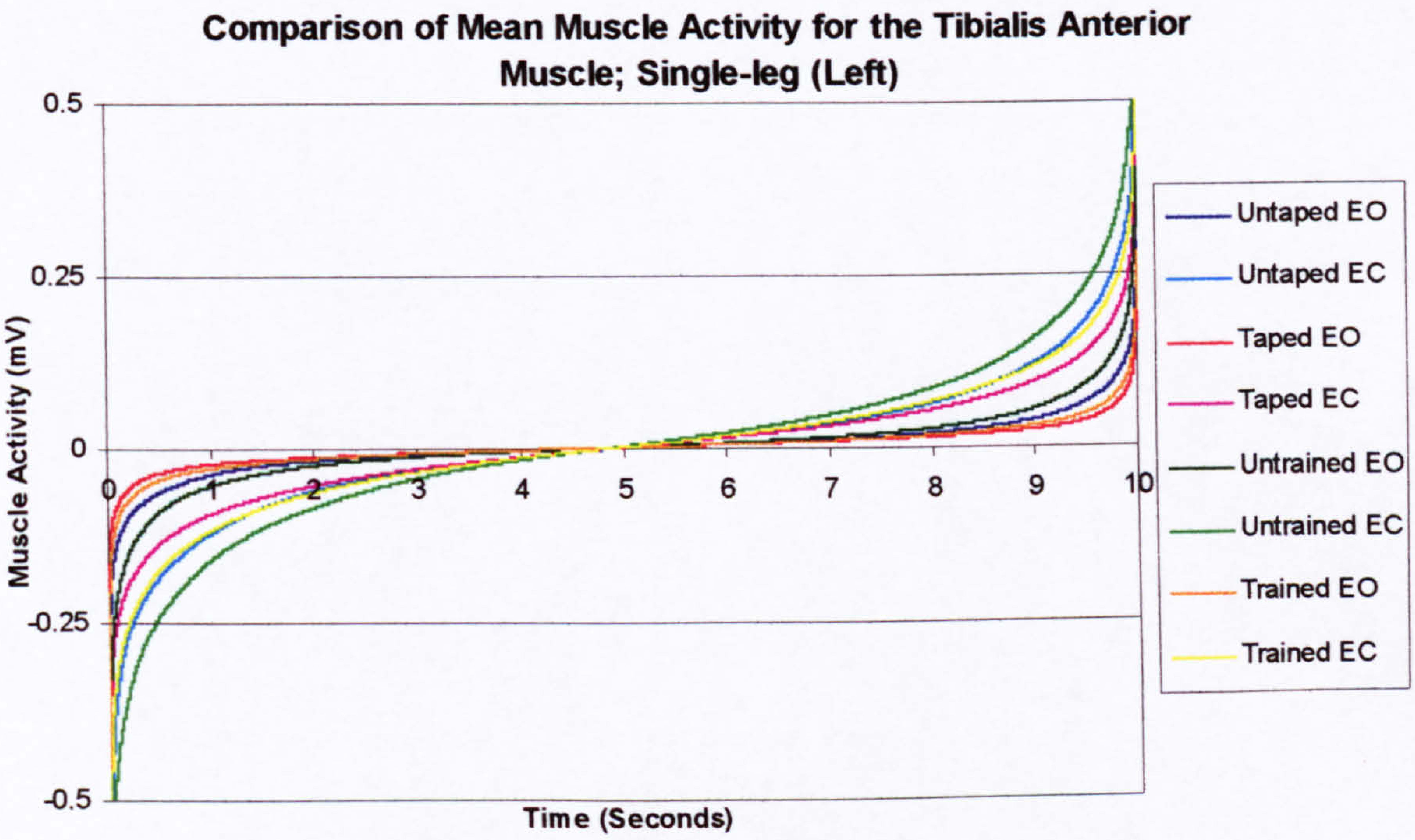
Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean	1.51 E-06	-1.50 E-06	-4.24 E-07	1.06 E-05	6.83 E-06	4.96 E-06	-7.20 E-07	-5.50 E-06
StD	0.042	0.006	0.025	0.027	0.032	0.030	0.018	0.017
EO Untaped	1							
EC Untaped	0.935	1						
EO Taped	0.952	0.822	1					
EC Taped	0.962	0.839	0.998	1				
EO Untrained	0.972	0.855	0.93	0.998	1			
EC Untrained	0.972	0.846	0.994	0.998	0.999	1		
EO Trained	0.972	0.969	0.878	0.890	0.902	0.901	1	
EC Trained	0.968	0.988	0.874	0.890	0.905	0.898	0.986	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

8.4.2.3 Tibialis Anterior – Mean Ten Second Balance Results

Comparison of the eight test conditions for Single-leg (Left) is displayed in *Figure n° 882* from which it can be seen that muscle activity for the tibialis anterior muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition.

Figure n° 882 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Left)



Separation into the taping (*Figure n° 883*) and training (*Figure n° 884*) groups reveals an increase in muscle activity on closing the eyes in both groups. For the taping group there is a relative decrease in activity Taped compared to Untaped for both visual conditions.

The training group also shows a decrease in muscle activity Trained compared to Untrained for both visual conditions.

Figure n° 883 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Left) in the Taping Group

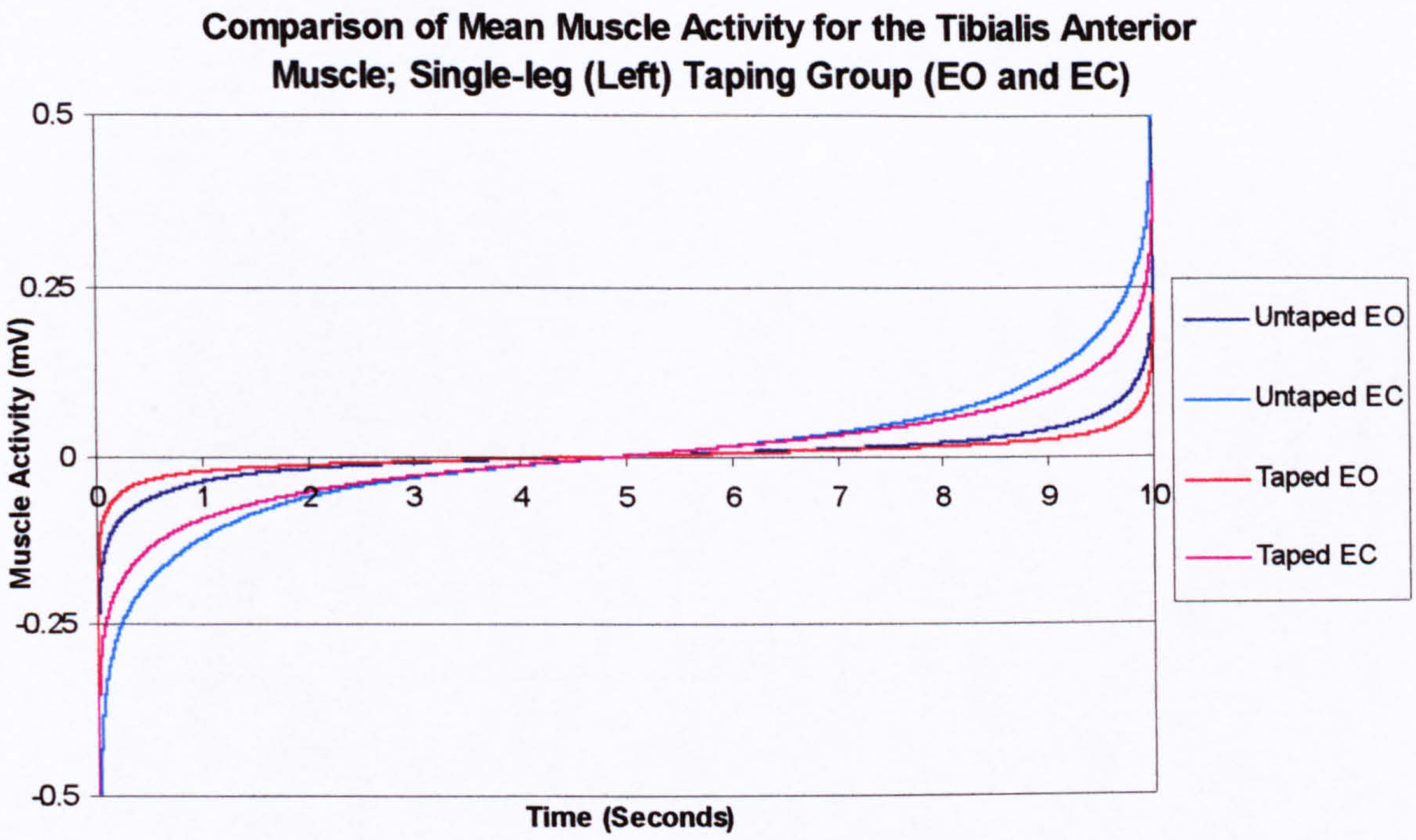
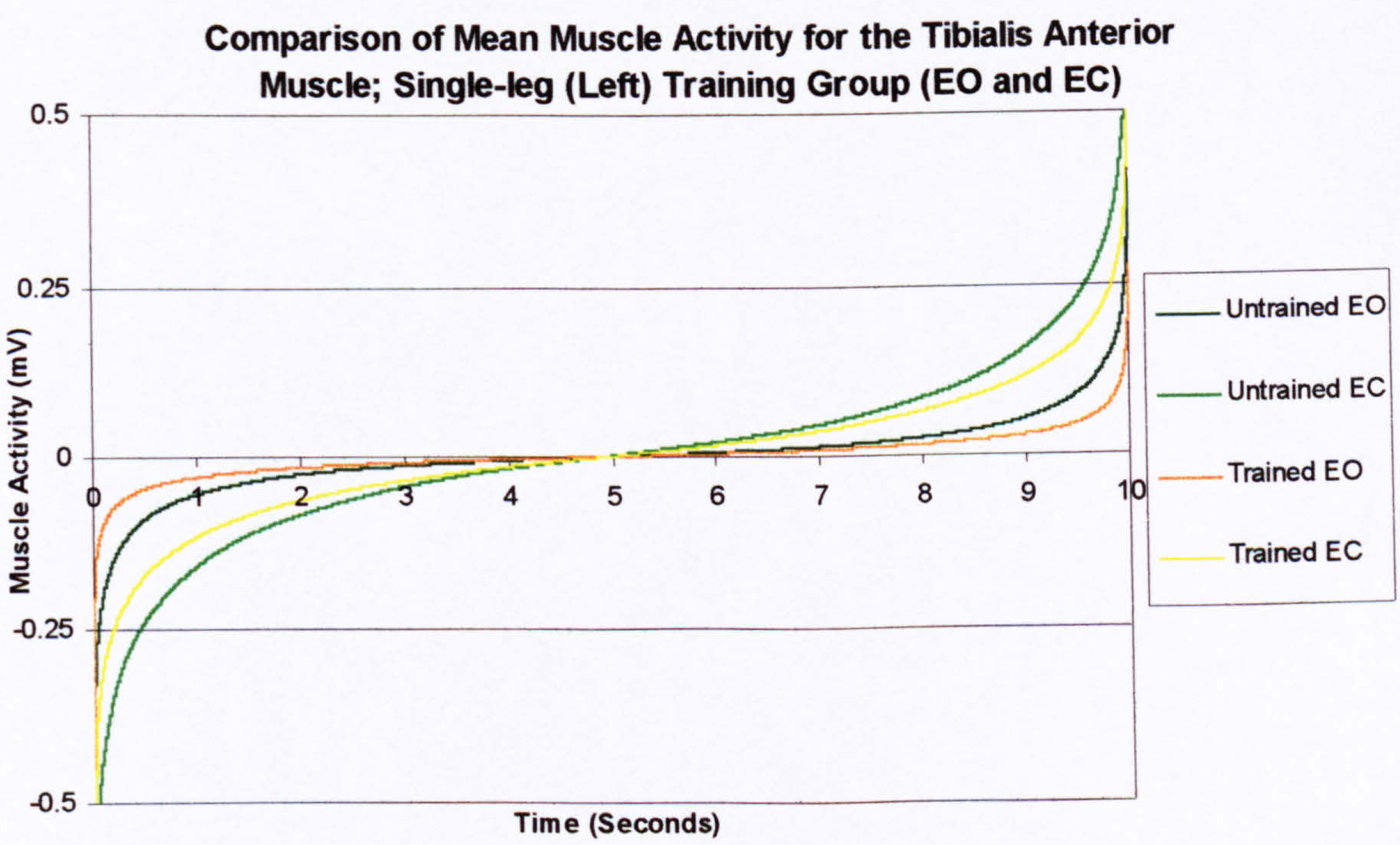


Figure n° 884 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Left) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.95* or between the groups as analysed by independent t-tests *Table n° 8.96*. All test conditions also have a high degree of correlation as presented in *Table n° 8.97*.

Table n° 8.95 Paired t-test Analysis on Single-leg (Left) Within Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	**EO UNTAPED Vs EC UNTAPED**	**EO TAPED Vs EC TAPED**	**EO UNTRAINED Vs EC UNTRAINED**	**EO TRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.030	0.041	0.010	0.041
p-Value	0.976	0.967	0.992	0.967
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.023	-0.002	0.005	0.061
p-Value	0.982	0.998	0.996	0.952

EO = Eyes Open EC = Eyes Closed

Table n° 8.96 Independent t-test Analysis on Single-leg (Left) Between Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	**EO UNTAPED VS EO UNTRAINED**	**EC UNTAPED Vs EC UNTRAINED**	**EO TAPED Vs EO TRAINED**	**EC TAPED Vs EC TRAINED**
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.007	-0.005	0.023	0.011
p-Value	0.995	0.996	0.982	0.991

EO = Eyes Open EC = Eyes Closed

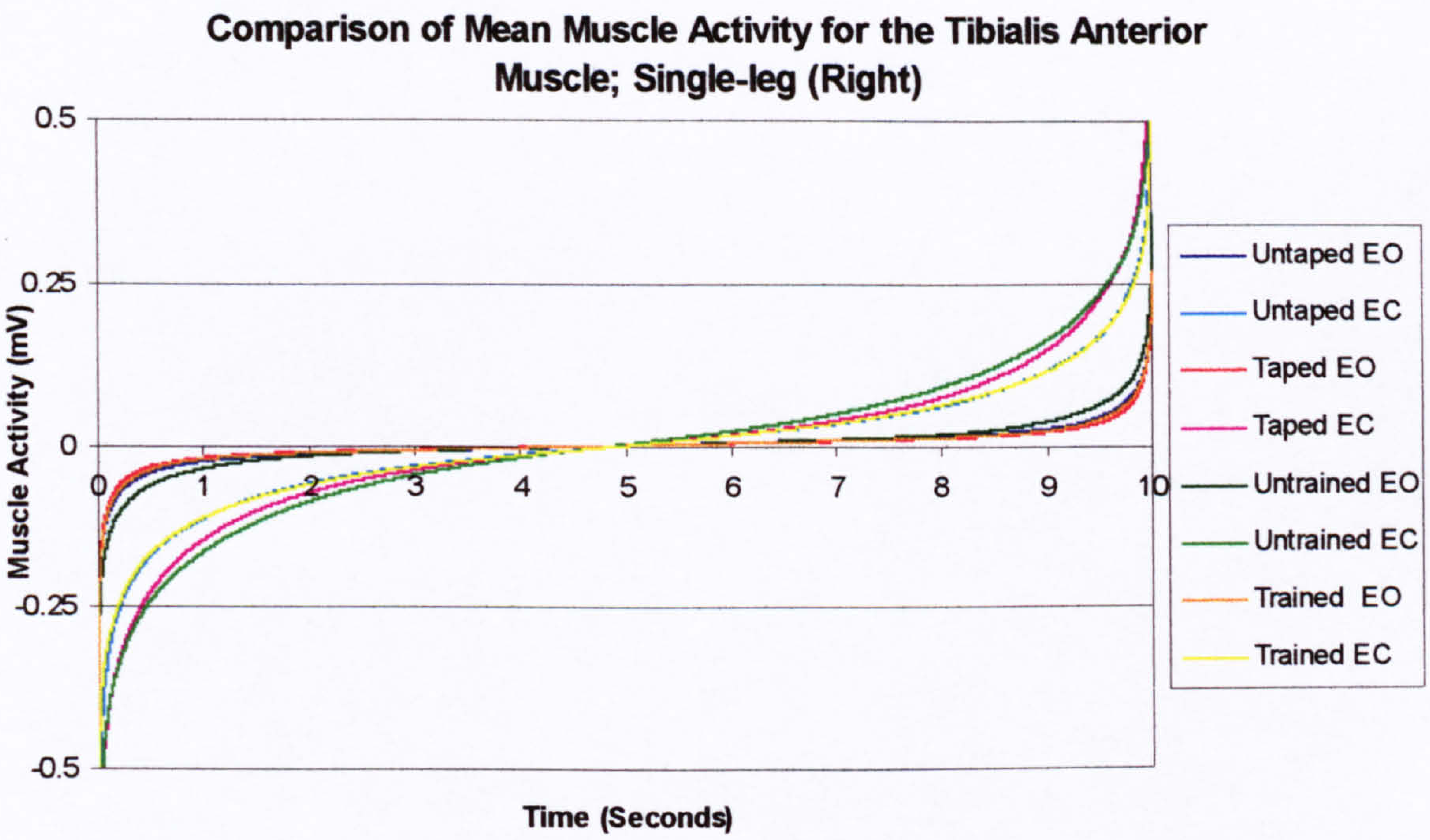
Table n° 8.97 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Left); Tibialis Anterior Muscle

Test Condition	***EO Untaped***	***EC Untaped***	***EO Taped***	***EC Taped***	***EO Untrained***	***EC Untrained***	***EO Trained***	***EC Trained***
Mean (E-05)	4.35	2.45	4.88	2.52	4.06	3.27	3.93	1.01
StD	0.041	0.110	0.026	0.082	0.059	0.140	0.032	0.103
EO Untaped	1							
EC Untaped	0.991	1						
EO Taped	0.994	0.981	1					
EC Taped	0.983	0.998	0.973	1				
EO Untrained	0.999	0.990	0.991	0.981	1			
EC Untrained	0.985	0.999	0.973	0.999	0.984	1		
EO Trained	0.997	0.984	0.999	0.976	0.996	0.977	1	
EC Trained	0.985	0.999	0.974	1.000	0.993	1.000	0.977	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Single-leg (Right) is displayed in *Figure n° 885* from which it can be seen that muscle activity for the tibialis anterior muscle in single-leg balance is greater in the eyes closed condition than the eyes open condition and that muscle activity in the two groups is virtually the same.

Figure n° 885 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Right)



Separation into the taping (*Figure n° 886*) and training (*Figure n° 887*) groups reveals virtually no change in muscle activity between Untaped and Taped eyes open conditions, but a slight increase in muscle activity with taping in the eyes closed condition. By comparison, in the training group there is a decrease in muscle activity with training.

Figure n° 886 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Right) in the Taping Group

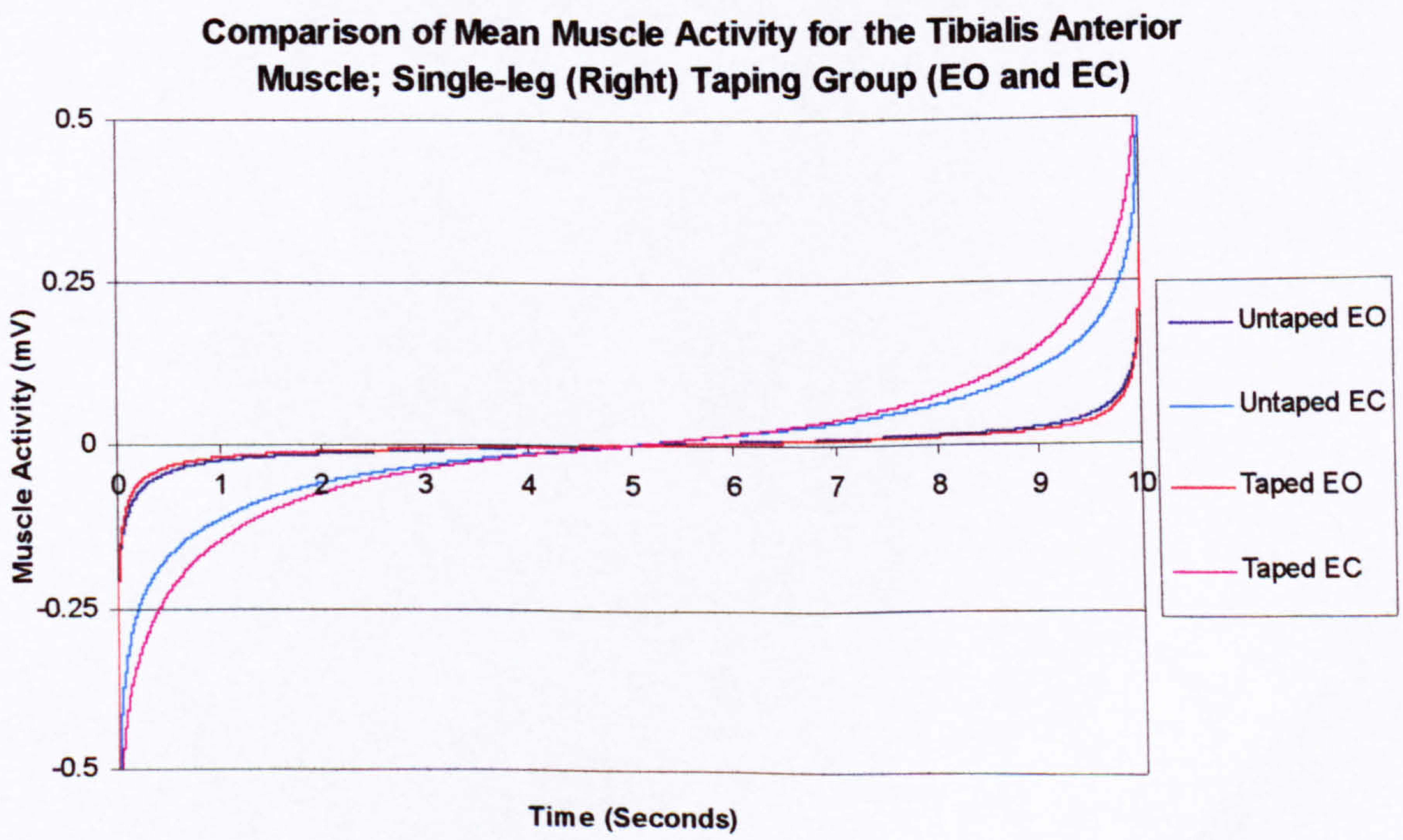
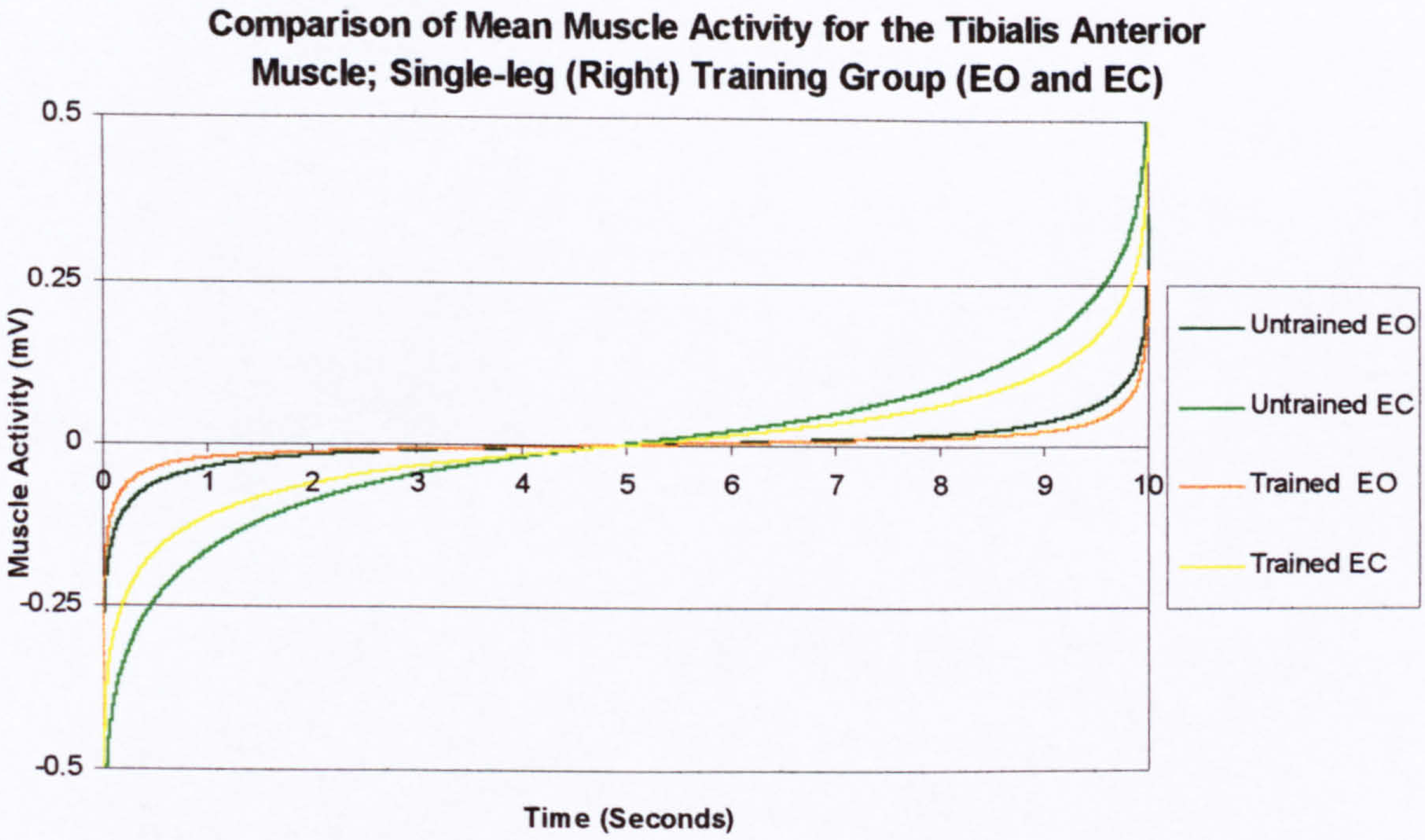


Figure n° 887 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Single-leg (Right) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.98* or between the groups as analysed by independent t-tests *Table n° 8.99*. All test conditions also have a high degree of correlation as presented in *Table n° 8.100*.

