

***Qualitative and Quantitative Assessment of  
Functional Performance Before and After  
Reconstruction of Anterior Cruciate Ligament in  
people from non-elite/professional sporting  
background***

**Adel A. Almangoush**

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**Adel A. Almangoush**

School of Health Sciences College of Health and Social Care

University of Salford, Salford, UK

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## ***Abstract***

Reconstruction surgery is a very common management option following rupture of an anterior cruciate ligament (ACL). There is currently no study assessing ACL patients following surgery in Egypt (or other Arabic countries) or in people who are not from competitive sports background. The aims of this thesis were to evaluate the quantity and quality of functional performance, postural stability and rehabilitative outcomes of non-high competitive sports patients following ACL reconstruction in Egypt. To accomplish these research aims, five separate studies were performed;

**Study one:** A systematic scoping review of the ACL reconstructed patients' outcomes and the measures used to evaluate them following the surgery including functional performance testing and patient reported questionnaires. The findings of this review suggested a more extensive series of tests to measure both the quantitative and qualitative aspects of functional performance and control stability for people participating in non competitive sports and who had the ACL reconstruction. Also The KOOS and the IKDC questionnaires are both measures that are increasingly being used for ACL reconstruction throughout the last decade; **Study two:** One hundred and twenty nine Egyptian patients were included to assess the reliability and validity of an Arabic version of the Knee KOOS. The results demonstrated acceptable psychometric characteristics of the Arabic version of KOOS with similar qualities to the original American-English language version among the Egyptian population.

**Study three:** Four subjects and four assessors were involved in this preliminary study to assess the test retest (inter- intra tester) reliability of a qualitative scoring system of limb alignment during single leg squat (QASLS). The results indicated that the qualitative evaluation method may allow clinicians and researcher to standardize the categorization of functional movements of single-leg loading such as the SLS regardless of the equipment, time and a venue.

**Study four:** An observational and prospective study with repeated measurements of eighty nine ACL reconstructed Egyptian patients were included and functionally evaluated before surgery and three, six and twelve months following surgery. All functional performance testing and self-reported outcomes are improved at six and twelve months postoperatively compared with preoperatively data and regardless of rehabilitation achieved.

Finally, **study five:** A retrospective study of a twenty four patients were collected from private clinics in the UK and evaluated in the period between six and nine months following their ACL reconstructions, then matched with similar group of patients from study four to identify the relation between the prospective and the retrospective study by comparing their results.

## CANDIDATE CONTRIBUTIONS

### Papers

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# *Chapter one*

## **1.1 General introduction**

The anterior cruciate ligament (ACL) is the primary passive restraint against anterior tibial translation and hyperextension of the knee. As a secondary stabiliser, it restrains the varus and valgus as well as internal stresses (a back-up at knee joint displacements) and external stresses (block a positive clinical laxity test conducted with low manual forces) on the knee (Butler, Noyes & Grood, 1980). The cruciate ligaments have been known since Ancient Egyptian times and their anatomy was described in the famous Smith Papyrus (3000 BC) (Davarinos, O'Neill & Curtin, 2014). Rupture of the ACL is a common injury in active people, and one of the most common knee injuries in sports. The risk factors that predispose an individual to an ACL injury are multifactorial - anatomical, biomechanical, neuromuscular and environmental. ACL injuries involve over-stretching or tearing of the ACL ligament in the knee (Shaarani, Moyna, Moran, & O'Byrne, 2012). The injury is characterized by joint instability that leads to pain, decreased activity and function, poor-knee-related quality of life and an increased risk of osteoarthritis of the knee (Shaarani et al., 2012).

Global statistics on ACL injuries are mainly limited to the Western hemisphere. The USA has an annual incidence of 200,000 ACL injuries Injury (Griffin, Albohm, Arendt, Bahr, Beynnon et al., 2006). Among collegiate athletics the rate of ACL injuries increased 1.3%

between 1988 to 2004, with a subsequent time loss of > 10 days in 88% of the injured athletes and at a cost of USD1 billion for ACLRs alone (Hootman, Dick & Agel, 2007). According to the incidence figures quoted in the Swedish anterior cruciate ligament (ACL) registry which assumed that in a UK population of around 60 million, approximately 60,000 ACL ruptures a year could be expected (Gabr, O'Leary, Bollen, Spalding & Haddad, 2015). The Swedish registry expects about 50% to require/undergo reconstruction which means 30,000 patients a year in the UK. A total of 2854 ACLR procedures were registered in the UK National Ligament Registry (NLR) between December 2012 and February 2015 (Gabr et al., 2015). The average age for patients undergoing ACLR is 30 years. The rates in Egypt were compatible with this figure (The 63rd Annual International congress of the Egyptian Orthopaedic Association, Cairo, 2012). There is now clear evidence that women have a 2 to 8 times greater of suffering an ACL injury than are men when exposed to the same activity level (Gwinn, Wilckens, McDevitt, Ross & Kao, 2000; Anderson, Dome, Gautam, Awh & Rennirt, 2001). There is no difference in outcome between men and women after ACL reconstruction, certainly in patients with hamstring tendon autograft and interference screw fixation (Salmon, Refshauge, Russell, Roe, Linklater et al., 2006). Nowadays, ACL reconstruction surgery is a major area of research worldwide. This is partly due to the large number of athletes being involved in professional sports where a fast recovery and rehabilitation are essential for a quick return to sport. It is also due to the greater awareness in the general public of their own healthcare and the higher expectations for performance now evident in amateur sports-persons and non-sports-persons alike.

There are many possible ways to evaluate the knee after an ACL injury. Various aspects of the injury require different evaluation methods. For a complete evaluation of a knee-injured subject, assessment of impairment after, for example, an ACL injury could include magnetic resonance imaging (MRI), arthroscopy and laxity testing. Activity and activity limitations are usually evaluated by means of an activity related knee score, functional performance tests and postural control. The subject's ability is evaluated with an activity score. Quality of life could be assessed with a generic score such as the SF-36 (Jenkinson, Wright & Coulter, 1993) or KOOS (Roos, Roos, Lohmander, Ekdahl & Beynnon, 1998), which makes comparisons to other impairments or diseases possible.

The researchers anticipate that the functional performance tests are being used clinically as outcome measures to evaluate improvements, to define recovery in terms of function, and to determine if a patient is able to achieve the previous activity level. Functional performances are assessed by means of qualitative and quantitative information related to specialized motions involved in functional activities (Reiman & Manske, 2009). The tests are often utilized for assessment of patients' pain, muscle strength and power, lower extremity joint stability in multiple planes of movement, endurance, muscle flexibility, balance, proprioception, speed, agility, and level of aerobic and anaerobic condition (Reiman & Manske, 2009).

A common observation made by both physicians and physical therapists, who deal with this category of patients, is the lack of confidence in the patient concerning the injured knee in spite of a restored objective and subjective stability. Psychological factors, such as fear of a painful re-injury and low self-efficacy beliefs, the patients' 'desired' physical activity level and social factors, such as family or work career, are also frequently discussed (Kvist, Ek, Sporrstedt & Good, 2005; Thomeé, Währborg, Börjesson, Thomeé, Eriksson et al., 2008; Langford, Webster & Feller, 2009; Arden, Webster, Taylor & Feller, 2011). Furthermore, it has been noted that patients' compliance decreases over time during the rehabilitation process (Beynon, Johnson & Fleming, 2002). ACL-reconstructed athletes express frustration that the progress during rehabilitation is much slower than they had expected. As a result, the compliance of some patients decrease, some will even give up, while others increase their efforts and continue with their rehabilitation (Heijne, Axelsson, Werner & Biguet, 2008).

The instruments of measurement are important in order to identify different functional problems but also to evaluate objectively the results of an intervention. Several instruments and questionnaires are available to assess patients' subjective and objective recovery outcomes after an ACL injury or reconstruction, and numerous functional performance tests and self reported outcomes can be used to evaluate the recovery of patients suffering a lower extremity injury, such as an ACL reconstruction. These researchers are unaware of a comprehensive review of the literature that has examined the

utility of the functional performance tests and self reported outcomes in clinical practice in the last decade.

## **1.2 The rationale which led to this project**

To the best of our knowledge there is no study in Egypt that evaluated the functional outcomes and rehabilitation following the ACLR. There is also a lack in studies worldwide that tested the functional performance preoperative and 3, 6 and 12 months postoperatively. To our knowledge there is no study that investigated dynamic postural stability before and after ACLR especially with measurement like the star excursion balance test (SEBT). There is no study that qualitatively evaluated the quality of lower extremity movement during loading for ACLR patients. All previous studies have included athletics or competitive sports participants with high level of activity, therefore it is now necessary for this research study to provide answers to some of these questions. There is a need to know the outcomes of patients with low level of activity in new and different regions with different cultures. This study will explore the compliance and rehabilitation provided to ACL patients in Egypt, at present there is no measure of quality of the outcomes of Egyptian surgery. The last outcome for this project was to find the differences in the recovery outcome of patients following ACL surgery in the UK and Egypt.

### **1.3 Aims**

Reconstruction surgery is a very common management option following rupture of an anterior cruciate ligament (ACL). There is currently no study assessing ACL patients following surgery in Egypt or other Arabic countries, or in people who are not from competitive sports backgrounds. The aims of this thesis were to evaluate the quantity and quality of functional performance, postural stability and rehabilitative outcomes of non-high competitive sports patients following ACL reconstruction in Egypt.

### **1.4 Objectives**

To accomplish these research aims five separate studies were performed;

**Study one:** A systematic scoping review of the ACL reconstructed patient outcomes and the measures used to evaluate them following surgery including functional performance testing and patient reported questionnaires in the last decade.

**Study two:** One hundred and twenty nine Egyptian patients were included to assess the reliability and validity of an Arabic version of the Knee injury and Osteoarthritis Outcome Score (KOOS).

**Study three:** Four subjects and four assessors were involved in this preliminary study to assess the test retest (inter- intra tester) reliability of a qualitative scoring system of limb alignment during the single leg squat (QASLS).

**Study four:** An observational and prospective study with repeated measurements of eighty nine ACL reconstructed Egyptian patients were included and functionally evaluated before surgery and three, six and twelve months following surgery.

**Study five:** A retrospective study using twenty four patients from private clinics in the UK were evaluated between six and nine months following their ACL reconstructions, then matched to a similar group of 24 Egyptian patients from the study five to identify the relationship between the prospective and the retrospective study by comparing their results to determine the quality and differences between them.

This chapter has introduced the background for this thesis and given the reasons for the investigations. The following chapter presents a scoping systematic review of the literature showing which more modern and current functional performance and self-reported outcome measurements are available to evaluate ACL reconstruction patients following surgery in the last decade.

## *Chapter two*

### **Functional performance testing and patient reported outcomes following ACL reconstruction: a systematic scoping review**

#### **2.1 Introduction**

Reconstruction surgery is very common to restore a rupture of an anterior cruciate ligament (ACL). There is currently a multiplicity of functional performance tests and patient reported outcome measures to determine the success of this surgery and rehabilitation (Linko, Harilainen, Malmivaara & Seitsalo, 2000; Phillips, Benjamin, Everett & Deursen, 2000; Tegner & Lysholm, 1985; Shaw, Chipchase & Williams, 2004). For instance; the review done by Brealey and Gillespie found more than 15 patient-assessed health instruments specific to the knee in the 31 studies that were included (Brealey & Gillespie, 2004). Also, Wang et al. identified twenty-four unique instrument outcomes measurements for the knee (Wang, Jones, Khair & Miniaci, 2010). Regarding functional performance tests the review done by Clark reported more than 18 tests were used to evaluate the function of lower extremity following an ACL deficiency or ACL reconstruction (Clark, 2001). In light of the abundance of tests available, there appears no consensus regarding which test or combination of tests is most appropriate for evaluating recovery following ACL reconstruction (Phillips et al., 2000). It has been recommended that a multiplicity of assessments, incorporating both functional performance testing and patient reported tools, are important to evaluate functional ability and outcome for patients following ACL reconstruction (Phillips et al., 2000), but which of these tests or

combination of tests provides the most rigorous test for outcome remains unclear. As no single instrument or functional performance test is currently capable of measuring all the multitude of parameters believed to relate to outcome, it is rational to accept that a range of tests should be administered to facilitate a full comprehensive evaluation of outcome.

Functional performance testing is likely to indicate the outcome of the neuromuscular training and appears to consist of two components (Ageberg, 2002). The first component is the quantity of movement that could be defined as the interrelationship between displacement, velocity and acceleration, both linear and angular (Kinematics) or forces that change motion - using Newton's Laws, impulse and momentum, in linear and angular terms (Kinetics)( Hamill & Knutzen, 2006), or the capabilities of the production of the force, for example: muscle strength measurements and hop tests (Ageberg, 2002). The second component is the quality of movement that look at occurrence, alignment and deviation of the body or a part of body movements, for example the total of knee flexion when landing from a jump or the occurrence of dynamic knee valgus (Ekegren & Miller, 2009; Von Porat, Holstrom & Roos, 2008). Although qualitative assessment of movement is by nature a subjective judgment, this does not mean that it is unorganized, vague, or arbitrary (Knudson, 2013).

These two components are important in rehabilitation and prevention of ACL recurrent injuries or surgery failure (Ageberg, 2002; Thomeé, Kaplan, Kvist, Myklebust, Risberg et

al., 2011; Paterno, Schmitt, Ford, Rauh, Myer et al., 2010). Most papers describing the functional performance following ACL reconstruction are using the limb symmetry index (LSI) and thus are limited to quantitative measurements (Maletis, Cameron, Tengan & Burchette, 2007; Heijne & Werner, 2010). Functional performance testing using qualitative methods evaluates compensation, or asymmetry, through clinical observation (Lephart & Henry, 1995).

The limb symmetry index (LSI) calculation is commonly used when reporting the results of functional hop tests. The LSI is the percentage deficit of the distance hopped on the involved leg compared with the contra-lateral non-involved leg (Clark, 2001). The use of the LSI minimizes the probable confounding variable of the biological variation between people, from influencing the results (Sward, Kostogiannis & Roos, 2010). The work of Munro and Herrington (2011) showed LSI needs to be in excess of 90% to be deemed normal. A functional outcome is a predicted result of care that is meaningful and practical for the patients and sustainable beyond the rehabilitation environment (Keskula, Duncan, Davis & Finley, 1996). Functional outcomes not only assess benefits but also provide cost-benefit data. There are advantages and limitations to each measure used independently or in conjunction with other measures (Keskula et al., 1996). The practicality of functional outcome measures employed in the clinical/research setting is an important consideration (Keskula et al., 1996). Functional or performance tests provide an objective assessment of components of the patients' ability in a structured, controlled

setting. Combining several tests to assess function may serve to minimize any trade-offs between specificity and sensitivity (Portney & Watkins, 2008).

Regardless of which tests are selected, it is imperative that they be standardised, reliable, valid and responsive to change with time as well as being clinically relevant (Johnson & Smith, 2001; Hammond, 2000; Law, 1987). Ideally, outcome measures in research and clinical practice should be low-cost, take an acceptable length of time to administer, be convenient for researcher and clinicians to use, and be acceptable to the participants under investigation (Hammond, 2000; Law, 1987). Therefore, the purpose of this scoping review was to identify and explore a number of commonly used outcome measures for patients following ACL reconstruction, and postoperative rehabilitation to assess both aspects (quantitative and qualitative) of functional performance tests, and self-reported questionnaires that have been used in last decade.

## **2.2 Methodology**

We adopted a “systematic” scoping review approach – this is a combination of a scoping review methodology – to ensure the inclusion of broad areas of research and study designs, and a systematic review of the methodology of the reviews (Arksey & O'Malley, 2005). A scoping review is a relatively new type of study providing an assessment of available evidence from the literature in a broad area of research such as the compliance in the reporting of clinical studies to established guidelines. It also serves to identify

information gaps in the field and provide recommendations for implementation (Arksey & O'Malley, 2005).

The methodology of scoping reviews was first described in detail by Arksey and O'Malley (2005) in their pivotal paper published in 2005, which provided the foundation for carrying out a scoping review. This framework was further refined, and five stages were proposed to be followed when conducting a scoping review, including: (1) the identification of a research question; (2) finding the relevant studies; (3) the selection of studies to be included in the review; (4) data extraction from the included studies; and (5) assembling, summarizing, and reporting the results of the review (Brien, Lorenzetti, Lewis, Kennedy & Ghali, 2010).

### **2.2.1 Search strategy**

A PRISMA compliant search strategy was used for study selection. The inclusion criteria of studies were: (1) At least one lower extremity/knee functional performance test used as an outcome measurement of the article and/or patient reported outcomes, (2) Subjects who were post ACL-reconstruction, (3) Studies which were either randomised control trial (RCTs), cross-sectional or cohort designs. (4) Studies published in English between April 2004 and April 2014. Later updated up to July 2015.

The electronic database used were: MEDLINE, (MeSH terms), PubMed, Cochrane Library (systematic reviews and controlled trials registers), EMBASE, CINAHL, SPORTDiscus, PEDro (Physiotherapy Evidence database) and AMED (Allied and Complementary Medicine Index). In order to capture as many relevant references as possible, an expanded search was performed, including hand-searching the reference lists of all relevant articles, texts and systematic reviews.

Search was conducted using the terms “knee” AND “ACL injuries” OR “functional performance” AND “measure” OR “test” OR "screen" OR "assessment" Or "patient reported". The keyword search was also performed on PubMed utilising the key terms “anterior cruciate ligament” AND "surgery" AND "injury" AND "physical performance outcome measurements" to ensure a detailed and comprehensive search strategy, the additional search was performed in academic textbook that contained an extensive review of functional performance tests (Reiman & Manske, 2009).

**Table 2-1:** Search terms for a Medline search strategy.

Number	Search term
1	Functional
2	Performance
3	measure
4	screen
5	assessment
6	objective
7	Subjective
8	questionnaire
9	Surgery
10	ACL
11	Knee
12	Injury
13	anterior cruciate ligament

### **2.2.2 Study identification**

Two reviewers (AA, LH) independently reviewed all titles and abstracts that were identified from the search strategy. In accordance with the predefined eligibility criteria the full-text manuscripts for all potentially eligible studies were obtained, and then in accordance with the predefined eligibility criteria the reviewers independently reviewed them a second time.

### **2.2.3 Data extraction**

Data extraction for each eligible paper was performed independently by two reviewers (AA, LH) using a predefined spreadsheet. The reviewers' spreadsheets were amalgamated to create an agreed extraction form. The standardised data extraction form included details on (a) focus of study, study design, participant details, outcome measure (functional performance tests and patient reported outcomes), and results. In cases where insufficient data were provided within the publication, attempts were made to contact all corresponding authors to identify such data.

**Table 2-2:** Summary of the studies reviewed

Eligible Studies	Focus of study	Study design	Participant details Gender (F/M) Subject (Age)	Knee laxity	Functional performance tests		Patient reported tools	Results (LSI)
					Quantitative assessment	Qualitative assessment		
(1) Ageberg et al. 2008	Investigate of functional performance for ACLR patients at 2–5 years after injury.	Cohort study	54 patients (ages 18–35 years) physical activity level (5–9) on the Tegner Activity Scale	N/A	One-leg hop for distance  Vertical jump  Side hop	N/A	KOOS  Tegner	One-leg hop for distance  LSI 99.5%  Vertical jump LSI 96.4%  Side hop LSI 97.9%
(2) Baltaci et al. 2013	Determination of an acceptability of a Nintendo Wii Fit compared to a conventional rehabilitation as a therapy tool for ACLR patients.	RCT	30 men Wii Fit (n = 15; mean age, 29 ± 7 years) or conventional rehabilitation (n = 15; mean age, 29 ± 6 years)  physical activity level not stated	N/A	Functional squat tests  SEBT	N/A	N/A	N/A
(3) Ben Moussa et al. 2009	“To analyse postural stability and single-leg hop” measurements in post-ACLR subjects and compare them with an age- and activity-matched control group.	RCT	26 patients soccer players	N/A	Hop for distance  One-leg stance postural	N/A	N/A	N/A

					stability			
(4) Beynnon et al. 2005	Investigation of any difference in the patient satisfaction and functional performance when provide rehabilitation with either an accelerated or non-accelerated program.	RCT	22 patients 11 M/ 11 F Tegner scale of 5 or greater before injury	Kt-1000	One-leg hop for distance	N/A	KOOS IKDC	N/A
(5) Beynnon et al. 2011	Investigation of any difference in patient satisfaction, functional performance, activity level, between patients treated with accelerated versus non-accelerated rehabilitation programs.	RCT	36 patients 22 M/ 14 F Tegner scale of 5 or greater before injury	Kt-1000	One-leg hop for distance	N/A	KOOS IKDC Tegner	N/A
(6) Delahunt et al. 2013	Investigation of dynamic postural stability as quantified by the SEBT and simultaneous hip- and knee joint kinematics in participants with previous ACL reconstructions.	Cohort study	17 patients All female athletes	N/A	SEBT	N/A	KOOS IKDC	N/A
(7) Halinen et al. 2006	Determination of whether a non-operative and early operative treatments of grade III medial collateral ligament rupture leads to similar results.	RCT	47 patients 27 F/ 20 M IKDC Activity level scale 2.7 (4-1)	Kt-1000	One-leg hop for distance	N/A	IKDC Lysholm score	N/A

(8) Halinen et al. 2009	Evaluate of the effect of early repair of the concomitant medial collateral ligament injury on the range of motion of the knee in ACLR patients.	RCT	47 patients  Physical activity level not stated	Lacham	One-leg hop for distance	N/A	N/A	One-leg hop for distanceAt 52 weeks  Group I LSI 83.1% Group II LSI 86.1% t 104 weeks Group I LSI 90.2% Group II LSI 93.4%
(9) Hartigan et al. 2010	Determination of an effective interventions for improving readiness to return to pre surgery activity.	RCT	40 patients  29 M/11 F  (average age of 28.4 years)  IKDC activity level I or II	Kt-1000	Single hop crossover hop, and triple hop tests for distance, and the 6-meter timed hop test for speed	N/A	N/A	<b>6-meter timed hop test,</b> Group I LSI 89.2% Group II LSI 89.8% <b>One-leg hop test,</b> Group I LSI 83.7% Group II LSI 83.1% <b>Crossover hop test,</b> Group I LSI 81.7% Group II LSI 85.6% <b>Triple hop test,</b> Group I LSI 82.4% Group II LSI 86.4%
(10) Lindstrom et al. 2013	Using computed tomography (CT) to analyse muscle cross-sectional area and attenuation ratios (operated/non operated knee).	Cohort - study	37 patients 23 M/ 14 F (mean age 26.5 Yea, range=16-54)  Tegner activity level  7.5 (6–10)	Rolimeter	One-leg hop  Triple hop  Square hop  6-m timed hop	N/A	KOOS  Lysholm knee score  Tegner activity level rating scale	One-leg hop  Pre-operative LSI 0.82%  Post-operative LSI 0.93%
(11) McDevitt et al. 2004	Determination of postoperative functional knee and its influences outcomes.	RCT	100 patients  Physical activity level not stated	Kt-1000	Single-legged hop test	N/A	IKDC  Lysholm scores,	N/A

(12) Moksnes et al. 2009	Comparison of the functional outcome between ACLR and non- operative treatment.	Cohort study	125 Patients (ages between 14 and 60 years)  IKDC activity level I or II	Kt-1000	One-leg hop test, the triple hop, the triple crossover hop, and the 6-m timed hop test	N/A	KOS-ADLS) IKDC Global rating of knee function (VAS 0–100)	Single hop, LSI 91.8%  Triple hop 91.4%  Triple crossover hop LSI 93.5%  6-m timed hop test LSI 94.2%
(13) Risberg et al. 2007	Determination the effect of a 6-month neuromuscular training (NT) program versus a traditional strength training (ST) program following ACL surgery.	RCT	75 patients 27 F / 47 M (mean age 28.4 Yea, range=16.7– 40.3)  Physical activity level not stated	Kt-1000	One-leg hop test, triple-jump test, and stair hop test  Balance was recorded using static and dynamic balance tests	N/A	The Cincinnati Knee Score  Two VASs were included: one for pain intensity and one for global knee function.  SF-36	<b>One-leg hop test,</b> Preoperative: Group I LSI 93.7% Group II 90.1% at 6 months following surgery Group I LSI 81.0% Group II LSI 84.9% <b>Triple-jump test,</b> Preoperative: Group I LSI 94.6% Group II LSI 91.8% At 6 months following surgery Group I LSI 83.1% Group II LSI 88.5% <b>Stair hop test</b> Preoperative: Group I LSI 84.8% Group II LSI 78.4% At 6 months following surgery Group I LSI 79.8% Group II LSI 79.8%

(14) Salmon et al. 2006	Determination if there is any difference in outcome between men and women after anterior cruciate ligament reconstruction	Cohort study	200 patients 100 M/ 100 F Physical activity level not stated	Kt-1000	Single-Legged Hop Test Kneeling Pain	N/A	IKDC Lysholm Knee Score	N/A
(15) Shaw et al. 2005	The investigation of the effectiveness of quadriceps exercises following anterior cruciate ligament reconstruction.	RCT	103 patients 28 F/ 75 M Physical activity level not stated	Kt-1000	Single-leg hop test Triple hop	N/A	Cincinnati Knee Rating System	Single-leg hop test No quadriceps exercise LSI 81.7% Quadriceps exercise LSI 83.8% Triple hop No quadriceps exercise LSI 81.8% Quadriceps exercise LSI 83.7%
(16) Trulsson et al. 2010	The correlation between a novel test set, and commonly used tests of knee function.	Cohort study	53 patients (mean age 30 years, range 20-39) Tegner Activity Scale (5-9)	N/A	vertical jump, the one-leg hop and the side hop	Test for Substitution Patterns (TSP)	KOOS	Subjects had higher TSP scores on their injured side than on their uninjured side (median 4 and 1 points; interquartile range 2-6 and 0-1.5, respectively)
(17) Valkering et al., 2015	The investigation of whether ACL reconstruction in an outpatient setting is equally safe as in an inpatient setting and whether comparable functional outcomes can be achieved.	A prospective randomized controlled trial	Male/female 34/12 Age in years (SD) 29 (11.0) Physical activity level not stated	N/A	N/A	N/A	The Lysholm, Tegner and IKDC	No significant differences were found between the study groups in all the outcome measures at 12 months following the ACL surgery

#### **2.2.4 Critical appraisal**

Each study's methodological quality was assessed by using an appraisal tool devised to specifically evaluate functional performance testing and patients' reported questionnaires of studies that included those patients following ACL reconstruction. This was based on the Critical Appraisal Skills Programme (CASP) critical appraisal tool (CASP, 2007), which have been widely used and employed in previous systematic reviews to evaluate the methodological quality of clinical studies (Reilly, Barker & Shamley, 2006; Smith, Walker & Russell, 2007; Smith, Davies & Hing, 2013).

The tool assessed domains such as the identification of the research questions, appropriateness of the research design, surgery and rehabilitation outcomes, the accuracy of description of methodology and population, appropriateness of analysis methods and interpretation of findings. The appraisal was independently undertaken by two aforementioned reviewers (AA & LH). If any disagreements arose regarding the study selection, data extraction or appraisal score, these were sorted out through discussion between the two reviewers until a consensus was met. Studies were excluded if they achieved a very low methodological score of less than 50% through the CASP scoring system. A total score was calculated by adding up all positive items.

