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ABDOMINAL/ADDUCTOR STRENGTH IMBALANCE IN SOCCER PLAYERS WITH OSTEITIS PUBIS

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ABSTRACT

Background and Objective

The muscle imbalance between abdominal and hip adductor muscles as an etiology for osteitis pubis is not well understood. The concept of a relationship between eccentric/concentric ratios at the pelvis and osteitis pubis in athletes is limited. This study aimed to compare the eccentric/concentric ratios for abdominal/adductor, abdominal/back, and hip adductor muscles as well as eccentric abdominal/eccentric adductor muscles in soccer players suffering from osteitis pubis with those in healthy athletes.

Material and Methods

Twenty male soccer athletes with osteitis pubis were recruited to participate and 20 healthy male soccer athletes were recruited to participate. Peak torque/body weight (PT/BW) for the hip adductor, abdominal, and back muscles during isokinetic concentric and eccentric contraction modes at a speed of 180°/s was recorded for healthy players and soccer athletes with osteitis pubis. Eccentric/concentric ratios for the abdominal/adductor, abdominal/back, and hip adductor muscles and the eccentric abdominal/eccentric adductor muscles were measured for both groups.

Results

There was a significant decrease in the eccentric abdominal/concentric hip adductor muscles ratio ($p = 0.000$) and in the eccentric/concentric hip adductor muscles ratio ($p = 0.016$) between the osteitis pubis group and the healthy control group.

Conclusion

Soccer players with osteitis pubis present with strength imbalance. The osteitis pubis group displayed eccentric weakness of the abdominal and adductor muscles, resulting in imbalances in the normal eccentric abdominal/concentric adductor and eccentric/concentric adductor ratios. Therefore, exercises that increase the eccentric strength of abdominal and hip adductor muscles may be beneficial to include in rehabilitation programs of patients with osteitis pubis.

Osteitis pubis (OP) refers to a painful, inflammatory, non-infectious condition of the symphysis pubis and surrounding structures.[1] OP may present as acute abdominal, pelvic, or groin pain.[2] The natural history of OP is one of progressive deterioration with continued activity, requiring a prolonged rehabilitation period and time away from the sport.[3] In addition, OP is one of the most common causes for groin pain in athletes.[4] The initial presentation of OP often includes the insidious onset of hip adductor pain and abdominal discomfort, along with pain in the pubic symphysis.[5,6]

In soccer, the incidence of groin pain has been demonstrated to be as high as 5–13%.[7] OP is a potential cause of groin pain that can lead to missed playing time during training and competition for the soccer athlete and can potentially be a career-ending condition.[6,8] Playing soccer involves sprinting, twisting, turning, cutting, and kicking; the pathomechanics of these activities produce forces leading to severe biomechanical strain on the symphysis pubis and its associated supporting structures.[2,9] In OP, a microtear may occur at the pubic attachment of the adductor longus. This tear is frequently a primary event, followed by the development of osteitis. The induced muscular instability, laxity, and impaction of surfaces at the symphysis may also produce OP. Why a microtear at the adductor attachment occurs so frequently in soccer players is unclear. The small adductor attachment may increase the susceptibility of the adductor longus muscle to strain/overuse, and a microtear might occur as a consequence of tendon stretching and applied traction due to twisting and turning or, more likely, secondary to both.[9]

The most likely mechanism of OP development is repetitive stress from increased shearing forces on the pubic symphysis or from increased stress placed on the joint from traction exerted by the pelvic musculature, especially in the presence of muscle imbalance.[10] Muscle imbalance between the abdominal muscles and hip adductors has been suggested as an etiologic factor in OP. The abdominal and adductor muscles have a central point of attachment – the "pivot point" – on the symphysis pubis. However, these muscles act antagonistically toward each other during kicking activity, predisposing the pubic symphysis to opposing forces.[11] Muscle imbalance across the pubic symphysis occurs because of eccentric loading and overloading from abdominal muscle pulling superiorly and hip adductor muscles pulling inferiorly. When an athlete kicks, the kicking limb is hyperextended at the hip while the trunk is rotated laterally in the opposite direction.[2,11] To estimate the balance or imbalance of muscle forces acting on a joint, the torque ratios of muscles around the joint must be determined. The appropriate ratio is important for reducing the risk of athletic injuries. If unbalanced forces exist, the weaker group of muscles may be subjected to abnormal mechanical stress.[12]

Eccentric muscle contraction plays a significant role in the activities of daily living and athletic exercise, such as when the body is decelerating during walking, running and lifting.[13] Dvir, Keating [14] have suggested that the eccentric strength of the trunk extensors was higher than the concentric strength at the same angular velocity by a factor of 11–60%. Moreover, the importance of eccentric strength testing is derived from the fact that the eccentric deficiency may be different from its concentric counterparts and hence may constitute an additional risk factor.