Table n° 8.98 Paired t-test Analysis on Single-leg (Right) Within Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.050	0.060	0.016	-0.012
p-Value	0.960	0.952	0.986	0.990
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.055	0.083	0.021	-0.056
p-Value	0.956	0.934	0.984	0.955

EO = Eyes Open EC = Eyes Closed

Table n° 8.99 Independent t-test Analysis on Single-leg (Right) Between Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.007	-0.010	0.022	-0.038
p-Value	0.994	0.992	0.983	0.969

EO = Eyes Open EC = Eyes Closed

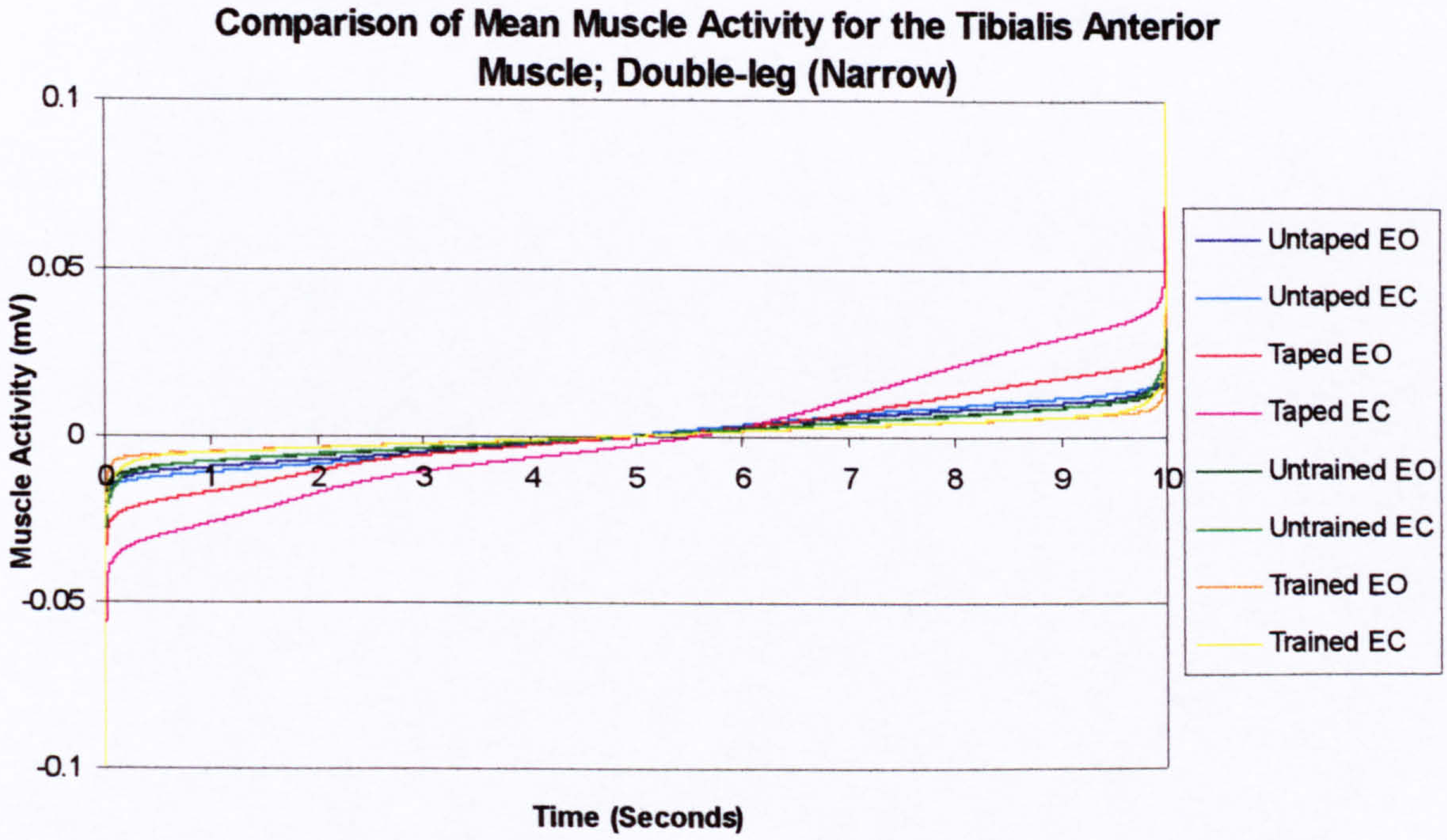
Table n° 8.100 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Right); Tibialis Anterior Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean (E-05)	3.74	5.12 E-07	3.99	-2.50	3.35	1.80	3.08	3.97
StD	0.032	0.105	0.029	0.136	0.043	0.140	0.030	0.102
EO Untaped	1							
EC Untaped	0.975	1						
EO Taped	0.995	0.951	1					
EC Taped	0.973	0.999	0.949	1				
EO Untrained	0.997	0.981	0.990	0.981	1			
EC Untrained	0.956	0.997	0.925	0.996	0.964	1		
EO Trained	0.998	0.966	0.998	0.964	0.996	0.943	1	
EC Trained	0.968	0.999	0.942	0.999	0.975	0.999	0.957	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Narrow) is displayed in *Figure n° 888* from which the muscle activity for the tibialis anterior muscle in Double-leg balance can be seen for all test conditions.

Figure n° 888 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Narrow)



Separation into the taping (*Figure n° 889*) and training (*Figure n° 890*) groups shows the activity more clearly. For the taping group, there is an increase in muscle activity Taped compared to Untaped. There is an increase in activity eyes closed compared to eyes open in the Taped condition, but not noticeable in the Untaped condition.

For the training group, there is very little difference between eyes open and eyes closed conditions or between Untrained and Trained test conditions.

Figure n° 889 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Narrow) in the Taping Group

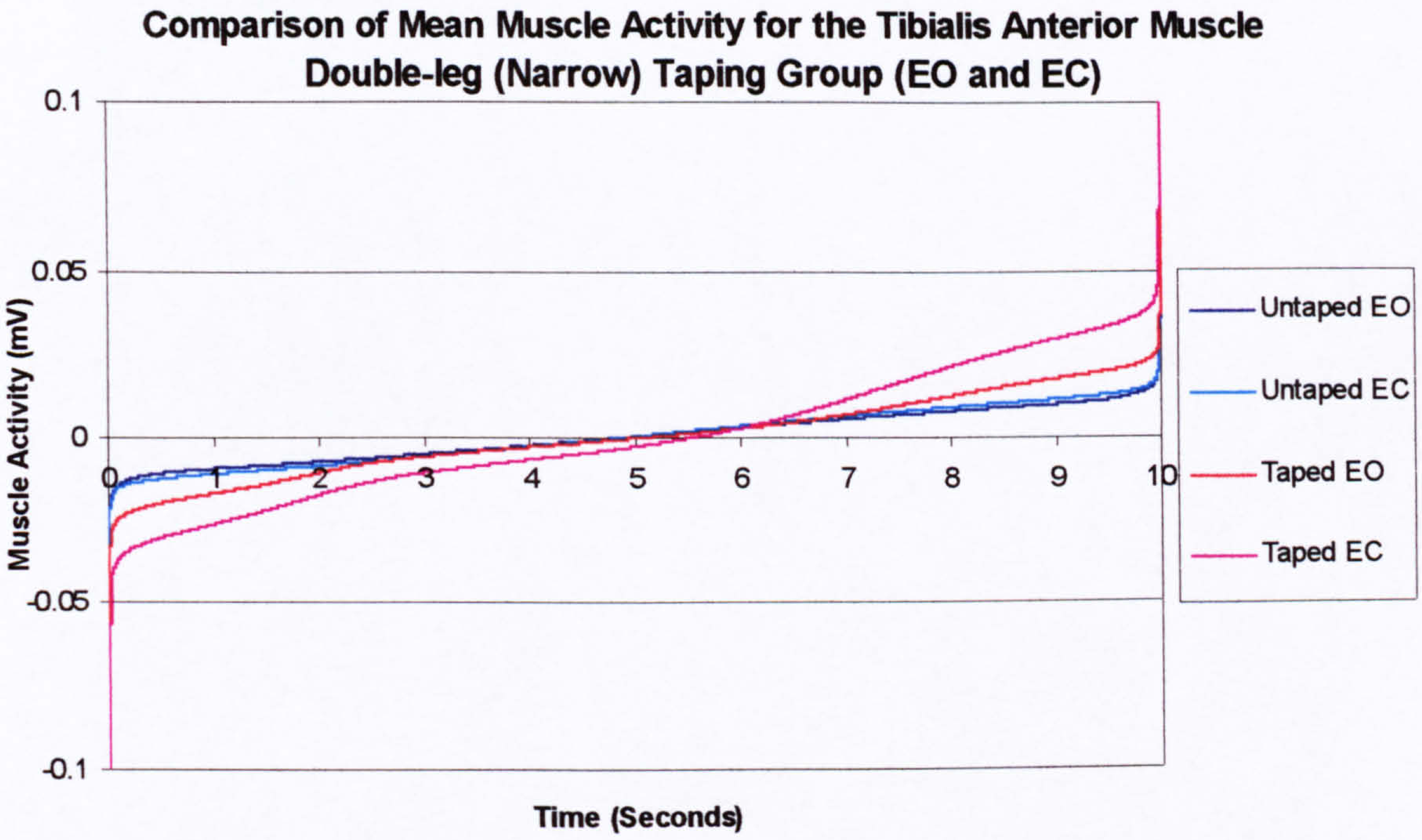
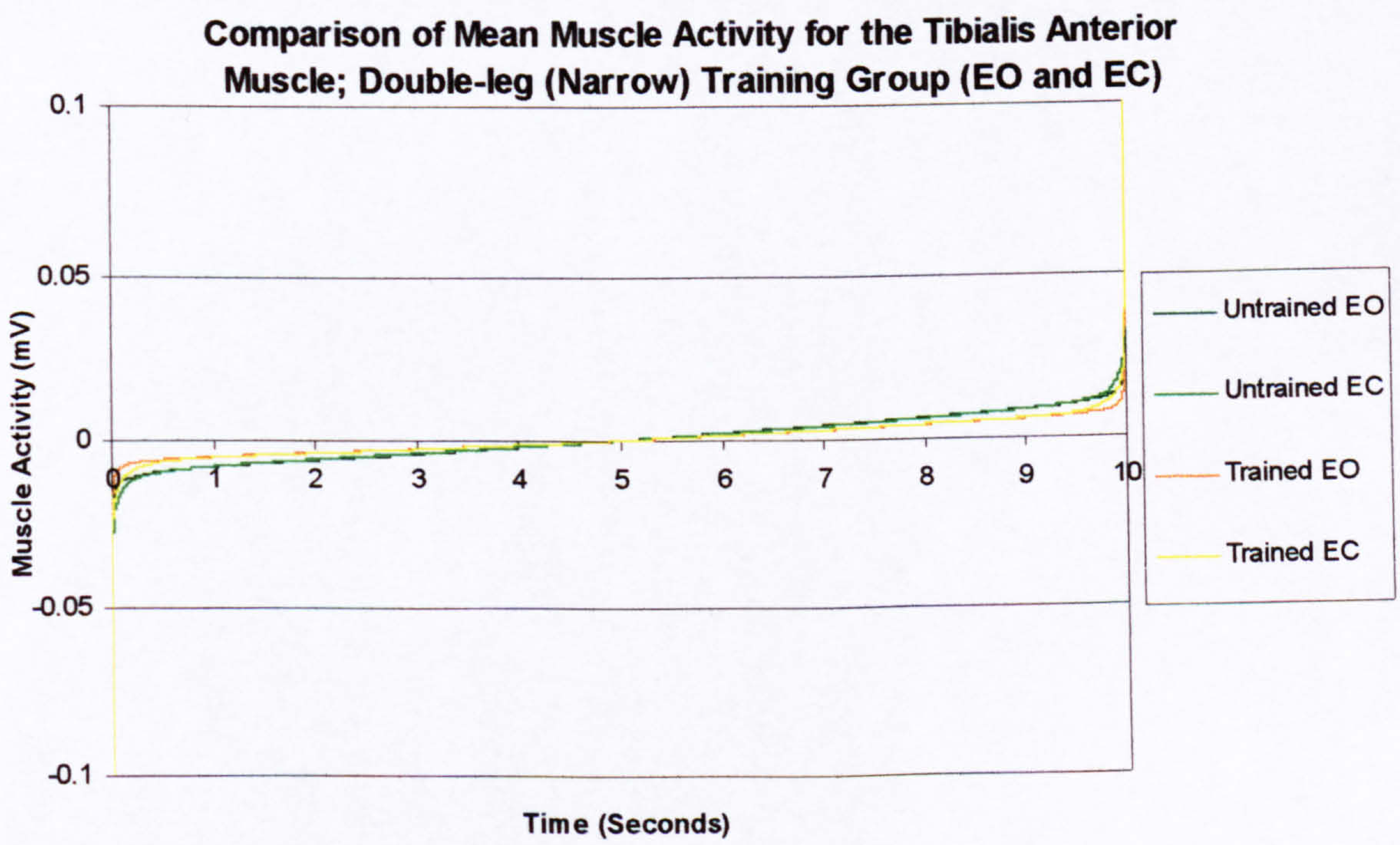


Figure n° 890 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Narrow) in the Training Group



Statistical analysis of the mean results reveal no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.101* or between the groups as analysed by independent t-tests *Table n° 8.102*. In the case of Double-leg (Narrow) for the tibialis anterior muscle, all test conditions have a high degree of correlation as presented in *Table n° 8.103*.

Table n° 8.101 Paired t-test Analysis on Double-leg (Narrow) Within Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle *($p < 0.05$ for Significance)*

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.069	-0.018	0.033	0.041
p-Value	0.924	0.969	0.973	0.967
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.022	-0.020	0.063	0.091
p-Value	0.982	0.984	0.950	0.928

EO = Eyes Open EC = Eyes Closed

Table n° 8.102 Independent t-test Analysis on Double-leg (Narrow) Between Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle *($p < 0.05$ for Significance)*

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.006	0.008	0.010	0.023
p-Value	0.995	0.994	0.992	0.982

EO = Eyes Open EC = Eyes Closed

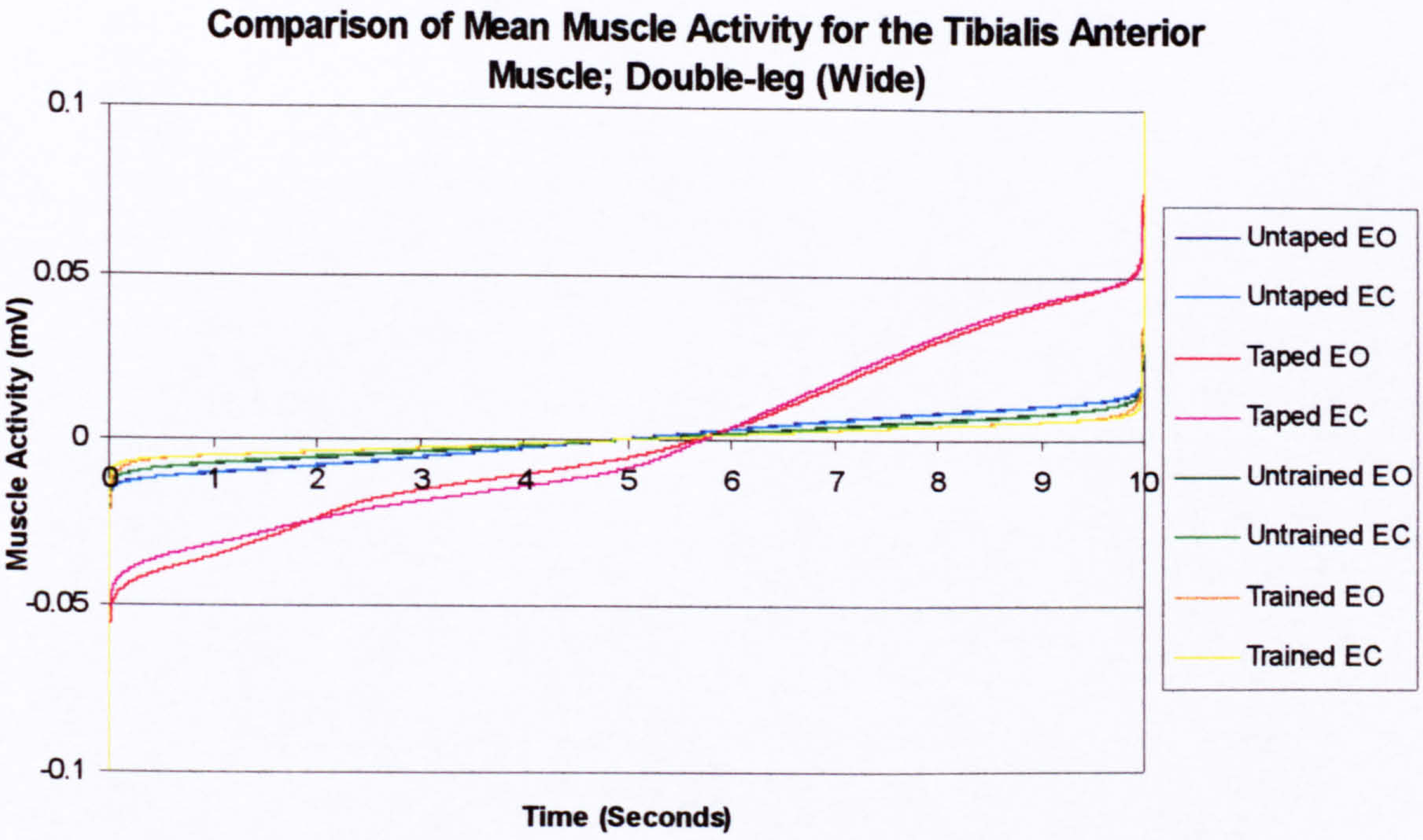
Table n° 8.103 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Narrow); Tibialis Anterior Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean	2.48 E-07	2.05 E-06	1.39 E-06	4.42 E-06	1.12 E-06	8.00 E-07	-3.50 E-07	-9.60 E-07
StD	0.010	0.012	0.015	0.022	0.010	0.011	0.010	0.009
EO Untaped	1							
EC Untaped	0.999	1						
EO Taped	0.982	0.976	1					
EC Taped	0.937	0.925	0.981	1				
EO Untrained	0.988	0.991	0.949	0.878	1			
EC Untrained	0.985	0.987	0.947	0.878	0.997	1		
EO Trained	0.930	0.940	0.858	0.753	0.975	0.972	1	
EC Trained	0.957	0.961	0.900	0.811	0.987	0.992	0.991	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Wide) is displayed in *Figure n° 891* from which it can be seen that muscle activity for the tibialis anterior muscle in Double-leg balance almost the same for all test conditions, with the exception of the Taped test condition.

Figure n° 891 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Wide)



Separation into the taping (*Figure n° 892*) and training (*Figure n° 893*) groups shows the difference more clearly. An increase in muscle activity is evident with taping, but no difference is apparent within the taping conditions between eyes open and eyes closed visual conditions.

In the training group there is virtually no difference either between conditions of Untrained and Trained or within those test conditions between visual conditions.