#### **2.2.5 Data analysis**

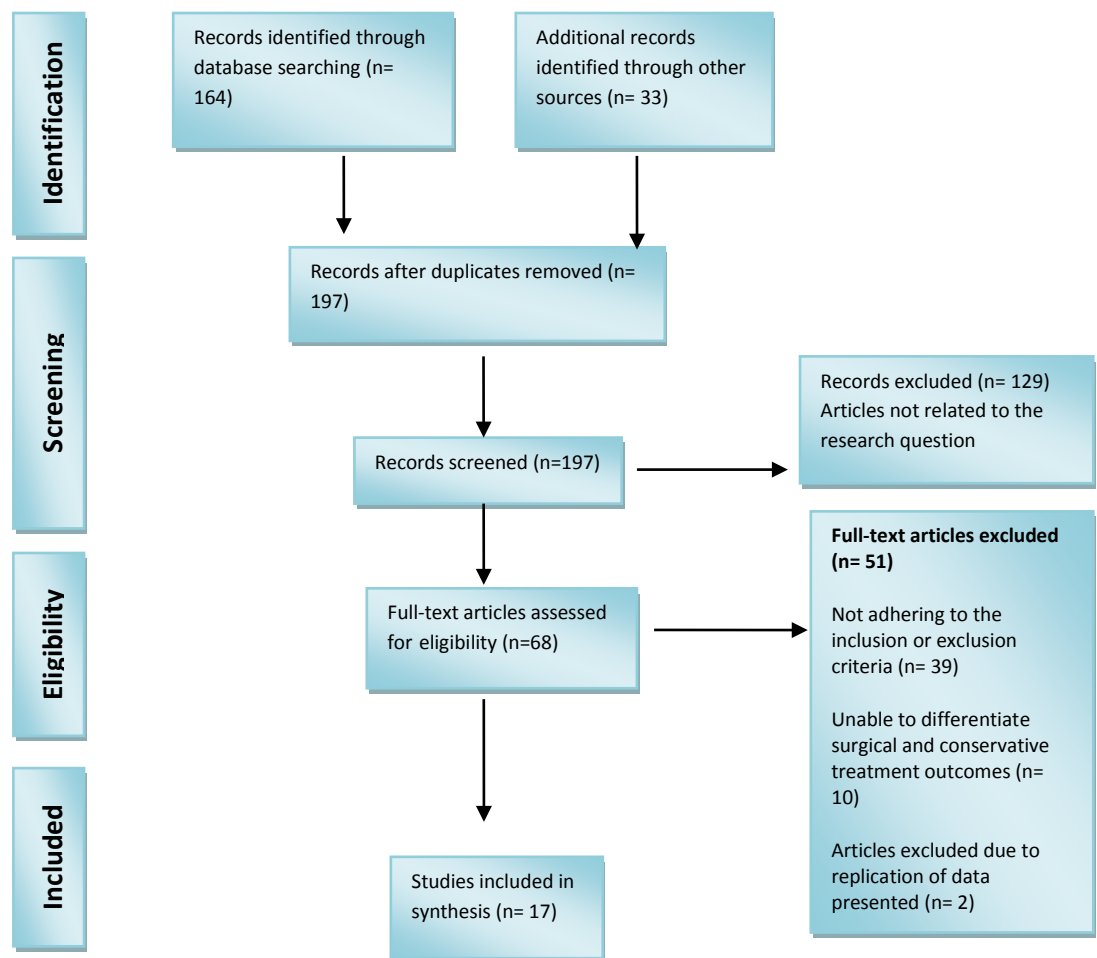
All analyses were initially undertaken by one reviewer (AA) and verified by the other reviewer (LH). A narrative review was undertaken of all included literature. An

assessment of the quantity and quality of functional performance testing and patient reported tools of those patients following ACL reconstruction by means of a meta-analysis was planned. However, unfortunately due to the heterogeneity of the studies, in particular the information regarding surgery and rehabilitation outcomes, it was not possible to complete this analysis.

## **2.3 Results**

### ***Search strategy***

A PRISMA compliant search strategy was used, and results are presented in a PRISMA flow diagram (Figure 2-1) (Moher, Liberati, Tetzlaff & Altman, 2009). As Figure (2-1) demonstrates, a total of 196 citations were identified through the search strategy. Seventeen papers satisfied the eligibility criteria and were therefore included in the review. This included 11 randomised controlled trials and 6 cohort studies. These were summarised in Table (2-2).



**Figure 2-1: PRISMA** follow diagram to depict search strategy results.

### *Critical appraisal*

The findings of the critical appraisal are summarised in Table (2-3). On analysis, the literature presented with a number of methodological limitations. Only seven papers (41%) justified their sample sizes based on power calculations. Whilst the surgery management strategies undertaken were clearly described in most of these papers, only

six publications presented sufficient information to reproduce their methodologies for physiotherapy treatments and described the rehabilitation programs undertaken (35%). Furthermore, whilst all studies reviewed used appropriate outcome measures to evaluate their participants, only a few of them defined the presence of an observer. Whilst inferential statistics were presented in all included publications, confidence intervals were only provided in five papers (29%). No study presented a standard error of measurement. None of the included studies evaluated the patients before the ACL operation, except one recent randomised controlled trial (RCT) that conducted by Valkering and his colleagues (Valkering et al., 2015). However, all authors interpreted their findings appropriately and related these results in a suitable manner to clinical practice and the existing evidence base. All papers passed more than 50%.

**Table 2-3:** The Critical Appraisal Skills Program results (CASP)

The Criteria	(1) Ageberg et 2008	(2) Baltaci et al., 2013	(3) Ben Moussa et al., 2009	(4) Beynon et al., 2005	(5) Beynon et al., 2011	(6) Delahunt et al., 2013	(7) Halinen et al., 2006	(8) Halinen et al., 2009	(9) Hartigan et al., 2010	(10) Lindstrom et al., 2013	(11) McDevitt et al., 2004	(12) Moksnes et al., 2009	(13) Risberg et al., 2007	(14) Salmon et al., 2006	(15) Shaw et al., 2005	(16) Trulsson et al., 2010	(17) Valkering et al., 2015
Study design	N	Y	N	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Focused question	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Appropriate design	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Population defined	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Recruitment methods Acknowledgd	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	N
Sample size defined by power	Y	N	N	N	Y	N	N	Y	Y	Y	N	N	Y	Y	N	N	Y
Study setting described	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N
Interventions described (Surgery)	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
Rehabilitation described	N	Y	N	Y	N	N	N	N	N	Y	N	N	Y	N	Y	N	Y
Outcome measures defined	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observers defined	Y	N	N	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N
Statistical methods described	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Variance described	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y
Inferential statistics employed	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Confidence intervals presented	Y	N	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	N	Y
Appropriate interpretation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Generalizability	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Relevance to present evidence base	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Clinical relevance discuss	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
The Score	16	15	13	16	16	14	13	12	16	17	15	16	17	17	16	13	16

### **2.3.1 Study description**

### **2.3.2 Outcome Measures**

A variety of different functional performance tests and patient reported outcomes measures have been reported in patients following ACL reconstruction. These were assessed individually as shown below.

### ***2.3.3 Functional performance testing***

### **2.3.4 Hop tests**

A number of different assessment methods were used to determine the functional performance of patients following ACL reconstruction. These methods included the one-leg hop for distance, this is a commonly used functional performance test of both strength and confidence in the tested leg; it correlates positively with muscle strength and power (Clark, 2001; Wisløff, Castagna, Helgerud, Jones & Hoff, 2004). The one-leg hop for distance, was assessed in fourteen studies (88%) of the papers included. Triple hop test for distance, was evaluated in four papers (Hartigan, Axe & Snyder-Mackler, 2010; Lindström, et al., 2013; Moksnes & Risberg, 2009; Shaw et al., 2005). Three studies described a 6-meter timed hop test for speed (Hartigan, Axe & Snyder-Mackler, 2010; Lindström, et al., 2013; Moksnes & Risberg, 2009). Crossover hop of distance, was assessed in two studies (Hartigan, Axe & Snyder-Mackler, 2010; Moksnes & Risberg, 2009) side hop and vertical jump were also assessed in two studies (Hammond, 2000; Trulsson et al., 2010) triple-jump test and stair hop test were evaluated in one study only

(Risberg et al., 2007) and functional squat test assessed in only one study also (Baltaci et al., 2013). More than 50% of studies used the hop tests as a measurement of function within the battery of different tests completed. Only seven studies used multiple hop tests (44%), and only seven papers (less than 50%) reported limb symmetry index (LSI) comparing the injured with uninjured leg. Only one study described the quality of movement whilst carrying out the test (e.g. dynamic knee valgus or knee flexion angle (Trulsson et al., 2010)).

### ***2.3.5 Postural control***

Postural stability of patients following ACL reconstruction was assessed in four studies by using different measurement methods. Baltaci et al. and Delahunt et al. used the modified star excursion balance test (SEBT) to evaluate the postural control of their patients (Baltaci et al., 2013; Delahunt et al., 2013). Risberg et al. (2007) and Moussa et al. (2009) used the NeuroCom Balance Master platform system to measure the postural stability. Balance was recorded using static and dynamic balance tests on an instrumented unstable platform (KAT2000).

### ***2.3.6 Patient Reported Outcomes***

Several reported questionnaires presented in the papers were evaluated in this scoping review. Whereas KOOS and IKDC were assessed in the most of the selected papers. Only five studies used Lysholm Score (Halinen et al., 2006; Lindström et al., 2013; McDevitt

et al., 2004; Salmon et al., 2006; Valkering et al., 2015), four papers assessed the Tegner activity level rating scale (Ageberg et al., 2008; Beynnon et al., 2011; Lindström et al., 2013; Valkering et al., 2015), and only two studies per each score evaluated the global rating scale (Hartigan, Axe & Snyder-Mackler, 2010; Moksnes & Risberg, 2009), the KOS-ADLS questionnaire (Hartigan, Axe & Snyder-Mackler, 2010; Moksnes & Risberg, 2009) and The Cincinnati Knee Score (Risberg et al., 2007; Shaw et al., 2005). Kocher, Steadman, Briggs, Zurakowski, Sterett et al., (2002) made a comprehensive analysis of determinants of patient reported outcomes after ACL reconstruction. They concluded that subjective variables are more important for evaluation of patient reported outcomes than objective findings. They found 7 “key” symptoms that together accounted for 83% of the variability in patients reported outcomes.

## **2.4 Discussion**

The authors of the current review aimed to identify existing functional performance testing and patient reported outcomes for patients following ACL reconstruction in the last decade. The most important finding of the present study was that all included articles used limited quantitative measurements to determine functional performance, except the study done by Trulsson et al. (2010). In the last decade most of the studies included in this review were focusing on the hop tests especially the single-leg hop test and few of these studies looked at a postural stability. Regarding the reported outcomes the focus was on the KOOS and IKDC questionnaires.

### ***Functional performance testing***

Although, the included articles reported the use of several hop tests, fourteen studies used a single-leg hop for distance as the gold standard for measuring functional performance after ACL reconstruction because the reliability of this test is high (ICC ranging from 0.86 to 0.95) (Gustavsson, Neeter, Thomeé, Silbernagel, Augustsson et al., 2006; Reid, Birmingham, Stratford, Alcock & Giffin, 2007). The relative reliability of the single hop for distance test in patients 1 to 2 years following ACL reconstruction has previously been reported (Hopper, Goh, Wentworth, Chan, Chau et al., 2002). However, several studies showed that the sensitivity increases when two or more different hop tests are performed (Reid et al., 2007; Hopper et al., 2002; Barber, Noyes, Mangine & DeMaio, 1992). By using a multiple of hop tests, therefore their qualities can be assessed and thereby the opportunity to detect discrepancies in hop performance increases (Gustavsson et al., 2006). There is a strong relationship between crossover hop performance and functional outcome (Trulsson et al., 2010) correlating significantly to IKDC subjective and KOOS questionnaire scores (Reinke, Spindler, Lorrington, Jones, Schmitz et al., 2011). The most reliable and valid of the multitude of hop tests in relation to the ACLR patient would appear to be the single hop for distance and the crossover hop tests (Clark, 2001; Reid et al., 2007; Logerstedt, Grindem, Lynch, Eitzen & Engebretsen et al., 2012). The ability of the ACLR patient to perform well during hop tests is of paramount importance when judging functional performance.

Hop testing has frequently been proposed as a practical performance-based outcome measure that reflects the integrated effect of neuromuscular control, strength (force-generating capacity), and confidence in the limb and requires minimal equipment and time to administer (Petschnig, Baron & Albrecht, 1998). Based on a review of the potential use of hop tests as measures of dynamic knee stability, Fitzgerald, Lephart, Hwang & Wainner, (2001) suggested that hopping may be appropriate for use as a predictive tool for identifying patients who may have future problems as a result of knee injury or pathology and as an evaluative tool to reflect change in the patient status in response to treatment.

Within the published literature, the ‘gold standard’ is often regarded as having a limb symmetry index (LSI) of greater than 85% (Clark, 2001), indicating that anything less than a 15% deficit in strength between the operated and non-operated limb is acceptable. This works on the assumption that the uninjured limb is ‘normal’ in terms of its strength (Clark, 2001). A study conducted by Schmitt, Paterno, & Hewett, (2012) has shown that the contralateral (non-injured) leg is significantly weaker than matched controls. Therefore, this assumption of normality should be viewed with caution, as the period of time both pre-operative and during post-operative rehabilitation is likely to have caused atrophy of the non injured leg. However, using the LSI is debatable because recent studies have shown that an ACL injury could lead to a cross-over effect in the uninvolved leg resulting in strength and function loss based on biomechanical and neuromuscular changes (Sward et al., 2010).

### ***Postural control***

To the best of the knowledge of this study's researchers, there are few published studies that search for postural stability following ACL reconstruction (Howells, Ardern, & Webster, 2011). For example the SEBT outcome measure offers a simple, reliable, valid and low-cost alternative to more sophisticated instrumented methods, to assess dynamic balance ability (Hertel, Miller & Denegar, 2010; Olmsted, Carcia, Hertel & Shultz, 2002), unlike force plates or electronically controlled balance platforms, it is an easy and highly portable test that could be employed in a range of clinical environments. According to Herrington, Hatcher, Hatcher & McNicholas, (2009) the grid required testing for ACL deficiency patients, three lines are positioned on the grid (anterior, medial and lateral reach distance) which are labelled according to the direction of excursion relative to the stance leg.

High inter-tester reliability of the SEBT has previously been reported (Hertel et al., 2010). Whilst previous studies have evaluated intra-tester reliability (Hertel et al., 2010), only one study has evaluated between-session reliability of the SEBT with normalised scores with ICC values ranging from 0.89 to 0.93 (Plisky, Rauh, Kaminski & Underwood, 2006). However, only 3 reach distances, anterior, postero-medial and postero-lateral were evaluated. Therefore, further study of between-session reliability of all reach directions is warranted.

Previous research has suggested that the SEBT is reliable and sensitive enough to detect dynamic postural control deficits in patients with an ACL-deficient (ACL-D) limb (Herrington et al., 2009; Hertel, Braham, Hale & Olmsted-Kramer, 2006). In these studies, patients who were injured were shown to have lower SEBT scores compared to those of their uninjured limb and those of healthy participants. In particular, Herrington et al. (2009) found that patients with ACL deficiency showed functional deficits in the anterior, medial, lateral and posterio medial reach directions.

Functional tests are a quick and inexpensive method of obtaining an objective measure of lower limb function following surgery (Barber et al., 1992). These tests are thought to provide an indication of muscle strength and power, neuromuscular control and confidence (Bandy, Rusche & Tekulve, 1994; Borsa, Lephart & Irrgang, 1998). Additionally, a number of authors have highlighted that a single functional test may not be sensitive enough to detect performance limitations and that at least two functional tests should be used (Hopper et al., 2002; Barber et al., 1992; Petschnig et al., 1998).

Furthermore, all included studies reported quantitative data such as distance and/or time. Only one study described the quality of movement whilst carrying out the test (e.g. dynamic knee valgus or knee flexion angle (Trulsson et al., 2010). High quality trials focusing on prevention showed that the risk for ACL injuries was reduced with training (Alentorn-Geli, Myer, Silvers, Samitier, Romero et al., 2009; Hewett, Lindenfeld, Riccobene & Noyes, 1999; Petersen, Braun, Bock, Schmidt, Weimann et al., 2005). For

ACL injury screening, Ekegren and his colleagues examined dynamic knee valgus during a drop-jump task. The drop jump turned out to be a reliable and valid instrument in observing the dynamic knee valgus (Ekegren, Miller, Celebrini, Eng & Macintyre, 2009). Von Porat et al. investigated video-taped functional performance tests in ACL injured subjects, they reported that observation is a reliable and valid instrument for assessing knee flexion angles of the one-leg hop for a distance (Von Porat, Holstrom & Roos, 2008). The single-leg squat (SLS) test is a cost-effective and simple movement to determine lower extremity alignment in the coronal plane. Carried out with a single camera in any setting, this procedure can visibly identify a valgus lower extremity alignment on landing, which is considered to be a potential risk factor for a possible non contact ACL injury (Paterno, Schmitt, Ford, Rauh, Myer et al., 2010). The SLS test has been described in a number of studies as a useful clinical measure to identify hip muscle function and dynamic knee control (Pinczewski, Lyman, Salmon, Russell, Roe et al., 2007).

### ***Patient Reported Outcomes***

Patient reported instruments are normally related to signs and symptoms experienced by the patient and/or the functional tasks that individuals are able to achieve during their activities of daily living (Borsa, Lephart & Irrgang, 1998). A commonly used knee outcome instrument is the Cincinnati knee scoring scale, and although it has been demonstrated to be an adequate tool to evaluate knee function following ACL reconstruction (Risberg, Holm, Steen & Beynnon, 1999), it also includes manual and

instrumented stability testing to assess symptoms and function, thus it becomes more difficult to separate various aspects of knee function following ACL injury.

The International Knee Documentation Committee (IKDC) developed a scoring system for knees with ACL injuries. The IKDC is reliable and the validity and responsiveness were found to be good (Irrgang, Allen, Arthur, Christopher, Masahiro et al., 2001). The IKDC, the Cincinnati knee scoring scale and the first version of the Lysholm score are assessor reported scores, which have been exposed to be biased when applied to individuals with an ACL injury (Hoher, Bach, Munster, Bouillon & Tiling, 1997). On the other hand, the Lysholm-Tegner system is much simpler, but mainly evaluates symptoms and activity. Carlos argued that for those clinicians and researchers considering using only the IKDC as their patient-reported outcomes for ACL reconstruction, they should include as a minimum, the KOOS subscales that address broader areas of concern, including quality of life and emotional health that are most important to patients following ACL reconstruction and which are not wholly represented in IKDC (Rodriguez-Merchan & Carlos, 2012). Moreover, there is a suggestion that the KOOS is perhaps more suitable for the assessment of patients in the longer term unlike the IKDC (Roos & Toksvig-Larsen, 2003). The KOOS has shown good validity and demonstrated that it is responsive to ACL reconstruction and rehabilitation, it shows that it is a reliable instrument for patients undergoing ACL surgery and rehabilitation (Roos & Toksvig-Larsen, 2003). KOOS has been used in an extensive amount of current research protocols and it has been translated and culturally adapted into various languages (Almangoush,

Herrington, Attia, Jones, Aldawoudy et al., 2013). Clinicians and researchers looking to use a patient-based score measure of outcomes must consider the specific patient population in which it has been evaluated. Using a diagnostic algorithm that measures the anatomic parts of the knee as separate constructs may solve this dilemma, allowing for the measurement of treatment outcomes across patient groups and the selection of the optimal clinical intervention.

In general, the papers in this literature review included poorly described sample sizes and whether or not the sample size was based on power calculations. Accordingly, the samples recruited may not necessarily have been big enough to identify a difference in outcome following a rehabilitation programme, irrespective of whether or not a difference existed (Polgar & Thomas, 2000). The papers weakly described who had assessed the subjects. Accordingly, it was not possible to determine whether measurement error influenced the results obtained, or whether the experiences or training of the assessors was a variable which may have accounted for any between-study differences.

## **2.5 Limitations**

There are limitations of this systematic scoping review that should be acknowledged. For instance the authors established very specific inclusion/exclusion criteria for selection of functional performance tests included in this review. This included only the functional performance tests for an ACL reconstruction patients after surgery. Many tests were excluded because the studies were performed on healthy people, or subjects with various

neurological or debilitating co-morbidities. Therefore, it is possible some functional performance tests were not identified. This may modify the interpretation of the values attained for a specific functional performance test, this was also the reason for the small number of studies included.

Future studies are required to establish the reliability and validity of existing functional performance tests or explore new, relevant quality measurements of the functional performance tests to be used in patients following ACL surgery.

## **2.6 Conclusion**

The review undertaken highlighted that the majority of studies in this area had either assessed an athletic very physically active population, or had not stated the physical activity level of participants. Therefore, data of patients with low activity level is still vague. Following the ACL reconstruction, the one-leg hop for distance or a combination of different hops and the limb symmetry index (LSI) of functional performance tests was used as a main outcome parameter of several studies. No extensive research has been carried out over the past 10 years to measure the control stability of patients following ACL reconstruction. Furthermore, no observation or videotaping were used to assess the quality of any test of any functional performance and control stability of ACL patients following surgery except for one study. Because previous studies discuss additional important parameters, a more extensive battery of tests is suggested to measure both the quantitative and qualitative aspects of functional performance after the ACL

reconstruction. The KOOS and the IKDC are both measures that are increasingly being used for ACL reconstruction during the last decade.

## ***Chapter three***

Presented in this chapter is how the KOOS questionnaire was developed into an Arabic version, which is the first time it has been developed for this language

### **Cross-cultural adaptation, Reliability, Internal Consistency and validation of the Arabic version of the Knee injury and Osteoarthritis Outcome Score (KOOS) for Egyptian people with knee Injuries**

#### **3.1 Introduction**

One of the most significant discussions in clinical outcome research is the evaluation of the benefits and cost effectiveness of new diagnostics, surgical intervention and rehabilitation for the management of knee injuries (Irrgang & Anderson, 2002). In a systematic review done by Almangoush and Herrington (2014) they stated that in the last decade regarding the reported outcomes the focus was on the KOOS and IKDC questionnaires. There is a strong relationship between crossover hop performance and KOOS questionnaire scores (Reinke, Spindler, Lorrington, Jones, Schmitz et al., 2011).

Rodriguez-Merchan and Carlos (2012) argued that for those clinicians and researchers considering using only the IKDC as their patient-reported outcomes for ACL reconstruction, they should include as a minimum, the KOOS subscales that address broader areas of concern, including quality of life and emotional health that are most important to patients following ACL reconstruction and which are not wholly represented

in IKDC (Rodriguez-Merchan & Carlos, 2012). Moreover, there is a suggestion that the KOOS is perhaps more suitable for the assessment of patients in the longer term unlike the IKDC (Roos & Toksvig-Larsen, 2003). The KOOS has shown good validity and demonstrated that it is responsive to ACL reconstruction and rehabilitation, it shows that it is a reliable instrument for patients undergoing ACL surgery and rehabilitation (Roos & Toksvig-Larsen, 2003). The KOOS has been used extensively in current research protocols and it has been translated and culturally adapted into various languages (Almangoush, Herrington, Attia, Jones, Aldawoudy et al., 2013).

One of the most widely used subjective knee measurement tools is the Knee injury and Osteoarthritis Outcome Score (KOOS), this study is planning to evaluate patients' views about their knee injuries and related problems using this measurement tool. This tool is a comparatively new, simple self-administered instrument developed to assess both the short and long-term symptoms and function of people suffering from knee injuries and osteoarthritis (Roos, Roos, Lohmander, Ekdahl & Beynnon, 1998). There is already available literature which demonstrates strong findings relating to reliability, validity and responsiveness of KOOS for people who have a number of different knee pathologies, injury periods, ages and activity levels (Lysholm & Tegner, 2007). It has been translated and culturally adapted into different languages including: Singapore- English and Chinese (Xie, Li, Roos, Fong & Yeo et al., 2006), Korean (Seo, Chung & Kim, 2006), Persian (Salavati, Mazaheri, Negahban, Sohani, Ebrahimian et al., 2008) and Italian (Monticone,

Ferrante, Salvaderi, Rocca, Totti et al., 2012). However, there is no Arabic version available at present.

In order to administer this questionnaire to Arabic-speakers in Egypt a rigorous process of cross-cultural adaptation and validation is required in order to reach equivalence between the original publication and target version of the questionnaire (Beaton, Bombardier, Guillemin & Ferraz, 2000). The major consideration with this kind of application is the process of evaluating it across cultures; even items well translated linguistically need to be adapted culturally in order to preserve the content validity of the instrument (Beaton et al., 2000). The aim of the present study is to translate and culturally adapt KOOS into Arabic to suit Egyptian patients with various knee injuries and to test its psychometric characteristics (reliability, validity and dimensionality).

### **3.2 Material and methods**

Before this study began permission to adapt the original version was granted from Professor. EM Roos (Approval document, appendix 3). The study was approved by Alexandria Knee Centre and Salford University (Ethical Application HSCR 12/16).

### ***3.3 Translation and Cross-cultural adaptation***

This process followed previously established guidelines (Beaton et al., 2000). The American/English KOOS (Roos et al., 1998a), was translated into Arabic by three Egyptian Arabic native speakers (One physical therapist experienced in knee

rehabilitation, one Orthopaedic surgeon specialist in knee surgery and one professional translator). The obtained Arabic translations were back translated to American/English by two teachers of English and one English professional translator all of whom were native American/English speakers, none of whom had prior knowledge of the original version. The multidisciplinary committee consisted of two orthopaedic surgeons (one of whom had had an ACL reconstruction recently), a physiotherapist, a psychologist and a professional translator. They were all bilingual and contributed to this study by checking and discussing the translations of the questionnaires.

The committee reviewed the translations and reached a consensus on any discrepancy to develop a pre-final version of the questionnaire for field testing and produced translations which would be comprehensible to a majority of people, using language that could be understood by a 12 year old child (Beaton et al., 2000). The advantage of having all translators presented to the committee is that discrepancies can be modified and inappropriate items rejected. New items can be generated and any word changes done immediately. Items, instructions, response options and scoring documentation were all considered.

### **3.4 Pilot study of the pre-final version**

The pre-final version of the questionnaire was tested on 37 Egyptian patients all of whom spoke Arabic to ensure that there was complete understanding of the questionnaire and they completed this satisfactorily. They were all patients at the Alex Knee Centre in

Alexandra suffering from ACL reconstruction and combined injuries. The researcher tried to document any problems that occurred during administration of the questionnaire. The researcher was asked each patient to provide comments about the questionnaire and identify any words that were difficult to understand at the end of the interview to confirm that the all items of the questionnaire were understandable and included all the expected concepts. All questions and response options were considered satisfactorily comprehensible by the subjects. Therefore, this version was not subjected to any additional modifications and was considered the final version.

Finally, a committee meeting took place to develop the final version of the Arabic KOOS questionnaire based on the findings of the pilot. The cross-cultural adaptation of the KOOS required not only translation but adjustment of cultural words, idioms, and colloquialism. This process involved substantial transformation of some items to capture the essence of the original concepts, therefore simple formal Arabic words with colloquial idioms that could be understood easily was adapted to make the questionnaire clear and understandable (Beaton et al., 2000).

### ***3.5 Patients***

From June to Oct 2012, a convenient sample of 129 patients with knee injuries was recruited from a private hospital setting (Alexandria Knee Centre, Egypt). Invitation letters and participant information sheet were provided to the potential participants and

the level of education (high school or higher) was as a condition for participation (see appendix). Subjects were informed about the study and gave their consent to participate, the inclusion criteria were patients diagnosed as anterior cruciate ligament (ACL), meniscus and combined injuries by their orthopaedic surgeon(s), based on clinical and Magnetic Resonance Imaging findings (MRI), an age of 18 years or older. All patients were Egyptian and Arabic native speakers with good educational levels in order for them to understand and answer the questionnaire. The exclusion criteria were the involvement of other joints affecting lower extremity or lower back, Osteoarthritis, neurological or vascular conditions and psychiatric disorders. A self-report instrument package (patient's characteristics, the KOOS and RAND-36-item health survey 1.0 questionnaire with VAS numeric pain scale) was distributed to each patient, directly after their enrolment to the study, for them to complete unaided during a visit to the surgeon's clinic.

### ***3.6 Instruments***

The KOOS is a 42-item self-questionnaire with five subscales: Pain (P), Symptoms (S), Activities of Daily Living (ADL), Sport and Recreation (Sport/Rec) and Knee-related Quality of Life (QoL). A five-point Likert scale ranging from 0 (no problems) to 4 (extreme problems) was used to score each item and the scores of each subscale were individually transformed into a 0 to 100 scale (0 = extreme knee problems, 100 = no knee problems) (Roos et al., 1998a).