The pathogenesis of OP remains obscure; previous studies[1,15,16] were restricted to specific issues, such as demonstrating the clinical picture of patients and the radiographic findings of the symphysis pubis in OP. Other studies[5,7] the effects of specific treatment protocols on OP recovery, and one study[17] found hip muscle imbalances in athletes with OP during concentric contraction. There is a paucity of literature on isokinetic evaluation of the abdominal and adductor muscles ratios in athletes with OP. Therefore, the purpose of our study was to determine and compare the eccentric/concentric (E/C) ratios for the abdominal/adductor, abdominal/back, and hip adductor muscles and for the eccentric abdominal/eccentric adductor muscles in soccer players suffering from OP with those in healthy soccer players.

METHODS

Participants

Twenty male soccer athletes suffering from OP were recruited to participate as volunteers in this study. A sports medicine specialist and a team of orthopedic surgeons, who referred the OP patients to our isokinetic lab, conducted the clinical examinations. The criterion for diagnosing OP was that the athlete complained of pain combined with tenderness over the symphysis area that radiated inferiorly (adductors area) and/or superiorly (lower abdominal area). The diagnosis was confirmed by magnetic resonance imaging (MRI). Another group of 20 healthy (control) male soccer athletes were matched with the OP patient group according to age, body weight, body height, and years of playing (both groups were collected from youth and first teams). They had no history of lower extremity surgery or trauma to the back or hip. The uninjured athletes and the athletes with OP were right-leg dominant. The number of subjects was determined a priori based on statistical power analysis to ensure type I error did not exceed 0.05 and type II error did not exceed 0.20. This analysis indicated that 36 subjects were required to find a power of 96% and level of significance of 95%. Table 1 presents the demographic data of the participants in this study. Prior to undergoing actual measurements, the participants received an explanation of the study procedures and provided their written informed consent. This study was approved by the university's institutional review board.

Instrumentation

A Biodex 3 Multi-Joint Testing and Rehabilitation System (Biodex Medical Systems, Shirley, NY, USA) was used. Torque values were gravity adjusted. Calibration of the Biodex dynamometer was automatically performed at the beginning of each session.

Procedures

Participants executed a 10-minute warm-up procedure prior to entering the laboratory and undergoing hip and trunk strength measures. The warm-up procedure consisted of stretching exercises, which were performed for 10 min (10 seconds hold stretch/10 seconds relax). The muscle groups (trunk and hip muscles) for all subjects were tested in a randomized order to prevent a dependent ordering effect. Rest periods of 5 min were provided between each muscle group test. Throughout testing, the participants were verbally encouraged to perform maximal contractions through their range of motion (ROM).

For hip adductor muscle testing, the involved (affected) side of the OP group was tested; such as in the injured athletes, the kicking side was that with unilateral inguinal and adductor pain, whereas the dominant limb was tested in the healthy athlete (control) group. Leg dominance was demonstrated according to the preferred kicking leg. Testing was performed with the participants in the standing position, which is the most functional position despite being associated with less stabilization. To allow hip movement tests to be performed from the standing position, the hip attachment was inserted into the knee adaptor and secured to the dynamometer. The participants performed isokinetic concentric and eccentric hip adduction at an angular velocity of 180°/s, as previously recommended in the literature.[18] During hip abduction and adduction, the player was placed in the standing position facing away from the dynamometer, with the axis of the dynamometer aligned with the anterior superior iliac spine. The ROM for hip abduction/adduction was 65° (recorded from 20° adduction to 45° abduction).