Figure n° 892 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Wide) in the Taping Group

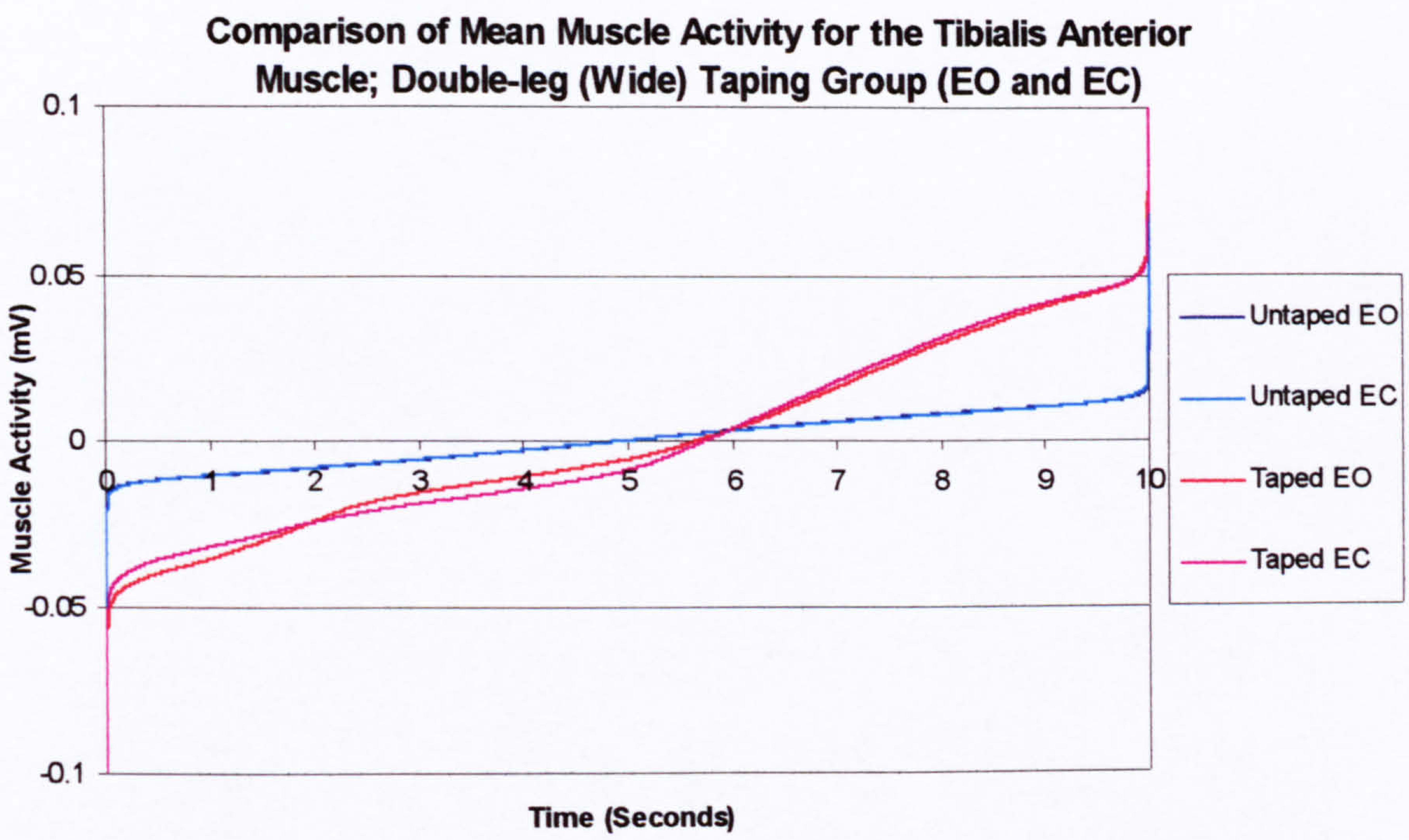
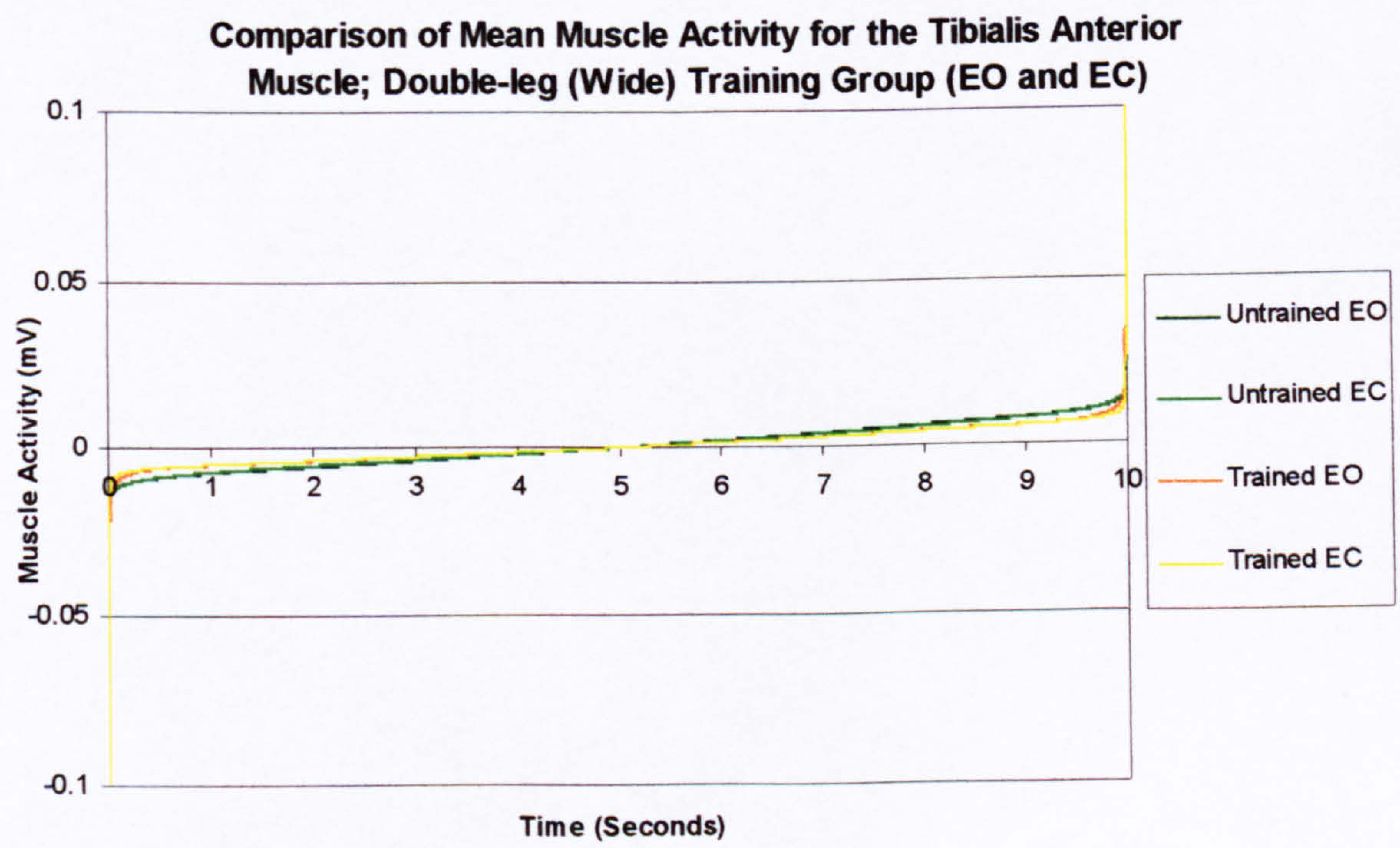


Figure n° 893 Mean Muscle Activity (mV) for the Tibialis Anterior Muscle Double-leg (Wide) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.104* or between the groups as analysed by independent t-tests *Table n° 8.105*. In the case of Double-leg (Wide) all test conditions have a relatively high degree of correlation as presented in *Table n° 8.106*.

Table n° 8.104 Paired t-test Analysis on Double-leg (Wide) Within Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.269	0.674	0.260	0.049
p-Value	0.788	0.500	0.795	0.960
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.013	0.069	-0.054	-0.085
p-Value	0.990	0.945	0.956	0.932

EO = Eyes Open EC = Eyes Closed

Table n° 8.105 Independent t-test Analysis on Double-leg (Wide) Between Groups for Mean EMG Results of Ten Second Balance Trials; Tibialis Anterior Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.022	0.020	0.015	-0.040
p-Value	0.982	0.984	0.988	0.968

EO = Eyes Open EC = Eyes Closed

Table n° 8.106 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Wide); Tibialis Anterior Muscle

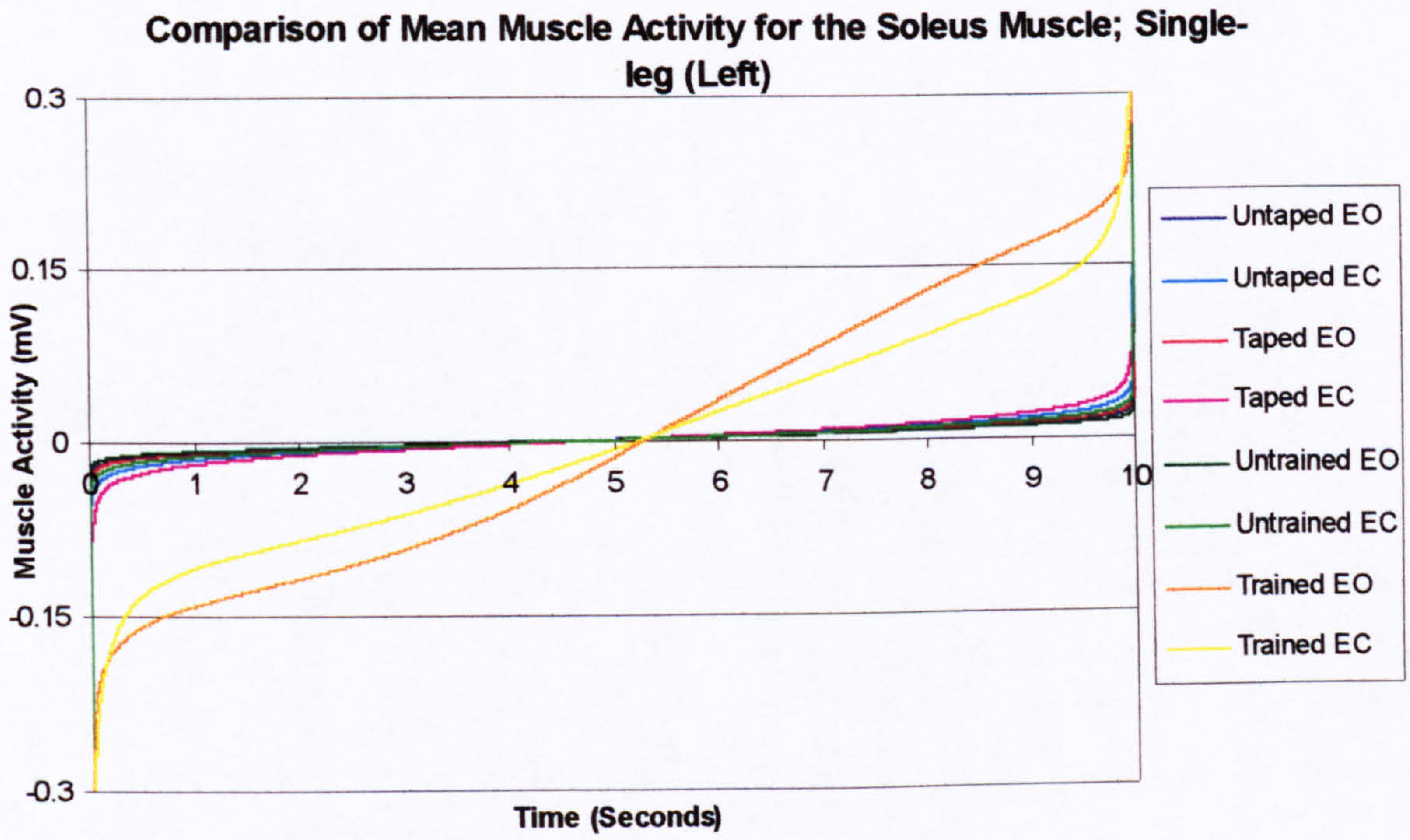
Test Condition	***EO Untaped***	***EC Untaped***	***EO Taped***	***EC Taped***	***EO Untrained***	***EC Untrained***	***EO Trained***	***EC Trained***
Mean	2.82 E-06	1.61 E-06	5.31 E-06	-1.20 E-05	-3.90 E-07	-1.30 E-06	6.95 E-07	1.56 E-07
StD	0.011	0.010	0.029	0.029	0.010	0.010	0.010	0.009
EO Untaped	1							
EC Untaped	0.999	1						
EO Taped	0.927	0.935	1					
EC Taped	0.919	0.926	0.996	1				
EO Untrained	0.978	0.973	0.840	0.829	1			
EC Untrained	0.972	0.967	0.827	0.816	0.999	1		
EO Trained	0.921	0.914	0.727	0.715	0.981	0.986	1	
EC Trained	0.931	0.923	0.741	0.730	0.986	0.990	0.999	1

StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

8.4.2.4 Soleus – Mean Ten Second Balance Results

Comparison of the eight test conditions for Single-leg (Left) is displayed in *Figure n° 894* from which it can be seen that muscle activity for the soleus muscle in single-leg balance does not differ greatly, with the exception of the Trained test condition.

Figure n° 894 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Left)



Separation into the taping (*Figure n° 895*) and training (*Figure n° 896*) groups reveals an increase in muscle activity on closing the eyes in the taping group. There is also a slight increase in activity with taping for both visual conditions within the taping group.

The training group also shows an increase in muscle activity Trained compared to Untrained, but there is less muscle activity in the eyes closed Trained condition than the eyes open.

Figure n° 895 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Left) in the Taping Group

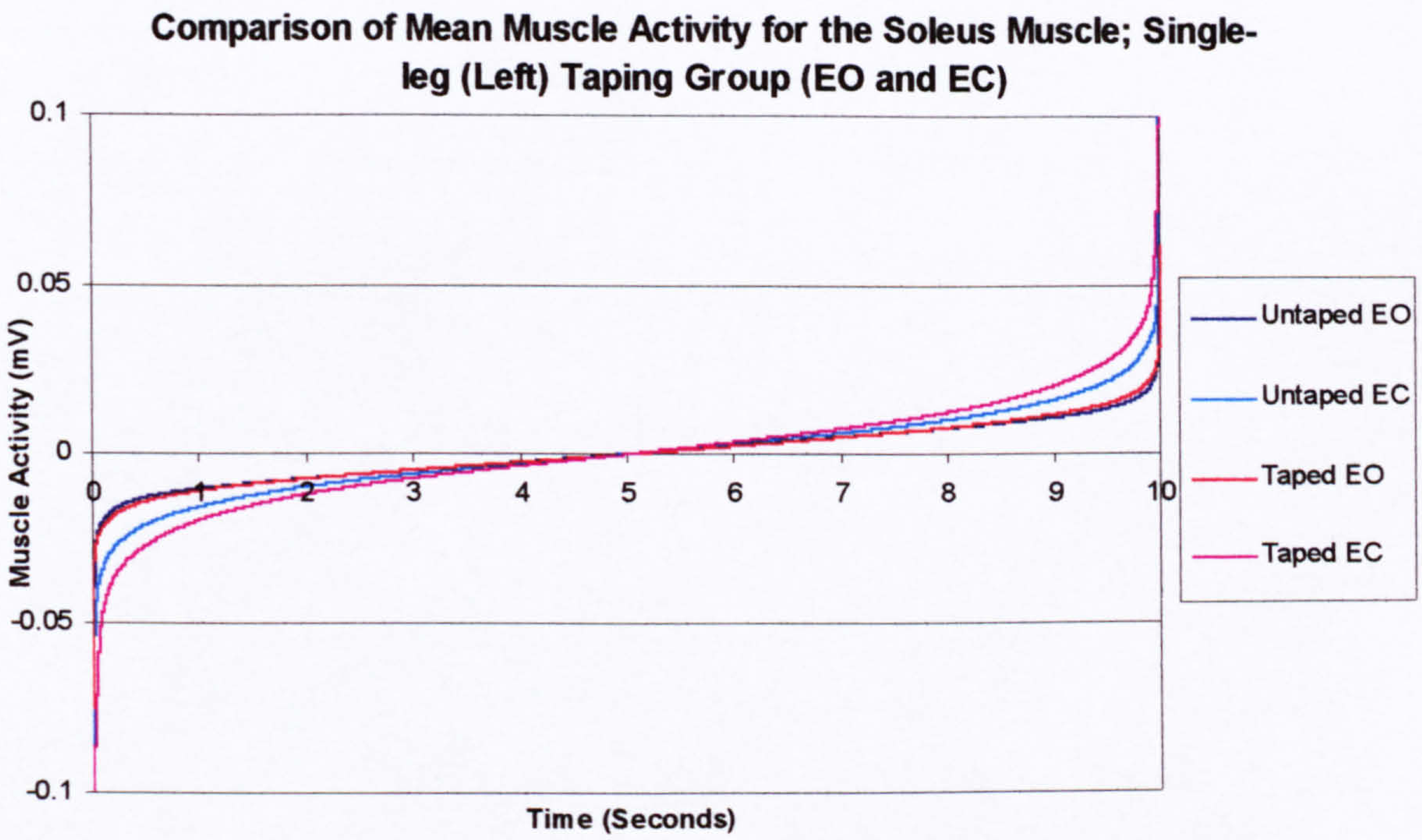
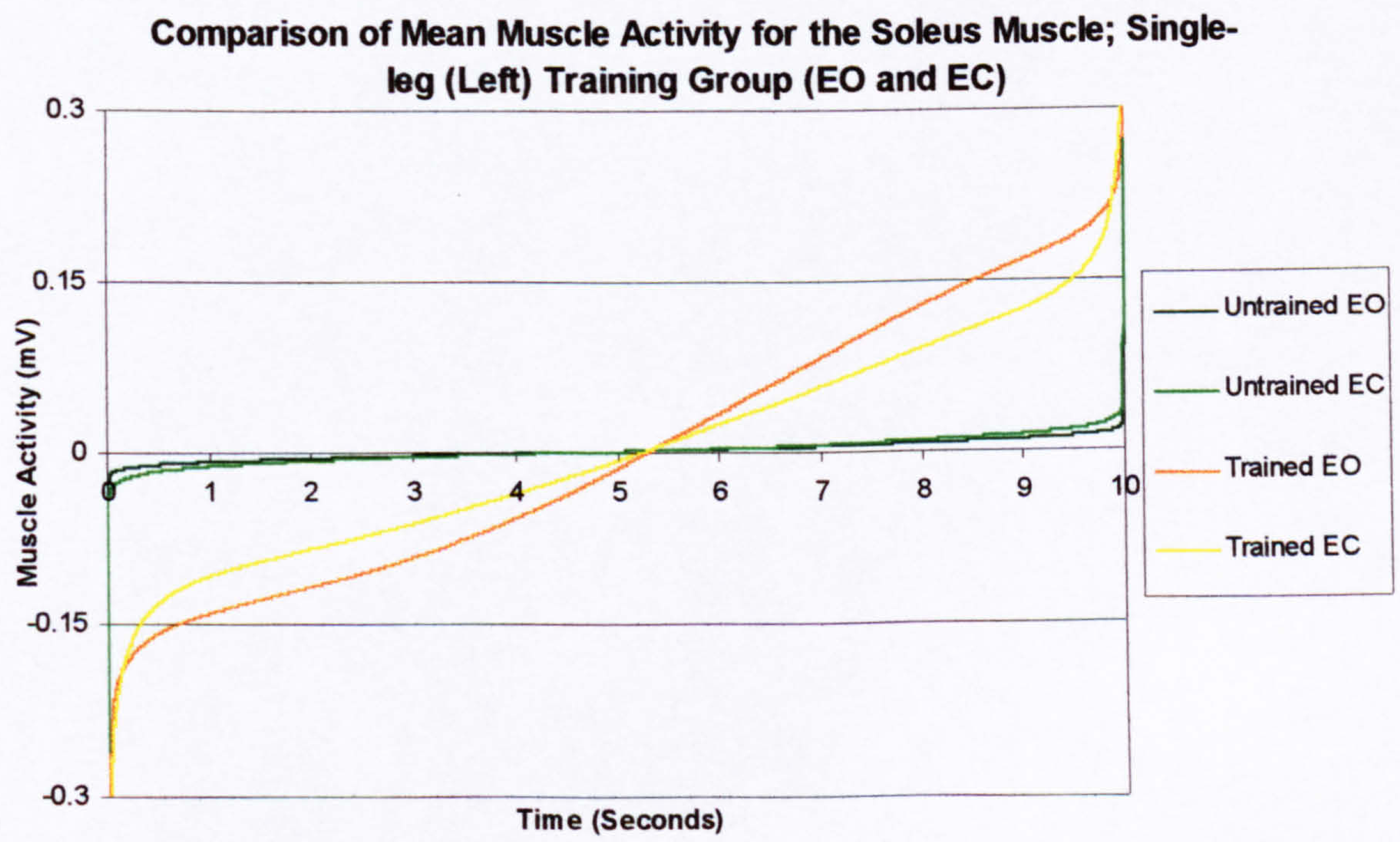


Figure n° 896 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Left) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.107* or between the groups as analysed by independent t-tests *Table n° 8.108*.

Table n° 8.107 Paired t-test Analysis on Single-leg (Left) Within Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle (p < 0.05 for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.122	0.053	-0.424	-0.136
p-Value	0.903	0.958	0.672	0.892
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.913	0.985	0.176	0.207
p-Value	0.361	0.9325	0.860	0.836

EO = Eyes Open EC = Eyes Closed

Table n° 8.108 Independent t-test Analysis on Single-leg (Left) Between Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle (p < 0.05 for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.303	0.241	0.043	0.008
p-Value	0.762	0.809	0.966	0.993

EO = Eyes Open EC = Eyes Closed

For the soleus muscle, not all test conditions show a high degree of correlation and as presented in *Table n° 8.109* low correlation is seen between Untaped and Taped, Untaped and Trained, Taped and Untrained and Untrained and Trained.

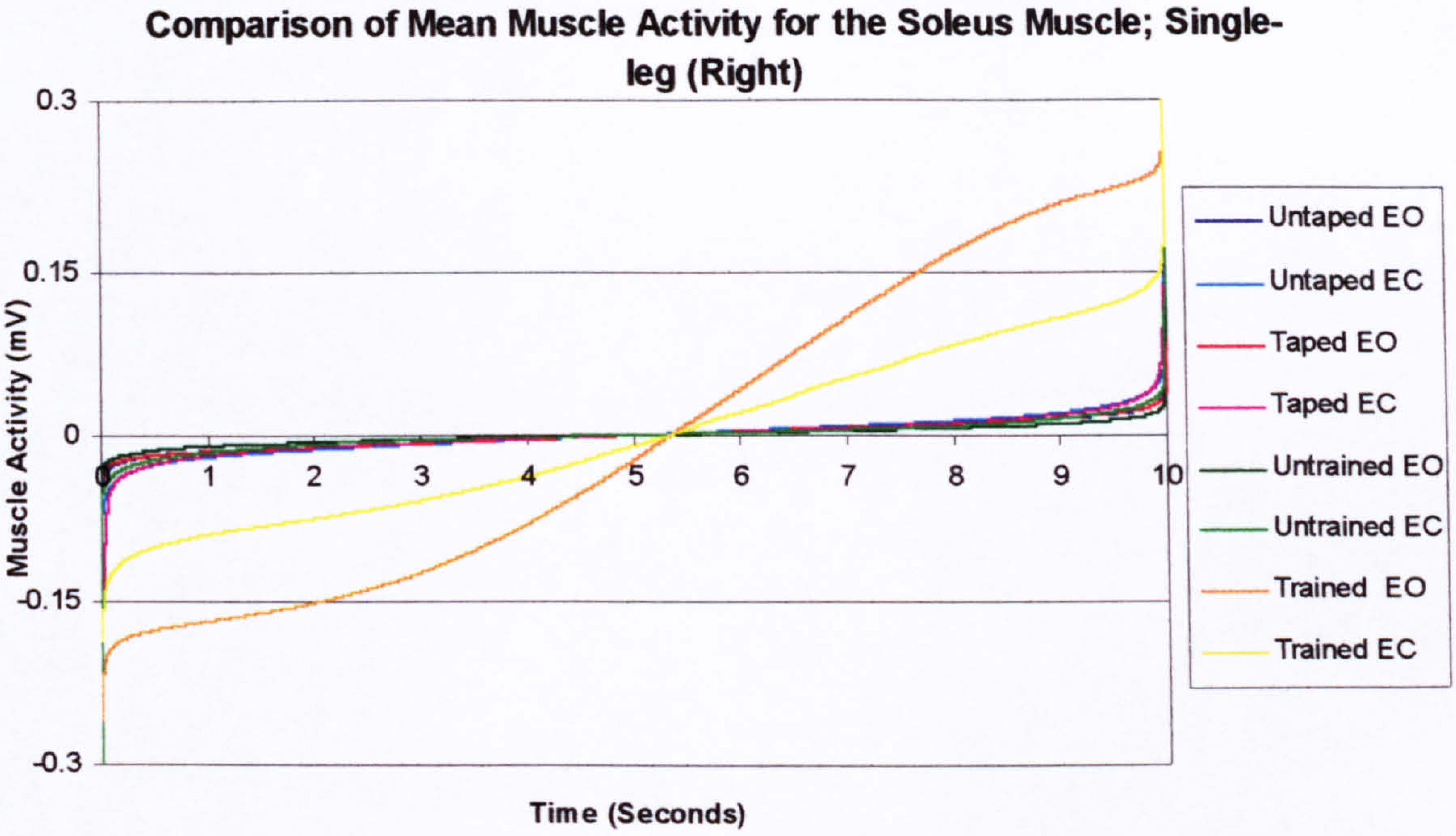
Table n° 8.109 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Left); Soleus Muscle

Test Condition	***EO Untaped***	***EC Untaped***	***EO Taped***	***EC Taped***	***EO Untrained***	***EC Untrained***	***EO Trained***	***EC Trained***
Mean	0.0003	0.0003	4.16 E-06	-4.5 E-07	0.0001	0.0002	-4.7 E-05	-7.8 E-06
StD	0.030	0.032	0.009	0.018	0.018	0.022	0.118	0.095
EO Untaped	1							
EC Untaped	0.991	1						
EO Taped	0.411*	0.524*	1					
EC Taped	0.446*	0.559*	0.986	1				
EO Untrained	0.994	0.999	0.508*	0.537*	1			
EC Untrained	0.976	0.996	0.595*	0.625*	0.994	1		
EO Trained	0.350*	0.456*	0.974	0.929	0.447*	0.529*	1	
EC Trained	0.397*	0.508*	0.996	0.975	0.493*	0.579*	0.987	1

* = Low Correlation
StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Single-leg (Right) is displayed in *Figure n° 897* from which it can be seen that muscle activity for the soleus muscle in single-leg balance is virtually the same for all test conditions, with the exception of the Trained group.