The Arabic version of RAND-36 generic self-administered instrument of health status consists of eight subscales: Physical Functioning, Role limitations due to physical problems, Role limitation due to emotional problems, Vitality, Emotional well-being, Social Functioning, Pain and General health (Cons, Alabdulmohsin, Draugalis & Hays, 1998). The subscales are scored from 0 to 100, with higher scores indicating better health status.

The VAS numeric distress scale ranged from 0 (no problem) to 10cm (extreme problem) was used to assess the average of intensity of the overall impression of knee pain during the last week. The VAS has been found to be reliable and valid in evaluating patients with knee-specific conditions (Flandry, Hunt, Terry & Hughston, 1991). The above scales were accepted to establish the validity of KOOS in the original and other versions.

### ***3.7 Psychometric scale properties and data analysis***

**3.7.1 Acceptability:** This was assessed by studying the percentage of: 1. refusals, 2. completed questionnaires, 3. missing items, and time taken to complete the questionnaire, as well as the acceptability of the questionnaire, which comprises of the percentage of items, items that were hard to understand or confusing, and the willingness to fill out the questionnaire a second time.

**3.7.2 Reliability:** Internal consistency was calculated on the first administration using Cronbach's alpha which considered acceptable if the value is 0.70 or above (Terwee, Bot, de Boer, van der, Windt et al., 2007). During the period from June to Oct 2012 patients were provided with stamped envelopes addressed to the researcher, in which to return the second group of questionnaires. A follow-up phone call on the seventh day reminded the patients to complete the second group of questionnaires. Any questionnaires arriving later than 5 days after the scheduled (reminded call) date of completion were excluded. To minimize the chance of memorisation the RAND 36 and KOOS were made into one document so the RAND 36 would be completed first and returned together as one questionnaire. Finally, 112 (87%) of the participants returned the completed questionnaire after the allotted week. The test-retest stability was assessed by intraclass coefficient correlation (ICC) that was equal or greater than 0.7 was considered acceptable (Terwee et al., 2007).

Measurement error is the systematic and random error of a patient's score that is not attributed to true change in the construct to be measured. Standard error of measurement (SEM) for absolute agreement was calculated based on the sample standard deviation (SD) and the calculated intraclass correlation coefficient and was collected within the population sample of the study according to the following formula:  $SEM = SD \sqrt{1-ICC}$  (Atkinson & Nevill, 1998).

**3.7.3 Dimensionality:** This was assessed by performing principal component factor analysis on the whole study population to determine if the individual items loaded on a single factor. Failure to load on a single factor suggests that the items in the scale do not all estimate the same aspect. A value criterion of 1.0 was used for these factor analyses (Norman & Streiner, 1986), and the results are given in terms of the percentage of variance in the scale score explained by the principal factor. The numbers of meaningful factors based on the Scree plot were identified; the interpretation of the factor solutions accepted, then the factor structure and factor loadings after vari-max rotation were examined. The factor analysis was performed to determine whether the KOOS questionnaire actually consists of 5 subscales.

**3.7.4 Validity:** Construct validity was confirmed through Pearson correlation coefficient ( $r$ ) and it addressed the ability of whether the questionnaire measured what it was intended to measure (Terwee et al., 2007). Evidence for construct validity can only be accumulated by a priori hypothesized pattern of associations with other related and validated instruments (Kirschner & Guyatt, 1985; Terwee et al., 2007). Construct validity was assessed by comparing the KOOS with the VAS and the subscales of the RAND-36. It was hypothesised that: (1) correlations between the KOOS Pain and RAND-36 pain subscale would be high; (2) negative correlations between the KOOS subscales and VAS should be moderate to high; (3) correlations between the KOOS ADL and Sport/Rec subscales and the SF-36 Physical function subscale would be high; and (4) correlations between the KOOS subscales and the RAND-36 subscales of Physical Health (Physical

Functioning, Role limitations due to physical problems and Pain) would be higher than those between the KOOS subscales and the Rand-36 subscales of Mental Health (Role limitation due to emotional problems, Vitality, Emotional well-being, Social Functioning and General health). Pearson correlations:  $r < 0.30$  = low;  $0.30 < r < 0.60$  = moderate;  $r > 0.60$  = high was used to assess construct validity (Streiner & Norman, 2003). The construct validity of the KOOS questionnaire was defined as good if 75% of the hypotheses were confirmed (Terwee et al., 2007).

**3.7.5 Floor/ceiling effects:** If floor or ceiling effects are present, it is likely that extreme items are missing in the lower or upper end of the scale, indicating limited content validity (Terwee et al., 2007). Floor and ceiling effects refer to specific limitations encountered when measuring health status scores. An awareness of these limitations is important because of the problems that can occur in the interpretation of the results obtained regardless of the domain being measured or the instrument that is being used. Floor/ceiling effects were considered present if more than 15% of the participants achieved either the lowest-possible or highest-possible score of the scale (Terwee et al., 2007). The analyses were made using SPSS 20.0 software.

## **3.8 Results**

### ***Subjects***

The study included 99 males [76.7%] and 30 females [23.3%], an age at surgery, mean (SD) years 30.8 (7.8); 63 (48.8%) married; 68 (52.7%) employed, 34 (26.4%) students

and 27 (20.9%) self employed; 93 (72.1%) practice sports regularly; 49 (38.0%) had ACL injuries, 36 (27.9%) meniscus injuries, and 44 (34.1%) combined injuries. The mean duration of knee injuries before their operations was 7.2 months with range (1 to 36) months and mean period of 5.4 months with a range (3 to 9) months postoperative.

## ASSESSMENT OF PSYCHOMETRIC PROPERTIES

***Acceptability:*** Acceptability of the Arabic KOOS: The questionnaires were completed in 98.4% of cases. The amount of missing data was only 0.21% of all answered items, indicating that the questionnaire had good acceptability. The questionnaire completion took typically 9-12 minutes. Only 0.31% of the items were considered to be confusing and these items were: QoL (1) How often are you aware of your knee problem? and QoL (2) Have you modified your life style to avoid potentially damaging activities to you knee?. No multiple answers were found. All respondents were prepared to fill out the questionnaire for a second time and 87% returned the questionnaires a second time.

### ***Dimensionality***

***Factor analysis:*** The Scree plot indicates that two factors may be adequate to describe the data. This initial solution accounted for 58.7% of the total variance for the Arabic version of the KOOS questionnaire (eigenvalue of 22.4 for the first factor and 2.2 for the second factor). Many items loaded on both factors when the two factor solution are used. Therefore, a forced one-factor solution was chosen which accounted for 53.3% of the variance. The loading factors ranged from 0.34 – 0.89. The loading factor of the questions

S3, S4 and QoL2 were the lowest but QoL2 was even lower than 0.40 as this indicated in Table (3-1).

**Table 3-1:** Results of factor analysis: The 42-item of Arabic version of the KOOS questionnaire loaded on one factor.

KOOS subscales and items	Factor 1
<b>P</b>	
P1. How often do you experience knee pain?	.887
P2. Twisting/pivoting on your knee?	.842
P3. Straightening knee fully?	.714
P4. Bending knee fully?	.746
P5. Walking on a flat surface?	.575
P6. Going up or down stairs?	.806
P7. At night while in bed?	.681
P8. Sitting or lying?	.729
P9. Standing upright?	.707
<b>S</b>	
S1. Do you have swelling in your knee?	.652
S2. Do you feel grinding/friction, hear clicking/cracking or any other type of noise when your knee moves?	.789
S3. Does your knee jam or lock when moving?	.508
S4. Can you straighten your knee fully?	.530
S5. Can you bend your knee fully?	.621
S6. How severe is your knee joint stiffness after first wakening in the morning?	.721
S7. How severe is your knee stiffness after sitting, lying or resting later in the day?	.636
<b>ADL</b>	
ADL1. Descending stairs	.829
ADL2. Ascending stairs	.787
ADL3. Rising from a sitting position	.736
ADL4. Standing	.731
ADL5. Bending to floor/pick up an object	.658
ADL6. Walking on a flat surface	.581
ADL7. Getting in/out of a car	.726
ADL8. Going shopping	.758
ADL9. Putting on socks/stockings	.703
ADL10. Rising from bed	.845
ADL11. Taking off socks/stockings	.732
ADL12. Lying in bed	.719
ADL13. Getting in/out of bath	.742
ADL14. Sitting	.738
ADL15. Getting on/off toilet	.778
ADL16. Heavy domestic duties	.876
ADL17. Light domestic duties	.797
<b>Sport/Rec</b>	
Sport/Rec1. Squatting	.758
Sport/Rec2. Running	.842
Sport/Rec3. Jumping	.728
Sport/Rec4. Twisting/pivoting on your injured knee	.772
Sport/Rec5. Kneeling	.849

QoL	
QoL1. How often are you aware of your knee problem?	.665
QoL2. Have you modified your life style to avoid potentially damaging activities to you knee?	<b>.343</b>
QoL3. How much are you troubled with lack of confidence in your knee?	.707
QoL4. In general, how much difficulty do you have with your knee?	.812

**Table 3-2:** Mean KOOS scores (0 to 100, worst to best scale) at test and retest administrations one week apart, test-retest reliability and internal consistency.

KOOS subscales	Mean (SD)	Median	Range	% Floor effect	% Ceiling effect	Cronbach's alpha ( $\alpha$ )	ICC (95% CI)	S.E.M
Pain	25.97(18.95)	25.0	3-72	0	0	.916	.954 (.934-.968)	4.1
Symptoms	24.20(15.65)	21.4	4-64	0	0	.821	.931 (.901-.952)	4.1
ADL	22.81(16.99)	17.6	0-62	0	3.1	.954	.957 (.939-.970)	3.5
Sport/Rec	42.29(23.31)	40.0	5-100	1.6	0	.906	.941 (.915-.959)	5.7
QoL	25.97(18.95)	43.8	3-72	0	0	.804	.875 (.823-.912)	6.7

Abbreviations: ICC Intraclass correlation coefficient, SEM Standard error of measurement, ADL Activities of daily living, QOL Quality of life.

**Table 3-3:**

1) Validity: Pearson's correlation between Arabic KOOS, VAS and RAND-36 subscales

Outcome measures		p	S	ADL	Sport/R ec	QoL
RAND-36	VAS	-.805	-.726	-.784	-.735	-.707
	Physical functioning	.810	.767	.808	.711	.659
	Role limitations due to physical health	.488	.504	.529	.514	.642
	Role limitations due to emotional problems	.265	.314	.346	.351	.464
	Vitality	.709	.664	.720	.634	.755
	Emotional well being	.562	.526	.565	.575	.621
	Social functioning	.689	.586	.667	.548	.478
	Pain	.825	.755	.787	.784	.639
	General health	.665	.609	.588	.556	.570

Correlation is significant at the 0.01 level (2-tailed).

### ***Reliability***

Table (3-2) presents the Cronbach's alpha of all subscales of the KOOS questionnaire which ranged from .804 to .954 and indicated a good internal consistency of all items in these subscales. ICCs ranged from .875 to .957 and this indicates a strong relationship between the data collected on these two occasions. There were no differences between the means of test-retest values. The SEM ranged for all subscales of the KOOS questionnaire between 3.5 and 6.7.

### ***Construct validity***

Table (3-3) shows the correlations between the scores of KOOS, VAS and the RAND-36 subscales. A priori hypotheses were supported and confirmed in 75% of cases by the presence of the high correlation between KOOS Pain and RAND-36 pain ( $r = .825$ ), high negative correlations between the KOOS subscales and the VAS ( $r = -.805$  to  $-.707$ ), high correlation between KOOS ADL and RAND-36 Physical functioning ( $r = .808$ ) and high correlation between KOOS Sport/Rec and RAND-36 Physical functioning ( $r = .711$ ). Higher correlations were found between KOOS subscales and RAND-36 subscales of Physical Health than between KOOS subscales and RAND-36 subscales of Mental Health with the exception of correlations between the RAND-36 Role limitations due to physical problems subscale and the KOOS subscales, which were moderately lower than expected.

***Floor/ceiling:***

As there were only 4 subjects (3.1%) who scored the highest value at ADL subscale and only 2 subjects (1.6%) who scored the worst possible scores in the subscale sport/Rec, we consider that the floor or ceiling effects were not present in the Arabic KOOS, because these values are less than 15% (Terwee et al., 2007).

**3.9 Discussion**

There is a need for a reliable and valid instrument of Arabic versions of KOOS that can be used to conduct research and measure outcome in people with knee injuries in Arabic countries. There is at present no valid and tested version of KOOS for use in Arabic speaking countries. Therefore, our aim was to cross-culturally adapt the English-American version of the KOOS questionnaire into Arabic. The psychometric properties of the translated version were evaluated and found to be satisfactory. The rigorous testing for reliability and validity performed in this study demonstrated that the questionnaire could provide reliable results for other research studies. The participants in this study had received knee surgery (meniscectomy, or/and ACL reconstruction) and the percentages per case of pathological conditions in the present study did not differ from those in the sample of Salavati et al. (2008) and Seo et al. (2006), studies, and were bigger than other similar studies, giving the sample ecological validity.

The acceptability of an Arabic version of KOOS was in general very good, no disturbing questions, few confusing items, very low percentage of missing data for items and scales, and the time taken to complete the questionnaire was relatively short. These facts confirm the absence of problems related to translation, and that it is a reliable and valid measure for Egyptian patients with ACL- ACL and mensical injuries. The mean scores of the sport and recreation function subscale was markedly higher than the scores of other KOOS subscales, and have been previously reported (Salavati et al., 2008 & Monticone et al., 2012), however this result could be related to the age of the patients (mean age 30.8 years) and the fact that 71% of them practice sports regularly.

The test-retest reliability coefficients were high for all subscales in the present study, with ICCs ranging from .875 to .957, revealed satisfactory stability of KOOS over time in our participants. This is comparable to findings in studies done in other languages with similar conditions including the original study 0.75-0.93 by Roos et al. (Roos et al., 1998a), and 0.75-0.89 by Seo et al. (2006), 0.61-0.91 by Salavati et al. (2008), 0.85-0.95 and by Monticone et al. (2012). The methodology chosen in this current study for reliability testing is comparable to other studies (Salavati et al., 2008 & Monticone et al., 2012).

The internal consistency was satisfactory for all of five subscales, with the correspondent items properly correlated with each other. This was consistent with similar patient groups of versions of Italian (0.78-0.98) (Monticone et al., 2012), Persian (0.74-0.96) (Salavati et

al., 2011) and slightly better than the Korean (0.73-0.81) (Seo et al., 2006). Our results are in line with a study carried out by El Meidany, El Gaafary & Ahmed, (2003) using the translated version of the original health Assessment Questionnaire (HAQ) in 184 Arabic patients with rheumatoid arthritis (RA), from different Arabic countries and 42% of them are Egyptian, they found Cronbach's alpha to be strong reliability for the subscales ranging from 0.94 to 0.95 (El Meidany et al., 2003) is very similar to our study.

In the present study, the factor analysis was performed on the whole study population and showed that all items of the Arabic version of the KOOS questionnaire loaded on one factor. These results are in line with the conclusion of de Groot, Favejee, Reijman, Verhaar & Terwee, (2008) and in contrast with the Swedish version of the KOOS questionnaire, when the KOOS items loaded on five factors (Roos, et al., 1998), only these two previous studies used factor analysis to investigation KOOS. Also, our results are in contrast with other another study that used factor analysis of a sample of 103 participants with knee Osteoarthritis (OA) to test the Arabic translation version of McMaster Universities osteoarthritis index (WOMAC), but they had extracted four extra factors (Guermazi, Poiraudau, Yahia, Mezganni, Fermanian et al., 2004) In the present study, the factor loading of the question QoL2 (Have you modified your life style to avoid potentially damaging activities to your knee) was lower than 0.40 suggesting that this item might be excluded from the questionnaire (Fayers & Machin, 2000) for this population. In our preliminary results we retained in our analyses the original subscales of the Swedish version of the KOOS questionnaire (Roos, Roos, Ekdahl, & Lohmander,

1998). However, based on our findings we would recommend additional factor analyses on other data sets, before changing items or subscales of the Arabic version of the KOOS questionnaire.

Construct validity was supported by the presence of higher correlations between the KOOS subscales and RAND-36 subscales measuring similar constructs (convergent construct validity) and lower correlations between the subscales measuring dissimilar constructs (divergent construct validity). These findings are similar to those of the original developers (Roos et al., 1998) and most cross-national adaptations (Salavati et al., 2008 & Monticone et al., 2012). It is noted that KOOS subscales correlated weakly with RAND-36 role limitations due to emotional problems as seen in the original KOOS validation study (Roos et al., 1998), and other adapted versions. Only 1 value had unanticipated findings, that was the relatively low correlations between the Rand-36 role limitations due to physical problems sub-scale and the KOOS subscales. This could be due to the younger age of the patients included in our study than other studies. Also, our participants having ACL, meniscus and combined rather than OA and having a relatively short period since injury means that secondary disability had not yet occurred. The level of economic and educational status could also be the cause. VAS scores were moderately negatively correlated with KOOS scores, results that were compatible with the recent Italian version (Monticone et al., 2012).

A limitation of this present study is that the questionnaire was only administered to younger individuals with ACL and meniscal knee injuries, further work may be required administering the questionnaire to those individuals with knee osteoarthritis of an older age. Future research is proposed to assess the responsiveness of the questionnaire which makes it a valid instrument for evaluation of the effectiveness of surgical and rehabilitative interventions. Although, this questionnaire was translated into an Arabic language so that it could be easily understood by all Arabic speaking communities in urban and rural subcultures, some caution is needed in interpreting the results of this study. It should be noted that the cohort of patients studied is not representative of the general patients with knee problems, such as women, older people, and those with a low level of education and poor economic status. This would give emphasis to the need for further research with a wider group of participants.

**3.10 Conclusion,** the Arabic-version of KOOS is a valid and reliable instrument for Egyptian patients with various knee injuries. Also could be used for all Arabic knee patients anywhere, because it is understandable language for any Arabic people due to public and common use in the TV and media.

## *Chapter four*

### **A preliminary reliability study of a qualitative scoring system of limb alignment during single leg squat**

#### **4.1 Introduction**

It has been proposed that functional movements, such as the single-leg squat (SLS), can be measured to assess predisposition to common degenerative and traumatic musculoskeletal injuries of the lower limb (Hewett, Myer, Ford, Heidt, Colosimo et al., 2005; McLean, Walker, Ford, Myer, Hewett et al., 2005; Chmielewski, Hodges, Horodyski, Bishop, Conrad et al, 2007; Willson, Ireland & Davis, 2006). For example, evidence indicates that an excessive valgus angle at the knee during functional tasks is a risk factor for noncontact anterior cruciate ligament injury (Hewett et al., 2005; Griffin, Albohm, Arendt, Bahr, Beynnon et al., 2006; Munro, Herrington & Comfort, 2012) and is also associated with overuse injuries such as patellofemoral pain (Myer, Ford, Barber Foss, Goodman, Rauh et al., 2010). Preventing a medial position of the knee is suggested to reduce the risk of ACL injuries (Yamazaki, Muneta, Ju & Sekiya, 2010; Noyes, Barber-Westin, Fleckenstein, Walsh & West, 2005) and forms an integral component of ACL rehabilitation through neuromuscular training interventions (Ageberg, Bennell, Hunt, Simic, Roos et al., 2010). A knee-medial to- foot position, i.e., when the knee is not aligned over the ankle in the frontal plane, is related to an increased risk of anterior

cruciate ligament (ACL) injury (Hewett, Myer & Ford, 2006; Hewett, Torg & Boden, 2009), and is related to poorer patient-reported function after knee injury (Trulsson, Garwicz & Ageberg, 2010).

Three dimensional motion capture is regarded as the gold standard for assessment of movement (McLean et al., 2005; Ekegren, Miller, Celebrini, Eng & Macintyre, 2009). But, the use of these measurement methods to detect abnormal movement patterns during functional activities are expensive, time consuming and technically complicated, and difficult to replicate these types of movement analyses in the clinical setting (McLean et al., 2005; Willson & Davis, 2008). A number of studies have attempted to undertake visual assessment from observation of video, which proved to be effective and pragmatic tools to measure and provide immediate feedback to the patient during the performance of functional tasks (Stensrud, Myklebust, Kristianslund, Bahr & Krosshaug, 2011). Recently, greater emphasis has been placed on visually analyzing movement patterns during functional tasks to identify candidates for knee injury prevention programs or neuromuscular control interventions during knee rehabilitation (Cook, Burton & Hoogenboom, 2006; Kibler, Press & Sciascia, 2006; Willson, Dougherty, Ireland & Davis, 2005; Whatman, Hing & Hume, 2012).

The SLS test is said to be a simple functional task and offers a safe clinical examination in comparison with single leg landing (Yamazaki et al., 2010). It also provides an

attractive and clinically-efficient means of identifying undesirable movement patterns during screening and rehabilitation (Weeks, Christopher, Carty & Horan, 2012).

In recent years, there has been an increasing amount of literature on the visual evaluation of limb alignment including SLS tasks. These studies investigated the reliability of visual assessment of SLS or single limb mini squat tests or the small knee bend (SKB) which have disclosed inconsistent results (inter-observer = slight to excellent; intra-observer = fair to excellent) (Whatman, 2012). Ageberg et al. (2010), Weir, Darby, Inklaar, Koes, Bakker et al. (2010), Crossley, Zhang, Schache, Bryant & Cowan, (2011), Pousen & James, (2011), Örtqvist, Moström, Roos, Lundell, Janarv et al. (2011), Weeks et al. (2012), Whatman et al. (2012) and Whatman, Hulme & Hing (2013) reported the use of a variety of protocols that included differences in the amount of knee flexion, foot position, arm position, head position and movement tempo. Some studies used a small box to squat from (Crossley et al., 2011) or allowed finger tip balance (Ageberg et al., 2010). The different protocols may present different challenges to neuromuscular control and result in different movement patterns that influence reliability. Therefore generalisation of reliability reported from studies is not appropriate unless the protocol conditions are similar.

To standardise the performance of SLS, several studies have relied on monitoring the amount of knee flexion (Levinger, Gilleard & Coleman, 2007; Willson, Ireland & Davis, 2006). This is likely to not be the major clinical concern compared to knee valgus for

example. Furthermore, regulation of knee flexion angle is not likely to be achievable in the clinic due to the extra time and equipment required. Ageberg et al. (2010) had participants looking at the position of the anterior aspect of their knee, relative to tape on the floor to try to standardise the amount of knee flexion. While eye focus on a target is a simple technique that can assist clinical use, and probably reliability (although this was not reported), it alters the natural trunk/head posture and consequently may well not be the most relevant assessment of movement quality/dynamic alignment (Whatman, 2012). Variation in agreement on rating is likely to be due to differences in the functional tests themselves as well as those rated by the population, the methods used for rating, variations in the amount of training and experiences for those responsible for rating, and differences in analysis. There is evidence that visual ratings are the most accurate at determining differences in 2D kinematics (pelvis and knee) (Ageberg et al., 2010; Stensrud et al., 2011; Whatman et al., 2013).

There are several studies that have attempted to undertake screening of lower limb movement using observational (video) analysis of knee alignment and control. But the inter and intra-rater reliability and accuracy of visual rating of lower extremity movement quality, particularly of various body segments in subjects with current or potential musculoskeletal disorders, has still not been well defined (Whatman, 2012).

The objective of this paper is to assess the inter- and intraobserver reliability of the new assessment tool, to determine if it shows similar or better reliability than other qualitative

assessment methods of limb alignment during SLS tasks. The aim of this study is to test the hypothesis that the qualitative scoring system of limb alignment during single leg squat will show excellent inter- and intraobserver reliability as evidenced by minimal differences in scores between examiners and during the session. If the test proves to have strong reliability then it gives the clinician and researcher another testing option when looking for methods to assess lower limb alignment control, muscle strength and endurance.

## **4.2 Method**

### **4.2.1 Subjects**

Four observers, all expert musculoskeletal physiotherapists (PhD or Masters qualified and all senior physiotherapist with an average of 12 years clinical experience) independently viewed and scored 4 recorded videos of the performance of the SLS test. All the observers received written and verbal instruction on how to score the test, in a single training session. All the participants videoed were free from lower limb, pelvis or spinal injury and gave informed consent to participate in the study which was approved by the university research ethics committee. The participant group, who had no experience of or preconceptions around how to undertake correct movement patterns during squat comprised of two male and two female subjects all recruited from the postgraduate sports science course (mean age 25.6 $\pm$ 1.3years; height 1.76 $\pm$ .18m; weight 78.6 $\pm$ 10.1kg), who were all physically active participating in a minimum of 3 hours or more of aerobic

exercise per week. All single leg squats were undertaken on the dominant (right in all cases) leg.

### *Ethical Approval*

The project was approved by the University of Salford Research ethics committee.

All subjects signed consent documents to participate.

### **4.2.2 Visual assessment procedure**

All ratings were recorded on a standardised rating sheet specifically designed for this study (Figure 4-1 or Figure 4-2). The independent assessors received a CD ROM containing the video clips to be rated. The participants used their dominant leg only, because the use of the contralateral knee as a reference may be inappropriate, as strength deficits are also seen contra-laterally following a knee joint injury (Hiemstra, Webber, MacDonald & Kriellaars, 2000).

All individuals performed the SLS test, they wore their comfortable sport shoes, with their arms held relaxed by their side and wore a tight fitting sleeve-less shirt (rolled up to expose their lower trunk/upper pelvis) and a pair of tight fitting shorts. All individuals on the video were given standardised verbal instructions prior to each test and the researcher demonstrated the test in a standardised manner. The instructions given were to stand on a tape mark on the floor, place arms relaxed by sides, bend non weight bearing knee to 90 degrees, keeping the thigh in a slightly flexed position, then squat down as though going

to sit on a chair. Stensrud et al. (2011) demonstrated that a two-dimensional video analysis method has been shown to successfully screen subjects at increased risk of ACL injury arising from large valgus motions and kappa showed good to excellent agreement between 2D video analysis and subjective assessment for SLS. Therefore, previous work of Herrington, Myer & Munro, (2013), was chosen as a method of capturing 2D knee motion by using a digital video camera (model DCR-HC40; Sony Electronics, Inc., Oradell, NJ, USA) that was positioned on a tripod with height set to equate with the participant's waist. It was positioned approximately 2 meters away in front of the subject to record a frontal plane view of the SLS. The image was adjusted so that the subject was visible in at least two thirds of the viewing area when the person was in a neutral standing position. The participants were unaware of what was being assessed during the test. All participants were allowed a maximum of three practice attempts. In accordance with previous investigations (Weeks et al., 2012; Crossley et al., 2011; Dwyer, Boudreau, Mattacola, Uhl & Lattermann, 2010), squat depth was not standardised in keeping with an approach that most closely resembles clinical practice.

#### **4.2.3 Qualitative assessment tool**

The qualitative analysis of single leg squat (QASLS) is a new scoring system designed to identify segmental sub optimal behaviour following performance of a single leg squat. A qualitative scoring system was devised by one of authors (LH) based on the previously reported scoring systems of Crossley et al. (2011) and Whatman et al. (2013). It involved dichotomous scoring of the movement strategy occurring in individual body regions (arm,

trunk, pelvis, thigh, knee, foot). Scoring was defined as a zero for appropriate strategy (of the relevant body part) and one point for each inappropriate movement which occurred, for each body part with best overall score being 0 and worst 10 points, that is zero movements away from the optimal, or a maximum of 10 errors or incorrect movements. The scoring sheet is shown in figure (4-1) and examples of appropriate and inappropriate movement strategies in figure (4-2). The qualitative scoring system used was based on those previously reported in the literature which had attempted to analyse single leg squat and had shown good to excellent intra and inter tester reliability (Crossley et al., 2011; Whatman et al., 2013). The scheme incorporated the region criteria similar to that used by both Crossley et al. (2011) and Whatman et al. (2013), following the assertion from both Chmielewski et al. (2007), Onate, Cortes, Welch & Van Lunen, (2010) and Whatman et al. (2013) that this increased content validity. The scheme used was modified from those studies to also take into account trunk and pelvis motion which Crossley et al. (2011) and Whatman et al. (2013) regarded as significant factors in the alteration of lower limb alignment and load. Similarly, a dichotomous scale was used when classifying motion within each of the regions which has been shown to increase reliability by Whatman et al. (2013).