For trunk muscle testing, each subject was allowed to sit on the adjustable seat of the Biodex isokinetic dynamometer system. This sitting position was preferred, as the lower extremity muscles could influence trunk muscle strength.[19,20] The subjects were secured in place using the available straps to prevent unwanted motion. Two curved anterior leg pads were positioned to adjust the knee block position. In addition, a lumbar support pad was positioned against the lower spine. The pelvis was stabilized to minimize contributions from the hip muscles and to prevent as much motion from the pelvis as possible, allowing for lumbar motion only. Both thighs were stabilized by two straps, and the feet were held in a dorsiflexed position above the foot support of the dynamometer chair. The axis of the dynamometer was aligned at the intersection of the mid-axillary line and the L_5/S_1 disc space in the vertebral column. The dynamometer's ROM during trunk flexion/extension was 80° (20° hyperextension to 60° flexion).[21–23] Participants performed isokinetic concentric and eccentric trunk flexion and extension at a speed of 180°/s.[24,25]

The subjects were instructed to perform three to four submaximal contractions through the predetermined ROM to familiarize them with the dynamometer before the actual test. Maximum voluntary efforts were recorded when the subjects were instructed to perform trunk flexion and extension in both concentric and eccentric modes for a total of 5 repetitions/set, and 2 sets were performed. All the subjects were encouraged to exert maximum effort during the tests. In the same manner, maximum voluntary efforts were recorded from the hip adductor muscles when the subjects performed two sets of adductions at the same angular velocity and in the same contraction mode.

The highest value of the five repetitions in one set was recorded, and the mean value of the two sets was used for statistical analysis. The outcome parameter was the peak torque (PT; expressed in Nm), which was normalized to each participant's body weight (expressed in Nm/kg) in an effort to reduce inter-subject variability in the raw scores of the quantitative muscle tests.

Statistical Analysis

Data were analyzed using SPSS (version 20.0 for Windows; SPSS Inc., Chicago, IL, USA). A two-way multivariate analysis of variance (MANOVA) was conducted for the abdominal/adductor, abdominal/back, and hip adductor muscle E/C ratios and for the eccentric abdominal/eccentric adductor muscle ratios to compare the groups. In case the F ratio was significant, the differences between peak torque/body weight (PT/BW) were examined using Tukey's test. The level of significance was set at $p < 0.05$ for all statistical tests.

RESULTS

For this study, 30 male soccer athletes suffering from OP were identified as potential participants (Figure 1), 7 athletes from screened participants were excluded because they failed to fulfill the inclusion criteria and three athletes refused to participate in the study. Thus, 20 athletes with OP were included in the study (Table 1).

The values for PT and PT/BW for the hip adductor, abdominal, and back muscles at 180°/s angular velocity are shown in Table 2. MANOVA was conducted for the hip adductor, abdominal and back muscle ratios of the healthy athlete and OP groups in both concentric and eccentric modes.

FIG. 1 Study flowchart of the OP soccer players participants.

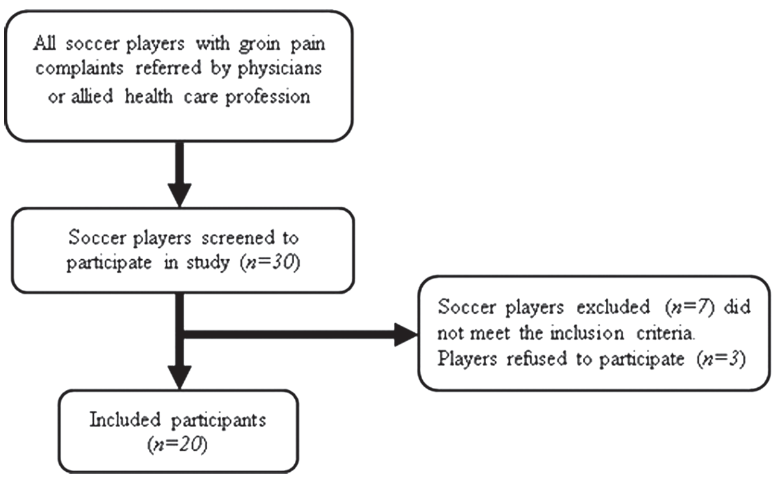

TABLE 1 Demographic Data for Healthy and Athletes with Osteitis Pubis Groups

Groups	Healthy athletes group Mean ± SD	Osteitis Pubis group Mean ± SD
Age (years)	20.78 ± 3.35	19.94 ± 3.51
Height (cm)	176.00 ± 4.15	176.16 ± 4.93
Weight (kg)	71.33 ± 7.35	70.91 ± 7.26
Body mass index	22.92 ± 1.33	22.78 ± 1.07

TABLE 2 The Peak Torque (Nm) and the Peak Torque/Body Weight (Nm/kg) of Hip Adductors, Abdominal, and Back Muscles of Healthy and Athletes with Osteitis Pubis Groups