Figure n° 897 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Right)



Separation into the taping (*Figure n° 898*) and training (*Figure n° 899*) groups reveals virtually no change in muscle activity between Untaped and Taped test conditions, with a slight increase in activity on closing the eyes.

By comparison, in the training group although there is an increase in activity in the Trained group compared to Untrained there is a visible decrease in activity with eyes closed Trained.

Figure n° 898 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Right) in the Taping Group

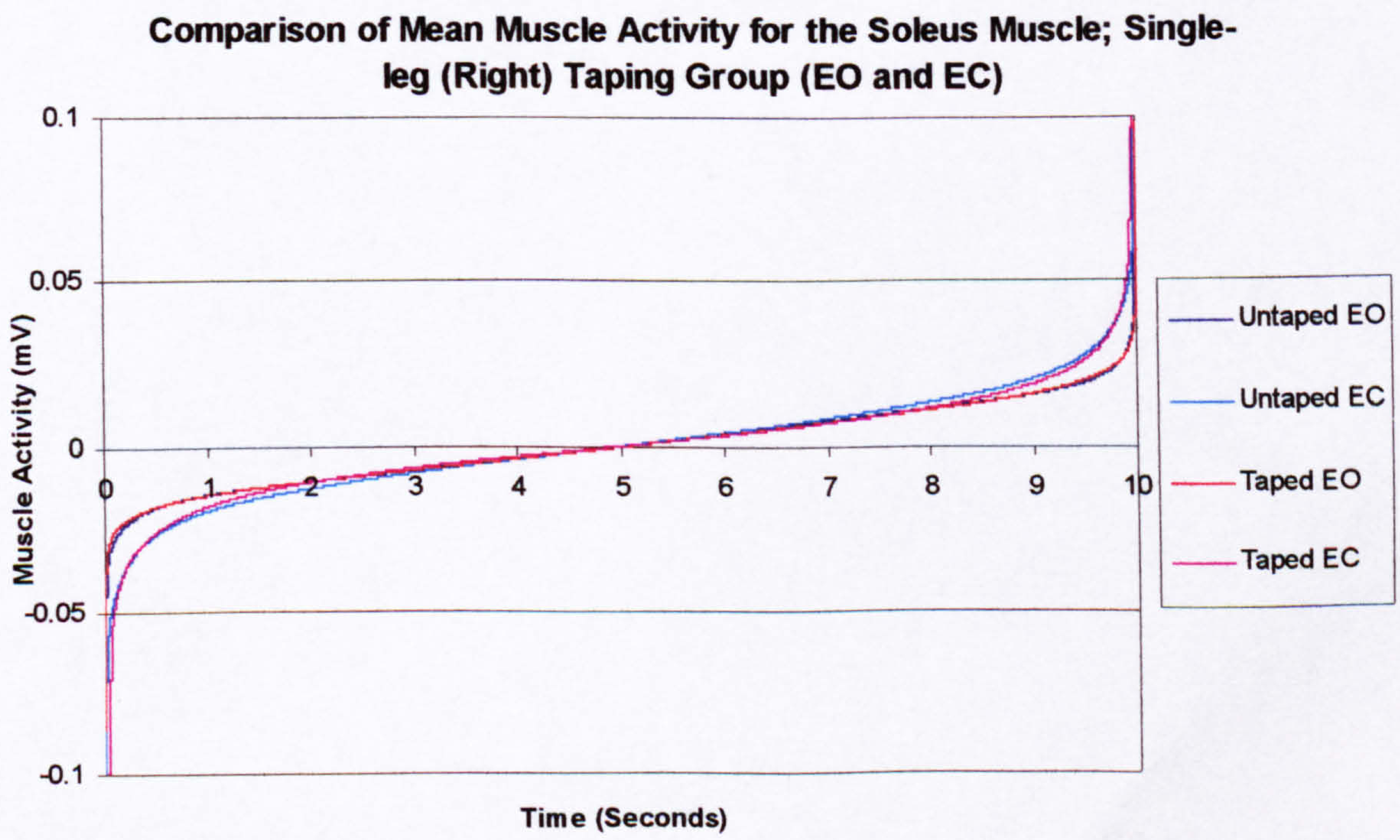
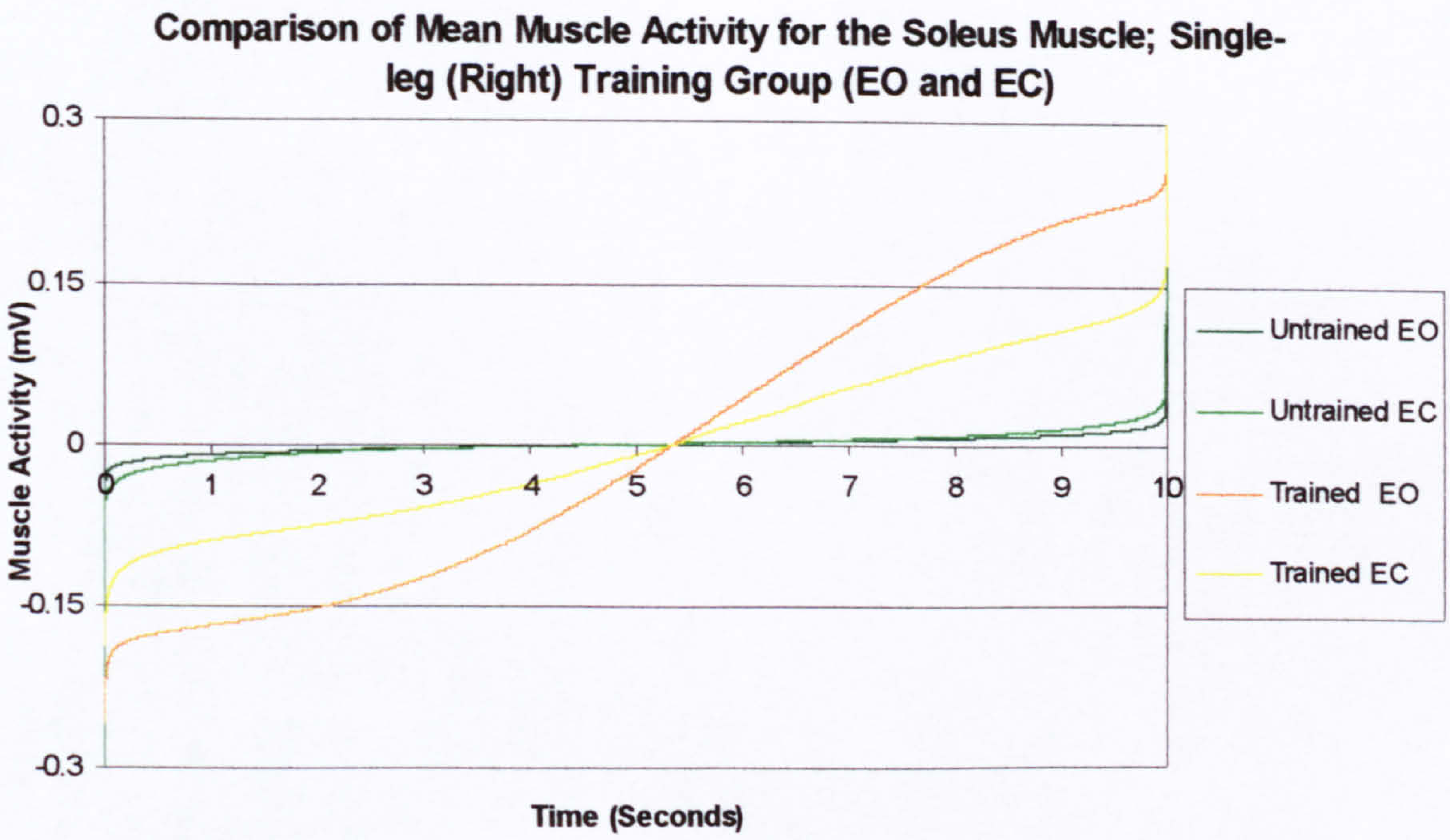


Figure n° 899 Mean Muscle Activity (mV) for the Soleus Muscle Single-leg (Right) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.110* or between the groups as analysed by independent t-tests *Table n° 8.111*.

Table n° 8.110 Paired t-test Analysis on Single-leg (Right) Within Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.142	0.411	-0.680	-0.061
p-Value	0.887	0.681	0.497	0.952
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.973	1.259	0.135	0.294
p-Value	0.331	0.208	0.893	0.769

EO = Eyes Open EC = Eyes Closed

Table n° 8.111 Independent t-test Analysis on Single-leg (Right) Between Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	0.377	0.186	0.034	-0.042
p-Value	0.706	0.853	0.973	0.966

EO = Eyes Open EC = Eyes Closed

For the soleus muscle, not all test conditions show a high degree of correlation and as presented in *Table n° 8.112* low correlation is seen between Untaped and Taped, Untaped and Trained, Taped and Untrained and Untrained and Trained.

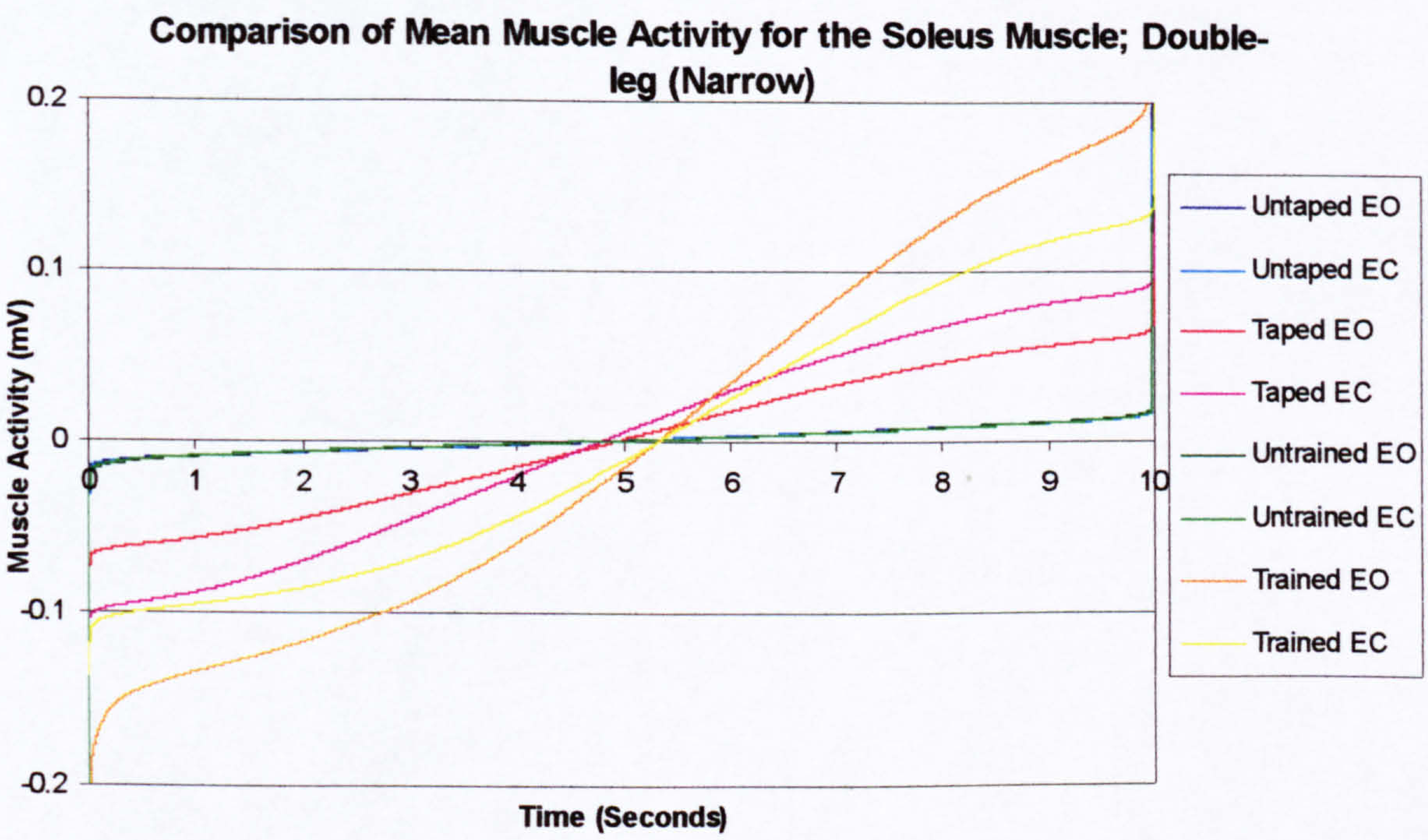
Table n° 8.112 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Single-leg (Right); Soleus Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean	0.0003	0.0003	-4.00 E-06	-4.40 E-05	0.0001	0.0002	-5.30 E-05	-1.20 E-05
StD	0.032	0.034	0.012	0.019	0.017	0.024	0.0143	0.075
EO Untaped	1							
EC Untaped	0.990	1						
EO Taped	0.497*	0.597*	1					
EC Taped	0.628*	0.722*	0.912	1				
EO Untrained	0.992	1.000	0.592*	0.716*	1			
EC Untrained	0.981	0.998	0.623*	0.751*	0.997	1		
EO Trained	0.420*	0.507*	0.964	0.796*	0.502*	0.521*	1	
EC Trained	0.445*	0.537*	0.984	0.841	0.533*	0.556*	0.996	1

* = Low Correlation
StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Narrow) is displayed in *Figure n° 8001* from which the muscle activity for the soleus muscle in Double-leg balance can be seen for all test conditions.

Figure n° 8001 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Narrow)



Separation into the taping (*Figure n° 8002*) and training (*Figure n° 8003*) groups shows the activity more clearly. For the taping group, there is an increase in muscle activity Taped compared to Untaped. There is an increase in activity eyes closed compared to eyes open in the Taped condition, but not in the Untaped condition.

For the training group, there is no difference between eyes open and eyes closed conditions in the Untrained test conditions, however, an increase in activity is seen with training. In contrast to the Taped condition, there is a decrease in activity eyes closed compared to eyes open in the Trained condition.

Figure n° 8002 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Narrow) in the Taping Group

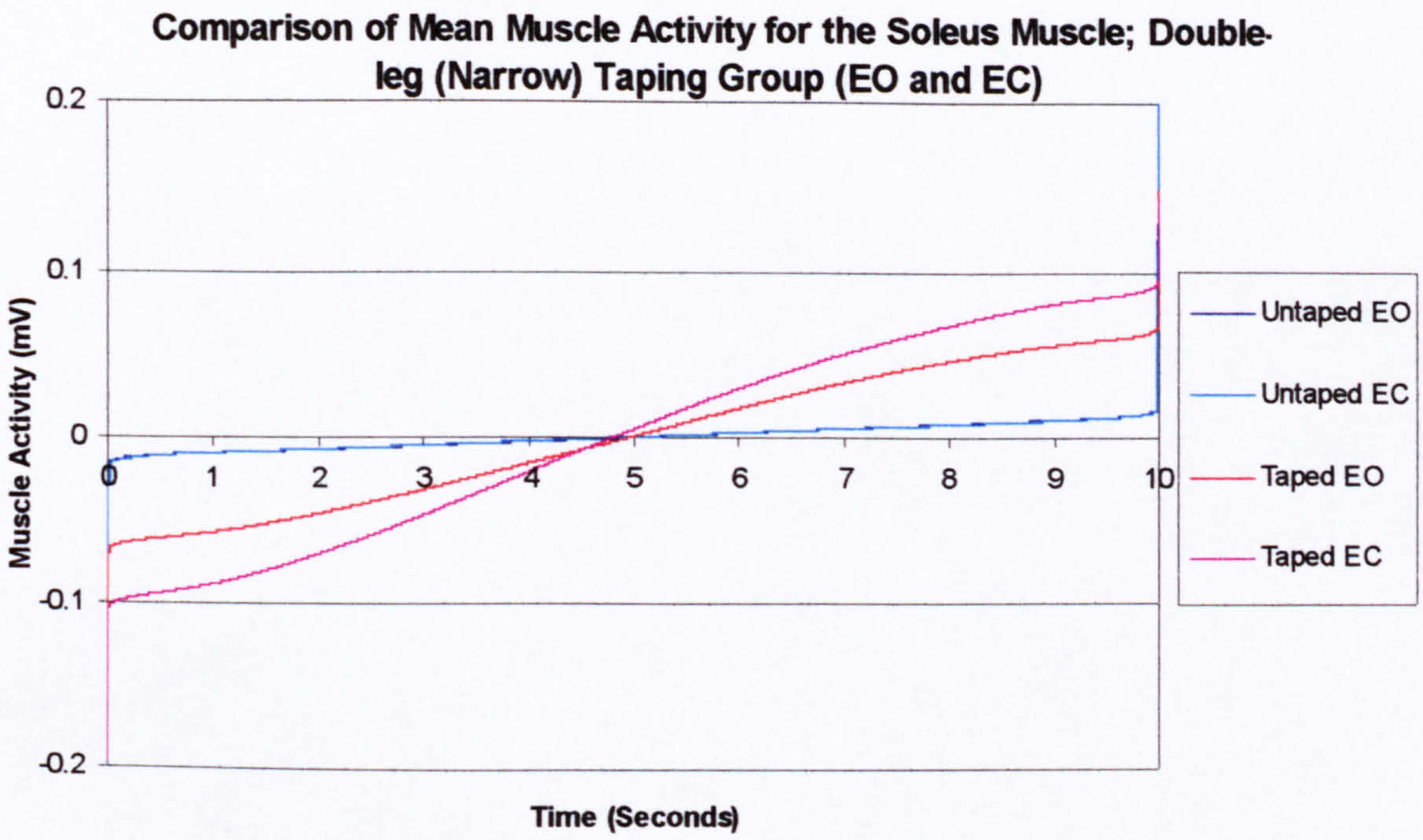
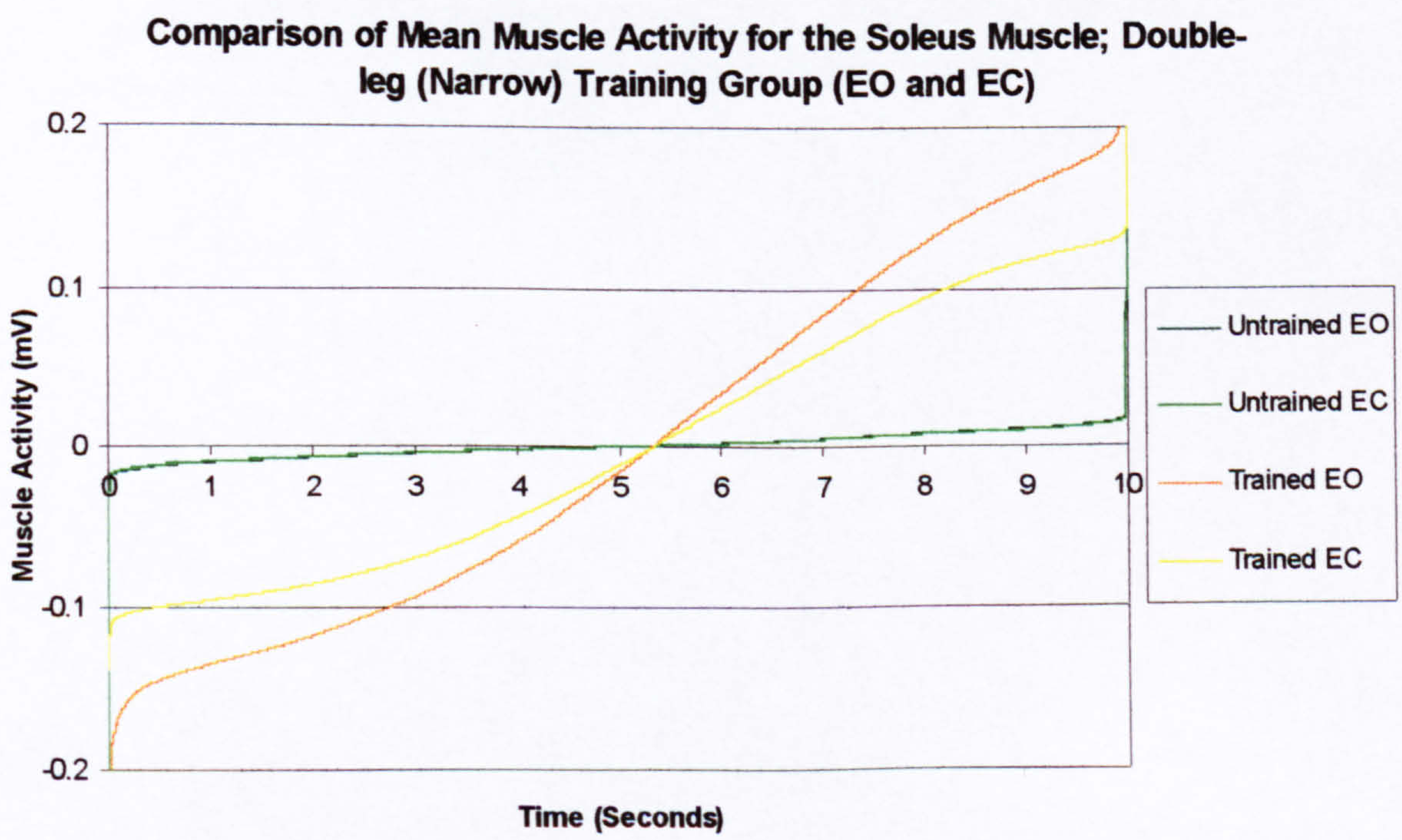


Figure n° 8003 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Narrow) in the Training Group



Statistical analysis of the mean results reveal no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.113* or between the groups as analysed by independent t-tests *Table n° 8.114*.

Table nº 8.113 Paired t-test Analysis on Double-leg (Narrow) Within Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.017	-0.085	0.536	0.027
p-Value	0.986	0.932	0.592	0.978
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	0.030	-0.004	0.001	0.011
p-Value	0.976	0.997	0.999	0.991

EO = Eyes Open EC = Eyes Closed

Table nº 8.114 Independent t-test Analysis on Double-leg (Narrow) Between Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.002	0.002	-0.013	0.011
p-Value	1.000	0.999	0.990	0.991

EO = Eyes Open EC = Eyes Closed

In the case of Double-leg (Narrow) for the soleus muscle, not all test conditions have a high degree of correlation as presented in *Table nº 8.115*, low correlation is seen between Untaped and Taped, Untaped and Trained, Taped and Untrained and Untrained and Trained.