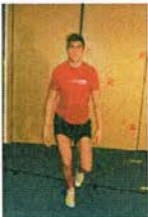





The QASLS scoring system is a segmental method of analysing and a set of tests to rate the single leg loading specifically, which focus on the knee impairments (ACL injury and prevention, ACL rehabilitation and control through neuromuscular training interventions,






and patellofemoral pain) (Ageberg et al., 2010; Hewett et al., 2006; Hewett et al., 2009). Therefore it is not a global balance test as the Berg Balance Scale (Blum & Korner-Bitensky, 2008).

**Figure 4-1:** Qualitative analysis of single leg loading (QASLS)

QASLS	Task: Single leg squat	Score	
		Left	Right
Arm strategy	Excessive arm movement to balance		
Trunk alignment	Leaning in any direction		
Pelvic plane	Loss of horizontal plane		
	Excessive tilt or rotation		
Thigh motion	WB thigh moves into hip adduction		
	NWB thigh not held in neutral		
Knee position	Patella pointing towards 2 <sup>nd</sup> toe (noticeable valgus)		
	Patella pointing past inside of foot (significant valgus)		
Steady stance	Touches down with NWB foot		
	Stance leg wobbles noticeably		
	<b>Total Score</b>		

Movement analysis is subdivided into six categories - arm strategy, trunk alignment, pelvic plane, thigh motion, knee position and steady stance. Pelvic plane, thigh motion, knee position and steady stance each have two performance points. One point is given for each sub-optimal behaviour that the patient demonstrates. The patient is scored between 0-10, with a higher score indicating a higher risk of injury or a poorer performance. The QASLS scoring sheet is provided in figure (4-1).

QASLS category	Error	Optimal	Sub-optimal example
Arm strategy	Excessive arm movement to balance		
Trunk alignment	Leaning in any direction		
Pelvic plane	Loss of horizontal plane		
	Excessive tilt or rotation		
Thigh motion	WB thigh moves into hip adduction		
	NWB thigh not held in neutral		

Knee position	Patella pointing towards 2 <sup>nd</sup> toe (noticeable valgus)		 
	Patella pointing past inside of foot (significant valgus)		 
Steady stance	Touches down with NWB foot		
	Stance leg wobbles noticeably		

**Figure 4-2:** Examples of optimal and sub-optimal strategies during single-leg loading tasks. Adapted with permission from Herington et al., (2013). (Continued)

### 4.3 Statistical analysis

Four observers independently viewed and scored 2 female & 2 male subjects' recorded video performance of the SLS test. For the scoring performance, in each film only the frontal plane view was viewed three times at normal speed and the score then marked. The frontal plane was used as the majority of errors relate to excessive movement within the frontal or transverse plane. Standard speed was used so as to make the test more clinically applicable, three views of the video was allowed to make sure no errors were missed. The investigator compared the scores and analysed the scores for each participant. The four observers then re-examined the same videos one month later, blinded to the original scores. The scores were analysed for percentage of agreement (PA) [PA = (agreed/agreed + disagreed) x 100] and Cohen's Kappa for both inter- and

intraobserver reliability. Calculation of Cohen's kappa was performed according to the following formula:

$$k = \text{Pr}(a) - \text{Pr}(e) / 1 - \text{Pr}(e)$$

Where  $\text{Pr}(a)$  represents the actual observed agreement, and  $\text{Pr}(e)$  represents chance agreement, using the observed data to calculate the probabilities of each observer randomly saying each category. If the observers are in complete agreement then  $k = 1$ . If there is no agreement among the observers other than what would be expected by chance (as defined by  $\text{Pr}(e)$ ),  $k = 0$  (McHugh, 2012).

Theoretically, the confidence intervals are represented by subtracting the kappa from the value of the desired CI level times the standard error of kappa. Given that the most frequent value desired is 95%, the formula uses 1.96 as the constant by which the standard error of kappa ( $\text{SE}_k$ ) is multiplied. The formula for a confidence interval is:

$$K - 1.96 \times \text{SE}_k \text{ to } k + 1.96 \times \text{SE}_k \quad (\text{McHugh, 2012})$$

The level of inter-observer agreement based on initial ratings only. The overall percentage agreement and the kappa coefficient were used in this study due to this categorical data. Based on a scale proposed by Landis & Koch, (1977): 0.01-0.20 = slight; 0.21-0.40 = fair; 0.41-0.60 = moderate; 0.61-0.80 = good/substantial; 0.81-1.0 = almost perfect/excellent.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 20.0 for Windows (SPSS, Chicago, IL, USA).

## 4.4 Results

### 4.4.1 Inter-observer

Average percentage exact agreement (PA) between the four observers across all scoring criteria for all subjects was excellent (range 83-100%). All observers were in absolute 100% agreement in 5 out of 10 of all of the scoring criteria of all subjects. The kappa measure of Agreement ranged from 0.63 to 1.00 which is good to almost perfect. In three of the scoring criteria the observers disagreed by a single point once on Q1, Q7 & Q8, and disagreed by two points on Q2 and disagreed by four points on Q3.

**Table 4-1:** Inter-observer agreement of observational ratings of SLS

No	Rater	Number of agreement	Total tasks	Percentage of agreement	Kappa agreement	Lower 95% CI** kappa	Upper 95% CI** kappa
1	Rater 1 vs. Rater 2	8.3	10	.83	0.6310	0.27210	0.99066
2	Rater 1 vs. Rater3	8.3	10	.83	0.6268	0.24665	0.99066
3	Rater 1 vs. Rater4	8.3	10	.83	0.6268	0.24665	0.99066
4	Rater2 vs. Rater3	9.5	10	.95	0.9000	0.76822	1.00000
5	Rater2 vs. Rater4	9.5	10	.95	0.9000	0.76822	1.00000
6	Rater3 vs. Rater4	10	10	1.0	1.0000	1.00000	1.00000

#### 4.4.2 Intra-observer

The average PA for observer 3 across all viewing sessions was 100% with kappa measure of agreement was  $k = 1.0$  which is excellent agreement. The average PA for observers 1, 2 & 4 across all viewing sessions were 95%. The kappa measure of agreement for observers 2 & 4 were  $k = 0.90$  for each and for observer 1 was  $k = 0.89$  which is very good/excellent across all tests.

**Table 4-2:** Intra-observer agreement of observational ratings of SLS

Observer	Percentage of agreement	Kappa Value (95% CI)
Observer 1	95.0%	.89 (.71-1.00 )
Observer 2	95.0%	.90 (.72-1.00 )
Observer 3	100%	1.00 (1.00- 1.00 )
Observer 4	95.0%	.90 (.72-1.00 )

#### 4.5 Discussion

The objective of this study was to assess the inter- and intraobserver reliability of the new assessment tool, to determine if it shows similar reliability to other qualitative assessment methods of SLS tests.

The level of inter-observer agreement achieved by the observers was good to excellent in total, PA = 83 to 1.0% and kappa coefficient ranged from  $K = .63$  to 1.0. This findings are greater than most related studies testing the SLS performance visually (Whatman et al., 2012; Weeks et al., 2012; Weir et al., 2010; Poulsen & James, 2011; Örtqvist et al., 2011;

Whatman et al., 2013) and only agreed with a study conducted by Ageberg et al. (2010) who reported high level of agreement PA= 96% with  $K = 0.92$ . The study conducted by Ageberg et al. (2010) provided explicit guidelines and training for the two experienced physiotherapists who on a single occasion rated 25 healthy subjects (18-37 yrs) on their medio-lateral knee position during a single limb mini squat. However they used a simple dichotomous rating scale of one body segment and anatomical references (knee relative to foot). All these factors and the experienced nature of the small number of physiotherapists probably helped to achieve the high level of agreement.

Mean intra-observer agreement was almost perfect for all physiotherapists. This was achieved by using a evaluation system prepared to reflect recent clinical practice, suggesting this level of agreement is reachable in the clinic (Whatman, 2012) and considered adequate for clinical use ( $\geq 0.75$ ) (Portney & Watkins, 2009), when assessed with a 10-point visual evaluation score. Although not easy to compare, due to differences in purpose and analysis (Whatman, 2012) the level of intra-observer reliability of the qualitative scale measures in this study was excellent. This is higher than the previous studies including those from Chmielewski et al. (2007), Weir et al. (2010) and Örtqvist et al. (2011) that used visual scales of SLS test for healthy subjects. Chmielewski et al. (2007) used a similar segmental rating method (with less detailed criteria and including a rating of segment oscillation) and reported a lower agreement ( $\kappa = 0.35$  to  $0.53$ , 32% to 48% agreement) for visual ratings for movement quality during a unilateral squat task. These ratings were made 10 weeks apart. This study's results were comparable to other

studies that used different visual measures to assess the SLS which reported acceptable levels of reliability such as: The highest agreement ( $\kappa = 0.61$  to  $0.80$ , 73-87% agreement) was reported recently by Crossley et al. (2011) in a study using experienced physiotherapists, where example ratings were provided as training prior to repeat ratings made one week apart. Providing examples and training in rating have probably contributed to the substantial agreement reported. As the authors referred to digital images it was unclear whether the ratings were made from still images or videos and how many times the videos were viewed. Nevertheless the rating method used involved a relatively complex evaluation of the trunk, pelvis and knee in a manner similar to common clinical practice. This study also showed that two physiotherapists with musculoskeletal postgraduate qualifications and more experience, achieved a higher agreement than a graduate physiotherapist. This influence of experience on intra-observing agreement was also reported by Poulsen & James (2011) intra-observer ranged from  $0.38$  to  $0.94$  when determined through the generalized quadratically weighed kappa coefficient. Whatman et al., (2012) used a similar segmental method to rate a range of movements (small knee bend "SKB", single leg SKB, lunge and hop lunge) over three to four weeks, 33 physiotherapists showed a wide range of intra-rater agreement ( $AC1 = 0.01$  to  $0.96$ ). Our finding is in agreement with Weeks and colleagues (2012) who demonstrated similarity in ratings between observers for the SLS test, showing that intra-observer reliability was excellent for physiotherapists ( $ICC = 0.81$ ). Whatman et al. (2013) reported similar agreement but with more variation in a group of 26 physiotherapists (without additional training) rating young athletes ( $AC1 = 0.14$  to  $0.92$ ).

Agreement in these studies when rating children and young athletes was similar to that achieved with adults intra-observer PA: 79% to 88%, AC1 = 0.60 to 0.78.

Finally, our results suggest that clinicians and researchers can use the qualitative scoring system of limb alignment during single leg squat test with confidence to identify undesirable movement patterns, at least in generally healthy individuals. Although, the value of this kind of visual assessment tools from observation of videos going to increase due to the variety and availability of monitor devices like; computer screen, smart phone, tablet etc. The variation of these video screen sizes and pixel density may present different challenges to judge a performance and result in non visible movement patterns that influence reliability.

#### **4.6 Limitations**

The major limitations of this study were the rating of small number of healthy subjects and that ratings were made via video, from an anterior view only. Most use of movement assessment in the clinical setting is likely to be through watching patients move in a live situation. Therefore, the implications for reliability of movement in the clinical setting remain unknown. Despite this limitation, using video images was the only method that could limit the introduction of error that might occur due to variation in what was being assessed by the observer. Exclusion of participants with lower limb pathology may be considered a limitation.

Further studies are required to assess the use of these tests in identifying readiness for return to sport and progress during rehabilitation with injured subjects determining the value of this clinical measure. Thus, additional studies are needed for generalisation to people with musculoskeletal pathology and injury.

**4.7 Conclusion,** the test is feasible and easy to administer in the clinical setting and in research to address lower extremity movement quality. However, both intra-observer and inter-observer reliability of the qualitative scale measures successfully exceeded levels necessary for application of this measurement method in the clinical setting and research.

## *Chapter five*

Presented in this chapter is the main study of the thesis which involves a prospective assessment of outcome from ACL reconstructive surgery in a non-elite male Egyptian population. This is the first study of its kind assessing this population.

### **Qualitative and Quantitative Assessment of Functional Performance Before and After ACL surgery in Egyptian people from a non-elite/professional sporting background: A prospective study**

#### **5.1 Introduction**

The anterior cruciate ligament (ACL) is the most frequently injured (30 per 100,000 per annum) of all knee ligaments (Miyasaka, Daniel, Stone & Hirshman, 1991). The highest incidence is seen in men aged between the ages of 21 and 30 with 225 injuries per 100,000 people per year (Ageberg, Bennell, Hunt, Simic, Roos et al., 2010). Through a personal communication with Prof A. Abdulaziz he also claimed that the rates in Egypt were compatible with this figure (personal communication, December 15, 2012). Anecdotally, the Alex Knee Centre which is one of the largest orthopaedic clinics in Egypt and is the base for this study, reports undertaking about 200 ACLR per year. Arthroscopic assisted reconstruction of the ACL has become a standard procedure in orthopaedic sports medicine (Spindler, Kuhn, Freedman, Matthews, Dittus et al., 2004; Beynnon, Johnson, Abate, Fleming & Nichols, 2005). Most series report a success rate of

more than 90% (Forster & Forster, 2005; Spindler et al., 2004; Trees, Howe, Dixon & White, 2006). These studies often define success as return to pre-operative levels of activity. However, this has been questioned by Laxdal, Kartus, Ejerhed, Sernert, Magnusson et al. (2005) who reported in a retrospective review of 948 patients that only 69% of the patients were classified as normal or nearly normal according to the International Knee Documentation Committee evaluation system.

There is considerable variability in rehabilitation protocols after anterior cruciate ligament reconstruction (ACLR) (Hohmann, Tetsworth & Bryant, 2011). A large number of protocols exist (Wilk, Reinold & Hooks, 2003; Grant, Mohtadi, Maitland, & Zernicke, 2005; Shelbourne & Klotz, 2006; Canale & Beaty, 2007), despite this the rehabilitation appears to exhibit similar principles: control of pain and swelling in the early postoperative phase; early weight-bearing and strengthening exercises. What tends to differ is the mode of delivery of the rehabilitation, this could be one to one with a therapist, in supervised exercise classes or as home exercise programmes done with limited supervision. It is currently unknown as to whether patients can achieve a satisfactory level of postoperative function without the direct supervision of a physiotherapist. In this respect, postoperative rehabilitation interventions led by a physiotherapist have recently been questioned (Thomson, Handoll, Cunningham & Shaw, 2002; Trees et al., 2006). Therefore, it is important to elucidate what level of direct

supervision is required for the patient to attain a successful outcome (Beynnon et al., 2005).

Outcome from ACLR would generally be judged as successful if the patient has good functional performance at the end of their rehabilitation. Functional performance can be defined as the result of neuromuscular training and consists of two components. The first component is the quantity of movement, such as muscle strength measurements (concentric and eccentric) and hop tests (Ageberg, 2002). The second component is the quality of movement, for instance the occurrence of dynamic knee valgus or the amount of knee flexion when landing from a jump (Ekegren, Miller, Celebrini, Eng & Macintyre, 2009; von Porat, Holmström, & Roos, 2008). Both components are important in rehabilitation and prevention of ACL (re)injuries (Ageberg, 2002; Paterno, Schmitt, Ford, Rauh, Myer et al., 2010; Swärd, Kostogiannis & Roos, 2010; Thomeé, Kaplan, Kvist, Myklebust, Risberg et al., 2011). Most studies describing the functional performance after ACL reconstruction are limited to quantitative measurements, which are collected by the use of questionnaires or force, time or distance during the follow-up period combining the results of Bone-patellar tendon-bone (BPTB) and Semitendinosus-gracilis group (STG) (Tow, Chang, Mitra, Tay & Wong, 2005; Maletis, Cameron, Tengan & Burchette, 2007; Heijne & Werner, 2010). However in all these studies the selection of measurement instruments is unknown.

Few prospective or longitudinal studies have evaluated the pattern of functional recovery prior to and after ACL reconstruction (de Jong, van Caspel, van Haeff, & Saris, 2007; Risberg & Holm, 2009). The restoration of limb symmetry appears to be a vital component in the functional recovery after ACL reconstruction (Shelbourne & Klotz, 2006; Myer, Paterno, Ford & Hewett, 2008; Hartigan, Axe & Snyder-Mackler, 2010). Attainment of high limb symmetry may reduce an asymmetrical loading on the reconstructed ligament, and also reduce the risk of further injury (Shelbourne & Klotz, 2006; Paterno et al., 2010) and contribute to walking and jogging patterns similar to uninjured subjects (Lewek, Rudolph, Axe & Snyder-Mackler, 2002). Additionally, varying standards in limb symmetry indexes have previously been suggested as the milestone for determining normal limb symmetry (Noyes, Barber & Mangine, 1991; Hartigan et al., 2010).

The sensitivity to change in performance-based and self-reported outcomes may provide insight in detecting when a meaningful change has occurred over time and provide clinical guidance regarding functional recovery after ACL reconstruction. Patients with an ACL injury usually improve with treatment after ACL reconstruction (de Jong et al., 2007; Moksnes & Risberg, 2009; Risberg & Holm, 2009; Hartigan et al., 2010). But age, sex, body mass index (BMI), culture, habits, smoking, concomitant injuries, and physical impairments before and after surgery are important determinants of expected and final outcomes after ACL reconstruction (Risberg, Holm, Tjomsland, Ljunggren & Ekeland,

1999; Irrgang, Snyder-Mackler, Wainner, Fu & Harner 1998; Irrgang, Anderson, Boland, Harner, Neyret et al., 2006), but do not fully explain the observed variance in knee function after the reconstruction and rehabilitation. Although The cruciate ligaments have been known about since old Egyptian times and their anatomy was described in the famous Smith Papyrus (3000 BC) (Davarinos, O'Neill & Curtin, 2014), to our knowledge the present study is the first of its kind to be undertaken in Egypt to evaluate the recovery of functions following an ACL reconstruction.

### **5.1.1 Aim**

The aim of this prospective and longitudinal observational study was to investigate the qualitative and quantitative functional outcomes prior to and up to 12 months after ACL reconstruction in Egyptian patients from non-elite/professional sporting background. We hypothesized that any involved limb performance and self-reported measures will improve from baseline testing to 12 months after ACL reconstruction even in patients with low activity level undertaking relatively uncontrolled and structured rehabilitation programmes. Furthermore, although the patients would have improved they would still have not reached normal levels of function by this point.

## **5.2 Material and Methods**

### **5.2.1 Participants**

Between Sep 2012 and July 2014, a total of 237 patients who had an ACL tear visited the Alex Knee Centre in Alexandria, Egypt. These patients were invited to participate in this study and were screened to determine if they met the eligibility criteria. Patients were

excluded before surgery if they had a previous injury or operation to either knee; were either younger than 18 or older than 50 years of age; had a simultaneous fracture or a concurrent injury to the posterior cruciate ligament, posterior lateral corner, or lateral collateral ligament; had a grade II or III medial collateral ligament tear or radiographic evidence of osteoarthritis; suffered from a disease such as rheumatoid arthritis. Only patients from grades (III) and (IV) were included, this criteria based on the International Knee Documentation Committee formula activity levels: 4, jumping, pivoting, hard cutting, football, and soccer (I); 3, heavy work, skiing, and tennis (II); 2, light manual work, jogging, and running (III); 1, sedentary work and activities of daily living (IV) (Hefti et al., 1993).

At the time of surgery patients were excluded from the study if a significant portion of the ACL remained intact, they had cartilage lesions with exposed bone, or if they underwent meniscal repair. Those who required debridement or partial meniscectomy were included. Reconstruction was performed with the same technique in all cases (Passler, 2010). Due to un-availability of a KT-1000 arthrometer at this clinic, the Lachman Test and Pivot Shift Test were applied to evaluate the ligament stability. The diagnosis was confirmed with MRI, and possible concomitant injuries were detected.

### **5.2.2 Sample size**

Physical medicine and rehabilitation differ from other areas in medicine. Whereas the majority of the physical medicine and rehabilitation studies begin as empirical or are

based on clinical observation with a small sample size (Fregni, Imamura & Chien, 2010), in order to provide an adequate power, the sample size calculation is important, because a study with low power will fail to detect relevant clinical effects and to yield significant results. Also, homogeneity is more difficult due to the multiple impairments of the participants in this kind of study, which is often more complex. Therefore, precise sample size calculations turn out to be even more important with the potential limited number of patients for recruitment (Tate, 2006).

Due to the purpose of this study which is primarily to describe, with means and proportions, one or more characteristics in one particular group, sample size is important because it affects how precise the observed means or proportions are expected to be. In the case of a descriptive study, the minimum expected difference reflects the difference between the upper and lower limit of an expected confidence interval (CI), which is described with a percentage.

The sample size of this study is a single group and this study is designed to estimate a mean, the equation for the sample size (Dniel, 1999: Snedecor & Cochran, 1989) is:

$$N = 4\sigma^2 (z_{crit})^2 / D^2 \quad (\text{Altman, 1991})$$

Where N is the sample size,  $\sigma$  is the assumed SD for the group, the Zcrit value is 1.960 that meets 0.05 (95) of significance criterion (Eng, 2003), and D is the total width of the expected CI. From the previous related study (Reid, Birmingham, Stratford, Alcock & Giffin, 2007) it is known that the SD of the overall combination of (Single, Triple, and Crossover) hops: limb symmetry index at 22 weeks postoperatively is 8.5 and the CI of

overall combination of hop tests is 3.81; based on these assumptions,  $D = CI = 3.81$ ,  $\sigma = SD = 8.5$  and  $z = 1.960$

$$N = 4(8.5)^2 \times (1.960)^2 / (3.81)^2 = 76 \quad (\text{patients})$$

Therefore the project needed to recruit a minimum target of 76 participants. This was set as a minimum target and the investigator attempted to obtain additional 10 - 20% subjects to allow adjustment of other factors such as withdrawals, missing data, lost to follow-up etc.

The study was approved by the Human Research Ethics Committee of the University of Salford (HSCR12/21), and local ethical approval was obtained from the Alex Knee Centre, each subject gave informed consent. The flow diagram for subject participation for this study is illustrated in Figure (5-8).

### **5.2.3 Operative technique**

An arthroscopic ACL reconstruction was achieved by using semitendinosus-hamstring grafts, and using press-fit fixation without hardware Implant-free press-fit (Passler, 2010). All patients were examined under anaesthesia. Routine diagnostic arthroscopy and meniscal surgery were performed, followed by ACL reconstruction.

The number of ACL reconstructions using a hamstring tendon autograft is gradually increasing in Egypt. The main reason for this is probably that a number of randomized

studies have shown comparable results between these hamstring tendon autografts and a patellar tendon autograft, apart from donor-site morbidity and anterior knee problems, which are more frequent after using a patellar tendon autograft (Laxdal et al., 2005; Lidén, Ejerhed, Sernert, Laxdal, & Kartus, 2007).

## **5.3 Methods**


### **5.3.1 Procedures**



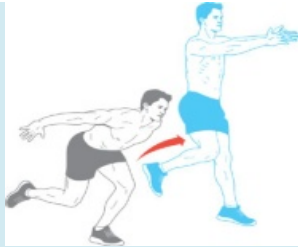
Testing was performed on 4 separate occasions, the day before surgery and at 3, 6 and 12 months postoperatively. All tests were performed in the same location by the same examiner, and where possible, under constant environmental conditions. Subjects were requested to wear the same pair of shoes on each test occasion but were not allowed to wear a brace. Anthropometric data (height and weight) were collected, and limb dominance was determined by asking the participants with which limb they would prefer to kick a ball (Myer, Schmitt, Brent, Ford, Barber Foss et al., 2011). No single 'gold standard' outcome evaluation has been established for ACL reconstruction (Shaw, Williams & Chipchase, 2004). A combination of objective and subjective (patient reported) measures, which assessed disability and impairment, were used (Phillips, Benjamin, Everett & van Deursen, 2000; Risberg 1999).

The entire testing protocol takes approximately 40 minutes (Figure, 5-1). Verbal instructions from the examiner were standardized. On each testing occasion, prior to data

collection, subjects were allowed 2 practice trials of each functional test for each limb, to facilitate familiarization with the tests and to minimize possible learning effects. The order of testing of the functional tests was considered, and the un-injured limb was chosen to be tested first in order that the patients could understand the test procedure thus reducing their fear and increasing their confidence. Three trials were performed for each functional test, with adequate rest periods (2-3minutes) ensured between each trial to avoid fatigue.

**Figure 5-1:** Testing protocol takes

No	Outcome measures	Discription	Time for testing	Measur- ements (data)	Limb Invo- lved	Time duratio n
1 ↓	Koos	Self-adminstrated Questionnaire	Day before Operation and 3, 6 & 12 months after surgery	Score	N/A	10 minutes
2 ↓	Rehabilitation	Self-adminstrated Questionnaire	Day before Operation and 3, 6 & 12 month after surgery	Score	N/A	7 minutes
3 ↓	ROM		Day before Operation and 3· 6 & 12 month post surgery	Angle 'degree'  Was taken by  A universal	both limbs	5 minutes

				goniometer		
4 ↓	Star Excursion		Day before Operation and 3, 6 & 12 month post surgery	Distination 'cm' by standara tape measure	Both limbs	5 minutes
5 ↓	Single-Leg Squat		Day before Operation and 3, 6 & 12 month post surgery	A digital video camera (2D- Cam) was used	Both limbs	5 minutes
6	Hop tests		_ Day before Operation and 3, 6 & 12 month post surgery	Distination 'cm' by standard tape measure	Both limbs	8 minutes
Total Time Duration of the Session						40 minutes

### 5.3.2 KOOS

The Knee Injury and Osteoarthritis Outcome Score (KOOS) subscales is a 42 self-reporting instrument and comprises 5 subscales: KOOS pain (9 items), KOOS symptoms (7 items), KOOS ADL (function in daily living; 17 items), KOOS sport (5 items), and KOOS QoL (knee-related quality of life; 4 items). For each subscale, the score is

normalized to a 0–100 scale with higher scores representing better levels of knee status. By using both scales, we endeavoured to determine how ACL reconstruction influences overall knee-joint function and symptoms as well as important specific domains such as those included in the KOOS (Roos, Roos, Lohmander, Ekdahl & Beynnon, 1998; Roos & Lohmander, 2003). Previous work has validated an Arabic version of KOOS, demonstrating that it is a reliable instrument for Egyptian patients undergoing ACL reconstruction and rehabilitation (Almangoush et al., 2013).

### 5.3.3 Range of Motion

A universal 360° standard plastic goniometer with 18-cm plastic movable limbs were used for flexion and hyperextension measurements (Ekstrand, Wiktorsson, Oberg & Gillquist, 1982; Peters, Herbenick, Anloague, Markert & Rubino, 2011). Knee ROM was evaluated with the patient lying supine and was measured with a goniometer as described by Norkin and White (2009).



**Figure 5-2:** Hand goniometry-flexion

The patient's heel was elevated on a bolster to allow the knee to go into hyperextension if present (Figure, 5-3). The knee was then passively flexed by the therapist into full passive

flexion, by bending the knee to slide the heel toward the buttocks as far as possible, then the measurement was obtained while the patient held the knee in the position in which it was placed (Figure, 5-2). The knee joint was measured by placing the goniometer on the lateral epicondyle of the femur, the axis (point of rotation) while the stationary arm was lined up with the greater trochanter of the femur. Finally, the moveable arm of the goniometer was lined up with the lateral malleolus of the fibula and a measurement was taken using the degree scale on the circular portion of the tool.



**Figure 5-3:** To measure knee extension & hyperextension, the heel of the foot is placed on a bolster so the knee can fall into hyperextension, if it is present. Knee range of motion is measured with a goniometer.