Test statistics	Healthy athletes		Osteitis Pubis	
	PT Mean ± SD	PT/BW Mean ± SD	PT Mean ± SD	PT/BW Mean ± SD
Abdominal (Eccentric)	73.04 ± 12.55	1.01 ± 0.11	45.77 ± 11.34	0.65 ± 0.15
Back (Concentric)	181.36 ± 23.19	2.26 ± 0.18	100.85 ± 23.90	1.44 ± 0.33
Hip adductors (Concentric)	124.11 ± 7.24	1.79 ± 0.19	120.06 ± 5.44	1.74 ± 0.14
Hip adductors (Eccentric)	89.94 ± 15.61	1.12 ± 0.16	57.68 ± 14.62	0.74 ± 0.11

PT = peak torque; PT/BW = peak torque/body weight; SD = standard deviation.

There were no significant differences between the healthy and injured groups for the eccentric abdominal/concentric back and eccentric abdominal/eccentric hip adductor muscle ratios ($p > 0.05$). However, there were significant decreases in both the eccentric abdominal/concentric hip adductor muscle ratio ($p = 0.000$) and the eccentric/concentric hip adductors muscle ratio ($p = 0.016$) in the OP group, as shown in Table 3.

DISCUSSION

Our study was conducted to compare the E/C ratios for the abdominal/adductor, abdominal/back, and hip adductor muscles and the eccentric abdominal/eccentric adductor muscles between soccer players with OP and healthy soccer players. An angular velocity of 180°/s was chosen to imitate the muscular performance during high-speed sports-specific activities such as sprinting, kicking, and cutting, which were reported to be provocative.[26]

Historically, clinicians and researchers have used comparisons of the concentric strength values from the same muscle groups in opposite extremities to evaluate the differences in muscle activity between normal athletes and OP.[17] However, isokinetic assessment provides technological advances to improve the evaluation of many sports problems by using the eccentric mode of contraction, given that many muscles work concentrically and eccentrically while

TABLE 3 The Hip Adductors, Abdominal, and Back Muscle Ratios of Healthy Athletes and Athletes with Osteitis Pubis

Test statistics	Healthy athletes ratios	Osteitis Pubis ratios	p value
	Mean ± SD	Mean ± SD	
Eccentric Abdominal/Concentric Back	0.77 ± 0.19	0.83 ± 0.12	0.216
Eccentric Abdominal/Eccentric Adductor	1.04 ± 0.27	1.24 ± 0.39	0.311
Eccentric Abdominal/Concentric Adductor	0.61 ± 0.06	0.38 ± 0.09	0.000*
Hip adductors Eccentric/Concentric	0.64 ± 0.06	0.43 ± 0.08	0.016*

**Significant < 0.05*

kicking. Consequently, any abnormalities in eccentric/concentric ratios may reveal pathologies or identify athletes who may be at risk for injury.[27]

The high eccentric abdominal/concentric back ratio in the OP group results from both back and abdominal muscles imbalances, including concentric weakness of the back muscles and eccentric weakness of the abdominal muscles (see Table 2). Both imbalances result in non-significant differences in eccentric abdominal/concentric back muscle ratios between healthy and OP athletes. In the same context, Mohammad, Abdelraouf, Abdel-aziem[28] assessed the trunk muscles in healthy soccer players, compared them to soccer players with OP and found significant decreases in concentric and eccentric contractions of the back and abdominal muscles, respectively. A possible explanation they proposed for these observations was an increased anterior pelvic tilt produced by decreased hip flexor length [29] and an increased PT/BW value of the hip flexor muscles in OP.[17] Conneely, Sullivan, Edmondston [30] reported excessive extension of the lumbar spine and anterior pelvic tilt in OP patients during hip extension due to their inability to actively isolate these movements. This excessive anterior pelvic tilt puts a strain/passive tension on the insertion of the abdominal muscles. Stretching of the abdominal muscles may lead to pain and to reflex inhibition of back muscles rather than to actual weakness. In addition, eccentric weakness of the abdominal muscles leads to less effective stabilization capacity and uncontrolled eccentric contraction, resulting in more stretch and shear on the symphysis pubis.

The absolute PT values for the concentric strength of the back muscles and the eccentric strength of the abdominal muscles for healthy athletes in the current study were 181.36 and 73.04, respectively (see Table 2). These values were compared to those observed by Müller, Müller, Stoll, Fröhlich, Baur, Mayer [31], who presented a nearly identical value for the PT of back muscles in healthy adolescent athletes (187 Nm) but a different value for abdominal muscles (146 Nm). This difference may be due to their use of a different angular velocity.