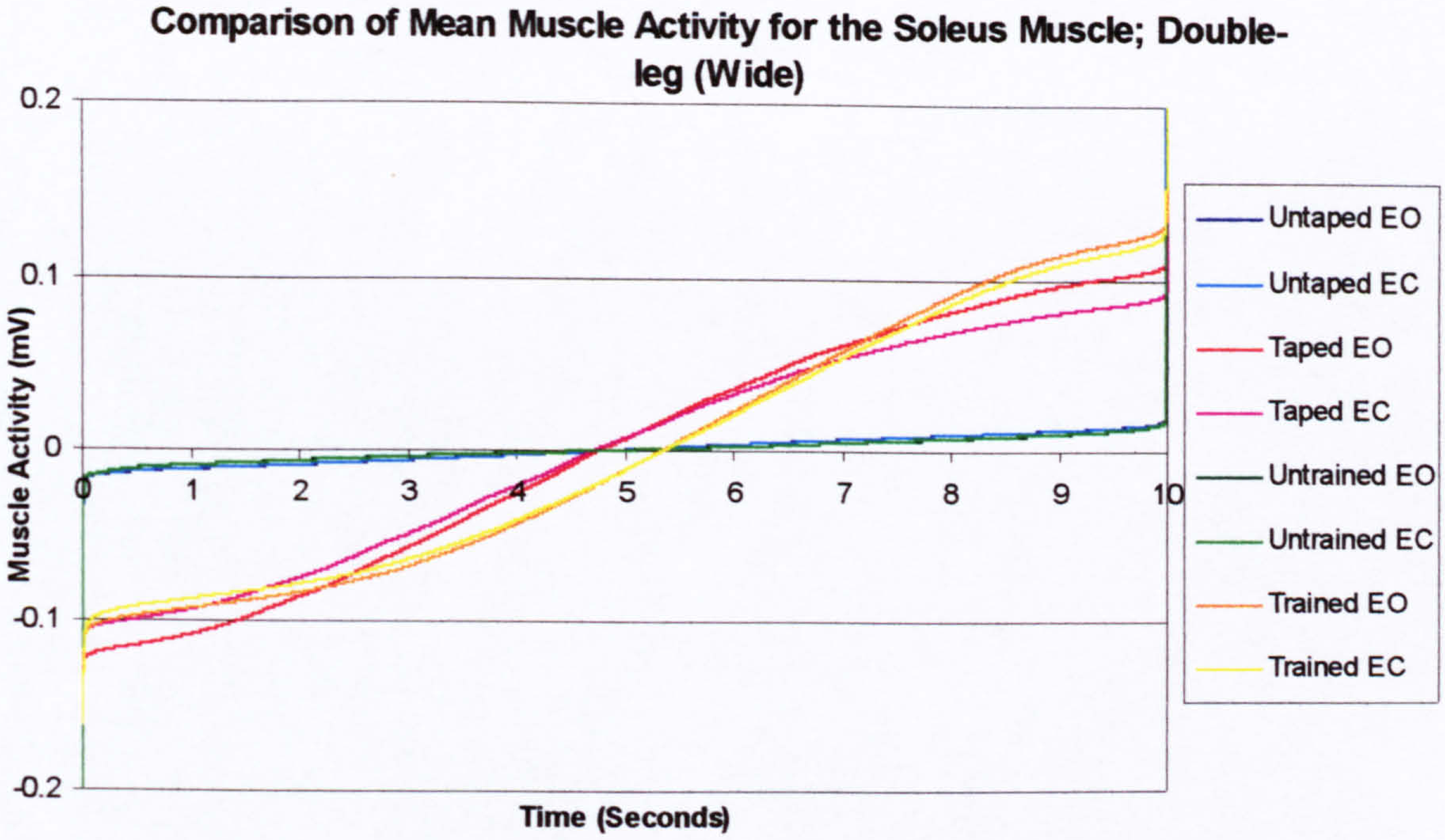
Table n° 8.115 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Narrow); Soleus Muscle

Test Condition	***EO Untaped***	***EC Untaped***	***EO Taped***	***EC Taped***	***EO Untrained***	***EC Untrained***	***EO Trained***	***EC Trained***
Mean	1.74 E-07	8.62 E-07	-1.40 E-05	3.31 E-06	1.84 E-06	5.99 E-08	6.63 E-07	-8.30 E-06
StD	0.046	0.041	0.042	0.062	0.027	0.027	0.113	0.080
EO Untaped	1							
EC Untaped	1.000	1						
EO Taped	0.233*	0.251*	1					
EC Taped	0.225*	0.242*	0.999	1				
EO Untrained	0.993	0.994	0.348*	0.339*	1			
EC Untrained	0.994	0.996	0.338*	0.328*	1.000	1		
EO Trained	0.225*	0.242*	0.993	0.987	0.339*	0.329*	1	
EC Trained	0.213*	0.230*	0.991	0.985	0.326*	0.316*	0.999	1

* = Low Correlation
StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

Comparison of the eight test conditions for Double-leg (Wide) is displayed in *Figure n° 8004* from which it can be seen that muscle activity for the soleus muscle in Double-leg balance the same for Untaped and Untrained test conditions, but markedly different to Taped and Trained test conditions.

Figure n° 8004 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Wide)



Separation into the taping (*Figure n° 8005*) and training (*Figure n° 8006*) groups shows the difference more clearly. An increase in muscle activity is evident with taping and training and within these conditions a slight decrease in activity on closing the eyes.

Figure n° 8005 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Wide) in the Taping Group

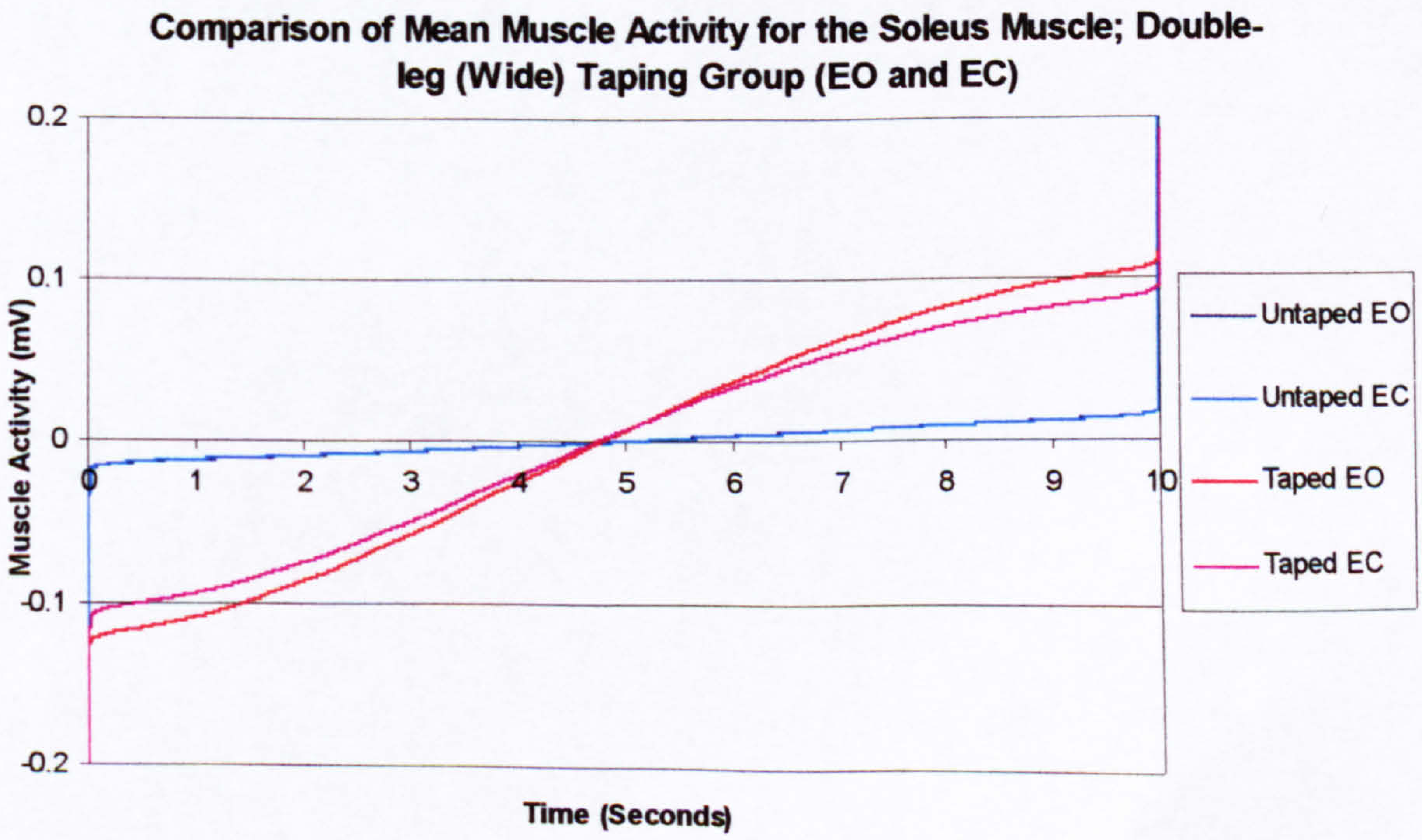
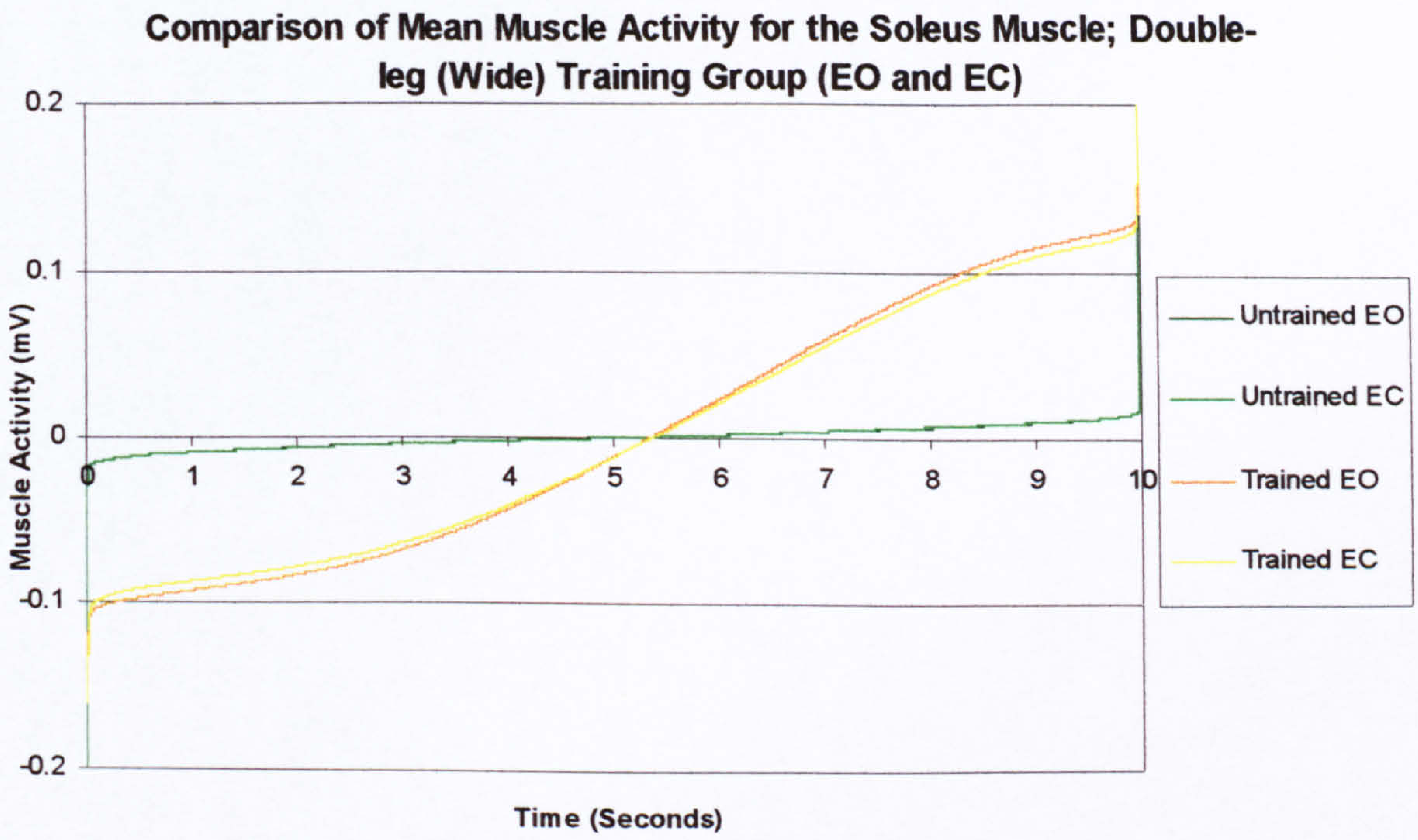


Figure n° 8006 Mean Muscle Activity (mV) for the Soleus Muscle Double-leg (Wide) in the Training Group



Statistical analysis of the mean results show no significant differences within the groups of taping and training as analysed by paired t-tests *Table n° 8.116* or between the groups as analysed by independent t-tests *Table n° 8.117*.

Table n° 8.116 Paired t-test Analysis on Double-leg (Wide) Within Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED Vs EC UNTAPED	EO TAPED Vs EC TAPED	EO UNTRAINED Vs EC UNTRAINED	EO TRAINED Vs EC TRAINED
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.258	0.144	0.269	-0.211
p-Value	0.796	0.885	0.788	0.833
TEST CONDITION	**EO UNTAPED Vs EO TAPED**	**EC UNTAPED Vs EC TAPED**	**EO UNTRAINED Vs EO TRAINED**	**EC UNTRAINED Vs EC TRAINED**
Degrees of Freedom	9999	9999	9999	9999
t-Value	-0.018	0.003	0.015	0.003
p-Value	0.985	0.998	0.988	0.997

EO = Eyes Open EC = Eyes Closed

Table n° 8.117 Independent t-test Analysis on Double-leg (Wide) Between Groups for Mean EMG Results of Ten Second Balance Trials; Soleus Muscle
($p < 0.05$ for Significance)

TEST CONDITION	EO UNTAPED VS EO UNTRAINED	EC UNTAPED Vs EC UNTRAINED	EO TAPED Vs EO TRAINED	EC TAPED Vs EC TRAINED
Degrees of Freedom	19998	19998	19998	19998
t-Value	-0.005	-0.002	0.021	-0.001
p-Value	0.996	0.998	0.983	0.999

EO = Eyes Open EC = Eyes Closed

In the case of Double-leg (Wide) for the soleus muscle, not all test conditions have a high degree of correlation as presented in *Table n° 8.118*, low correlation is seen between Untaped and Taped, Untaped and Trained, Taped and Untrained and Untrained and Trained.

Table n° 8.118 Means, Standard Deviations and Pearson Correlation Results in all Test Conditions for Double-leg (Wide); Soleus Muscle

Test Condition	EO Untaped	EC Untaped	EO Taped	EC Taped	EO Untrained	EC Untrained	EO Trained	EC Trained
Mean	-1.50 E-06	-3.70 E-07	1.29 E-05	-2.50 E-06	1.06 E-06	8.12 E-07	-1.00 E-05	-1.50 E-06
StD	0.047	0.046	0.076	0.065	0.027	0.027	0.078	0.074
EO Untaped	1							
EC Untaped	1.000	1						
EO Taped	0.247*	0.246*	1					
EC Taped	0.258*	0.258*	1.000	1				
EO Untrained	0.997	0.997	0.314*	0.326*	1			
EC Untrained	0.997	0.997	0.316*	0.328*	1.000	1		
EO Trained	0.247*	0.246*	0.984	0.981	0.314*	0.316*	1	
EC Trained	0.254*	0.253*	0.982	0.980	0.321*	0.324*	1.000	1

* = Low Correlation
StD = Standard Deviation
EO = Eyes Open
EC = Eyes Closed

CHAPTER NINE

CHAPTER 9: DISCUSSION

9.1 INJURY DATABASE

Several studies have looked at injury in football, many reporting ankle injuries to be the most frequently occurring. To verify this fact and investigate the pattern of injuries throughout a football season, a survey of injuries occurring at a second division club in the National Football League was conducted over two seasons. From this, a database of injuries was compiled.

9.1.1 Incidence of Injury

The differences between the results of the two periods illustrate the consequences of a change in injury definition. By restricting the recording of an injury to requiring a minimum of three days treatment for the 1997/1998 period, a 60% drop in injury incidence was observed. This emphasises the need for a standardised definition of injury to enable comparison of results between different studies and populations.

Of the total 81 players involved over the two periods, 84% were injured, 98% in the 1996/1997 period and 69% in the 1997/1998 period.

The incidence of injury as a percentage of match or training injuries is comparable to that found in the literature (*Lewin 1989, McMaster 1978, Poulsen 1991*), with 58% of injuries occurring during matches and 42% during training. Analysing this information by team reveals that the First team has a higher level of injury during the match situation than either the Reserve or Youth teams, with 70% of injuries occurring in matches in the First team, compared to 47% in the Youth team. Overall, this illustrates the more aggressive and competitive level of play at the higher level. The lower level of injury in the match situation seen in the Youth team can be attributed to a less aggressive play, with less associated stress than in senior games.

Describing the injury incidence per 1000 hours again demonstrates the higher incidence of injury in the match situation, with a four-fold increase in the incidence of injury in the match situation in 1996/1997 and five-fold increase in 1997/1998 compared to the incidence in training.

The injury incidence over the two periods is comparable with that found in the literature, bearing in mind the variation in level of play and injury definition within the study. With an overall incidence of injury for a player in the club ranging from 1.51 (1997/8) to 2.5 (1996/7) injuries /1000 hours, results are similar to those of *Kibler (1993)* who reported 2.38 injuries /1000 hours, but lower than the incidences reported in other studies. If the results are separated into the different teams comprising the club, and into training and match situations, match incidence of injury levels are comparable to those of *Ekstrand (1983a, 1983b), Engstrom (1990), Luthje (1996)* and *Nielsen (1989)*. In contrast, the level of incidence of injury during training is lower in this study than those in the literature. The higher level of injury during the match situation illustrates the more aggressive and competitive level of play involved. Comparison of the level of play reveals no significant difference between First and Youth teams for overall incidence of injury or for incidence of match injury. However, the incidence of training injury in the Youth team is nearly twice that of the First Team (2.08 injuries /1000 hours versus 1.28 injuries /1000 hours, 1996/1997).

Differences between the studies can be attributed to variations in the definition of injury, the type of period studied (season or tournament), and country of study and level of play, as all are factors influencing the risk of injury.

9.1.2 Type and Location of Injury

As in other studies (*Ekstrand 1983a, 1983b, Kibler 1993, Luthje 1996, McGregor 1995*), injuries to the lower extremity account for the majority of injuries (69%), with 16% of injuries being to the ankle. The commonest types of injuries are sprains and strains, accounting for 63% of all injuries, a result comparable to that in the studies of *Nielsen (1989)* and *Schmidt-Olsen (1991)*. With the high proportion of lower extremity injury, the side of injury was investigated. It was found that there is no significant difference between the side injured.

This study supports the evidence suggesting that ankle injuries comprise the majority of injuries. By attributing injuries incurred to category and severity, despite the high proportion of acute injuries, particularly occurring in the match situation, the majority of them are only minor to moderate in their severity (58%) with the player absent from training and/or matches for less than one month (1997/1998 period). As only 6% of injuries were overuse injuries, these results are analogous to those of *Aranson (1996)* and *Luthje (1996),* who reported values of 9% and 6% respectively.

9.1.3 Causal Factors

For the two periods, less re-injury occurred in the 1997/1998 period, but in both cases 8% of players incurred up to four injuries, the second injuries occurring between one and two months after the first.

9.1.3.1 Player Position Factor Analysis

Analysing the distribution of injuries by player position, assuming a team formation of 1:4:4:2, reveals no statistical significance in injury levels between the positions, confirming statements by both *Engstrom (1990)* and *Luthje (1996)*. However, by examining the location of injury by position, the difference in type of injury occurring at each position is revealed.

In all positions, barring the Goalkeeper, the most frequent site of injury is the lower extremity. More specifically, the ankle (33%) in Forwards, hamstring or knee (22%) in Midfielders and a variety of lower leg injuries (19%) in Defenders. This portrays the subtle difference in skill required for each position and the different demands and risks placed upon players in each position. It also illustrates the susceptibility of the ankle to injury, particularly in the position of Forward where there is a higher level of blocking contact caused by another player.

9.1.3.2 Activity at Time of Injury

Investigating the activity at time of injury reveals that 43% of injuries incurred are due to contact, either with another player, or the field. Tackling (37%) and kicking (6%) cause most contact injuries, confirming results by *Ekstrand (1983a, 1983b)* and *Mackay (1996)*.

9.1.3.3 Periodicity of Injury

As in the literature (*Lewin 1989, Luthje 1996*), peaks of incidence are found at match intensive periods. Also of note are the peaks at the beginning and end of the football season, suggesting low skill and fitness levels at the start and player fatigue, along with less enthusiasm and motivation towards the end, heightening the risk of injury to the player. This places a requirement to investigate the planning and execution of training pre-season and also during the latter stages of the football season. It also highlights the need to schedule matches evenly, to allow players sufficient recovery time between matches, and a reduction of the stresses and strains placed upon the body during match intensive periods.

9.1.3.4 Miscellaneous Injury Factors

As in the majority of studies, extrinsic factors such as the weather and field surface condition did not influence the injury rate, and distribution of injury by day and time is an indicator of training and match scheduling.

9.1.4 Overview

These results confirm reports that ankle injuries are a common injury in football and highlight the need for prophylactic measures to be implemented. Thus, the next step in the process was to investigate the effect of prophylactic measures upon performance, as neither player nor club will be inclined to use any form of prophylaxis that is likely to impair this.

9.2 ATHLETIC PERFORMANCE

External supports have been reported to have differing effects upon performance in jumping, sprint or shuttle activities, dependent upon the type of support tested. This being the case, it is difficult to conclude whether particular movement patterns are affected by external support of the ankle.

This study set out to investigate whether taping or proprioceptive training the ankle affected performance using the same performance tests that have previously shown contrasting results.

9.2.1 Vertical Jump Performance

Results for vertical jump performance show less variance of result within the Taped condition (33.35) than either the Untaped/Untrained (39.74) or the Trained (37.96) conditions. This indicates a dampening of the performance ability with ankles taped.

Statistical analysis by ANOVA reveals a significance at the 0.05 level ($p = 0.039$) for vertical jump. However, the Maulchly Sphericity Test to evaluate the homogeneity of covariance assumption was significant, ($p < 0.05$) and so the more conservative test of epsilon corrected Greenhouse-Geisser was implemented, revealing significance at the 0.1 level, but not the 0.05 level.

Paired t-test confidence intervals analysing the change in performance caused by test condition confirm the ANOVA finding of significance $0.05 < p < 0.1$ for Untaped versus Taped and Untrained versus Trained conditions. This confirms findings of studies by *Burks (1991), Juvenal (1972), Mackean (1995), Mayhew (1972)* and *Paris (1992).*

Examination of percentage differences in performance for vertical jump shows these significant differences to be an overall decrease in performance; 1.46% Taped and 0.66% Trained as compared to Untaped/Untrained. These values are similar to those of previous investigators, such as *Burks (1991)* who found a 4% decrease, *Mackean (1995)* a 1.59% decrease and *Paris (1992)* a 2.4% decrease.

By player position, no significant differences in athletic performance are seen between positions for vertical jump. Within positions, however, midfield players reveal significant differences between Untaped versus Taped and Untrained versus Trained conditions. An explanation for this could be the nature of the playing position and skills required. There would be less need for vertical jumping ability in this position than for a defender or forward. An external factor may therefore influence this performance because it is less well practiced for players in this position.