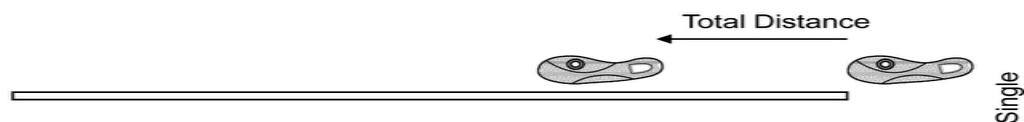
### **5.3.4 Assessment of Functional Activities**

#### **5.3.4.1 Hop Tests**

Functional activities were tested by use of hop tests to assess the combination of muscle strength, neuromuscular control, confidence in the limb, and the ability to tolerate loads related to sports-specific activities (Reinke, Spindler, Lorrington, Jones, Schmitz et al., 2011). These tests are commonly used to quantify knee performance in patients after ACL reconstruction (Sturgill, Snyder-Mackler, Manal & Axe, 2009; Reinke et al., 2011). The

single-legged hop test was chosen because it is well correlated with power, has the advantage of evaluating each leg in isolation, and is a highly reproducible test (Ageberg, Zätterström & Moritz, 1998). The most commonly used of these hop tests are the single and crossover, as they are simple to execute and do not require specialized equipment. The single-leg hop test has been evaluated extensively and is capable of detecting functional limitations up to 54 weeks postoperatively, with good test-retest reliability (Reid et al., 2007; Myer et al., 2011; Logerstedt et al., 2012).

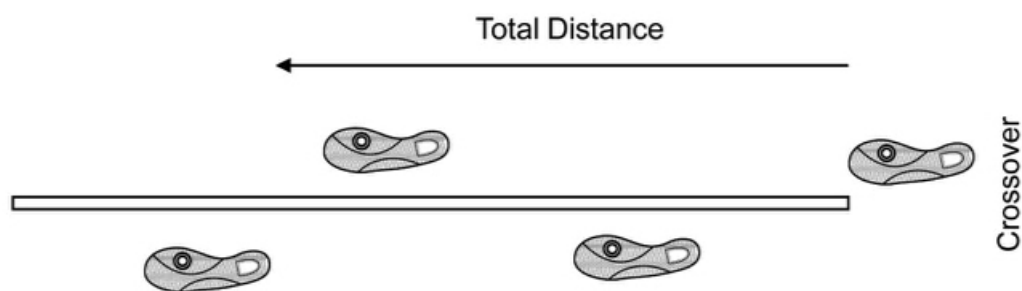
The LSI is calculated and considered as anything above 85 to be normal (Noyes et al., 1991). The LSI can be used to confirm suspected deficits in lower limb function. All patients performed identical tests with a standard protocol by the same physiotherapist at the time intervals described. Limb symmetry was calculated by dividing the mean score of the involved limb to the mean score of the uninvolved side and multiplying the result by 100 (D'Amato & Bach, 2003).



**Figure 5-4:** Single-leg hop for distance

The single hop for distance and crossover hop for distance have demonstrated good test-retest reliability in patients after ACL reconstruction (Reid et al., 2007). Reid et al. (2007)

showed ICC 2.1 for limb symmetry limb indexes in patients after ACL reconstruction ranged from 0.82 to 0.92. Minimum detectable change (MDC) at 90% confidence level ranged from 7.05 to 12.96%. Reliability of the hop tests has been reported to be excellent, with intraclass correlation coefficients ranging from 0.92 to 0.96 (Bandy, Rusche & Tekulve, 1994; Bolgla & Keskula, 1997). The one-leg hop test has shown good reliability, with ICCs ranging from .97 to .99 (Risberg, Holm, Myklebust & Engebretsen, 2007). After 2 practice episodes, the patient starts the tests with the uninvolved leg, followed by the involved leg. The single hop for distance was performed with the patient standing on the leg to be tested, hopping as far as possible, and landing on the same leg. For the crossover hop for distance, patients stood on one leg, then hopped as far as possible forward 3 times while alternately crossing over a 15-cm marked strip on the floor. The total distance hopped forward was recorded.



**Figure 5-5:** Cross-over hop for distance

The single hop and the crossover hop for distance were considered successful if the landing was stable. To be considered a valid trial, the landing must be on one limb, under complete control of the patient. If the patient landed with early touchdown of the

contralateral limb, had loss of balance, touched the wall, or had additional hops after landing, the hop was repeated. The hop distance was measured to the nearest centimetre from the starting line to the patient's heel with a standard tape measure. The hop tests were conducted by physical therapists who had undergone detailed training in the test procedures.

#### **5.3.4.2 Star Excursion Balance Test (SEBT)**

A recent systematic review has suggested that future authors examining postural stability in patients undergoing ACL reconstruction or after reconstruction should focus on assessments using dynamic postural-stability tasks (Howells, Ardern & Webster, 2011). The SEBT has been used to assess dynamic postural control in a number of studies (Kinzey & Armstrong, 1998; Hertel, Miller & Denegar, 2010; Olmsted, Carcia, Hertel & Shultz, 2002). It has been proposed to challenge dynamic postural control as the subject must maintain balance on a single limb, whilst the other limb carries out a series of reaching tasks (Olmsted et al., 2002). The SEBT has been shown to be sensitive enough to detect dynamic postural control deficits in patients with chronic ankle instability (Olmsted et al., 2002). The test has also been shown to have high intra and inter-tester reliability (Hertel et al., 2010) and validity (Herrington, Hatcher, Hatcher & McNicholas, 2009).

The SEBT test was performed with the subject standing in the middle of a grid on the leg to be tested. The subject undertook the test barefoot, foot position controlled by aligning the heel with the centre of the grid and great toe with the anteriorly projected line. As recommended by Herrington et al. (2009) three directions: anterior, medial and lateral reach distances only requiring testing for patients with ACL deficiency. The subject was instructed to reach as far as possible along each of the three lines (this position was then marked by an examiner) and return the reaching leg back to the start position; the subject repeated this process three times for each of the lines, the average score being recorded, during the test. Prior to testing each individual practiced the manoeuvring around the grid two times then had a three minute recovery before the testing. An individual trial would be repeated if the examiner felt the participant gained any substantive support from the reaching leg as it touched down or if the stance leg moved from its mark in the centre of the grid (Gribble & Hertel, 2003). The subject was instructed not to lift the stance heel off the ground during the test. The start point on the grid and direction of movement around the grid was undertaken in a block fashion. For normalisation of reach distances along the three lines they were divided by limb length, as measured from the anterior-superior iliac spine to the ipsilateral medial malleolus, and multiplied by 100 to calculate a dependent variable that represents the reach distance as a percentage of limb length (Gribble & Hertel, 2003). Unsuccessful trials were discarded, and additional trials were completed accordingly, an unsuccessful trial was defined as when a patient took excessive support from the reach leg, or lost balance.

#### **5.3.4.3 Qualitative analysis of single leg squat (QASLS)**

People at risk factor for ACL injuries could be evaluated significantly by the single-legged squat, and assumed that proper neuromuscular control during the SLS depicts ability for safe landing for the ACL. This task is considered to be a simple and safe clinical examination to correct unstable valgus positioning of the lower leg in ACL-injured patients (Olsen, Myklebust, Engebretsen & Bahr, 2004; Griffin et al. 2006).

The qualitative analysis of single leg squat (QASLS) during weight-bearing movements has a very good reliability (Almangoush et al., 2014b) and excellent validity (Herrington & Munro, 2014). The Single Leg Squat (SLS) test task has been described in detail previously (Almangoush et al., 2014b; Herrington & Munro, 2014). This is an observational test for evaluating the patients' ability to perform it. The patients had first take a single leg stance then to flex the knee from 45° to a maximum of 60° during 5 seconds, the range 45-60 degrees was chosen because the majority of patients can achieve this range comfortably, if the patient could not then they were excluded, this did not occur. The angle of knee flexion was checked during the practice trials using the standard goniometer, this test was observed by the same examiner throughout the trials. The trials were only accepted as correct if the squat test was performed to desired angle of knee flexion. Data was collected from three trials which met the inclusion criteria. The QASLS involved dichotomous scoring of the movement strategy occurring in individual body regions (arm, trunk, pelvis, thigh, knee, foot). Scoring was defined as a zero for an

appropriate strategy and one for inappropriate movements, for each region with best overall score being 0 and worst 10 points. The scoring sheet is shown in Figure (5-6).

Figure 5-6: Qualitative analysis of single leg loading (QASLS)

QASLS	Task: Single leg squat	Score	
		Left	Right
Arm strategy	Excessive arm movement to balance		
Trunk alignment	Leaning in any direction		
Pelvic plane	Loss of horizontal plane		
	Excessive tilt or rotation		
Thigh motion	WB thigh moves into hip adduction		
	NWB thigh not held in neutral		
Knee position	Patella pointing towards 2 <sup>nd</sup> toe (noticeable valgus)		
	Patella pointing past inside of foot (significant valgus)		
Steady stance	Touches down with NWB foot		
	Stance leg wobbles noticeably		
	<b>Total Score</b>		

All the tests were performed as blinded tests. The examiner was not given any information as to which leg was injured and both knee joints were covered to hide any scars remaining from knee surgery. The participants were not told what the examiner was looking for during the SLS tests.

### **5.3.5-Rehabilitation**

On discharge, all subjects were given a pair of crutches, and advice from a physiotherapist on proper use. Immediate postoperative weight-bearing was allowed as tolerated by the individual. Also, on discharge, patients were given a detailed handout which focused on maintaining the full knee extension range of motion, decreasing swelling, recovering knee extensor muscle strength, and normalizing gait. Other than providing the protocol to the physical therapists the rehabilitation program or measure compliance was not controlled, in an effort to increase the external validity of the study's findings (Paterno et al., 2010).

However, during the follow-up visits, subjects were specifically asked whether they had visited a private physiotherapist or used other services in order to speed up their recovery and were given the audit questionnaire with pictures of most of exercises usually advised to patients with ACL injuries which takes few minutes to answer (see appendix. 2). Most participants told that they tried to follow different protocols that were provided by a different physiotherapists in different places.

## **5.4 Data Analysis**

The material was tested for normality by using the Kolmogorov Smirnov test. All variables were summarized using standard descriptive statistics such as frequency, mean and standard deviation. The repeated-measures ANOVA design was used to describe the mean, standard deviations and range for the data from the questionnaires, and functional

tests. Also to see if there was any significant differences in outcomes during time periods, test occasion: pre-surgery, 3, 6 and 12 months post-surgery, for all outcomes including the LSI. Also, the final results of each patient were compared between the test intervals (pre-surgery vs 3months, pre-surgery vs 6 months, pre-surgery vs 12 months, 3 months vs 6 months, 3 months vs 12 months and 6 months vs 12 months post-surgery) using a 2-tailed paired t test assuming equal variance, with  $P < .05$  to investigate any improvements that might have occurred between these 6 hypotheses. The Bonferroni correction was conducted to maintain statistical power by dividing the critical  $P$  value ( $\alpha$ ) by the number of comparisons being made (Napierala, 2012). However, the cost of incurring a type 1 error was deemed minimal and therefore appropriate given the exploratory nature of the study. For all analyses, statistical significance was defined by a probability level of  $P$  less than .05 and was performed with the SPSS-20 program (SPSS Inc, Chicago, Ill).

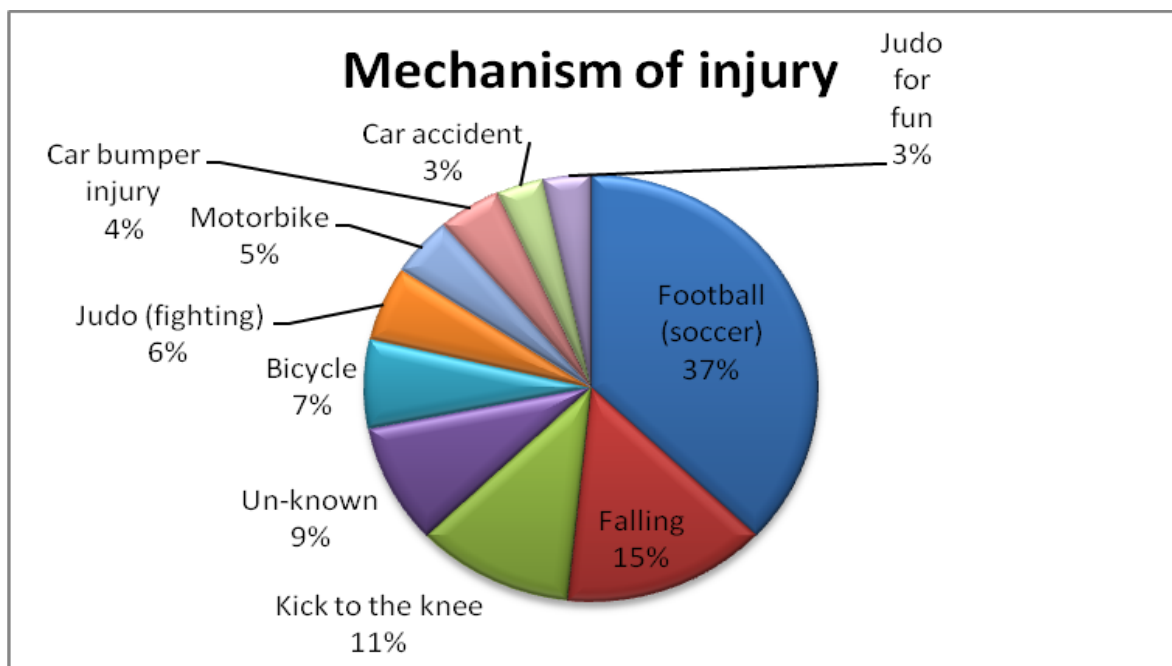
## **5.5 Results**

### **5.5.1 Subject demographics**

The mean age (y)  $28 \pm 7.4$  (19-48), Height (cm)  $176.6 \pm 7.1$  (162-191), Weight (kg)  $84.6 \pm 9.1$  (65-117), Body mass index  $27.1 \pm 2.1$  (22.6-38.7). The right limb was dominant in 63 (71%) and left 26 (29%) patients. Reconstruction was performed in the right limb in 41(46%) and left 48 (54%) of participants. The mean time from injury to surgery was 35.6 months (range 4-132). The activity levels of patients pre-injury were: 68% sporting sometimes and 32% non- sporting.

### 5.5.2 Mechanisms of Injury

The mechanisms contact sports: In the present study participation in football was the most common cause of ACL injuries- 37%, Judo (fighting) 6%, Traffic accidents: Car bumper injury 4% and Car accident 3, Motorbike 5%, Bicycle 7%, Falling 15%, and un-known 9%. The aetiology of the knee trauma also differs when compared with other studies. The reported mechanism of injury is displayed in Figure (5-7).



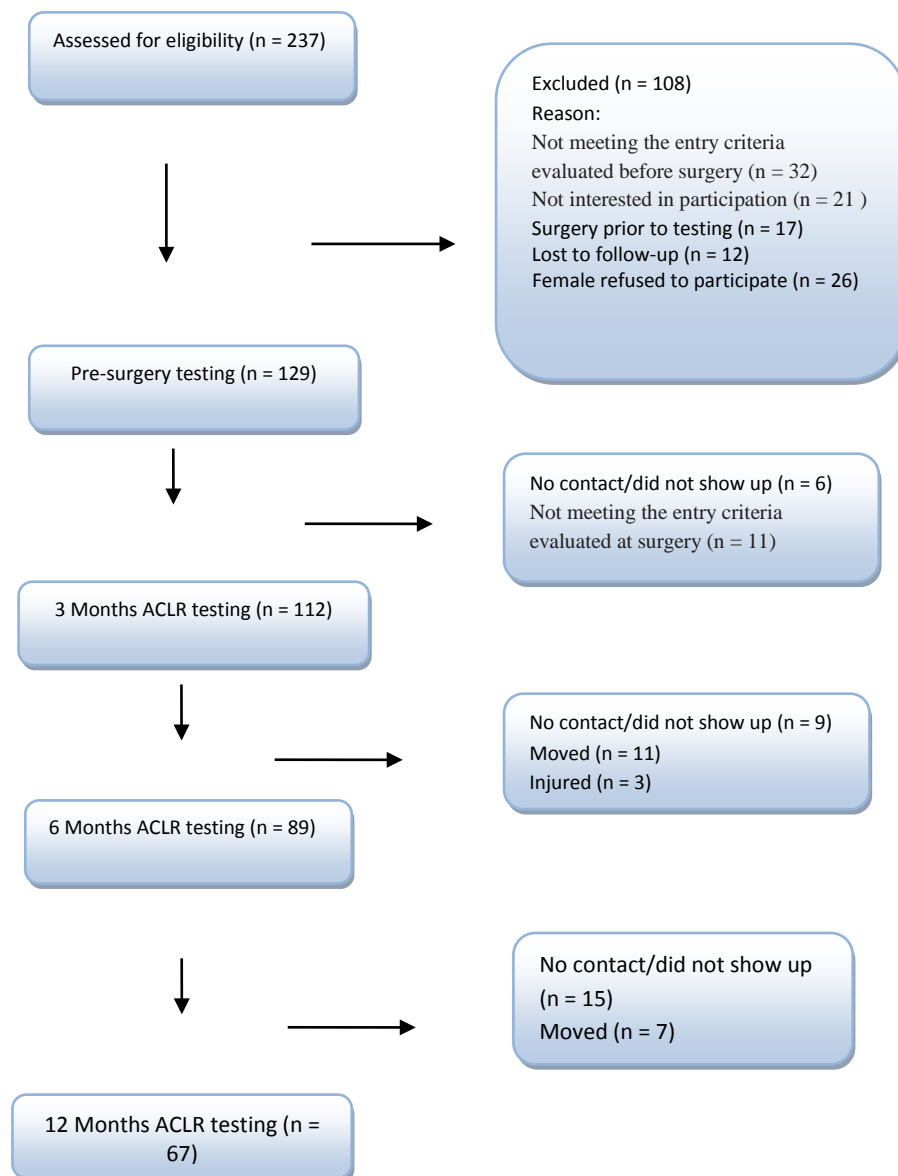
**Figure 5-7:** Mechanism of ACL injuries

### 5.5.3 Dropouts

It was not possible to follow every patient at every time interval. After the surgery 6 patients were lost and did not show up. After 3 months testing 11 patients moved and 9 patients did not show up and 3 sustained a re-rupture of their ACL. All data of these

dropped out patients and any who did not attend the 6 months session were excluded. After 6 months no contact/did not show up (n = 15) Moved (n = 7). Eighty-nine patients (80%) returned for follow-up examination at 6 months, and 67 subjects (60%) returned for follow-up examination at 12 months (Figure, 5-8).

**Figure 5-8:** Flow diagram for subject involvement



### 5.5.4 Range of Motion

The mean flexion of ACLR knees were: the values pre-surgery  $122.5^{\circ} \pm 4$  ( $113^{\circ}$ - $131^{\circ}$ ), post-operatively at 3 months  $120.5^{\circ} \pm 4.6$  ( $111^{\circ}$ - $128^{\circ}$ ), six months  $129^{\circ} \pm 2.3$  ( $122^{\circ}$ - $134^{\circ}$ ), and twelve months  $132.3^{\circ} \pm 2.4$  ( $123^{\circ}$ - $136^{\circ}$ ). The mean flexion of un-injured knees were: the values pre-surgery  $131.7^{\circ} \pm 2.5$  ( $125^{\circ}$ - $138^{\circ}$ ), post-operatively at 3 months  $130.8^{\circ} \pm 2.2$  ( $125^{\circ}$ - $136^{\circ}$ ), six months  $133.2^{\circ} \pm 1.6$  ( $128^{\circ}$ - $137^{\circ}$ ), and twelve months  $135.7^{\circ} \pm 1.8$  ( $130^{\circ}$ - $140^{\circ}$ ). Flexion was poorer in the reconstructed ACL knees than in the non-operated knees at all time intervals (Figure, 5-2), and the difference between the paired knees was significant ( $p < .001$ ) at all time intervals also; pre-surgery ( $122.5^{\circ}$  compared with  $131.7^{\circ}$ ), three months ( $120.5^{\circ}$  compared with  $130.8^{\circ}$ ), six months ( $120^{\circ}$  compared with  $133.2^{\circ}$ ), and twelve months ( $132.3^{\circ}$  compared with  $135.7^{\circ}$ ) post-operatively. Eight patients did not achieve as much flexion in the involved knee as was present in the uninvolved knee at 12 months following surgery  $> 5^{\circ}$  which considered abnormal flexion (Shelbourne et al., 2012); the absolute values of flexion deficit were  $6^{\circ}$ ,  $7^{\circ}$ ,  $7^{\circ}$ ,  $8^{\circ}$ ,  $9^{\circ}$ ,  $9^{\circ}$ ,  $13^{\circ}$  and  $15^{\circ}$ . No operative interventions were performed because of loss-of-motion complications.

**Table 5-1:** Range of motion "Flexion"

Injured Knee				Uninjured Knee			
Timing	Degree	SD	Range	Timing	Degree	SD	Range
Pre surgery	122.5	4.0	(113-131)	Pre surgery	131.7	2.5	(125-138)
3 months post	120.5	4.6	(111-128)	3 months post	130.8	2.2	(125- 136)
6 months post	129	2.3	(122-134)	6 months post	133.2	1.6	(128-137)
12 months post	132.3	2.4	(123-136)	12 months post	135.7	1.8	(130-140)

The mean extension of the reconstructed knee before surgery and at 3, 6 and 12 months, postoperatively were  $7.3^{\circ} \pm 4.3$  ( $0^{\circ}$ - $15^{\circ}$ ),  $7.5^{\circ} \pm 4.2$  ( $0^{\circ}$ - $15^{\circ}$ ),  $5.6^{\circ} \pm 3.2$  ( $0^{\circ}$ - $10^{\circ}$ ) and  $4.6^{\circ} \pm 2.7$  ( $0^{\circ}$ - $8^{\circ}$ ), and uninvolved knee were  $5.6^{\circ} \pm 3.2$  ( $0^{\circ}$ - $10^{\circ}$ ),  $5.9^{\circ} \pm 3.4$  ( $0^{\circ}$ - $10^{\circ}$ ),  $4.7^{\circ} \pm 2.7$  ( $0^{\circ}$ - $8^{\circ}$ ) and  $4.1^{\circ} \pm 2.3$  ( $0^{\circ}$ - $8^{\circ}$ ). Extension of the reconstructed knees was poorer than in the non-operated knees at all time intervals (Figure, 5-3), and the difference between the paired knees was significant at all time intervals ( $p < .001$ ); pre-surgery ( $7.3^{\circ}$  compared with  $5.6^{\circ}$ ), three months ( $7.5^{\circ}$  compared with  $5.9^{\circ}$ ), six months ( $5.6^{\circ}$  compared with  $4.7^{\circ}$ ), and twelve months ( $4.6^{\circ}$  compared with  $4.1^{\circ}$ ) postoperatively. Two patients did not achieve as much extension in the involved knee as was present in the uninvolved knee at 12 months follow surgery  $> 2^{\circ}$  which considered abnormal extension (Shelbourne, Urch, Gray & Freeman, 2012); the absolute values of extension deficit were  $3^{\circ}$  and  $4^{\circ}$ . No operative interventions were performed because of loss-of-motion complications.

**Table 5-2:** Range of motion "Extension"

Injured Knee				Uninjured Knee			
Timing	Degree	SD	Range	Timing	Degree	SD	Range
Pre surgery	7.5	4.3	(0-15)	Pre surgery	5.6	3.2	(0-10)
3 months post	7.3	4.2	(0-15)	3 months post	5.9	3.4	(0-10)
6 months post	5.6	3.2	(0-10)	6 months post	4.7	2.7	(0-8)
12 months post	4.6	2.7	(0-8)	12 months post	4.1	2.3	(0-8)

The patients who have hyper-extension (extension beyond  $0^{\circ}$  degrees) were measured separately to know how much these hyper-extension degrees are. The mean hyper-extension deficit of the reconstructed knee before surgery and at 3, 6 and 12 months,

postoperatively were  $-1.7^{\circ} \pm 3.5$ ,  $-1.8^{\circ} \pm 3.6$ ,  $-1.6^{\circ} \pm 3.1$ , and  $-1.4^{\circ} \pm 2.7$ , and uninjured knee were  $-1.7^{\circ} \pm 3.4$ ,  $-1.7^{\circ} \pm 3.3$ ,  $-1.5^{\circ} \pm 2.9$  and  $-1.3^{\circ} \pm 2.6$  (Fig. 5). There were only 19 patients who had a hyper-extension. The difference between the paired knees was not significant at 3 time intervals: before the surgery ( $-1.7^{\circ}$  compared with  $1.7^{\circ}$ ;  $p = .445$ ), six months ( $-1.6^{\circ}$  compared with  $-1.5$ ;  $p = .096$ ), and twelve months ( $-1.4^{\circ}$  compared with  $-1.3^{\circ}$ ;  $p = .058$ ) postoperatively. Except one interval time, three months after surgery ( $-1.8^{\circ}$  compared with  $-1.7^{\circ}$ ;  $p = .019$ )

**Table 5-3:** Range of motion "Hyper-extension"

Injured Knee				Uninjured Knee			
Timing	Degree	SD	Range	Timing	Degree	SD	Range
Pre surgery	- 1.7	3.5	(0-12)	Pre surgery	- 1.7	3.4	(0-10)
3 months post	- 1.8	3.6	(0-10)	3 months post	- 1.7	3.3	(0-10)
6 months post	- 1.6	3.1	(0-10)	6 months post	- 1.5	2.9	(0-10)
12 months post	- 1.4	2.7	(0-10)	12 months post	- 1.3	2.6	(0-10)

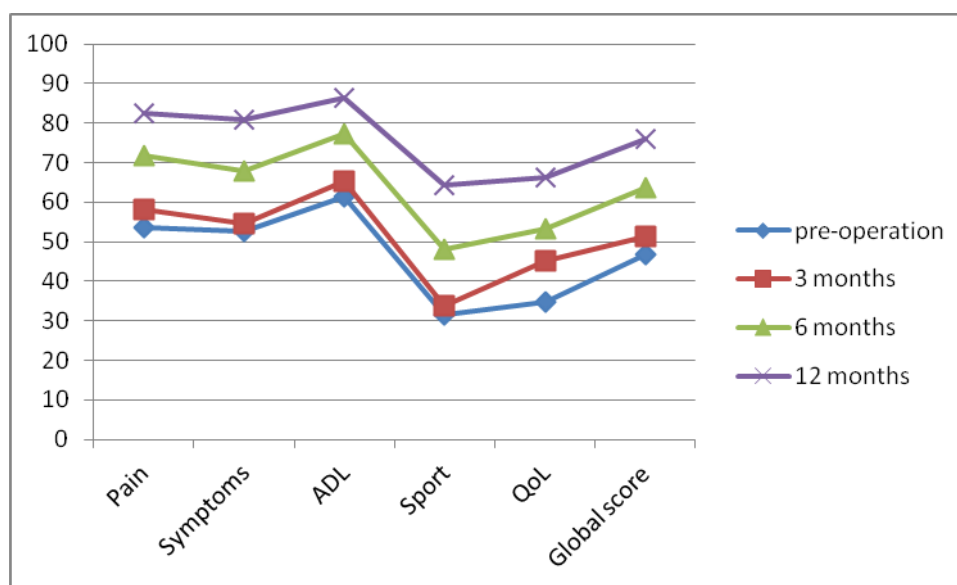
### 5.5.5 KOOS Values

The patients recorded a significant improvement in their KOOS scores between the baseline and 12 months follow-up interval ( $P < .0001$ ). The temporal response of the scores of 3 out of the 5 subscales (pain, symptoms, and activity of daily living), were nearly identical: these scores approached a value of 80 or above by the 12 months follow-up. The ADLs score (86.4) indicating a return to normal, or pre-injury status. In contrast, the sports and recreation participation and the knee-related quality of life scores plateaued

at values below 65 and 67, respectively, indicating that the index injury, surgery, and rehabilitation had a long-term effect on how patients perceived their quality of life. The global score plateaued at values below 77. Outcomes for each KOOS sub-scales are summarized in table (5-4) and presented in figure (5-9).

**Table 5-4:** Mean KOOS scores with standard deviation (SD) and range data for each domain recorded pre-operatively and at 3-, 6- and 12 months follow-up review following primary ACLR.