It has been suggested in the literature that OP in soccer players is related to the repetitive stress on the abdominal and hip adductor muscles during kicking,[32] without clarification or substantiation of the phase of kicking or the type of contraction during which this stress occurs. Our finding of a decreased eccentric abdominal/concentric hip adductor ratio observed in OP athletes compared to healthy athletes may have clinical relevance to this injury pattern. When an athlete kicks, the kicking limb is hyperextended at the hip in the backswing phase of kicking, while the trunk is rotated laterally in the opposite direction,[11,33] which results in eccentric loading and possibly overloading from abdominal muscles, which pull superiorly, while the adductor muscles pull inferiorly.

The backswing phase of kicking is followed by the acceleration phase, where the angular velocity of the thigh is positive until ball impact,[33] and during which concentric contraction of the adductor muscles occurs. Regarding the eccentric abdominal/concentric adductor ratio, as this ratio decreases, either the eccentric force has decreased compared to the concentric force or the concentric torque has increased compared to the eccentric torque. If one reconsiders the force-velocity relationship, the capacity of the abdominal muscles in the OP athletes to maintain eccentric torque production at the velocity used here was inadequate compared with the concentric torque of the hip adductors. These findings may help to explain the high incidence of OP and the susceptibility of healthy soccer players to injury. This observation may constitute the basis for the finding that persons with OP have fracture lines described as tension stress fractures when their pubic symphysis is scanned using MRI. These fractures may have been caused by excessive tensile or torsional stresses across the pelvis secondary to muscle imbalances,[34] which would then suggest that rehabilitation should include not only concentric muscle strengthening but also eccentric muscle strengthening, particularly for the abdominal muscles.

The eccentric PT values of hip muscles for OP soccer players are unique to this study. However, several studies have reported PT values of hip adductor muscles in normal athletes[18,35–37] or the effects of specific training programs on the symptoms of OP.[9] A reduced eccentric/concentric hip adductor muscle ratio was observed in the OP cases in this study. Since the magnitude of the moments produced by the concentric and eccentric modes are velocity dependent,[27] the eccentric/concentric ratio is velocity dependent and increases proportionately to the test velocity, which is relevant to soccer given that it is a high-speed sport requiring sudden directional changes. The higher eccentric strength in normal athletes may reflect the role of hip adductor contraction during the backswing phase of kicking. In contrast, the reduced eccentric/concentric ratio for the hip adductors in OP may be related to impaired neuromotor control of the adductors or may be due to either selective inhibition of their eccentric performance as a result of pain[38] or a rapid change in the mode of contraction from eccentric to concentric. The difference between normal and OP athletes in the eccentric/concentric ratios of the hip adductors at high velocity supports our hypothesis. The eccentric/concentric hip adductor strength ratio of 64% or lower shown in our study may be one of the greatest risk factors for OP.

Neural control of the lengthening contraction can be explained by two mechanisms: neural inhibition[39] or incomplete voluntary activation.[40] Duchateau, Enoka[39] suggested that during lengthening contractions, the augmented feedback from peripheral sensory receptors seems to be suppressed by centrally and peripherally mediated presynaptic inhibition of Ia afferents, which may explain the depression of voluntary activation that occurs during maximal lengthening contractions to prevent tissue damage. Additionally, this neural inhibitory control could be greatly reduced after a formal resistance training program, increasing the chance for overuse injuries to occur in response to the erratic pulling of eccentrically weak muscles. Serner, et al. concluded that specific hip adduction exercises can be used during different phases of groin injury prevention and treatment in soccer players.

CONCLUSION

This study revealed that eccentric/concentric ratios may help to predict the development of OP in soccer athletes. This information may help clarify the role of trunk and hip adductor muscles in the development of OP and may allow these muscle strength assessments to guide return-to-play decisions. Exercises that increase the eccentric strength of the abdominal and adductor muscles should be included in rehabilitation programs developed for patients with OP. Moreover, restoring the correct eccentric abdominal/concentric adductor and eccentric/concentric hip adductor ratios might be an important measure for preventing possible muscle imbalances, consequent instability of the pelvic region, and the subsequent risk of OP.

DISCLOSURE

The authors have no conflicts of interest to declare.

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