9.2.2 Broad Jump Performance

Results for broad jump performance show a greater variance of results than those for vertical jump. Within the Untaped/Untrained condition, the variance of results is 145.31, Taped 116.01 and Trained 80.13.

Statistical analysis by ANOVA revealed no significance ($p < 0.05$) between test conditions, a comparable result to that of *Burks (1991)*. Broad jump did however show significance at the 0.1 level between Untaped and Taped conditions as revealed by paired t-test analysis ($p = 0.074$). On examination of the percentage differences in performance for broad jump a decrease in performance is seen between all conditions, though greatest in the Taped condition (0.64%), a fact also reported by *Mayhew (1972)*.

Inspection of correlation coefficients and the resultant scatterplot for broad jump revealed a high correlation between the Untaped and Taped conditions (0.97), but low correlation between Untrained versus Trained and Taped versus Trained conditions; thus the results for training are less reliable for comparison than those for taping.

By player position, significance was found between forward and midfield players for broad jump performance (Taped). However, no significance was seen for any position by test condition.

9.2.3 Sprint Run Performance

Results for sprint run performance reveal no differences in variance. Statistical analysis by ANOVA and paired t-tests also result in no significant differences between test conditions at the 0.05 level.

Examination of percentage differences show a decrease in performance between condition, but these can be termed negligible for overall effect.

Inspection of correlation coefficients and the resultant scatterplot for sprint run show a high correlation (0.80 to 0.99) between test conditions, but not within either Untaped/Untrained or Taped trials as revealed by outliers on the scatterplot at the faster run times. These values are not sufficient to cause a significant effect.

No significance was seen for performance by test condition either between or within positions for sprint run.

9.2.4 Shuttle Run Performance

As with sprint run, shuttle run performance results reveal no differences in variance or significance by statistical analysis between test conditions at the 0.05 level.

Examination of percentage differences in performance reveals a decrease in performance with taping (21%), but no change with training. Although *Burks (1991)* reported that taping decreased performance of the shuttle run and sprint run, research by *Mayhew (1972) and Thomas (1971)*, along with this study, indicates that taping has no effect on sprinting or shuttle run performance.

Inspection of correlation coefficients and the resultant scatterplot show a high correlation of results between condition (0.93 to 0.98), but a low correlation between trials within Untaped and Taped conditions as indicated by outliers on the scatterplot. Again, these are not sufficiently disassociated to cause a significant effect upon performance.

By player position, significance is seen within the forward position between Taped and Trained conditions ($p = 0.046$).

9.2.5 Subjective Questionnaire for Taping

Subjects found the taping moderately comfortable, offering a fairly high level of support with 10.5% of subjects feeling that the tape enhanced their performance and 36.8% not thinking that taping affected their performance.

9.2.6 Overview of Athletic Performance Study

These results suggest that overall, neither taping nor training restricted or altered the foot and ankle motion that is required to perform the functional tasks. Along with previous research (*Burks 1991, Juvenal 1972, Mackean 1995, Mayhew 1982, Paris 1992, Thomas 1971*), this study indicates that the application of tape results in a decrease in performance for functional tasks. However, it is also agreed that this decrease is insignificant in all cases at the 0.05 level. *Burks (1991) and Mackean (1995)* reported significant differences in performance ability with taping in vertical and broad jump performance, and thus disagree with the previous statement, and although the present study did find significance at the 0.1 level for taping in these tests, so corroborating these results to a degree, it is not felt that this decrease in performance is sufficient to compromise the overall ability of the player.

Some limitations of these research findings should be mentioned, particularly those associated with the subject sample. Non-impaired individuals with no prior ankle injury history served as subjects for the present study. Thus results may not be applicable to patients who have incurred a recent ankle injury and so wear tape and include proprioceptive training as part of their rehabilitative regime. Clarification is required on the impact of these findings on injured players at different stages of treatment and with various histories of ankle injury. In these types of cases, these methods may have a positive effect on functional performance by means of perceived or real improvements in joint stability and proprioception.

The next stage of validation in the process is to investigate the influence of the prophylactic measures on proprioception, which is only one element of ankle function, the other being mechanical effects.

9.3 PROPRIOCEPTION STUDY

Decreases in central nervous system control of postural muscle tone and balance results in decreased reflex patterns and increases in postural sway (*Hasselkus 1975*). The swaying movement, together with concomitant changes in joint position, pressure distribution and states of muscle length and tension, may provide an automatic network of feedback controls designed to equilibrate stresses and maintain upright posture (*Murray 1975*). A high degree of sensorimotor interaction is entailed in containing the vertical projection of the centre of gravity within the areas bounded by the centre of balance. Although one is not conscious of the positions of the centre of gravity or the centre of pressure underfoot, one is well aware of the limits which cannot be exceeded during sustained weight bearing and the muscular responses are automatic.

The dynamic nature of upright stance is such that the centre of pressure underfoot fluctuates incessantly, traversing large total excursions throughout activity, even during the relatively quiescent act of double-leg standing. Apparently, the large total excursions of the centre of pressure result from the constant contraction and relaxation of the supporting muscles in reaction to the body movements.

The characteristics of the base of support determine to what extent the vestibular system is involved; the importance of the proprioceptive system increases when visual information is excluded (*Sahlstrand 1978*).

9.3.1 Postural Stability

Postural equilibrium is maintained by corrections at the ankle with displacement of the ankle and centre of pressure following changes in muscle activity. This study investigated the effect of taping and training on postural control by measurement of sway by the sway index and the left/right and anterior/posterior components of the sway index. Also examined were centre of balance measurements.

It must be borne in mind that these results are generalised only to the subject type population; that is football players.

9.3.1.1 Postural Sway

These results confirm previous findings (*Calmels 1991, Tropp 1984, Watson 1987*) suggesting that external supports, in this case taping, have a detrimental effect on postural control as evidenced by increases in postural sway. This may indicate that to a subject with good posturographic performance, being taped may have a negative effect. Opposing this are findings by *Kozar (1972)* and *Tropp (1988b)* who reported that taping had no effect on postural sway.

This study also found that proprioceptive training impaired postural control, which is in contrast to findings by *Hoffman (1995)* who found a significant decrease of postural sway with proprioceptive training and *Cox (1993)* who found no improvement following a training period in healthy subjects. This was attributed to short training times and the fact the subjects were uninjured. As subjects in the present study were also uninjured, if the findings from it had agreed with those of *Cox (1993)* it could have been suggested that subjects simply had no room for improvement. However, this was not the case and dissimilar results were observed.

Both taping and proprioceptive training may alter the nature or amount of proprioceptive input to the CNS (*Bennell 1994*), and this may be in the form of inaccurate, conflicting or overwhelming stimulation of the cutaneous receptors and/or a change in muscle activation patterns.

Increased sway with eyes closed confirms the strong stabilising influence of vision upon normal human postural control with standing (*Black 1982, Dickstein 1993*). Therefore, in an injured individual, if proprioception is impaired, the eyes closed condition should exacerbate their response.

Single-leg stance makes the base of support much more narrow than normal, and forces the reorganisation of the body's centre of gravity on a line along the only supporting leg. The eyes closed, single-leg stance being most challenging, it was found that results in single-leg stance differentiated between visual and testing conditions better than double-leg stance tests. This reflects the integrity of the proprioceptors, muscle stretch receptors, vestibular system, vision and motor control of postural muscles and activation or active contraction of several muscle groups (*Judge 1993, Patla 1990*). In contrast, double-leg stance does not require substantial strength of activation of muscles.

Postural sway was two to threefold greater when the eyes were closed than when they were open in accordance with *Era (1985)* and again two to threefold greater in single-leg stance than in double-leg stance. It should be borne in mind that maintenance of single-leg stance in the laboratory setting is a relatively easy task compared with the conditions under which posture is required to be controlled during high-speed sporting activities, when the subject may not be able to use the visual system to provide orientation information from the environment.

Confirming results of *Ekdahl (1989)* and *Nichols (1995)*, this study found that single-leg standing balance appeared to be more difficult with the right leg, than the left leg. This was evidenced by larger fluctuations in postural sway when challenged by changing test conditions. There may be several reasons for this, and contrary to the study by *Ekdahl (1989)*, a learning effect is not attributable due to the random ordering of the tests. One reason was thought to be leg dominance, however, as there were equal numbers of subject left and right-leg dominance, this cannot be validated. Other reasons could be the nature of the training that the subjects undergo in football, or the orientation of the investigator to the subject during the balance testing, as in all cases the investigator was stood to the left of the subject thus, balancing on the foot furthest away from sound orientation may have affected the balance strategy. These suggestions cannot however be verified and so further study is required to investigate this occurrence.

The amount of A/P sway was found to be double that of L/R, supporting findings of *Begbie (1969)* and was expected from considerations of the structure of the joints involved.

It is known that taping initially provides structural support, thus preventing excessive movement at the ankle joint. Consequently, this may place ligaments in a more optimal position to allow joint mechanoreceptors to detect perturbations to postural sway and offer enhanced tactile stimulation to the surface of the foot, improving proprioceptive feedback necessary for balance control (*Guskiewicz 1996b*). A repercussion from this may be increased postural sway due to increased muscle activity.

Variation in results could also stem from a repertoire of balance strategies that one can employ while still maintaining the stance position required (*Goldie 1989*). So by altering the proprioceptive mechanism, different balance strategies may be employed, resulting in the increased sway observed when ankles are taped or proprioceptively trained.

One disadvantage of using the sway index as the dependent measure, is the Chattecx Balance Systems' lack of sensitivity to touchdowns. When the subject completely loses balance and touches the contralateral limb down, no measurement is recorded by the force plate. Thus, the touchdowns must either be ignored, or the trial repeated as in this study, which may lead to impaired reliability of the results.

It has also been demonstrated that stance balance tests of healthy subjects which last longer than 15 seconds bear the danger of contamination by artifacts and of biasing measurement of test retest reliability (*Goldie 1989*) but *Cox (1993)* felt that a ten second data collection period may not be long enough to detect changes in a healthy population. Here it was found that a ten-second period was sufficient to detect changes in postural sway.

Neither anthropometric measurements, nor limb dominance were evaluated in this study. *Murray (1967)* reported that height did not affect either centre of gravity or centre of pressure measurements and *Nashner (1982)* stated that due to the relationship between height and foot length, approximately equal limits of stability for individuals of different sizes resulted. In addition to these previous studies, in the present study a repeated-measures analysis was used in which subjects served as their own control. Therefore, variables of height, weight and foot length should not have affected trends. Age has been found to affect postural sway (*Ekdahl 1989, Kollegger 1992, Maki 1987, Murray 1975*). This study evaluated changes in young adults and so age ranges should have no adverse effect.

9.3.1.2 Centre of Balance Positioning

It was expected that any improvement in proprioception would manifest as a movement of centre of balance (COB) co-ordinates to a point nearer zero, the point at which in single-leg stance, the ball and heel of the foot each carry a theoretical 50% of the body weight, and in double-leg stance, the point between the feet at which the ball and heel of each foot carries a theoretical 25% of the body weight (*Chattecx Balance System Literature*).

It was found that closing the eyes in Untaped and Untrained test conditions resulted in a movement of COB away from the central base of support (CBOS) for all cases, with the exception of double-leg (Wide), Untaped. This is illustrated in *Figure n^{os} 91* and *92*.

Index to abbreviations *Figure n°s 91 to 97*.

L = Single-leg (Left)
R = Single-leg (Right)
N = Double-leg (Narrow)
W = Double-leg (Wide)

Figure n° 91 Effect of Closing the Eyes on Centre of Balance in the Untaped Condition

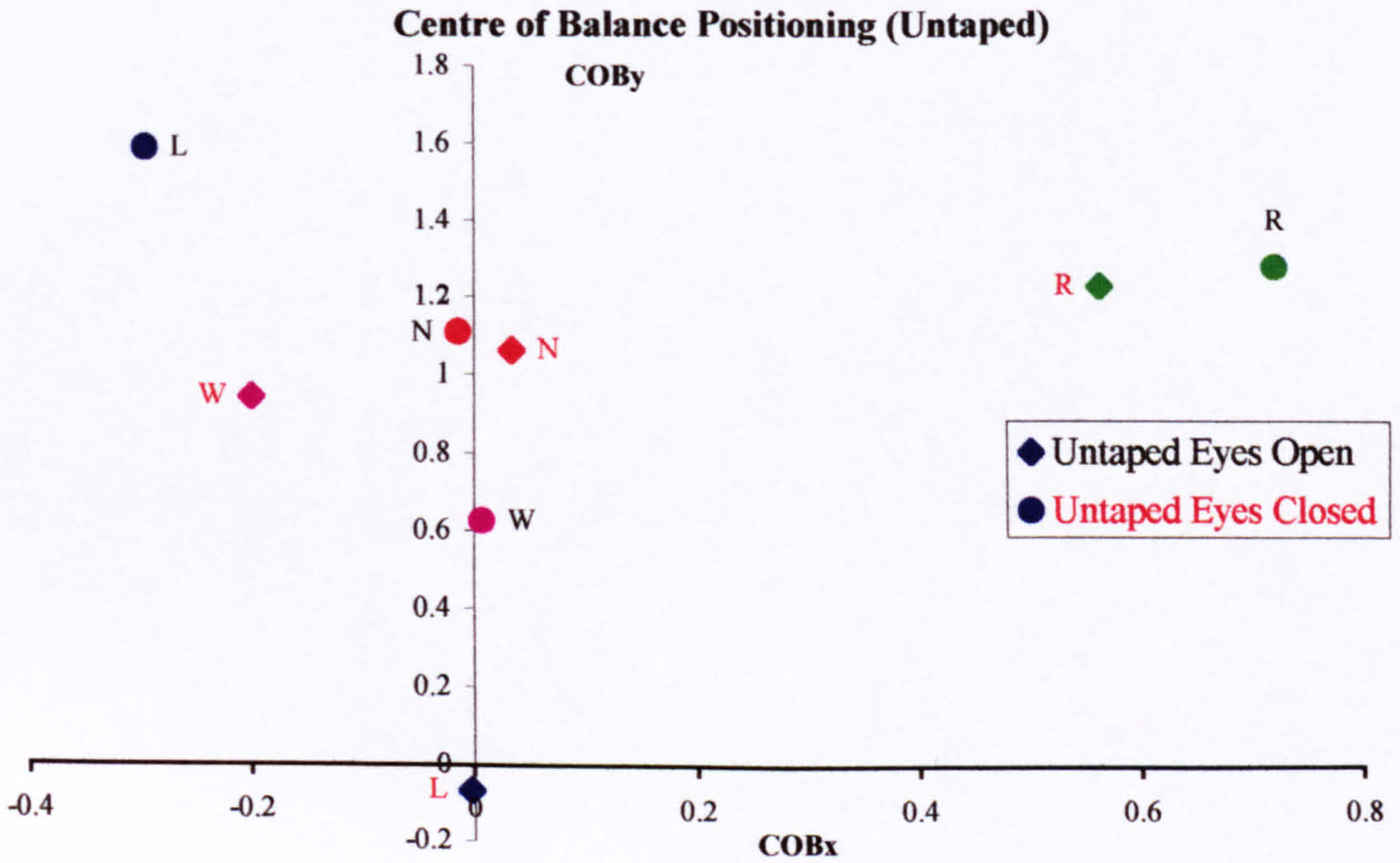
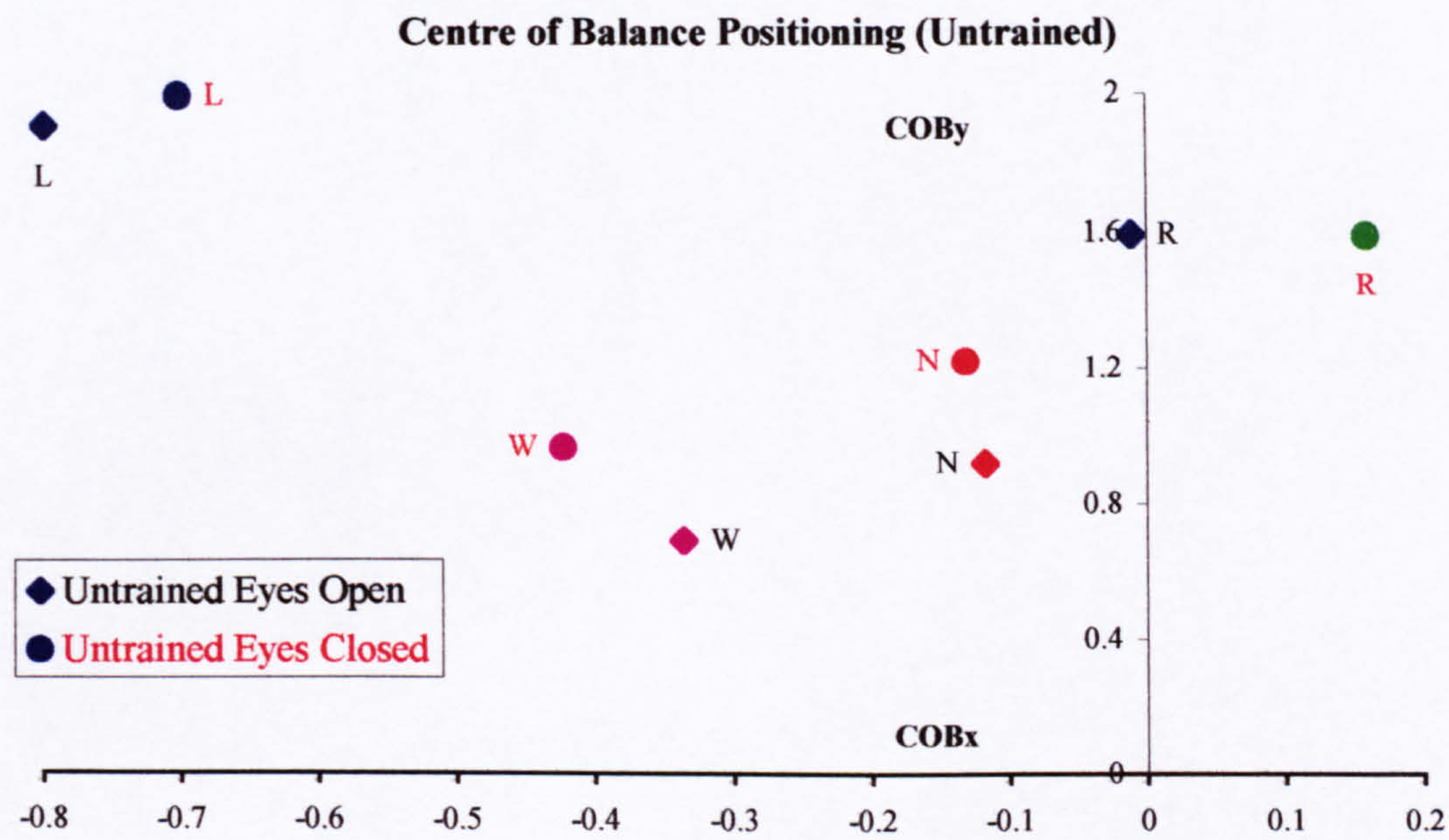


Figure nº 92 Effect of Closing the Eyes on Centre of Balance in the Untrained Condition



In the Taped (*Figure nº 93*) and Trained (*Figure nº 94*) conditions, closing the eyes caused a movement closer to the theoretical CBOS (zero x and y co-ordinates) in all Taped conditions and in the double-leg (Narrow) Trained condition. Closing the eyes in Trained single-leg (Left) and double-leg (Wide) resulted in a movement away from the theoretical CBOS.

Figure nº 93 Effect of Closing the Eyes on Centre of Balance in the Taped Condition

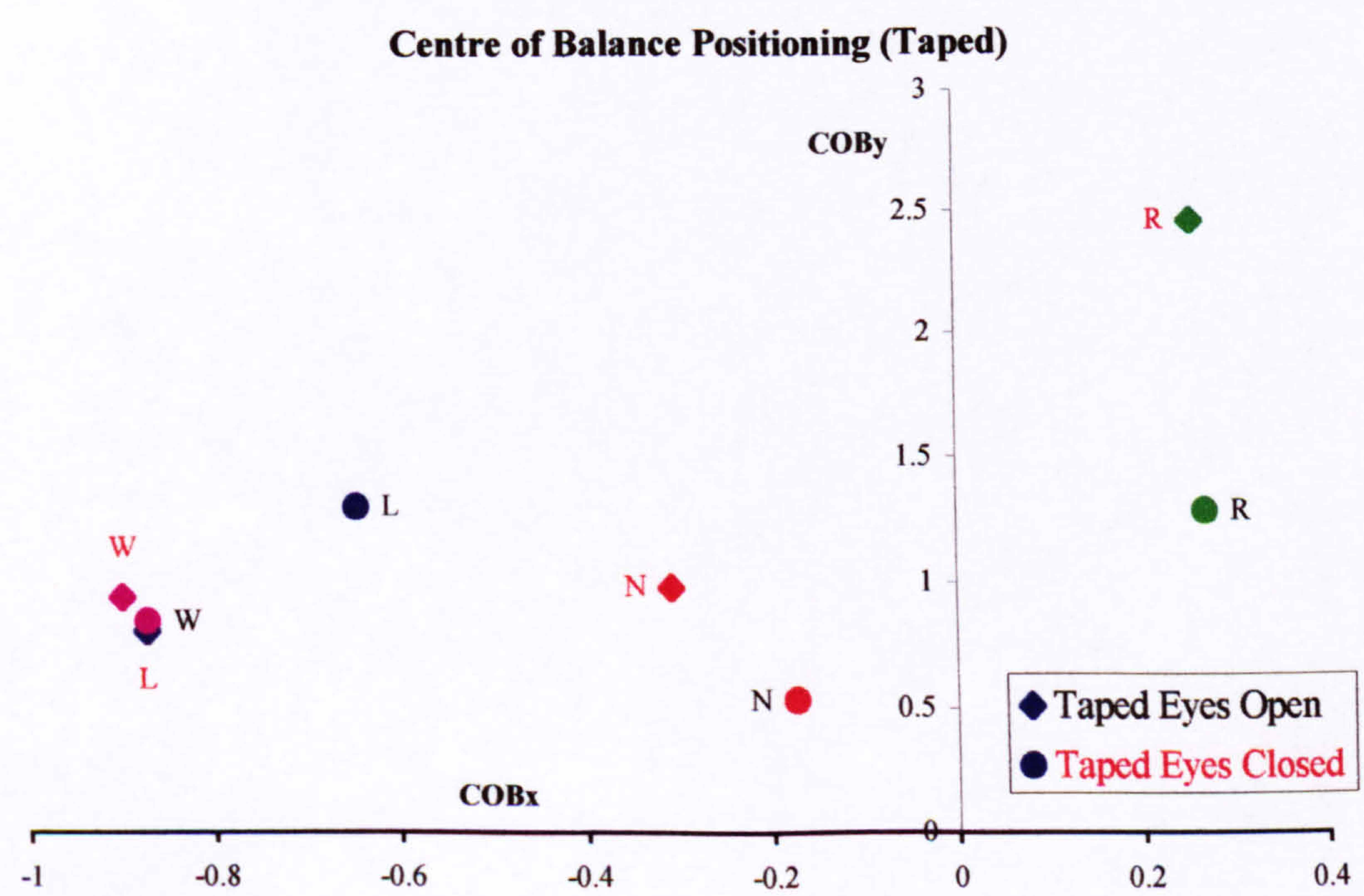
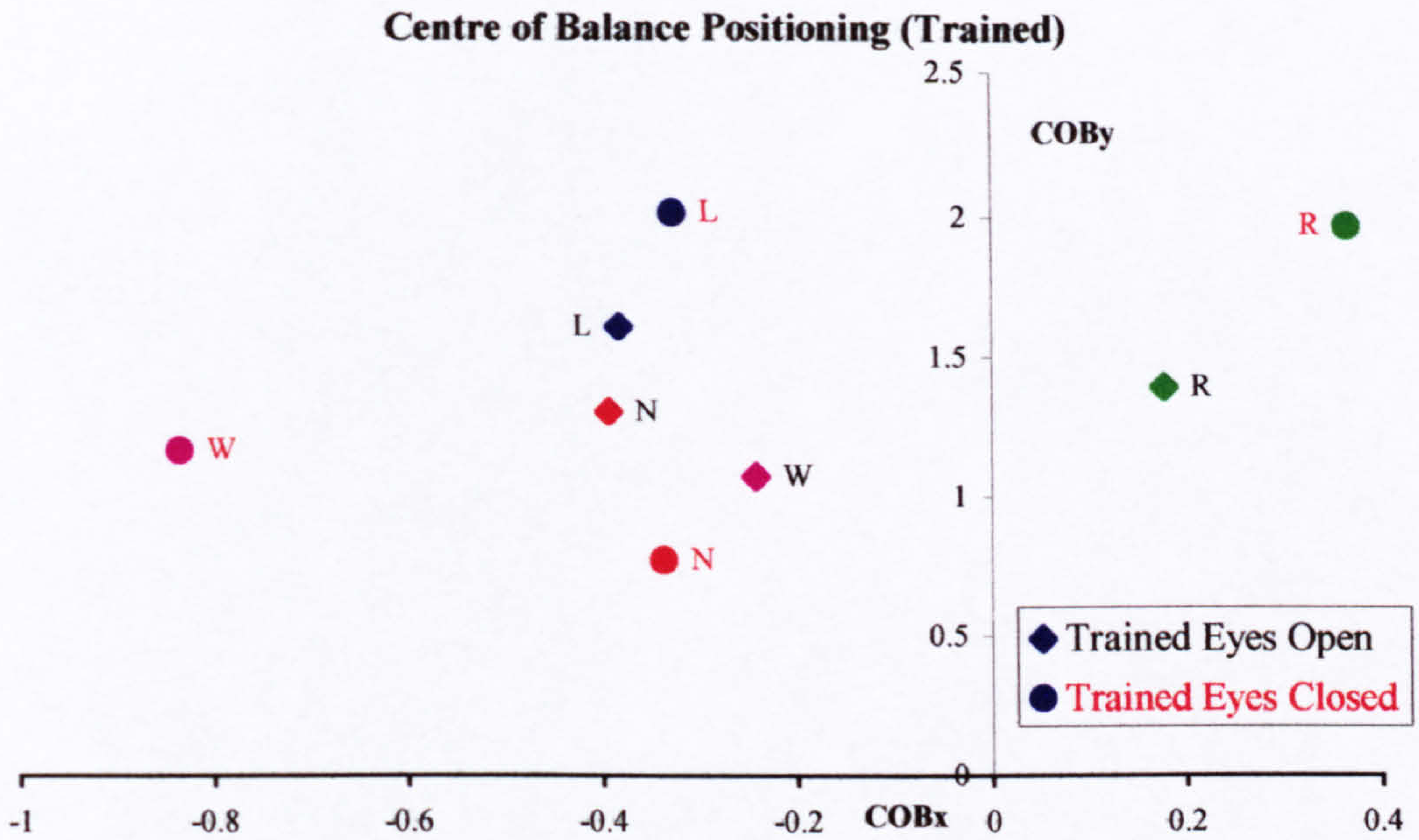