Domain	Pre-operation			3 Months			6 Months			12 Months		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Pain	53.5	19.6	19-100	58.1	17.5	25-97	69.4	15.1	31-100	82.5	14.3	42-100
Symptoms	52.5	15.6	21-86	54.5	15.1	25-88	67.8	14.3	32-96	80.8	13.7	36-96
ADLs	61.5	16.6	28-96	65.3	14.1	31-87	77.2	13.3	37-100	86.4	10.8	47-100
Sports/Rec	31.6	20.2	0-75	33.7	17.5	5-75	48.2	17.8	5-90	64.4	17.2	15-95
QoL	34.7	14.9	6-69	45.3	13.1	19-75	53.4	16.4	13-81	66.2	11.6	31-88
Global	46.8	16.2	16-81	51.4	13.7	22-78	63.7	14.9	28-89	76.1	12.8	41-94



**Figure 5-9:** Recovery profile of mean KOOS scores for each of the five domains following ACLR measured pre-operation and at 3, 6 and 12 months post-operation

According to the Bonferroni correction an adjustment made to  $P$  values when several dependent or independent statistical tests are being performed simultaneously on a single data set (Napierala, 2012). To perform a Bonferroni correction, the critical  $P$  value ( $\alpha$ ) was divided by the number of comparisons being made. The Bonferroni correction is used to reduce the chances of obtaining false-positive results (type I errors) when multiple pair wise tests are performed on a single set of data (Napierala, 2012). The paired samples T test of six comparisons between 4 different test times (before-surgery, 3, 6 and 12 months) for every subscale of KOOS plus the Global score were done, and  $p$  values were  $< .05$  except a comparison between (pre-surgery vs 3 months) of symptoms subscale and between (pre-surgery vs 3 months) of ADL subscale. Therefore, the Bonferroni correction was used to adjust the  $p$  value for each hypothesis to reduce this risk and  $p$  value corrected to .012 and .009, respectively. Bonferroni-corrected  $p$ -value symptoms at (Pre vs 3 months) were corrected to  $P = .074/6 = .012$ , Sports/Rec  $P = .056/6 = .009$ . All KOOS subscales recorded a significant improvement between the time intervals ( $p < .001$ ), the only exception being the symptoms and sports/rec scores between the baseline 3 months after surgery interval ( $p = .074$  and  $p = .056$ ) respectively. Looking at post-operative KOOS scores in Table (5-4) and Figure (5-9), KOOS improvements were observed and were generally higher than 10 points in terms of most KOOS subscales with the largest changes in KOOS over time of up to 30 points seen in the ADLs subscale.

**Table 5-5:** Bonferroni-corrected p-value

		<i>P</i> value	Bonferroni-corrected p-value			
Timing	Pain	Symptoms	ADLs	Sports/ Rec	QoL	Global
Pre vs 3 months	.001	.074	.019	.056	.001	.001
Pre vs 6 months	.001	.001	.001	.001	.001	.001
Pre vs 12 months	.001	.001	.001	.001	.001	.001
3 months vs 6 months	.001	.001	.001	.001	.001	.001
3 months vs 12 months	.001	.001	.001	.001	.001	.001
6 months vs 12 months	.001	.001	.001	.001	.001	.001

## 5.5.6 Functional Assessment

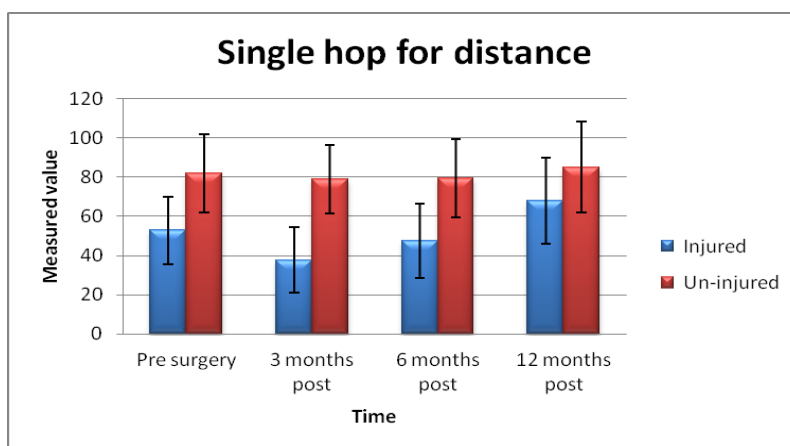
### 5.5.6.1 Single-leg hop

The patients' ability to perform the one-legged hop varied between participants. There was significant improvement over time intervals ( $P < .001$ ) and the participants in the present study improved their function in a similar manner during healing. The mean distance (centimetres) of the single leg hop of injured knees were: the values pre-surgery  $52.9 \pm 17.3$  (28-119), at 3 months  $37.7 \pm 16.8$  (21-110), six months  $47.7 \pm 19$  (30-129), and twelve months  $67.9 \pm 21.9$  (35-134) postoperation. In the involved limb, absolute changes were seen in single-leg hop between 6 time intervals ( $p < .001$ ), except between pre-surgery vs 6 months the  $p = .928$  (Table. 5-7). In the uninvolved limb, absolute changes were not seen in 3 time intervals during the 12 months following surgery in the single-leg

hop. Whereas, pre vs 3 months, pre vs 6 months and pre vs 12 months  $p = .340$ ,  $.552$  and  $.755$ , respectively. The mean distance (centimetres) of the single leg hop of un-injured knees were: the values pre-surgery  $81.9 \pm 19.8$  (53-151), and at 3 months  $78.8 \pm 17.5$  (54-141), six months  $79.5 \pm 19.9$  (45-163), and twelve months  $85 \pm 23.1$  (47-166) following surgery. Patients produced mean differences in hop distance between uninjured and injured limbs that were 29 cm, 41.1 cm, 31.8 cm and 17.3 cm at the preoperative and 3, 6 and 12 month follow-up time intervals, respectively.

**Table 5-6:** Single hop for distance

Injured Knee				Uninjured Knee			
Timing	Distance	SD	Range	Timing	Distance	SD	Range
Pre surgery	52.89	17.3	(28-119)	Pre surgery	81.89	19.8	( 53-151)
3 months post	37.73	16.8	(21- 110)	3 months post	78.80	17.5	( 54-141)
6 months post	47.70	19.0	(30-129)	6 months post	79.45	19.9	(45-163 )
12 months post	67.86	21.9	(35-134)	12 months post	85.14	23.1	(47-166 )



**Figure 5-10:** Comparison of injured and un-injured limb performance during the single-leg hop following ACLR measured pre-operation and at 3, 6 and 12 months post-operation

**Table 5-7:** T- test and Bonferroni-corrected *p*-value of single leg hop

N o.	T- test	P value		Bonferroni-corrected <i>p</i> -value	
		<i>inj</i>	<i>un</i>	<i>Inj</i>	<i>un</i>
1	Before vs 3 months	.001	.340	–	.056
2	Before vs 6 months	.928	.552	0.15	.092
3	Before vs 12 months	.001	.755	–	.126
4	3 months vs 6 months	.001	.032	–	.001
5	3 months vs 12 months	.001	.002	–	.001
6	6 months vs 12 months	.001	.001	–	.001

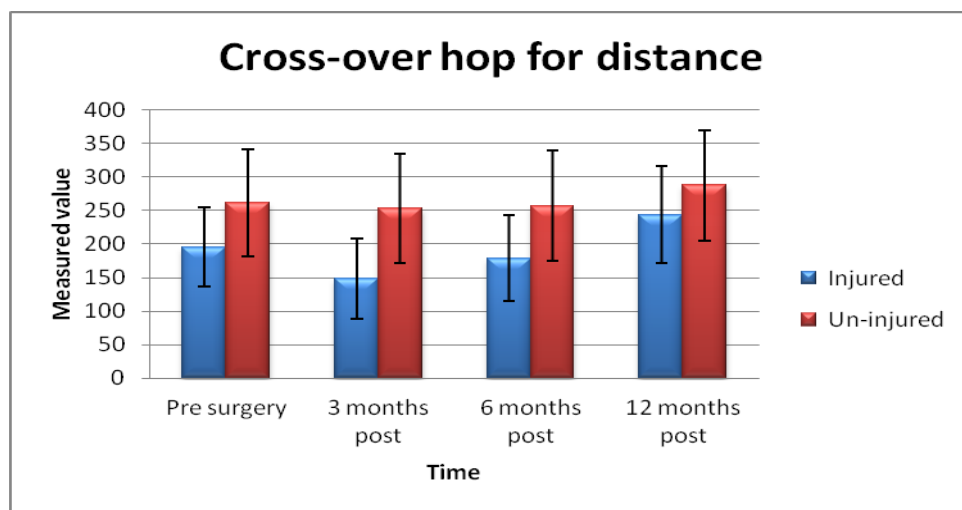
### 5.5.6.2 Cross-over hop

The mean distance (centimetres) of the crossover hop of injured knees were: the values pre-surgery  $195.5 \pm 59.4$  (114-366), at 3 months  $148 \pm 59.6$  (81-414), six months  $178.8 \pm 64.5$  (107-454), and twelve months  $243.6 \pm 72.7$  (130-474) post operation. In the involved limb, absolute changes were seen between all 6 time intervals comparison ( $p < .001$ ), except between pre-surgery vs 6 months post-operation, the  $p = .826$  (Table. 5-9). In the uninvolved limb, absolute changes were seen as well between all 6 time intervals comparison ( $p < .001$ ), over the 12 months following surgery. The mean distance (centimetres) of the crossover hop of un-injured knees were: the values pre-surgery  $261.9 \pm 79.8$  (157-559), and at 3 months  $253 \pm 82.1$  (153-551), six months  $257 \pm 82.5$  (155-574), and twelve months  $287.4 \pm 82.9$  (166-587) after the operation.

Patients had mean differences in the crossover hop distance between injured and uninjured limbs that were 66.4 cm, 105 cm, 77.9 cm and 43.8 cm at the preoperative and 3, 6 and 12 month follow-up intervals, respectively.

**Table 5-8:** Crossover hop for distance

Injured Knee				Uninjured Knee			
Timing	Mean of distance	SD	Range	Timing	Mean of distance	SD	Range
Pre surgery	195.47	59.4	(114-366)	Pre surgery	261.87	79.8	(157-559)
3 months post	148.00	59.6	(81-414)	3 months post	252.96	82.1	(153-551)
6 months post	178.80	64.5	(107-454)	6 months post	256.67	82.5	(155-574)
12 months post	243.62	72.7	(130-474)	12 months post	287.38	82.9	(166-587)

**Figure 5-11:** Comparison of injured and un-injured limb performance during the crossover hop following ACLR measured pre-operation and at 3, 6 and 12 months post-operation**Table 5-9:** T test and Bonferroni-corrected *p*-value Crossover hop

No .	T test	P value		Bonferroni-corrected <i>p</i> -value	
		<i>inj</i>	<i>un</i>	Inj	un
1	Before vs 3 months	.001	.004	-	-
2	Before vs 6 months	.826	.019	$P = .826/6 = .137$	-
3	Before vs 12 months	.001	.001	-	-
4	3 months vs 6 months	.001	.004	-	-
5	3 months vs 12 months	.001	.001	-	-
6	6 months vs 12 months	.001	.001	-	-

### 5.5.6.3 Limb Symmetry Indices (LSI)

To compare the outcome of functional tests, the LSI of all hop tests preoperatively and postoperatively were calculated. The LSI of the single hop test was 78.1 preoperatively, decreasing to 63.5 at 3 months postoperatively, followed by improvements at 6 and 12 months postoperatively, with LSIs of 75.6 and 82.9, respectively (Table, 5-10). For the crossover hop for distance test, the same trend was seen with LSIs of 78.7, 69.8, 77.4 and 84.4, respectively (Table, 5-11). Using a score greater than or equal to 85% as a criterion for normative limb symmetry (Noyes et al., 1991), normative scores were nearly recorded (84.4) in crossover hop at the 12 months test occasion, and the single leg hop (82.9) at the twelve months test occasion. At the 3 months post surgery test, the highest number of abnormal scores were noted in the both hop tests. Only 17, 3, 11 and 34 (38%) patients scored normative values 85% or above in the single leg hop pre-surgery and at 3, 6 and 12 months, respectively. The number of subjects showing normal limb symmetry increased over the last two test occasions. The crossover hop showed normative values of a number of patients and were: 20, 6, 20 and 42 (63%) pre-surgery and at 3, 6 and 12 months, respectively.

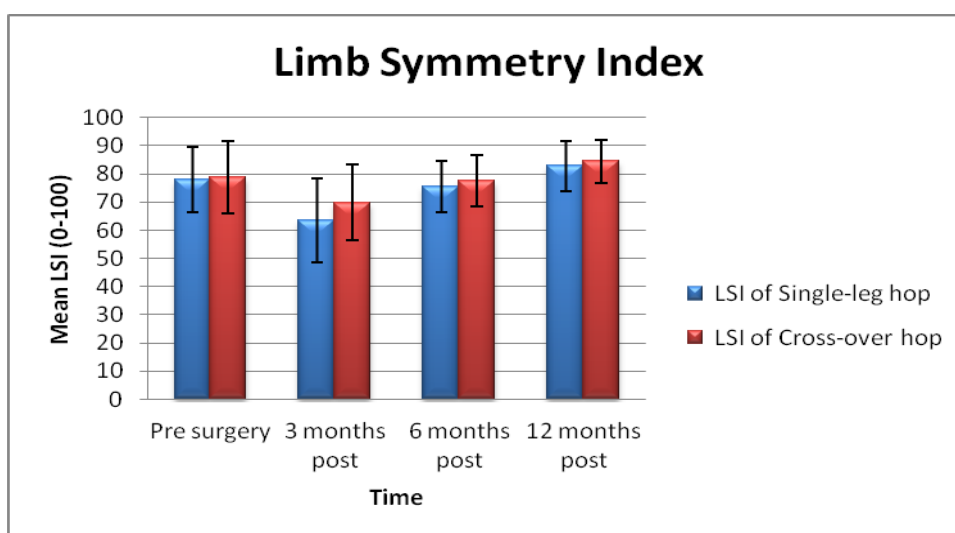
**Table 5-10:** Limb Symmetry Index of Single hop for distance

<b>Limb Symmetry Index of Single hop for distance</b>			
<b>Timing</b>	<b>Mean of distance</b>	<b>SD</b>	<b>Range</b>
<b>Pre surgery</b>	78.07	11.6	(28-94)
<b>3 months post</b>	63.48	14.8	(30-93)
<b>6 months post</b>	75.64	9.1	(45-96)
<b>12 months post</b>	82.86	8.9	(45-93)

The mean of distance of the LSI of crossover hops were: the values pre-surgery 78.7  $\pm$ 12.9, and at 3 months 69.8  $\pm$ 13.5, six months 77.4  $\pm$ 9.1, and twelve months 84.4  $\pm$ 7.8 following surgery.

**Table 5-11:** Limb Symmetry Index of crossover hop for distance

Limb Symmetry Index of Crossover hop for distance			
Timing	Mean of distance	SD	Range
Pre surgery	78.73	12.881	(28-94)
3 months post	69.84	13.477	(31- 93)
6 months post	77.38	9.126	(52-90)
12 months post	84.36	7.758	(62-98)



**Figure 5-12:** Comparison of LSI of single-leg and crossover hop for distance measured pre-operation and at 3, 6 and 12 months post-operation

#### 5.5.6.4 Star Excursion Balance Test (SEBT)

##### 5.5.6.4.1 Anterior

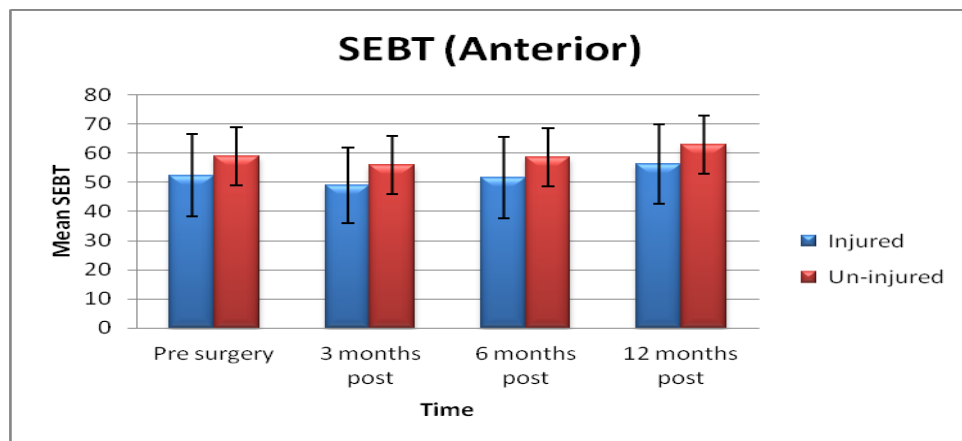
The patients' ability to perform the SEBT varied between participants. The participants in the present study also improved their function during healing. There was significant improvement over time ( $P < .001$ ) and the mean distance (centimetres) of the anterior direction of injured knees were: the values pre-surgery  $49.4 \pm 14.1$  (33-82), and at 3 months  $49 \pm 13.1$  (33-82), six months  $51.7 \pm 13.9$  (34-85), and twelve months  $56.3 \pm 13.6$  (34-89) after the operation. While the mean destinations of un-injured knees were: the values pre-surgery  $56.3 \pm 14.6$  (33-94), and at 3 months  $56 \pm 14.3$  (36-91), six months  $58.6 \pm 14.1$  (36-93), and twelve months  $62.9 \pm 12.9$  (40-94) post operation.

**Table 5-12:** SEBT of the anterior direction

Injured Knee				Uninjured Knee			
Timing	Mean of distance	SD	Range	Timing	Mean of distance	SD	Range
Pre surgery	52.42	14.1	(33-82)	Pre surgery	58.87	14.6	(33-94)
3 months post	48.95	13.1	(33-82)	3 months post	55.95	14.3	(36-91)
6 months post	51.56	13.9	(34-85)	6 months post	58.58	14.1	(36-93)
12 months post	56.29	13.6	(34-89)	12 months post	62.88	12.9	(40-94)

**Table 5-13:** T test and Bonferroni-corrected *p*-value of SEBT (interior)

No	T test	P value		Bonferroni-corrected p-value	
		<i>inj</i>	<i>un</i>	<b>Inj</b>	<b>un</b>
1	Before vs 3 months	.001	.001	–	–
2	Before vs 6 months	.001	.109	–	.01
3	Before vs 12 months	.001	.362	–	.06
4	3 months vs 6 months	.001	.001	–	–
5	3 months vs 12 months	.001	.001	–	–
6	6 months vs 12 months	.001	.001	–	–

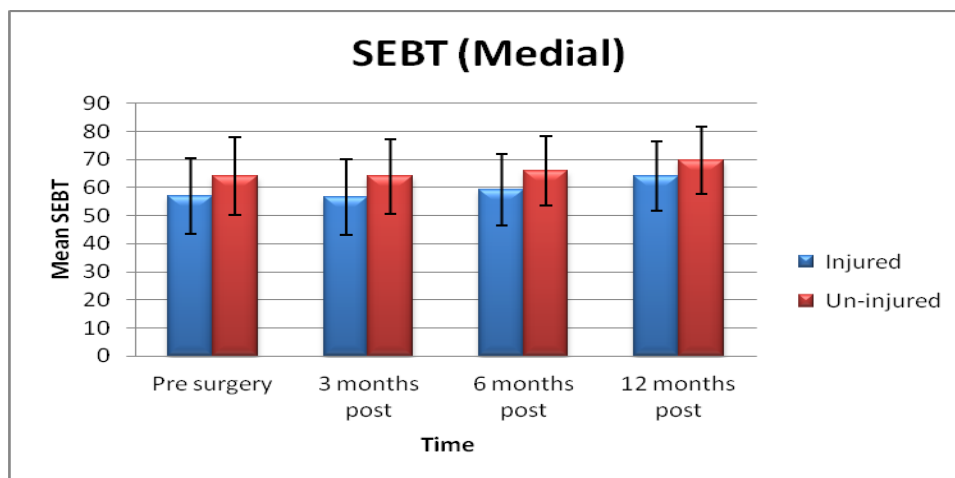
**Figure 5-13:** Comparison of injured and un-injured limb performance during the anterior direction of SEBT following ACLR measured pre-operation and at 3, 6 and 12 months post-operation

#### 5.5.6.4.2 Medial

The mean destinations (centimetres) of the medial direction of injured knees were: the values pre-surgery  $56.8 \pm 13.5$  (36-81), and at 3 months  $56.5 \pm 13.6$  (36-83), six months  $59.2 \pm 12.6$  (39-83), and twelve months  $64.1 \pm 12.4$  (42-84) postoperatively. While the mean of destinations of un-injured knees were: the values pre-surgery  $64.1 \pm 13.9$  (41-94), and at 3 months  $63.9 \pm 13.4$  (42-94), six months  $66 \pm 12.3$  (42-90), and twelve months  $69.8 \pm 12.1$  (46-92) postoperatively.

**Table 5-14:** SEBT of the medial direction

Injured Knee				Uninjured Knee			
Timing	Mean of distance	SD	Range	Timing	Mean of distance	SD	Range
Pre surgery	56.83	13.47	(36-81)	Pre surgery	64.12	13.88	(41-94)
3 months post	56.54	13.56	(36-83)	3 months post	63.90	13.38	(42-94)
6 months post	59.20	12.60	(39-83)	6 months post	65.97	12.29	(42-90)
12 months post	64.12	12.44	(42-84)	12 months post	69.75	12.07	(46-92)

**Figure 5-14:** Comparison of injured and un-injured limb performance during the medial direction of SEBT following ACLR measured pre-operation and at 3, 6 and 12 months post-operation**Table 5-15:** T test and Bonferroni-corrected *p*-value of SEBT (medial)

No.	T test	P value		Bonferroni-corrected p-value	
		<i>inj</i>	<i>un</i>	<b>Inj</b>	<b>un</b>
1	Before vs 3 months	.407	.687	.06	.11
2	Before vs 6 months	.001	.001	–	–
3	Before vs 12 months	.001	.001	–	–
4	3 months vs 6 months	.001	.001	–	–
5	3 months vs 12 months	.001	.001	–	–
6	6 months vs 12 months	.001	.001	–	–

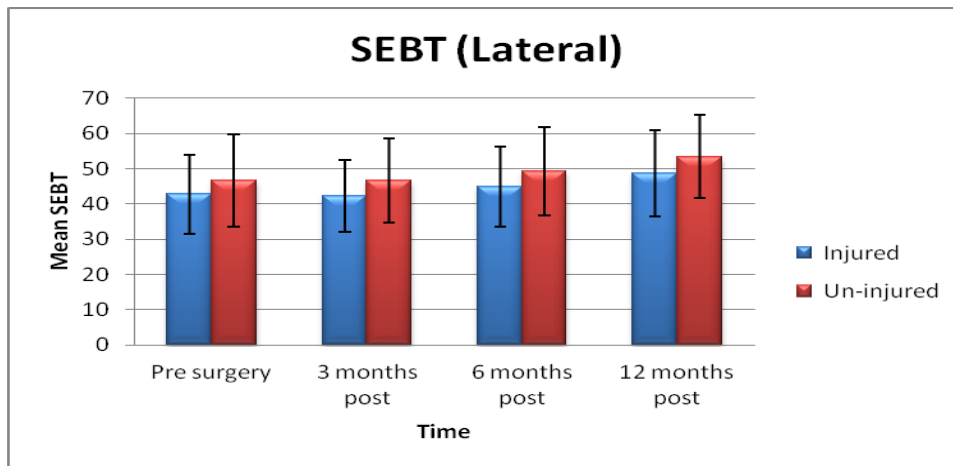
#### 5.5.6.4.3 Lateral

The mean distance (centimetres) of the lateral direction of injured knees were: the values pre-surgery  $42.8 \pm 11.2$  (33-82), and at 3 months  $42.3 \pm 10.2$  (33-81), six months  $44.8 \pm 11.4$  (33-83), and twelve months  $48.7 \pm 12.1$  (34-84) postoperatively. While the mean destinations of un-injured knees were: the values pre-surgery  $46.6 \pm 13.1$  (33-93), and at 3 months  $46.6 \pm 12$  (34-86), six months  $49.3 \pm 12.6$  (34-94), and twelve months  $53.4 \pm 11.9$  (36-93) following surgery.

In the both limbs, absolute changes were not seen over the 3 and 6 months following surgery of medial and lateral direction of SEBT. The interpretation of this discrepancy could be that the muscle function tests commonly used are not demanding enough or not sensitive enough to identify differences between injured and non-injured sides (Thomee et al., 2011).

**Table 5-16:** SEBT (lateral)

Injured Knee				Uninjured Knee			
Timing	Mean of distance	SD	Range	Timing	Mean of distance	SD	Range
Pre surgery	42.75	11.2	(33-82)	Pre surgery	46.56	13.1	(33-93)
3 months post	42.25	10.2	(33-81)	3 months post	46.59	12.0	(34-86)
6 months post	44.83	11.4	(33-83)	6 months post	49.27	12.6	(34-94)
12 months post	48.66	12.1	(34-84)	12 months post	53.44	11.9	(36-93)



**Figure 5-15:** Comparison of injured and un-injured limb performance during the lateral direction of SEBT following ACLR measured pre-operation and at 3, 6 and 12 months post-operation

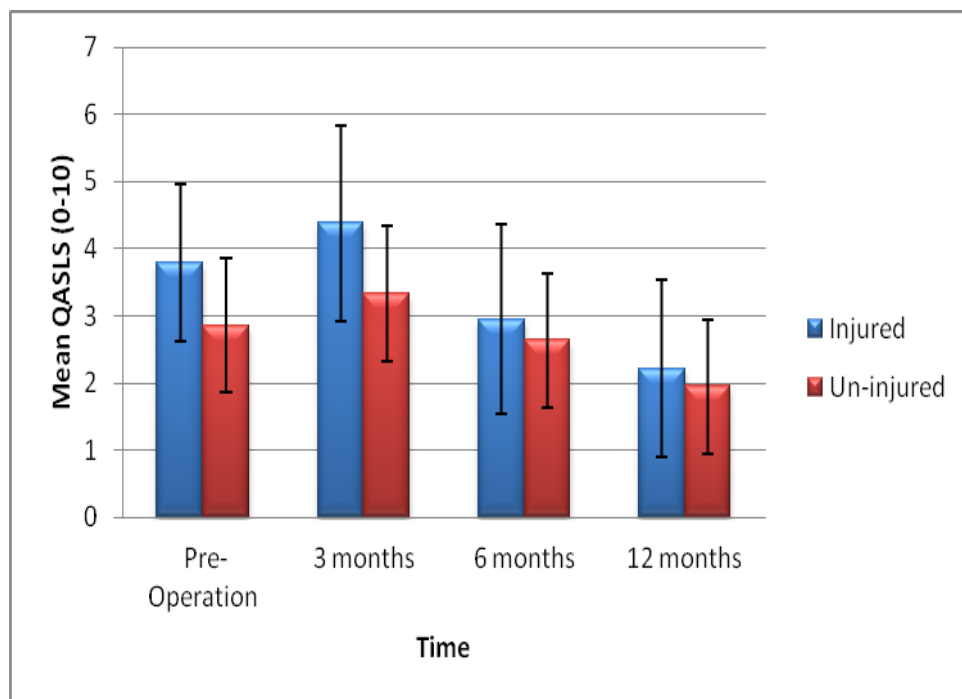
**Table 5-17:** T test and Bonferroni-corrected *p*-value of SEBT (lateral)

No.	T test	P value		Bonferroni-corrected p-value	
		<i>inj</i>	<i>un</i>	<b>Inj</b>	<b>un</b>
1	Before vs 3 months	.807	.186	.13	.03
2	Before vs 6 months	.001	.001	–	–
3	Before vs 12 months	.001	.001	–	–
4	3 months vs 6 months	.001	.001	–	–
5	3 months vs 12 months	.001	.001	–	–
6	6 months vs 12 months	.001	.001	–	–

### 5.5.7 Qualitative analysis of single leg squat (QASLS)

Irrespective of whether the knee had undergone ACL-reconstruction or not, there were a high QASLS total scores for both limbs .The QASLS total score in this study ranged from 0-7 points for the injured and uninjured sides (Table. 5-18). Statistically significant differences were found between the injured and uninjured sides for the four test

occasions, QASLS ( $p < 0.001$ ). Figure (5-16) shows the mean values for each of the four test occasions, for the injured and uninjured sides. Eleven subjects (12%) showed no substitution patterns on their injured side, while 17 subjects (19%) showed no substitution patterns on their uninjured side. There was no significant change of injured and uninjured legs before and at 3 months after surgery  $p = .054$  and  $p = .50$ , respectively. Also, of the un-injured limb before operation and 6 months after surgery  $p = .152$ .



**Figure 5-16:** Comparison of injured and un-injured limb performance during the QASLS following ACLR measured pre-operation and at 3, 6 and 12 months post-operation. (high score means less improvements).

**Table 5-18:** the mean values and standard deviation of QASLS measured pre-operation and at 3, 6 and 12 months post-operation

QASLS				
Time	Injured	SD	Un-injured	SD
Pre-Operation	3.79	1.18	2.86	0.98
3 months post	4.38	1.45	3.33	1.5
6 months post	2.95	1.41	2.64	1.37
12 months post	2.21	1.32	1.95	1.14

**Table 5-19:** T test and Bonferroni-corrected *p*-value of the QASLS

No	T test	P value		Bonferroni-corrected p-value	
		<i>Inj</i>	<i>un</i>	<i>inj</i>	<i>un</i>
1	Before vs 3 months	.054	.050	.054/6 = .009	.008
2	Before vs 6 months	.001	.152	–	.025
3	Before vs 12 months	.001	.001	–	–
4	3 months vs 6 months	.001	.001	–	–
5	3 months vs 12 months	.001	.001	–	–
6	6 months vs 12 months	.001	.001	–	–

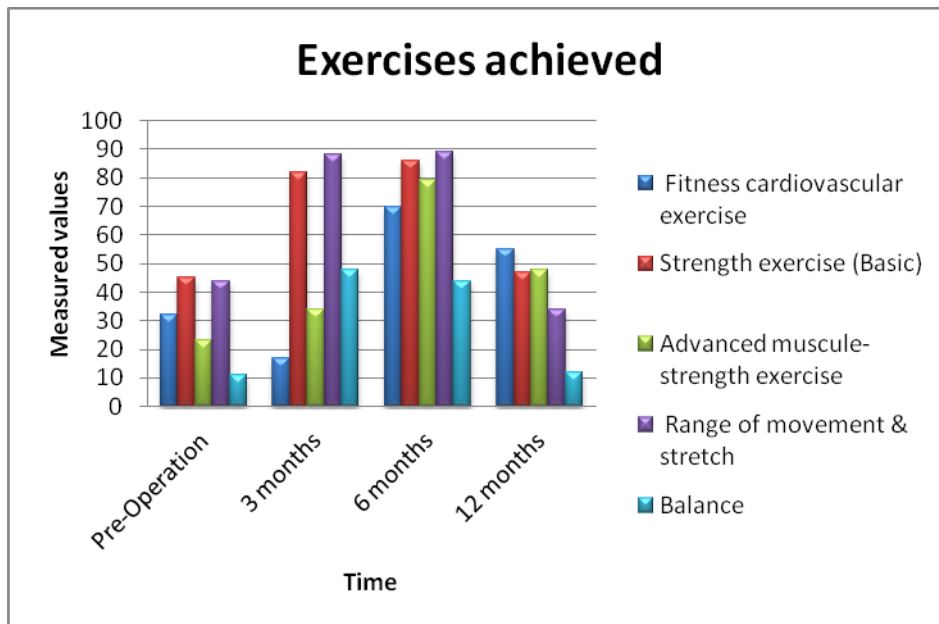
### 5.5.8 Rehabilitation

The pre and postoperative rehabilitation programs following ACL reconstruction play an important role in the clinical outcome and patients' satisfaction. In the present study patients expressed frustration that the progress during rehabilitation was much slower than they had expected. As a result, the compliance of some patients' decreased, some even give up, while others increased their efforts and continued with their rehabilitation, which is in line with the study conducted by Heijne and his colleagues (2008).

Furthermore, it has been noted that patients' compliance decreases over time during the rehabilitation process (Beynnon, Johnson & Fleming, 2002), especially, after 6 months following surgery.

The compliance over the duration of the rehabilitation was measured by the use of a unique rehabilitation questionnaire (see appendix. 2). However to this researcher's knowledge there have been very few quantitative studies giving data that demonstrated compliance with specific programmes and identified at what point in time the transition began to happen. This depends on many variables such as concomitant injuries, pain, swelling, age, original fitness, motivation level and anticipation.

Only 15% of patients in the present study had rehabilitation before operation, but 93% had rehabilitation postoperatively and up to 3 months post operatively, 71% of these patients then continued for up to 6 months post surgery to have rehabilitation. After that the number of patients who continued with rehabilitation up to 12 months decreased to 11%.



**Figure 5-17:** Exercises achieved before surgery and up to 12 months post operation

The range of movement and stretch, strength exercise (basic) exercises were the most practiced in the period from surgery up to 3 months following surgery. In the period from 3 to 6 months after operation the range of movement and stretch, strength exercise (basic), advanced muscle strength exercise, fitness cardiovascular exercise were all practiced by 71% of patients. Balance exercises were the least practiced both before and after surgery (Figure, 5-17).

## 5.6 Discussion

To date, there have been few reports focusing on the patients' reports of their recovery of their function during the first 12 months, despite that this is the time for the greatest

function changes. This is also the time that involves some degree of imposed activity restrictions for the patient which could affect their reported scores. Smith, Howell & Hull, (2011) suggested that the recovery of activity level, function and subjective satisfaction all appeared to plateau within the first 6 months of surgery. Evidence of such a plateau and its timing could cause surgeons and therapists to re-evaluate their post-operative rehabilitation protocols.

The average age of subjects in the current study was  $28 \pm 7.4$  years, which is consistent with ages reported in many previous studies of international populations of ACLR subjects (Shaw et al., 2005; Risberg et al., 2007; Hartigan et al., 2010; Xergia, Pappas, Zampeli, Georgiou & Georgoulis, 2013).

The patients were non-athletes and did sports sometimes for recreational activity, so their motivation for returning to preoperative activity might be low. Some of them expressed that they were satisfied with their postoperative activity levels and would prefer not to return to their recreational sport activity because of risk for reinjures.

The relatively long time period from injury to surgery with mean time 35.6 months and range (4-132 months) could have affected the reported outcome, as this has been shown to correlate to an increased number of meniscal and cartilage lesions at reconstruction

(Granan, Bahr, Lie & Engebretsen, 2009). In Egypt it could be accepted that this length of time is because most patients undergo a rehabilitation programme before the decision to perform the ACL reconstruction is made. For those who fail the rehabilitation protocol there is the high cost of ACL surgery which is generally available in private clinics only.

According to International Knee Documentation Committee (IKDC) criteria, normal knee extension is considered within  $2^{\circ}$  of the opposite normal knee, and normal flexion is considered to be within  $5^{\circ}$  of the opposite normal knee (Shelbourne et al., 2012). The present study showed normal ROM of 88% of patients at the end of 12 months follow-up whose flexion was within  $5^{\circ}$  of the opposite normal knee. It also showed normal ROM of 97% patients who had normal knee extension that was within  $2^{\circ}$  of the opposite normal knee.

In the present study there was no improvements seen in flexion of ACLR knees at 3 months post surgery which was ( $120.5^{\circ}$ ), this is not in agreement with Grant and colleagues (2005) who conducted a single-blinded prospective study to assess the ROM up to 3 months post ACL surgery and noted a better return to knee ROM in the home-based rehabilitation group. Fischer, Tewes, Boyd, Smith & Quick, (1998) compared, in a prospective study, a home-based programme which included six visits to the physiotherapist to a clinic-based programme for the duration of 6 months. At the 6-month endpoint, no significant differences were seen in the range of motion. In contrast the

present study showed better improvements at 6 months following surgery; 129° compared with 122.5° before surgery.

Shaw, et al. (2005) showed better improvement than the present study stated. They included patients following ACL surgery who had non quadriceps exercise: Active knee flexion ROM 139.9° (8) 142.6° (7.6) at 3 and 6 months respectively, active knee extension ROM 7.7° (4.5) 4.9° (4.2) at 3 and 6 months respectively, passive knee extension relative to neutral 3.8° (3.1) 2.3° (3.2) at 3 and 6 months respectively. One reason for this high improvement could be the shortness of time from injury to surgery. Marcacci, Zaffagnini, Iacono, Neri & Petitto, (1995) stated that early ACL reconstruction may provide better results than delayed ACL reconstruction, with no greater problems related to loss of motion. However the present study showed improvements for more than 10° from 122.5°  $\pm$ 4 (113°-131°) before operation to 132.3°  $\pm$ 2.4 (123°-136°) at 12 months follow-up.

This present study's major finding is the low pre-operative KOOS and the greater improvement in non-elite patients' KOOS score compared to the elite patients with ACLR (Beynon et al., 2005) or healthy young athlete (Paradowski, Bergman, Sundén-Lundius, Lohmander et al., 2006; Cameron, Thompson, Peck, Owens, Marshall et al., 2013). In the present study, KOOS score improvements were observed to be generally higher than 10 points across most KOOS subscales with the greatest changes in KOOS

over time of up to 30 points as seen in the ADLs subscale. Roos et al. (2003) considered that a difference in KOOS score of 8–10 points represented a clinically relevant difference, this though was not seen in patients who had not undergone an ACL reconstruction, in this group significant change scores are unknown.

Our results are consistent with The UK National Ligament Registry Report (Gabr, O'Leary, Bollen, Spalding & Haddad, 2015), and showed a similar trend of improvements at 3 time intervals: pre-operative, 6 and 12 months following surgery of all KOOS subscales except the sports/Rec subscale, our results presented lower scores, again the main reason for that our study was limited to patients with low activity level.

The preoperative KOOS scores were generally lower in our non-elite/professional sporting background patients. The most obvious reason for this is their lower baseline levels of activity. Another reason for this may be that these patients have overall lower KOOS scores related to impaired knee function, secondary to articular changes associated with ACL instability. These concomitant injuries may be explained by the longer time span between injury and surgery observed in non-elite/professional sporting background patients leading to further deterioration of the patients' knee function. It is, likely that the articular changes associated with ACL instability begin either at the time of injury or with subsequent continuous re-injury of the unstable injured knee (Chhadia, Inacio, Maletis, Csintalan, Davis et al., 2011).

However, the most plausible explanation for the lower pre-operative KOOS in the our sample patients is that they are a unique patient group in that patients from this group who undergo surgery have a suboptimal knee function at the time of surgery and in addition probably have higher demands on their knee function compared with the elite patient groups who are offered surgery much earlier. Non-elite patients may have overall lower expectations on the outcome of surgery and therefore are more satisfied with the results of surgery reflected in higher KOOS postoperatively. In overall terms, the present study is in line with a previous study conducted by Beynnon, et al., (2005) but, included active patients evidenced by a Tegner scale of 5 or greater before surgery.

It was noted that in the KOOS subscale "Function, sports and recreational activities" which asks about "Kneeling", most patients scored the lowest score. Also in the "pain" subscale the question "Bending knee fully" which represents a sitting position as in the Muslim prayer mode also scored the lowest points. In this thesis the term culture is defined as 'the whole way of life of a distinct people' (Williams 1981). The way of life in any social group is formed by many different processes. In spite of the influence of culture, people in Egypt are still considered relatively conservative and are usually practicing Muslims, and so go to prayers 5 times a day with a minimum of 20 kneeling sessions, which require a considerable range of movement (see appendix. 1).

The present study demonstrated a significant improvement ( $P < 0.001$ ) in each KOOS domain score over the first 12 months. In addition, there continued to be significant improvements in mean scores between each assessment point for all five domains ( $P < 0.001$ ), discounting the presence of a plateau effect, that is, there was significant improvement in all 5 domains between 6 and 12 months.

### **5.6.1 Functional Assessment**

Hop tests and LSI showed an improvement from 6 to 12 months postoperatively, compared with the preoperative performance. In the present study the LSI was below the “safe range”, the value of 85% was found in 12% of the patients at 6 months and 51% at 12 months postoperatively for the one single hop for distance. These findings are similar to those of Mattacola, Perrin, Gansneder, Gieck, Saliba et al., (2002) and Wilk et al. (2003) although, Mattacola et al. found that 43% of their patients still had an abnormal LSI at a mean of 18 months postoperatively. In a recent study conducted by Rohman and co-workers (2015), they found that the LSI of single-leg hop at 4 months following ACL surgery was 78.2 (73.3-80.9) and at 6 months was 90.3 (87.5-93.0), and the LSI of Crossover was 84.5 (79.8-87.4) at 4 months and 92.3 (89.4-95.1) at 6 months. Mohammadi, Salavati, Akhbari, Mazaheri, Mir et al. (2013) who compared the functional outcomes of a bone-patellar tendonbone group (BPTB) to a semitendinosus and gracilis tendon group (STG) of soccer players (Tegner score 9) at the time of their return to the

sports, they stated that, the LSI of a single hop were 90.41 (7.9) (BPTB) and 90.57 (8.4) (STG) group. For the Crossover hop the LSI were 85.52 (STG) and 90.94 (STG) group.

Shaw et al. (2005) stated that at 6 months single hop (LSI%) of non quadriceps exercise group (mean and SD) 81.7 (12.7), and for a quadriceps exercise group was (mean and SD) 83.8 (10.1). Xergia et al. (2013) included an athletic patients who had a minimum activity of level 4 on the Tegner activity scale from 6 to 9 months following ACL reconstruction, single-leg hop of injured knees in (centimetres)  $120 \pm 0.32$  and un-injured knees  $146 \pm 0.30$ , crossover hop of injured knees  $312 \pm 0.86$  and un-injured knees  $372 \pm 0.88$ . A medium-term follow-up study of both ACL-deficient and ACL-reconstructed patients by Ageberg et al. (2008) revealed that only 44–56% of patients had normal limb symmetry indices 2 to 5 years after injury or surgery.

Hartigan et al. (2010) studied a preoperative perturbation and strength training (PERT group) and found that a single hop 83.7, 92.6 and 94.9 at 3, 6 and 12 months, respectively. Crossover hop 81.7, 93.1, and 96.3 at 3, 6 and 12 months, respectively. Compared to the group who received strength training only (STR group); Single hop 83.1, 92.9 and 98.0 at 3, 6 and 12 months, respectively. Crossover hop 85.6, 95.2 and 97.7 at 3, 6 and 12 months, respectively. Anyway these patients were regular participants in IKDC level I or II activities (Hefti, Müller, Jakob & Stäubli, 1993). This participants of this

study were low activity which might be the reason for this difference shown in their rehabilitation programme.

All limb symmetry indexes improved over time from baseline to 1 year after ACL reconstruction. Only the single hop symmetry index improved greater than the minimal detectable change (8.09%) as reported by Reid et al. (2007). The single and cross over hop indexes showed improvement between 3 and 12 months and was sensitive to change after reconstruction.

Noyes et al. (1991) described that an LSI of 85 % or more would allow an athlete to return to his pre-injury level. This was based on the findings that 93 % of a healthy population scored an LSI of 85 % or more (Noyes et al., 1991). Many researches prefer to use an LSI of 90 % or more as normal (Moisala, Järvelä, Kannus & Järvinen, 2007; Lautamies, Harilainen, Kettunen, Sandelin & Kujala, 2008; Ageberg, Roos, Silbernagel, Thomeé & Roos, 2009). On the contrary, Asik, Sen, Tuncay, Erdil, Avci et al. (2007) described an LSI of 80 % or more as normal.

### **Who were not able to hop and why**

Surgery is traumatic to the knee, resulting in significant physical impairments, activity limitations, and participation restrictions (Risberg et al., 1999). The largest extent of

quadriceps weakness and hop performance is evident in the first months after reconstruction (Andrade, Cohen, Picarro & Silva, 2002; de Jong, et al., 2007). Deficits in hop performance are present after ACL injury (EitzEn, Moksnes, Snyder-Mackler, & Risberg, 2010; Moksnes & Risberg, 2008) and can still be evident months after ACL reconstruction.

There were many patients who were refused to hop or were not allowed to hop before surgery or at 3 and 6 months after surgery. Of the 89 patients who underwent ACL reconstruction, 77 (87%), 60 (67%) and 89 (100%) performed hop testing, both single legged hop and cross over hop tests before surgery and 3 and 6 months respectively, and 67 (100%) participated in 1- year on-site testing. Reasons for patients not completing hop testing were poor dynamic stability, marked quadriceps weakness and missed appointments. But the fear of re-injury was the most common reason for giving up hops participation or for returning to a lower level of sports (Ardern, Webster, Taylor & Feller, 2011). ACL re-injury occurs in 6–13% of ACL-reconstructed knees (Salmon, Russell, Musgrove, Pinczewski & Refshauge, 2005), and 2–6% sustained a contralateral ACL injury (Salmon et al., 2005; Sward et al., 2010).

### **5.6.2 SEBT Performance**

The SEBT has been previously established as a reliable and sensitive measure of dynamic postural stability (Kinzey & Armstrong, 1998). Although the SEBT has been most often used as a measure of dynamic postural stability in participants with Chronic ankle instability (CAI) (Gribble, Hertel & Plisky, 2012; Sesma, Mattacola, Uhl, Nitz & McKeon, 2008), to date, only 1 paper has been published on SEBT performance and ACL reconstruction (Delahunt et al., 2013). Delahunt et al. (2013) included seventeen female athletes and also used only a three direction SEBT (Anterior, Posterior-medial and Posterior-lateral). The mean of anterior direction reached  $68.54 \pm 3.8$ , posterior-medial  $96.06 \pm 7.56$  and posterior-lateral  $89.53 \pm 7.42$ .

In the present study, ACL-R participants' reached distances only on the anterior, medial and lateral directions of the SEBT as recommended by Herrington et al. (2009). Although our study included patients with low activities results and did not show much improvements but the findings are still in agreement with previous findings that competitive athletes who have returned to full sport participation after ACL reconstruction still exhibit postural-control deficits (Moussa, et al., 2009; Webster & Gribble, 2010).

### **5.6.3 QASLS**

In the present study patients had a less (better) qualitative total score (QASLS) on their un-injured side than on their injured side, which is in line with the quantitative results of single-leg and crossover hop tests of the same patients. Our results disagree with Trulsson et al. (2010) study who used another qualitative evaluation of their ACL injured patients and found that patients had a better qualitative total score on their injured side than on their un-injured side. In accordance with previous findings, we suggest that the QASLS reflects and quantifies the quality of a movement with respect to dynamic joint stability (Williams, Chmielewski, Rudolph, Buchanan & Snyder-Mackler, 2001) and postural orientation (Shumway-Cook & Woollacott, 2007). Taken together, these facts underline the complexity of neuromuscular control, and despite the fact that the sensorimotor aspect of the maintenance of quality of movement and postural orientation is of great importance, it is reflected by the test instruments commonly used in the rehabilitation of ACL injured subjects.

### **5.6.4 Rehabilitation**

Many of the patients in this study received ACL rehabilitation from their own physiotherapists after surgery, very few of them agreed that they followed these guidelines or/attended other professionally supervised physiotherapy sessions elsewhere. Whether or not attending physiotherapy sessions had an influence on outcome was assessed by Feller, Webster, Taylor, Payne & Pizzari, (2004), this study could not

demonstrate a significant difference between patients who attended regularly and patients with not attending all the scheduled sessions. Feller et al. (2004) confirmed previous findings by Treacy, Barron, Brunet & Barrack, (1997) who compared non-compliant (1.7 visits over 6 months) to minimally compliant patients (12 visits over 6 months) and compliant patients (90 visits over 6 months). Whilst there was no significant difference between compliant and minimally compliant patients, non-compliance resulted in suboptimal outcome. An earlier study by De Carlo & Sell, (1997) came to similar conclusions.

One of the possible explanations of a successful return to pre-injury activity after isolated anterior cruciate ligament reconstruction may depend on the individual motivation of the operated patient. Also, it could be argued that unsupervised patients should exceed the given guidelines for rehabilitation because they have to take responsibility for their own progress.

## **5.7 Study Limitations**

A weakness of our study is that our participants group were male patients due to the culture consideration, of Egyptian population. Therefore, our findings cannot be generalized to all ACLR patients in Egypt. The sample included was mostly low activity level or patients from non-elite/professional sporting background and the results of this study should not be generalized to individuals involved in highly demanding activities.

This study had some incomplete data. Some patients did not meet the minimal criteria for allowing hop testing (weakness, effusion, recurrent instability) at each time period. A percentage of patients did not complete 12 months testing, reducing the participants available for analysis. This study was observational and did not include comparison groups. Knee laxity was not evaluated with an arthrometer (KT 1000, ..etc) due to its unavailability. This could be a limitation of our study. However, knee laxity does not correlate with functional results in most studies as discussed by Hurd, Axe & Snyder-Mackler, (2008) and Herrington & Fowler, (2006).

Another limitation is that kinetic data were not included in this study due to unavailability of data, and these could have provided important information about the forces and moments during the hop tests. However this lack of data was compensated by using a multiple validated outcome measurements of functional recovery including a qualitative assessment. A final limitation of this study is due to the different mechanisms used for rehabilitation which could have affected the outcome. It was not possible have control over the rehabilitation program because patients had come from different areas of the country including Alexandria. The questionnaire offered a range of photos which explained each exercise for the patients to follow post ACL surgery in order to present uniformed rehabilitation.

## 5.8 Conclusions

In the present study, there was a general trend for slight improvements in raw performance scores for the injured and uninjured limbs when assessed quantitatively and qualitatively over the 4 test occasions, particularly at 6 and 12 months. This trend may perhaps reflect a lack of confidence in performing functional tests, or a detraining effect of the injured limb secondary to reduced physical activity. The used QASLS measure ensure that the clinician can confidently attribute differences in performance scores to actual changes in limb function, rather than to inconsistencies or variability in measurement of ACL patients following surgery.

Limb-to-limb asymmetries are reduced, and normal limb symmetry is almost restored at 12 months following surgery. Performance-based values on the involved limb and self-reported outcomes are sensitive to change over time and clinically relevant improvements were reported.

Useful data on an early recovery of limb function are presented from the measurements of the scores at 3 and 6 months. This data will give information to the rehabilitation teams so they can review the changes the rehabilitation programs and highlight potential benefits of the programs for patients in Egypt. The strength of this present study lies in the prospective repeated measurement methodology and the use of the multi-validated

outcome measures. This pragmatic trial permitted the patient to choose both a physiotherapist and the amount and intensity of the rehabilitation. This means that this study reflects reality and is applicable for use in daily practice.

## *Chapter six*

Presented in this chapter is a comparison study between UK and Egyptian patients investigated at 6 to 12 months intervals following surgery as described in the previous chapter. This is the first study of its kind assessing and comparing functional outcome following ACL reconstructive surgery between these two countries.

### **Comparison of functional outcomes of the UK's and Egyptian men following anterior cruciate ligament reconstruction with hamstring tendon graft**

#### **6.1 Introduction**

According to the incidence figures quoted in the Swedish anterior cruciate ligament (ACL) registry which assumed that given a UK population around of 60 million, then approximately 60,000 ACL ruptures a year could be expected (Gabr et al., 2015). The Swedish registry expects about 50% to require/undergo reconstruction that will be 30,000 patients a year in the UK. A total of 2854 ACLR procedures were registered in The UK National Ligament Registry (NLR) between December 2012 and February 2015 (Gabr et al., 2015). The average age for patients undergoing ACLR was 30 years. This reflects the increase in ACLR surgery in an older age group. Around 19% of patients who underwent ACLR surgery were above the age of 40 years. The NLR is accepted as a reliable platform for researchers and clinicians treating ACL injuries (Gabr et al., 2015). This increase could be attributed to the increased sports participation in this age group with patients continuing high level athletic activities for longer than before. Men in their 20s were the predominant group who underwent ACLR surgery. The percentage of men and

women who underwent ACLR surgery was 75% and 25% respectively with a male to female ratio of 3:1. Sports injuries were the leading cause for anterior cruciate ligament (ACL) tears in 87% of patients, football (soccer) was the most common sport activity associated with an ACL injury (Gabr et al., 2015). Among men, the second most common activity associated with ACL injury was rugby followed by snow skiing. However, snow skiing was the most common activity associated with an ACL injury in women followed by netball and football (Gabr et al., 2015).

The mean time between ACL injury and reconstruction was 359 days (range 1 day to 1460 days) (Gabr et al., 2015). Although this might appear as a long period between injury and surgery, it is similar to what has been reported by the Scandinavian registries (Ahldén, Samuelsson, Sernert, Forssblad, Karlsson et al., 2012). The reason for such a long delay is unknown. Possible explanations include delayed diagnosis, long surgical waiting lists and lengthy rehabilitation program for patients who were initially managed non-operatively.

Hakimi, Anand, Sahu, Johnson & Turner, (2012) stated that the four strand hamstring tendon autograft was the most frequently used in the UK. 61% of surgeons used both hamstring and patellar tendon grafts, 29% used only hamstring tendon graft (Hakimi et al., 2012).

As yet, to these researchers' knowledge, no study has comprehensively investigated functional performance and quality of movement of lower extremities in a group of patients 6 to 9 months post-ACLR in the UK. Nor has there been a study that has compared the UK outcomes to other country ACL patients' outcomes following reconstruction. There is a need for research that performs qualitative evaluation that may explain single leg squat (SLS) performance asymmetries. Such information would be useful in identifying neuromuscular deficits and, subsequently, may lead to recommendations for incorporating exercises that directly address these deficits.

The ACL injury is associated with mechanical instability and defective neuromuscular function (Ageberg, 2002; Risberg, Lewek & Snyder-Mackler, 2004). In the long term, there is an increased risk of further injury, increased joint loading (Thorstensson, Henriksson, von Porat, Sjö Dahl & Roos, 2007) and osteoarthritis (OA) (Lohmander, Englund, Dahl & Roos, 2007). Clinically, patients with ACL injury demonstrate altered quality movements, but to the best of these researchers' knowledge no one has applied a clinically useful method to systematically study quality of movement during SLS tasks in these patients.

### **6.1.1 Aim**

The aim of this study was to determine subjective and objective functional outcomes to assess asymmetry of hop test performance and quality of movement during specific tasks following ACLR with a hamstring tendon graft 6 to 9 months post surgery in the UK, then to compare these results with an Egyptian group of patients at 6 and 12 months' time intervals post-surgery. The hypothesis was that hop performance asymmetries would exist in the involved lower extremity of the ACLR patients. A secondary hypothesis was that UK results will differ from Egyptian group due to activity level and cultural considerations.

## **6.2 Methods**

### **6.2.1 Participants**

Patient records at two private hospitals in south of England were retrospectively reviewed to identify a population of patients with a unilateral, primary, isolated ACL reconstruction. The database was searched for clinical records on 11 August 2014 for all male patients aged between 18 and 50 years and had ACL surgery using hamstring tendon (HT) grafts, from 6 up to 12 months ago. Clinical records were excluded from further consideration if the patient did not undergo surgical reconstruction, if the patient had had a bilateral injury, if only preoperative data existed, or if demographic data for injury and surgery history were incomplete. From a pool of 61 potential subjects, demographic data (age, sex, surgical procedure, and past surgeries) were extracted for review. The Physiotherapy department of these two private hospitals cooperated with this study by

sending information sheets and consent forms for patient records to be released for retrospective analysis of outcomes. The rehabilitation program or measure compliance was not controlled in an effort to increase the external validity of our findings (Xergia et al., 2013).

Later the patients in this study were matched to other 24 Egyptian patients from the previous study. The results of these studies were compared to identify any relation or differences between them regarding the self reported questionnaire and functional tests at different time intervals.

### **6.2.2 Matching**

The Egyptian participants in this study were chosen from the previous study. For comparison, the Egyptian sample of 24 ACLR patients matched for age, gender, surgery, and time from surgery, were selected from the patients collected for a prospective study (previous chapter) that was conducted in Egypt. The UK's patients followed the same assessment procedure as the Egyptian patients including KOOS, single leg hop and QASLS. These methods have been detailed in the previous study and have demonstrated high reliability in obtaining variables of interest in individuals following ACLR.