Figure n° 94 Effect of Closing the Eyes on Centre of Balance in the Trained Condition



The overall effect of taping the ankle was seen to result in a shift of COB left along the x-axis *Figure n° 95*, whereas training invoked a shift of COB right for single-leg stance and left for double-leg stance (*Figure n° 96*).

Figure n° 95 Effect of Taping on Centre of Balance Positioning

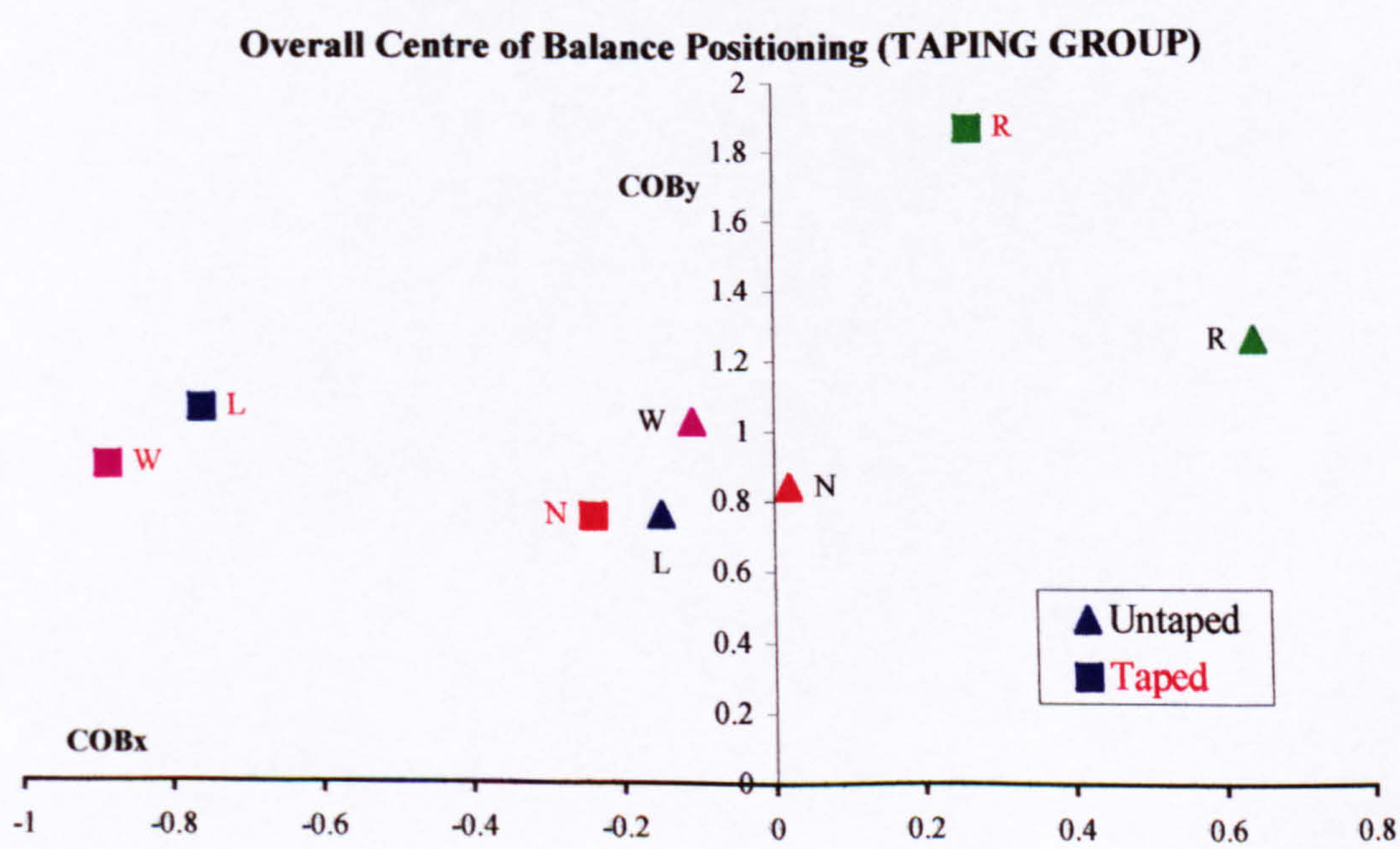
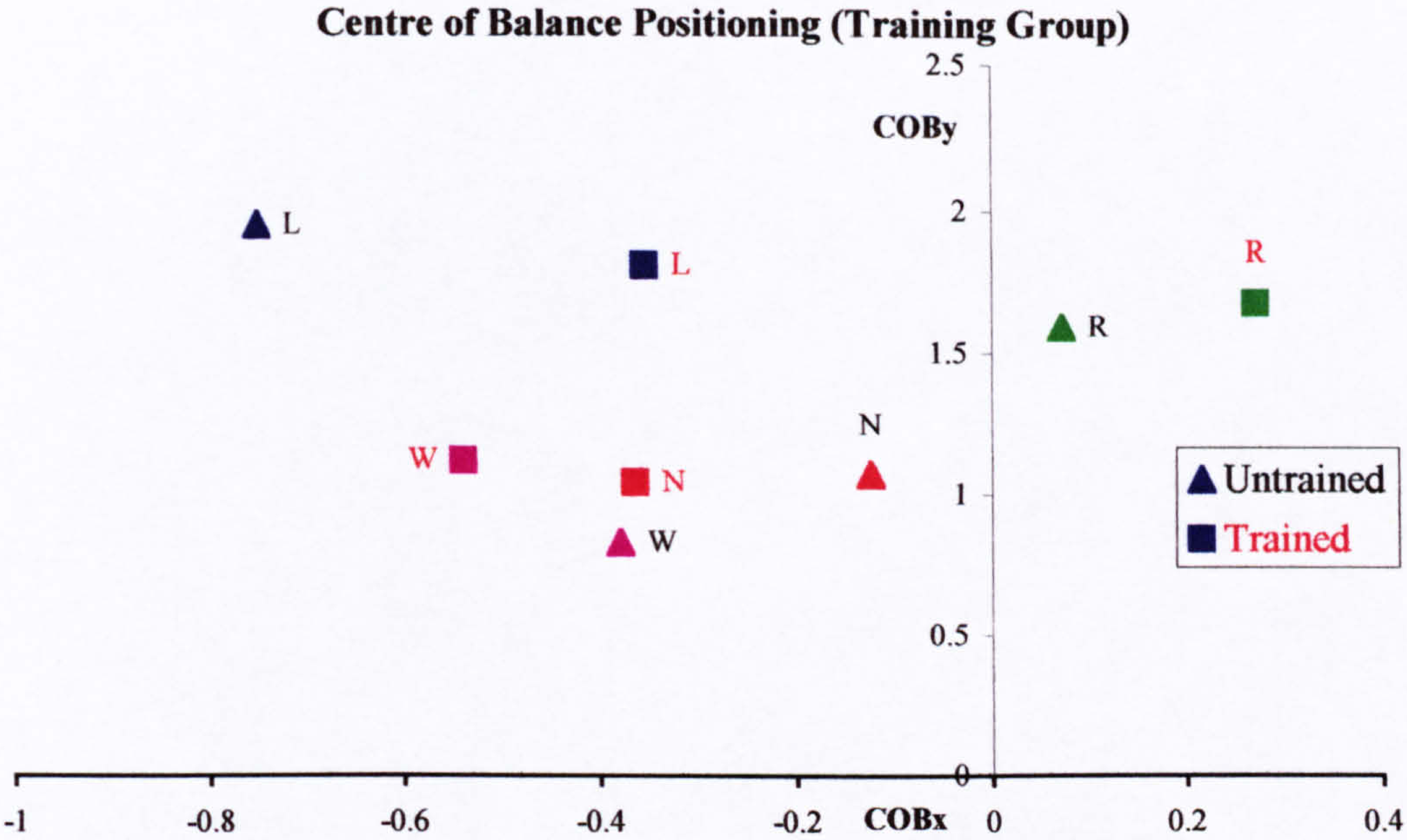


Figure n° 96 Effect of Training on Centre of Balance Positioning



Kirby (1987) stated that 'a more narrow base of support is more challenging, necessitating movement of COB further from the limits of stability'. This statement can be said to be true for these results where COB is seen to shift closer to the CBOS with double-leg stance, though more so for the narrow position than the wide position. A reason for this slight discrepancy would be that the double-leg (Wide) position is sufficiently wide for subjects to favour positioning their weight more over one foot than the other, as can be seen by the left shift of COB_X in the wide stance position.

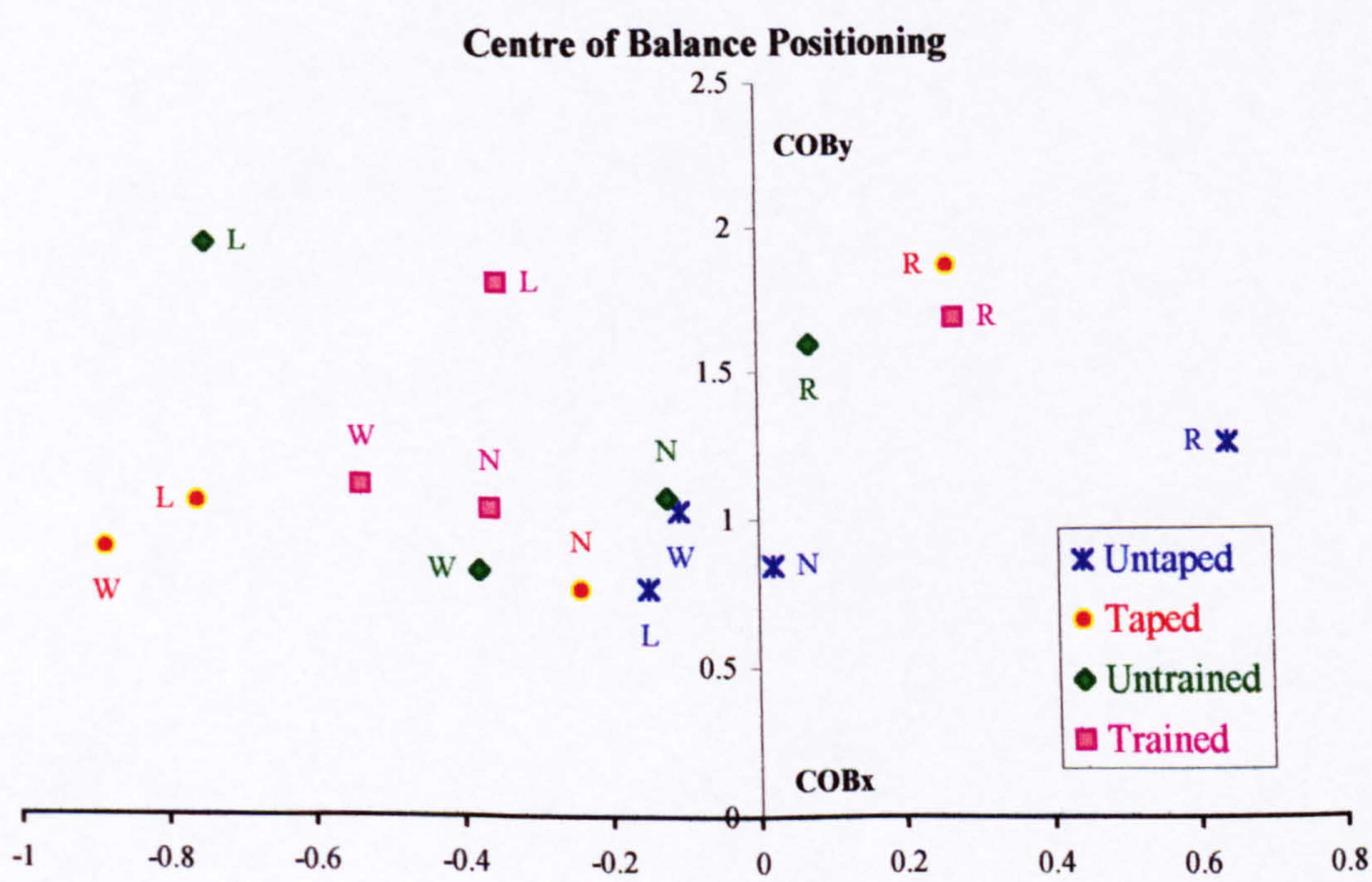
Taping the ankle is seen to invoke the same response as training for double-leg stance; moving COB away from X-axis zero. Opposite effects for single-leg stance are seen, with taping resulting in COB movement towards X-axis zero for the right leg and away from X-axis zero for the left leg. Training, on the other hand, resulted in COB movement away from X-axis zero for the right leg and towards the X-axis zero for the left leg.

The effect for overall COB_X positioning indicates that subjects tended to maintain their weight slightly to the left (*Figure n° 97*). This may be as a result of the side of the subject to which the investigator stood. In both the study by *Ekdahl (1989)* and this study, the investigator stood to the left of the subject which may have resulted in the subjects orientating themselves to the left, with the exception of single-leg (Right). The exception of single-leg (Right) can be attributed to the structure of the foot, where the lateral side is in contact with the floor and so the weight distribution will be through this side rather than the medial side of the foot, thus to the right in single-leg stance, right foot.

Shift of weight towards the left was found with taping as with *Dickstein (1984)*. This is in disagreement with findings of *Kirby (1987)* who reported a tendency for weight to shift to the right. When proprioceptively trained however, single-leg stance resulted in a shift of COB $_X$ to the right, but to the left in double-leg stance.

COB $_Y$ positioning for all test conditions except the single-leg (Left) eyes open, Untaped condition is anteriorly on the ball of the foot (*Figure n° 97*). In the Untaped and Untrained conditions COB $_Y$ positioning moved anteriorly, further away from the CBOS (exception double-leg (Narrow) Taped). When Taped, closing the eyes results in the same response for single-leg (Left), but single-leg (Right) and double-leg stance positions result in a movement posteriorly, towards CBOS.

Figure n° 97 Overall Centre of Balance Positioning in Taping and Training Conditions



If a movement towards the CBOS can be assumed to imply that as demands for maintaining balance are increased, the COB is brought closer to the geometrical CBOS (*Nichols 1995*), then single-leg stance COB would be expected to be closer than double-leg stance and eyes closed result in a movement of COB towards the CBOS. In fact, this study determined that COB for single-leg stance is further away from the CBOS than double-leg stance and no definite trend exists for movement of the COB either towards or away from the CBOS on closing the eyes. Movement of the COB is sensitive to rotation about the ankles, hips and at shoulder level, with sensitivity greatest at the ankle level (*Koles 1980*). However, activity at the other levels may influence the results, thus investigation of control of posture or movement at levels higher than the ankle needs to be addressed.

To summarise, increases in sway were seen on closing the eyes and in the Taped and Trained conditions with Anterior/Posterior sway twice that of Left/Right sway in all conditions. Closing the eyes also resulted in movement of COB away from the CBOS as expected due to impairment of one component of the proprioceptive mechanism. Taping and training in single-leg (Right) and double-leg (Wide) as well as taping in single-leg (Left) were seen to have this same effect on COB suggesting that these conditions impaired the proprioceptive mechanism. However double-leg (Narrow) Taped and Trained and single-leg (Left) Trained resulted in movement of COB towards the CBOS implying improvement in proprioception. This inconsistency in results emphasises the need for further study and clarification.

9.3.2 Muscle Activity

As results from postural stability were not conclusive as to the effect of taping and training on proprioception, the muscle activity during the balance tests was investigated to explore any increase in muscle activity due to an increase in proprioception. It was theorised that any improvement in proprioception would be accompanied by an increase in muscle activity due to corrections of posture at the ankle, stimulating receptors and resulting in contraction and relaxation of supporting muscles to achieve stability.

Research has shown that when the centre of balance is well within the base of support, a subject sways around the ankles as a fulcrum, recruiting muscles from distal to proximal (*Forrsberg 1982, Horak 1987*). Alteration of the amount or nature of proprioceptive input to the CNS will result in a change in the muscle activation pattern (*Bennell 1994*).

9.3.2.1 Gastrocnemius Muscle

From investigations of EMG results of the gastrocnemius muscle during balance testing, it was found that in all cases, there was an increase in muscle activity on closing the eyes. This is to be expected as it removes visual cues about the subject's surroundings and subsequently balance is controlled to a greater extent by proprioceptive feedback from joint and muscle receptors.

Single-leg stance resulted in muscle activity up to three times that of double-leg stance, with little difference between activity within left and right single-leg stance and narrow and wide double-leg stance positions.

The effect of taping on muscle activity in single-leg (Left) was to decrease the minimum and maximum values of activity and although an increase in activity with taping was seen in the eyes open condition, a decrease was seen with eyes closed. This reduced the difference in activity between the two visual conditions when taped and could be interpreted as a decrease in the effect of removing visual cues and thus an increase in proprioceptive control.

In contrast, the effect of taping on muscle activity in single-leg (Right) was seen as an increase in both overall and minimum/maximum values. Taping in double-leg stance positions also resulted in an increase in muscle activity, more so than seen in single-leg stance. This too could be said to be an effect of increased proprioception, though by an altered route to that seen in single-leg (Left) as denoted by the different result and an increase in activity in eyes open as well as closed conditions. Taping may have stimulated the cutaneous receptors invoking increased stimulation of the muscle.

Training increased muscle activity in the eyes open visual condition for single-leg stance positions, but not the eyes closed. Therefore the difference in muscle activity between Untrained and Trained conditions can be seen if visual conditions are intact. However, when the visual condition changes and orientation of the body by sight is removed, it would be expected that this difference would become more pronounced as balance becomes further challenged. As this is not the case, this prompts the suggestion of an alteration in motor activity or a learned response, which is affected by removal of one component such as vision, rather than a change in proprioception.

Training was seen to have no effect on muscle activity for the gastrocnemius in double-leg stance positions.

9.3.2.2 Peroneus Longus Muscle

For the peroneus longus muscle, closing the eyes was again seen to result in an increase in muscle activity and for single-leg stance activity to be two to three times that in double-leg stance positions.

The outcome of taping in single-leg stance was seen as an increase in muscle activity though more so in the left leg than the right. In double-leg stance positions, taping resulted in a change of activity to a level for both visual conditions between that of eyes open and closed untaped.

Training increased peroneus longus activity in the left leg with the eyes open, but no effect was seen in the eyes closed visual condition. For single-leg (Right) and double-leg stance positions, decreased muscle activity was seen with proprioceptive training.

9.3.2.3 Tibialis Anterior Muscle

Tibialis anterior muscle activity increases on closing the eyes in all test conditions. Muscle activity is seen to be up to five times greater in single-leg stance than is double-leg stance positions.

Taping results in a decrease in muscle activity in the left leg and right leg, eyes open condition but increases muscle activity in right leg, eyes closed and doubles activity in the tibialis anterior muscle in double-leg stance.

Training halves muscle activity in single-leg stance for the tibialis anterior muscle compared to the untrained condition but virtually no change in muscle activity is seen after training for double-leg stance.

9.3.2.4 Soleus Muscle

Closing the eyes in the Untaped and Untrained conditions had little effect on muscle activity in the soleus for double-leg stance positions and results in a slight increase in activity in single-leg stance. Soleus muscle activity does not however, vary greatly with stance condition.

Taping increases muscle activity slightly in single-leg stance and doubles it in double-leg stance.

Training is also seen to increase soleus activity producing higher levels of activity for the eyes open visual condition than the eyes closed visual condition, this increase in activity is observed to the same extent in all stance positions.

9.4 DISCUSSION SUMMARY

As in previous studies, the injury database confirmed previous reports of high incidence of ankle injury in football, highlighting the need for prophylactic measures in this area. It also demonstrated the divergent demands placed upon differing playing positions and thus a variation in risk of ankle injury, which needs to be addressed. To expand upon this knowledge, a more in-depth examination of injuries, their causes and consequences should be implemented. It ought to be noted at this point, that at present the Football Association is conducting a nationwide study of injuries in football in over 80 clubs in the Nationwide Football League. The results of this are greatly anticipated, in the hope that they will widen our knowledge and understanding of injuries occurring in the professional game.

On examination of the consequences of taping and training upon athletic performance, although some decreases in performance were seen, more so in jumping performances than running, it was not deemed that these decreases were so significant as to be detrimental to the overall performance of the player.

However, limited sample size and the fact that non-injured individuals were used means that results are not representative of effects that may be seen in injured and rehabilitating subjects and so recommendation of the utilisation of either measure cannot be given until these have been investigated.

Other limitations of this part of the study are the performance tests themselves. The tests were chosen to be comparable to previous studies in the literature, however, they cannot be said to be truly representative of performance activities in football. It would therefore be an idea to devise alternative performance tests that as well as being pertinent to the game of football, are also more inclined to the different playing positions and necessary variations in skills.

As ankle injury, particularly ankle sprain, is common in football, as well as in many other sports, the need for prevention is great. Prophylactic ankle taping is frequently used, but with little evidence being presented to confirm its value. The aim of taping is to support the ankle structure by providing external mechanical restriction to large range of motions that would result in ankle sprain. Possibly by increasing the activation of the muscles supporting the joint, taping reduces stress on the ligaments holding the joint together. This theory gains support from the evidence of this study. Prospective epidemiological studies have shown a decrease in the incidence of ankle injury with ankle support use, with effectiveness dependent upon the material properties and application and on the athletes level of ankle stability or previous injury.

An external support should protect against extreme inversion amplitudes if risk of injury is to be reduced (*Scheuffelen 1993*) and as tape can only provide limited mechanical support of the ankle joint complex, it may have proprioceptive effects. As well as initial mechanical support and proposed proprioceptive stimulation, taping may also work as a psychological reminder, so that ankle joint motion is consciously moderated.

Proprioceptive training is another approach to the prevention of ankle injury and is used to enhance the neuromuscular response to ankle motion. Theoretically, increasing flexibility would allow an ankle to go through particular range of movements without reaching the limits of motion at which ankle injury is more likely to occur. Increased muscle strength in the lower limb would allow the muscles to resist the motions that tend to result in ankle sprain. An increase in neuromuscular response time would also allow the individual to react more quickly to a possible injurious event.

Taping and training are both seen to increase postural sway, but not generally to affect performance of functional activities. This obviously implies an alteration in the proprioceptive mechanism. Other authors referred to an increase in sway as being detrimental, although this cannot be confirmed from the results of this study until further investigation has been carried out as to whether this results in changes in the incidence of ankle injury.

It is generally accepted that the body employs a variety of balance strategies, though the ankle strategy is most likely to be implemented in static standing balance. The changes in sway seen here could be associated with a change in the balance strategy being implemented, with the increase in sway an indicator of the change in balance strategy. Changes in postural sway with taping and training also implies an interference of the integration of the three sensory control systems, directly affecting the control of posture.

The nervous system is dynamic and the demands placed upon it are complex. During most functional activities, postural reactions are incorporated into the movements being produced, and they are programmed in an anticipatory fashion to compensate for both the active and reactive kinetic forces occurring during the movement. Postural reactions are less likely to be tested by a static stance paradigm that fails to measure the adaptive components of the postural response that are necessary and essential to dynamic balance during most functional activities. An increase in sway during quiet stance cannot be correlated with the sway dynamics that occur when external forces are imposed upon the body. The changing position of the body parts could shift the centre of balance without affecting stability (*Judge 1993*).

Posture and balance together represent a complex integration of mechanical, sensory and motor processing systems, which enable the maintenance of uprightness against gravity. Thus a high level of postural control is an integral part of sporting activity (*Bennell 1994*) and it should be expected that an inability to balance could increase a player's susceptibility to an ankle sprain. However, ankle sprains occur in the brief moments between heel strike and mid-stance, so the loss of balance must occur within these finite phases of gait (*Hertel 1996*). Perhaps assessment of postural sway over a ten-second balance period is an invalid predictor of balance and joint proprioception during functional activities and investigation of the actual moment at which ankle sprains are most likely to occur during the functional activity is required.

It is possible that athletic experience means that balancing ability has been learnt to a high level that cannot be improved upon significantly. Past athletic experience may act as a proactive inhibition and interfere with learning a new balancing skill (*Kozar 1972*).

Although increased sway, or increased limits that the sway reaches is observed, this does not necessarily indicate an increase in the total path travelled. Peaks may be caused by muscle function, therefore the pattern of association between the sway and muscle activity needs to be investigated.

Muscular work is needed for corrective efforts to stabilise the body after a change in the position of the body's centre of gravity, and thus a certain functional ability of stabilising the muscles is necessary, as seen here with increases in muscle activity with taping and training the ankles. Compensation of body sway involves movement primarily at the ankle joint, as torque exerted by ankle musculature propels the centre of mass back to a point of stability. Here, with subjects tending to lean forward, further muscle activity is produced to maintain this posture.

Increased muscle activity due to taping and/or proprioceptive training with a concomitant increase in postural sway and movement of COB away from the CBOS does not imply decreases in central nervous system control of postural muscle tone and balance as suggested by *Hasselkus (1975)*. It rather suggests that an increase in postural sway, along with an associated increase in muscle activity be derived from an increase in proprioception, as observed in both taping and proprioceptive training methods. The concern with this statement is that if there is an increase in postural sway, then this means that the subject is less stable and so the risk of injury is greater. However, it may also suggest that there is an increase in joint flexibility. Although this could be the case, it has not been investigated here. Nevertheless, if the increase in sway is still within the subject's own limits of stability then the effect cannot be determined as being detrimental. Additionally, it is suggested external influences that may cause injury may be counteracted by this increased muscle activity and thus actually be of benefit, resulting in faster stimulation of receptors and recruitment of fibres to evoke the resultant protective response.

Thus to summarise, the effects of taping and training on muscle activity offer a variety of conflicting outcomes. Increases seen in muscle activity can account for the increases also seen in postural sway, though whether this can be claimed to be a result of increased or decreased proprioception is questionable and cannot be fully determined here. Adjustments and alterations to the proprioceptive system caused by taping or proprioceptively training the player may occur, and it still needs to be resolved whether the change in both postural stability and muscle activity with taping or training increases the risk of injury to the player.

CHAPTER TEN

CHAPTER 10: CONCLUSIONS AND FURTHER WORK

10.1 CONCLUSIONS

- Confirming reports in the literature, examination of results of the injury database yielded a high incidence of ankle injury, thus warranting an investigation of prophylactic measures.

- There is a variation in risk of ankle injury depending on the player position and team demands.

- Peaks of incidences are found at three main points in the football season. The first is pre-season, the second mid-season when playing becomes more match intensive, and the third and the end of the playing season, most probably due to player fatigue.

- The consequence of taping and training upon athletic performance was a decrease in jumping performance. This was not however, deemed to affect the overall performance ability of the player and should be weighed against the risk of injury.

- Results obtained from the athletic performance tests do not fully represent effects that may occur if taping and training were carried out on injured subjects.

- Taping and training are seen to increase postural sway, suggesting an alteration in the proprioceptive mechanism or in the balance strategies employed by the body. This implies interference in the integration of the three sensory control systems directly affecting the control of posture.

- Despite results indicating an increase in postural sway with taping and training during quiet stance, this cannot as yet be correlated with adaptive components of the postural response that may occur during dynamic balance and functional activities.

- The addition of external forces may change the position of body parts and so shift the centre of balance. This does not however, result in a pernicious influence upon stability.

- Assessment of postural sway over a ten-second balance period is not a clear gauge of balance and joint proprioception during functional activities and so cannot predict improvement in proprioception and consequently cannot attest to the benefit of prophylactic measures such as ankle taping or proprioceptive training.

- Past athletic experience may act as a proactive inhibition and interfere with learning a new balancing skill. If this is the case, a 'healthy' player may already be at their peak proprioceptive level, resulting in a failure to improve proprioception.

- There is a definite relationship between muscle activity and the prophylactic measures implemented, suggesting that they act to stimulate the proprioceptive system, inducing muscle contraction to maintain balance and so stability.

- An increase in postural sway is seen, along with an increase in muscle activity on taping and proprioceptively training the ankle. Although previous studies have insinuated a decrease in postural sway to be indicative of a decrease in proprioception, this may not necessarily be the case. With the concomitant increase in muscle activity, an increase in postural sway intimates an increase in receptor stimulation and possibly joint flexibility. Since sway remains within the subject's own limits of stability, taping and training cannot be determined as being detrimental to the proprioceptive mechanism.

- Results of the investigation, though not conclusive as to a positive proprioceptive and thus prophylactic effect of taping or proprioceptively training the healthy ankle in football, do sanction further research into their proprioceptive effect, but more importantly their prophylactic effect.

10.2 FURTHER WORK

Due to the variability existing for postural sway measures, future research should address the effects of external support during dynamic exercise, as periodic measurements during game situations would provide a measure of the effectiveness for movements within particular situations. Experiments to determine the mechanism by which an external ankle support works and the different influences of mechanical and proprioceptive processes would aid in development of ankle support effectiveness in reducing ankle inversion injury.

As a suggestion, three dimensional video analyses with electromyography and force measurements could allow quantification of the effects of external support and proprioceptive training during sport.

Further research needs to examine postural sway during brief periods of time such as initial changes in support system movements (*Hertel 1996*).

A larger population study is required for healthy subjects to give a good baseline measurement of the various parameters. Along with this, studies of injured subjects are needed to investigate the proprioceptive processes throughout the rehabilitation regime. In connection with both of these, the effect of different methods of taping and external support and training should be examined to analyse their influence as both rehabilitative and prophylactic tools. In addition, other sports could be investigated to examine the different stresses placed on players of different sports.

Furthermore, investigations are necessary to determine the effects of ankle joint injury on centre of balance and postural sway. It is not yet clear whether COB adaptations seen in this study also occur in athletes with injuries to the lateral ankle ligaments. It is possible that interaction such as taping and proprioceptive training in injured players may alter adaptive responses and be of benefit.

Perhaps proprioceptive deficits are not caused by selective damage to proprioceptive system and it is the combination, or, more specifically, the interpretation of the inputs that becomes distorted. In recent years joint mechanoreceptors have been the focus of ankle joint proprioception studies (*Garn*

1988, Glencross 1981, Gross 1987a, Hertel 1996). These studies have led to varying results introducing more questions. It is possible that muscle and tendon mechanoreceptors could also become damaged following joint injury.

Nitz (1985) reported damage to the tibial and peroneal nerves following grade II and III ankle inversion sprains. If these large nerves are damaged, then neuromuscular interaction would be affected. It is also possible that the afferents arising from the muscles and tendons could become damaged during similar injury. If this were the case, it would make sense to assess proprioception in a manner that would combine the use of joint, skin and muscle mechanoreceptors, rather than selectively assessing each. Since it is impossible to selectively assess different receptors without anaesthetising them, it might make more sense to assess co-ordination of the interpretations of the various types if receptors (such as those that sense movement, velocity or position). This could be accomplished by measuring joint position sense at clinically relevant velocities in weightbearing and non-weightbearing positions and with varying amounts of force.

In the area of proprioceptive training, a more comprehensive investigation of proprioceptive processes and particular training regimes needs to be undertaken to widen our knowledge and aid in the prevention of injuries. In particular the examination of proprioceptive levels in the healthy and injured sportsperson.

With the Football Association conducting a nationwide study of injuries in football, a start has been made on research into understanding the cause of injuries, particularly occurring in the professional game. This will provide a basis from which research into specific injury prevention can move forward. An overall increase of research in the area of injury prevention and sports rehabilitation can only help to elucidate the influence of taping and training along with other prophylactic mechanisms. The ultimate aim is to improve conditions within the game, and reduce injury incidences and rehabilitation times and thus be of benefit to all concerned.

APPENDICES

APPENDIX ONE

INJURY QUESTIONNAIRE

INJURY RECORD.

PLAYER IDENTIFICATION	
1. INITIALS	
2. PLACE OF INJURY	1 ( ) TRAINING GROUND 2 ( ) FOOTBALL GROUND 3 ( ) OTHER 4 ( ) UNKOWN
3. INJURY NUMBER	( ) 1ST ( ) 2ND ( ) 3RD ( ) 4TH ( ) 5TH +

PLAYER DESCRIPTION	
4. TEAM	( ) FIRST ( ) RESERVE ( ) YOUTH
5. POSITION	

CLUB IDENTIFICATION	
6. NAME	PRESTON NORTH END
7. DIVISION	SECOND

INJURY DESCRIPTION	
8. NATURE OF INJURY	01 ( ) ABRASION 02 ( ) CONTUSION 03 ( ) CONCUSSION 04 ( ) DENTAL INJURY 05 ( ) DISLOCATION 06 ( ) FRACTURE 07 ( ) LACERATION 08 ( ) PUNCTURE WOUND 09 ( ) SPRAIN (MILD) 10 ( ) SPRAIN (SEVERE) 11 ( ) STRAIN - MUSCLE (MILD) 12 ( ) STRAIN - MUSCLE (SEVERE) 13 ( ) HEAT EXHAUSTION 14 ( ) OVERUSE 15 ( ) OTHER 16 ( ) UNKNOWN
9. BODY PART INVOLVED	( ) **HEAD & FACE** ( ) **NECK** ( ) **CHEST** ( ) **ABDOMEN** ( ) **MUSCULOSKELETAL** 01 ( ) VERTEBRAE 02 ( ) SHOULDER 03 ( ) CLAVICLE 04 ( ) UPPER ARM 05 ( ) ELBOW 06 ( ) FOREARM 07 ( ) WRIST 08 ( ) HAND 09 ( ) FINGER 10 ( ) PELVIS/GROIN 11 ( ) HAMSTRING 12 ( ) HIP 13 ( ) THIGH 14 ( ) KNEE 15 ( ) LOWER LEG 16 ( ) ANKLE 17 ( ) FOOT 18 ( ) TOE 19 ( ) OTHER
10. BODY SIDE OF INJURY	1 ( ) RIGHT 2 ( ) LEFT 3 ( ) NOT APPLICABLE 4 ( ) UNKNOWN
11. SEVERITY OF INJURY	1 ( ) FATAL 2 ( ) HOSPITALISED 3 ( ) INJURY WITH NO PARTICIPATION (LOST TIME) 4 ( ) INJURY BUT WITH PARTIAL PARTICIPATION 5 ( ) INJURY BUT WITH ACTIVE PARTICIPATION 6 ( ) UNKNOWN

12. DID THE PLAYER CONTINUE TO PARTICIPATE IN THE SAME GAME OR SESSION AFTER THE INITIAL INJURY SITUATION?	1 ( ) YES 2 ( ) NO

INJURY DESCRIPTORS	
13. GENERAL ACTIVITY	1 ( ) GAME 2 ( ) EXERCISE 3 ( ) DRILL 4 ( ) OTHER 5 ( ) UNKNOWN
14. ACTIVITY AT TIME OF INJURY	1 ( ) KICKING 2 ( ) TACKLING 3 ( ) RUNNING 4 ( ) OTHER 5 ( ) UNKNOWN
15. HALF OF INJURY (GAME INJURIES ONLY)	1 ( ) 1ST 2 ( ) 2ND

ENVIRONMENTAL FACTORS	
16. FIELD SURFACE CONDITION	1 ( ) DRY 2 ( ) WET/MUD 3 ( ) FROZEN 4 ( ) UNKNOWN
17. FIELD SURFACE TYPE	1 ( ) GRASS 2 ( ) ARTIFICIAL 3 ( ) UNKNOWN
18. MONTH OF INJURY	01 ( ) JAN 02 ( ) FEB 03 ( ) MAR 04 ( ) APR 05 ( ) MAY 06 ( ) JUN 07 ( ) JUL 08 ( ) AUG 09 ( ) SEPT 10 ( ) OCT 11 ( ) NOV 12 ( ) DEC
19. IF INJURY OCCURRED IN REGULAR SEASON, INDICATE WEEK OF PLAY OF SEASON.	01 ( ) 02 ( ) 03 ( ) 04 ( ) 05 ( ) 06 ( ) 07 ( ) 08 ( ) 09 ( ) 10 ( ) 11 ( ) 12 ( ) 13 ( ) 14 ( ) 15 ( ) 16 ( ) 17 ( ) 18 ( ) 19 ( ) 20 ( ) 21 ( ) 22 ( ) 23 ( ) 24 ( ) 25 ( ) 26 ( ) 27 ( ) 28 ( ) 29 ( ) 30 ( ) ( ) UNKOWN
20. DAY OF WEEK OF INJURY	1 ( ) MON 2 ( ) TUE 3 ( ) WED 4 ( ) THU 5 ( ) FRI 6 ( ) SAT 7 ( ) SUN 8 ( ) UNK

21.TIME OF DAY OF INJURY	1 ( ) 6 - 8.59 AM 2 ( ) 9-11.59 AM 3 ( ) 12- 2.59 PM 4 ( ) 3- 5.59 PM 5 ( ) 6-8.59 PM 6 ( ) 9-11.59 PM 7 ( ) 12-5.59 AM 8 ( ) UNKNOWN
22. TEMPERATURE AT TIME OF INJURY	
23. CLIMATE AT TIME OF INJURY	1 ( ) CLEAR OR CLOUDY 2 ( ) RAIN OR DRIZZLE 3 ( ) SNOW OR SLEET 4 ( ) UNKNOWN

PAST HISTORY	
24. WAS THIS A REINJURY OF A PREVIOUS TRAUMATIC CONDITION?	1 ( ) YES 2 ( ) NO 3 ( ) UNKNOWN
25. IF A REINJURY, HOW DID 1ST INJURY OCCUR?	1 ( ) ATHLETIC ACTIVITY 2 ( ) NON-ATHLETIC ACTIVITY 3 ( ) UNKNOWN

IF ANKLE, KNEE OR LEG INJURY ;	
26. DESCRIBE JOINT	1 ( ) TAPED 3 ( ) BRACED 5 ( ) UNKNOWN 2 ( ) WRAPPED 4 ( ) NONE
27. SHOE TYPE	1 ( ) LOWCUT 3 ( ) HIGHTOP 5 ( ) UNKOWN 2 ( ) MEDIUM 4 ( ) SOCCER 6 ( ) OTHER
28. CLEAT TYPE	1 ( ) NONE 3 ( ) SOCCER 5 ( ) RIPPLE 2 ( ) CONICAL 4 ( ) MULTIPLE 6 ( ) OTHER

ADAPTED FROM NFTI (National Tackle Football Injury) PROJECT.
JAMA 1970 213 438-447 KRAUS JF BURG FD

APPENDIX TWO

ATHLETIC PERFORMANCE INFORMED CONSENT

INFORMED CONSENT FORM

INFORMATION SHEET

ATHLETIC PERFORMANCE

After an ankle sprain occurs, practice and playing time can be lost while recovery is taking place. To try and avoid this problem, attention has been focused on prophylactic protection of the ankle during athletic participation. If performance is diminished by a prophylactic device, it is unlikely that it will gain wide acceptance.

Therefore, by focusing on performance, the effect of ankle taping or proprioceptive training can be evaluated.

Four performance tests are to be completed by subjects with ankles taped and untaped and after proprioceptive training to assess their effects on the athletic ankle whilst exercising.

The aim of the tests is to reveal any significant difference between the experimental conditions for any of the performance events tested.

The four tests are;

A) VERTICAL JUMP.

Subject stands perpendicular to the test wall, fingers chalked.
Subject crouches and then jumps vertically as far as possible.
The difference between the standing vertical reach and peak jump height is recorded as the vertical jump height. The distance is recorded to the nearest 0.5 cm.

B) SPRINT (40 yd).

From a standing start, the subject runs forward as fast as possible over the distance. The time taken is measured to the nearest 0.01 second.

C) BROAD JUMP.

From a standing start, the subject jumps forward as far as possible. The distance is measured to the nearest 0.5 cm.

D) SHUTTLE RUN.

From a standing start, the subject runs forward from the start line 5 yds to the right, touches the line and turns, then runs 10 yds to the left , touches the line and turns, then runs 5 yds to the right, crossing the start / finish line. Time is measured to the nearest 0.01 second.

Testing Procedure:-

Testing is to be performed on four separate days, with approximately 7 days between test sessions.

Test session 1 is used as a pre-test to allow subjects to become familiar with the performance test requirements and data collection procedure.

The performance tests are randomised within each test session to minimise the effects of fatigue, learning and the loosening effect of the tape.

Prior to the beginning of testing, subjects should complete a warm-up consisting of

- jogging for 8 minutes
- stretching
- submaximal trial for each performance test.

Subjects will be required to complete each test twice, the average score being taken as the criterion measure. Subjects are to rest approximately 2 minutes between trials and 10 minutes between performance tests.

The tests will be carried out on three occasions with ankles untaped and taped and on one occasion after proprioceptive training has been completed (untaped).

Please do not hesitate to ask if you have any questions regarding the testing procedures or any other part of the research.

INFORMED CONSENT FORM.

All information and data derived from the subject will remain confidential by the fact that at no time will subjects be identified by name in a manuscript or publication without their written consent.
All data will be protected and stored separately on secure disk and at no point will named information and derived data be kept together.

I understand that no disadvantage will arise from my decision to participate or not. I retain the right to withdraw consent at any time and discontinue participation without prejudice.

I agree to take part in this study.

SIGNED ______________________

DATE ________

Printed Name ____________________

Physiotherapist __________________

____

MELISSA FAITHFUL
Department of Rehabilitation
University of Salford

APPENDIX THREE

PROPRIOCEPTION INFORMED CONSENT

INFORMED CONSENT INFORMATION SHEET.

PROPRIOCEPTION.

A large proportion of injuries occurring in soccer today is taken up by ankle injury. In recent years a way of trying to prevent these injuries and also to help stabilise the ankle during rehabilitation is by the use of ankle taping.

To try to discover whether taping the healthy athletic ankle actually gives any proprioceptive benefit this study is looking at balance and EMG (electromyography) - to study of the activity of muscles in the lower leg, to gain an insight into the proprioceptive behaviour of the ankle and lower leg with and without taping and after proprioceptive training.

Testing.

The tests that you will be asked to carry out involve balance assessment and will be as follows:

1. Single leg stance - whilst focusing your attention at a point directly in front of you, you will be asked to maintain your balance while standing on one leg (both left and right legs will be tested), with your arms relaxed by your sides, and the other leg held at approximately 45° knee flexion. This test will last 10 seconds and be repeated 3 times for each leg.
2. Single leg stance - You will be asked to repeat the (1) above, but this time with your eyes closed.
3. Double leg stance 1 - whilst focusing your attention at a point directly in front of you will be asked to maintain you balance with your arms relaxed by your sides. This test will last 10 seconds and be repeated again with your eyes closed.
4. Double leg stance 2 - You will be asked to repeat (3), but this time with a wider base of support.

Throughout these balance tests, EMG (recordings of muscle activity) will be taken of four muscles in your lower leg. This will mean placing 9 surface electrodes on each leg, which will then be connected via leads, to a small box around your waist. You will encounter no discomfort during testing.

Please do not hesitate to ask if you have any questions regarding the testing procedures or any other part of the research.

INFORMED CONSENT FORM.

All information and data derived from the subject will remain confidential by the fact that at no time will subjects be identified by name in a manuscript or publication without their written consent.
All data will be protected and stored separately on secure disk and at no point will named information and derived data be kept together.

I understand that no disadvantage will arise from my decision to participate or not. I retain the right to withdraw consent at any time and discontinue participation without prejudice.

I agree to take part in this study.

SIGNED ——————————————

DATE ————

Printed Name ——————————————

Physiotherapist ——————————————

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University of Salford

APPENDIX FOUR

SUBJECT QUESTIONNAIRE ON TAPING DURING ATHLETIC PERFORMANCE TESTS

SUBJECT QUESTIONNAIRE.

ATHLETIC PERFORMANCE TESTS

Date completed:

Subject Number:

On a scale of 1 to 10 circle the appropriate number.

A) What level of comfort did the taping provide?

Very uncomfortable Very comfortable

1 2 3 4 5 6 7 8 9 10

B) What level of support did the taping provide?

No support Maximal support

1 2 3 4 5 6 7 8 9 10

C) What was your level of confidence when wearing the tape?

No confidence Very confident

1 2 3 4 5 6 7 8 9 10

D) How do you feel the taping affected your performance?

E) Any other comments:-

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