### **6.2.3 Procedures**

Each patient was evaluated using the KOOS and Tegner activity level scale. Functional performance was also evaluated using the one-leg hop test and QASLS, using the same method as outlined in the previous prospective study in this thesis. The physiotherapists who collected these data were offered the same training that was offered in the reliability study of QASLS and trained on how to record SLS videos, also on how a single hop test should achieve as well. The QASLS was scored by the researcher and all data were analysed by the researcher as well.

### **6.2.4 Time frames**

The 24 UK male patients were tested only once during a period from September 2014 to March 2015, which was in the period from 6 to 12 months following their ACL surgery, then it was necessary to compare these results with previous data collected for an Egyptian group of patients who tested at 6 and 12 months' time intervals post-surgery, from a prospective study (previous chapter) that was conducted in Egypt in the period between September 2012 and July 2014.

### **6.2.5 Ethics**

The Human Ethics Committee at the College of Health & Social Care of University of Salford approved this study (ref: HSCR14/39) along with the management board of the two private hospitals involved. All the patients gave their informed consent.

### **6.2.6 Statistical analysis**

Measurements for each patient were recorded. Comparisons were made between the involved and uninvolved leg for single hop and QASLS. The two independent samples t-test was used to compare the means of a normally distributed interval dependent variable for two independent groups. To find if there were any significant differences in outcomes during time periods, test occasions were performed at 6 and 12 months post-surgery and 6 to 9 months for the UK study, for all outcomes including the LSI. The level of significance was set at  $p < .05$ . All data collected were analysed with the SPSS-20 program (SPSS Inc, Chicago, Ill).

## **6.3 Results**

Twenty-four male patients who underwent ACL reconstruction procedure 6 to 9 (mean 6.9) months ago were under surveillance in this study. Average patient age was 30.2 years (range: 22-40 years). All these patients had a minimum Tegner activity level of 4 or above at the evaluation time and estimated their Tegner activity level of 7 or above before the injury.

### **6.3.1 Self-Reported Questionnaire (KOOS)**

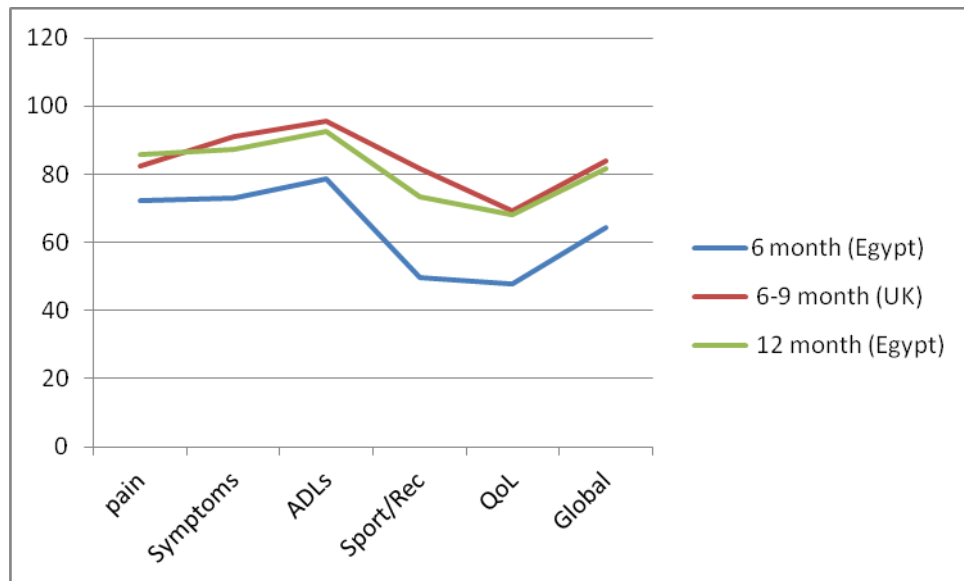
The UK patients recorded a significant improvement in their KOOS scores from 6 to 9 months post surgery. The temporal response of the scores of 4 out of the 5 subscales; pain

82.3, symptoms 90.9, ADLs 95.7 and sports and recreation participation 81.7, these scores indicating a return to normal to pre-injury status. In contrast, the knee-related quality of life scores plateaued at values below 69.1, indicating that the index injury, surgery, and rehabilitation had a long-term effect on how patients perceived their quality of life. The global score plateaued at values below 84.

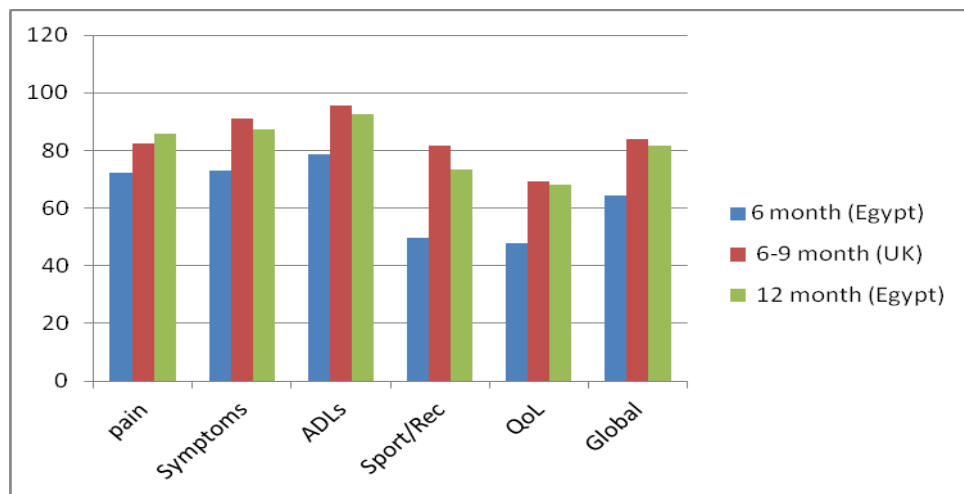
In contrast the Egyptian patients average age 29.9 years (range: 21-42 years) recorded a significant improvement in their KOOS scores between the 6 and 12 months follow-up interval. The temporal response of the scores of 3 out of the 5 subscales (pain, symptoms, and activity of daily living), were nearly identical: these scores approached a value of 85 or above by the 12 months follow-up indicating a return to normal, or pre-injury status. In contrast, the sports and recreation participation and the knee-related quality of life scores plateaued at values below 74 and 69, respectively, indicating that the index injury, surgery, and rehabilitation had a long-term effect on how patients perceived their quality of life. The global score plateaued at values below 82. Outcomes for each KOOS subscales are summarized in table (6-1) and presented in figure (6-1).

**Table 6-1:** Mean KOOS scores with standard deviation (SD) and range data for each domain recorded 6-9 months post for the UK patients and 6 and 12 months post of Egyptian patients.

Domain	6 months Egypt			6- 9 months UK			12 months Egypt		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Pain	72.3	15.4	(42-100)	82.3	11.1	(50-100)	85.8	6.7	(72-100)
Symptoms	73.1	10.7	(54-93)	90.9	8.6	(71-100)	87.2	5.3	(79-96)
ADLs	78.7	11.9	(56-100)	95.7	5.9	(82-100)	92.6	5.6	(84-100)
Sports/Rec	49.6	17.3	(20-85)	81.7	13.9	(55-100)	73.5	12.0	(50-90)
QoL	47.8	16.5	(19-75)	69.1	16.9	(31-100)	68.2	11.2	(44-88)
Global	64.3	13.9	(39-89)	83.9	9.3	(59-100)	81.5	7.1	(69-94)



**Figure 6-1:** Recovery profile of mean KOOS scores for each of the five domains following ACLR measured pre-operation and at 6 and 12 months (Egypt) and 6-9 months (UK) post-operation



**Figure 6-2:** Comparison of KOOS scores for each of the five domains following ACLR measured pre-operation and at 6 and 12 months (Egypt) and 6-9 months (UK) post-operation

**Table 6-2:** Two independent samples t-test was used to compare the means of KOOS between UK and Egyptian patients

No	Domain	Timing	P value	95% Confidence Interval of the Difference	
				Lower	Upper
1	Pain	UK 6-9 month vs Egypt 6 month	.013	-10.000	3.870
		UK 6-9 month vs Egypt 12 month	.041	5.708	2.697
2	Symptoms	UK 6-9 month vs Egypt 6 month	.001	-17.750	2.792
		UK 6-9 month vs Egypt 12 month	.578	1.125	2.003
3	ADLs	UK 6-9 month vs Egypt 6 month	.001	-22.875	3.648
		UK 6-9 month vs Egypt 12 month	.001	6.458	1.877
4	Sports/Rec	UK 6-9 month vs Egypt 6 month	.001	-32.083	4.540
		UK 6-9 month vs Egypt 12 month	.036	8.125	3.760
5	QoL	UK 6-9 month vs Egypt 6 month	.001	-30.939	-11.560
		UK 6-9 month vs Egypt 12 month	.833	.875	4.134
6	Global	UK 6-9 month vs Egypt 6 month	.001	-27.649	-13.883
		UK 6-9 month vs Egypt 12 month	.367	2.183	2.392

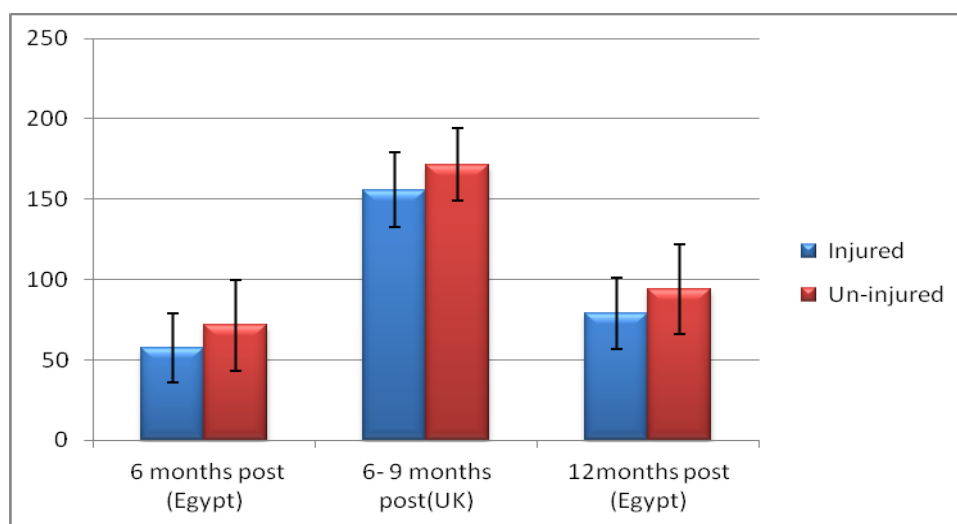
### 6.3.2 Single hop for distance

The UK patients scored high values at 6 to 9 months compared to the Egyptian patients who scored much lower values. The mean scores of the UK patients were  $155.7 \pm 23.2$

and  $171.5 \pm 22.5$  for injured and non-injured leg, respectively. In contrast the mean distance (centimetres) of Egyptian patients with injured knees were:  $57.4 \pm 21.4$  and  $79.0 \pm 22.4$  at 6 and 12 months respectively and their mean distances of un-injured knees were:  $71.5 \pm 28.3$  and  $93.9 \pm 28.1$  at 6 and 12 months following surgery respectively. The mean scores of the Egyptian patients were significantly improved over time intervals ( $P < .001$ ) but remained much lower than the UK values even 12 months post operation.

**Table 6-3:** Single hop for distance

Injured Knee				Uninjured Knee			
Timing	Distance	SD	Range	Timing	Distance	SD	Range
6 months post (Egypt)	57.4	21.4	(34-129)	6 months post (Egypt)	71.5	28.3	(44-163)
6- 9 months post(UK)	155.7	23.2	(109-199)	6- 9 months post(UK)	171.5	22.5	(128-207)
12months post (Egypt)	79.0	22.4	(46-134)	12months post (Egypt)	93.9	28.1	(56-166)



**Figure 6-3:** Comparison of injured and un-injured limb performance during the single-leg hop following ACLR measured at 6 and 12 months (Egypt) and 6 to 9 month (UK) post-operation

### 6.3.3 Limb Symmetry Indices (LSI)

To compare the outcome of functional tests, the LSI of the single hop tests were calculated. The LSI of the UK patients was  $90.42 \pm 6.4$  at 6 to 9 months postoperatively. In contrast the LSI of the Egyptian patients were  $80.79 \pm 7.2$  and  $84.62 \pm 4.3$  at 6 and 12 months respectively (Table. 6-5).

**Table 6-4:** Two independent samples t-test was used to compare the means of single leg hop for distance and LSI between UK and Egyptian patients

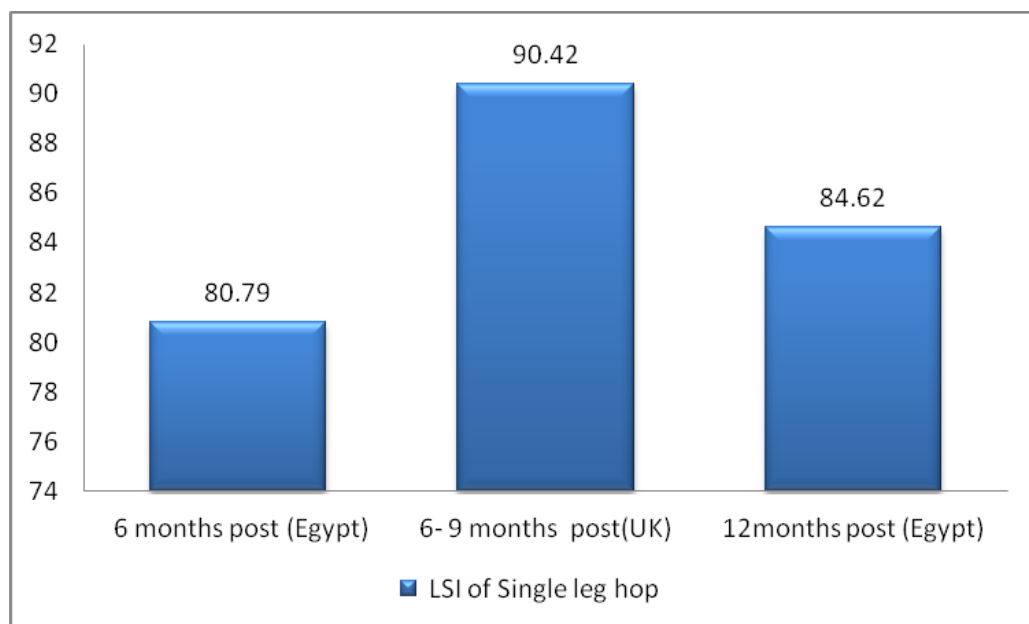
No.	Test	Timing	P value	95% Confidence Interval of the Difference	
				Lower	Upper
1	Single hop test - injured leg	UK 6-9 month vs Egypt 6 month	.001	-98.291	6.450
		UK 6-9 month vs Egypt 12 month	.001	76.625	6.583
2	Single hop test –un-injured leg	UK 6-9 month vs Egypt 6 month	.001	-99.958	7.384
		UK 6-9 month vs Egypt 12 month	.001	77.583	7.349
3	LSI	UK 6-9 month vs Egypt 6 month	.001	-9.625	1.972
		UK 6-9 month vs Egypt 12 month	.001	5.791	1.575

Using a score greater than or equal to 85% as a criterion for normative limb symmetry (Noyes et al., 1991), normative scores were recorded as 90.4 in the UK patients. Conversely, the Egyptian patients scored 80.8% at 6 months post operation, but slightly

improved at 12 months post-surgery almost reaching 85%. In the UK sample only 3 patients (13%) their LSI did not reach the 85%. In contrast only 7 patients (29%) and 12 (50%) reached the 85% and scored normative values at 6 and 12 months post surgery, respectively.

**Table 6-5:** Limb Symmetry Index of Single hop for distance

Limb Symmetry Index of Single hop for distance			
Timing	Mean of distance	SD	Range
6 months post (Egypt)	80.79	7.229	(69-96)
6- 9 months post(UK)	90.42	6.413	(76-104)
12months post (Egypt)	84.62	4.292	(76-95)



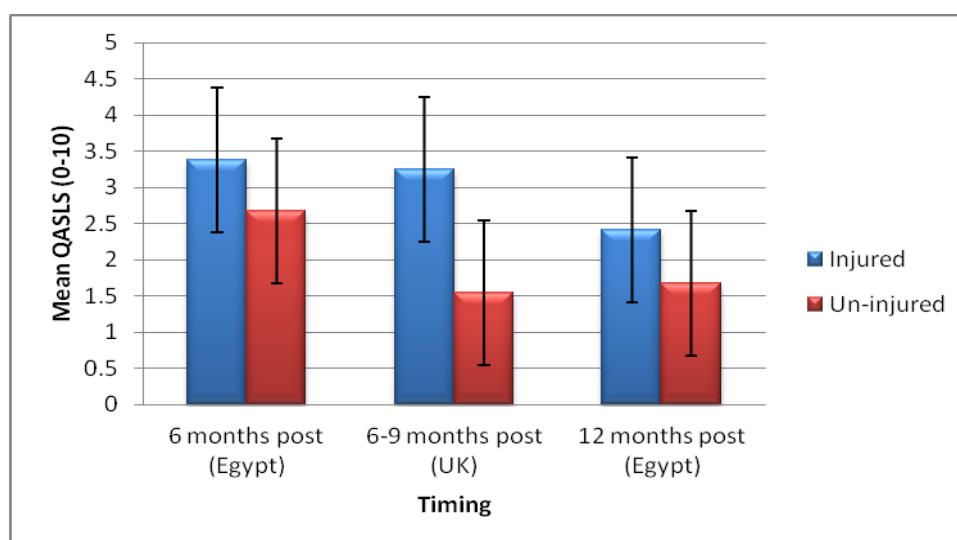
**Figure 6-4:** Comparison of LSI of single-leg hop for distance measured at 6 and 12 months (Egypt) and 6 to 9 month (UK) post-operation.

### 6.3.4 QASLS

The UK patients scored  $3.25 \pm 1.73$  for the injured knee and  $1.54 \pm .98$  for the un-injured knee at 6 to 9 months post operation. On the contrary, the Egyptian patients scored  $3.38 \pm 1.84$  and  $2.42 \pm 1.47$  for injury leg and score  $2.67 \pm 1.55$  and  $1.67 \pm 1.20$  for un-injured leg at 6 and 12 months post operation, respectively.

**Table 6-6:** Comparison of the mean values and standard deviation of QASLS measured at 6 and 12 months (Egypt) and 6-9 months (UK) post-operation

QASLS				
Time	Injured	SD	Un-injured	SD
6 months post (Egypt)	3.38	1.84	2.67	1.55
6- 9 months post (UK)	3.25	1.73	1.54	.98
12months post (Egypt)	2.42	1.47	1.67	1.20



**Figure 6-5:** Comparison of injured and un-injured limb performance during the QASLS following ACLR measured at 6 and 12 months (Egypt) and 6 to 9 month (UK) post-operation (**N.B.** High score means less improvements).

**Table 6-7:** Two independent samples t-test was used to compare the means of QASLS between UK and Egyptian patients

No	QASLS	Timing	P value	95% Confidence Interval of the Difference	
				Lower	Upper
1	QASLS of Injured leg	UK 6-9 month vs Egypt 6 month	.362	-.458	.498
		UK 6-9 month vs Egypt 12 month	.003	1.416	.444
2	QASLS of un-injured leg	UK 6-9 month vs Egypt 6 month	.001	1.375	.376
		UK 6-9 month vs Egypt 12 month	.247	-.375	.319

## 6.4 Discussion

In this retrospective study, the UK patients were evaluated 6 to 9 months post surgery, then compared to similar Egyptian patients at 6 and 12 months time intervals following surgery. The comparison between the UK patients 6 to 9 months post ACLR and Egyptian group tested at 6 and 12 months showed better results for the UK group in all domains of KOOS, except the comparison between UK patients and Egyptian patients tested at 12 months post ACLR in Symptoms, QoL and Global domains ( $p = .578, .833$  &  $.367$ , respectively). For the single leg hop test and LSI the UK patients showed much better results in all comparison ( $p < .001$ ). In contrast the QASLS evaluation test, showed better results for the Egyptian patients than the UK patients at 6 and 12 months post operation comparisons ( $p = .362$  &  $.247$ , respectively). Recent research (Paterno et al.,

2010; Ardern et al., 2011) has suggested that 9 months is not an adequate time for maximizing functional recovery after ACLR, which may explain the low scores in this sample and raises the possibility that further improvements may become evident later than 1 year. The UK patients 6 to 9 months post operation showed good improvements and reached normality at KOOS scores and appropriate values in LSI during the single leg hop for distance ( $p < .001$ ).

The KOOS is used to evaluate outcomes after ACLR. KOOS data from more than 60,000 patients are available from ACL registries in Sweden, Norway, Denmark, the United States, the United Kingdom, and Australia. Data from these registries show postoperative mean KOOS values corresponding approximately to mild pain (mean range, 84-89), moderate to mild symptoms (mean range, 60-86), no problems with activities of daily living (ADL) (mean range, 90-97), moderate to mild problems with sport and recreation (Sport/Rec) (mean range, 63-78), and moderate to mild reductions in knee-related QoL (mean range, 60-69) at 1 to 2 years after reconstructive surgery (Dunn & Spindler, 2010; Ingelsrud, Granan, Terwee, Engebretsen & Roos, 2015). The UK and Egypt results present a similar trend with these global data.

The acceptable threshold of the LSI for hop test performance for safely progressing to more intense sports-specific training after ACLR is 85% (Noyes, et al., 1991). In the present study only 29% and 12 (50%) of Egyptian patients reached the 85% and scored

normative values at 6 and 12 months post surgery, respectively. In a recent study (Ardern et al., 2011) it was shown that only one third (33%) of ACLR patients return to pre-injury activity levels 1 year after surgery. This contrasts with the LSI which was reached (85%) 6 to 9 months post surgery in 21 (87%) of the UK patients.

An interesting finding of this study was that the QASLS scores were nearly equivalent in Egyptian and UK patients. The UK patients scored  $3.25 \pm 1.73$  for the injured knee at 6 to 9 months post operation and the Egyptian patients scored  $3.38 \pm 1.84$  at 6 months and  $2.42 \pm 1.47$  at 12 months for the injured leg. This may indicate a learning effect, because Egyptian patients had practised this task several times before achieving this improved score. The differences in rehabilitation may have given differences in some of the outcomes such as hop, whilst some outcomes remained the same because of assessing the lower level functions eg. QASLS and KOOS.

Some caution is needed in interpreting the results of this study. It should be noted that the cohort of patients studied is not representative of the general Egyptian population of ACLR patients. Because the UK subgroup was selected first, the Egyptian patients were matched to this subgroup. However, the epidemiology of ACL in Egypt, the clinical characteristics of the Egyptian hospital-based population, QoL and culture differ considerably from those in the UK.

Finally, although the cultural difference between Egypt and the UK was one of the primary reasons for this study, the educational differences may have also limited the comparability of the results. Many Egyptian patients were illiterate, therefore, questionnaires were administered in a face-to-face interview with an investigator, whereas the UK questionnaires were in general self-completed. The presence of an investigator may have affected the patients' reporting of pain or physical functioning. Egyptian patients reported anterior knee pain and most of them complained of discomfort that occasionally caused difficulty in kneeling. It is well known that difficulty in kneeling may significantly affect some occupations, and religious and/or recreational activities (Brosseau, Balmer, Tousignant, O'Sullivan, Goudreault et al., 2001). An alternative graft choice, might reduce the number of patients with these problems (Eriksson, Anderberg, Hamberg, Olerud & Wredmark, 2001), although such a procedure is usually more expensive and the graft fixation is less secure.

## **6.5 Limitations of the study**

There are several limitations of this study that should be acknowledged. First, only men with ACLR using hamstring tendon grafts were studied. Therefore, these findings cannot be generalized to all ACLR patients. Another limitation is that kinetic data were not included in this study, and these could have provided important information about the forces and moments during the hop tests. In common with much survey research, this study achieved a relatively low response rate to all letter invitations sent. In the UK a

relatively small sample cohort of 24 young, athletic individuals was retrospectively enrolled in this study, which could potentially limit the generalizability of the results to other populations, but it could increase the confidence in the applicability of these results to the young, athletic population. A power calculation was not performed to determine the adequate sample size and not all of the enrolled cases were eligible for analysis, resulting in potential reporting bias. Finally, the rehabilitation protocol was not controlled because an assessment of ACLR patients receiving typical care was required. Also, measuring tools such as KT-1000 which may provide more accurate physical evaluation results was not available for the present study.

## **6.6-Conclusion**

Reconstruction of the ACL with the hamstring tendon grafts provides a good outcome based on physical and functional evaluation 6 to 9 months following surgery. UK patients showed better results than Egyptian patients at similar conditions in KOOS score or single hop test, But this could be due to the difference in the activity level between them, skilled surgeons and rehabilitation compliance. The QASLS scores were nearly equivalent in Egyptian and UK patients. This may due to a learning effect or because of assessing the functions of patients with lower activity level. The frequency of postoperative anterior knee pain should be under consideration in patients who are required to kneel for religious or occupational activities, and alternative grafts may be considered in these cases.

## *Chapter seven*

### **General Discussion, Limitation and Conclusion**

This thesis commenced with a systematic scoping review of the existing literature linked to ACL injury, the first focus of this review of RCTs and cohort studies published in the last decade, was to identify the gaps from previous studies (Almangoush et al., 2014a). This review tried to identify the functional performance tests and self-reported outcomes using questionnaires to evaluate the recovery for patients following ACL reconstruction. The result of this review, found most of studies were limited to Scandinavian countries, USA and Australia all of which follow similar health service systems and have similar cultures and life style. Therefore studies conducted out of these areas are urgently needed. All participants included in these studies were athletic and competitive sport players with a high level of activity or unspecified activity levels, limited information is therefore available on non-athletic or non-elite sports populations. No study evaluated the functional outcomes pre-operation and 3 and 6 months following the surgery other than via questionnaires. The effectiveness of rehabilitation appears to vary across the rehabilitative period and might be maximal during the early postoperative period. Therefore, this thesis aimed to investigate whether postoperative rehabilitation significantly altered the postoperative outcome for ACL reconstruction in early stages at 3, 6 and up to 12 months, rather than just a single time point.

The functional performance tests tested the main outcome parameters of the included studies by using the one-leg hop for distance, a combination of various hops and the limb symmetry index (LSI). Furthermore, the literature showed that no observation or videotaping were used to assess the quality of movement during any test or any functional performance and control stability of ACL patients following surgery except for one study (Trulsson et al., 2010). A more extensive battery of tests is suggested to measure both the quantitative and qualitative aspects of functional performance after the ACL reconstruction, following this review of the literature. Clinically applicable and simple qualitative tools are warranted to achieve this goal. The KOOS score was the most used in the current studies that evaluate the ACL reconstruction. Therefore, a reliable and valid Arabic version of KOOS to suit the Egyptian population was needed, and participants with low level of activity are also needed.

Reconstruction surgery is a very common management option following rupture of an anterior cruciate ligament (ACL). There is currently no study assessing ACL patients following surgery in Egypt (or other Arabic countries) or in people who are not from competitive sports background. The aims of this thesis were to evaluate the quantity and quality of functional performance, postural stability and rehabilitative outcomes of non-high competitive sports patients before and 3, 6 and 12 months following ACL reconstruction in Egypt.

To accomplish these research aims, five separate studies were performed:

The first study is a systematic scoping review of the ACL reconstructed patients outcomes and the measures used to evaluate them following the surgery including functional performance testing and patient reported questionnaires used within the last decade. As a result of this systematic review, these next studies were proposed and planed to fill the gap in the literature.

The second study in this thesis was the first to demonstrate the reliability and validity of Arabic versions of KOOS that can be used to conduct research and measure outcomes in people with knee injuries in Arabic countries. This reliability study was a fundamental step before beginning the prospective study to include Egyptian patients. The KOOS was decided upon because other scores such as IKDC, the Cincinnati knee scoring scale and the first version of the Lysholm had all been judged to have been biased when applied to those with an ACL injury (Rodriguez-Merchan, 2012). But Lysholm-Tegner' system is simpler only evaluating symptoms and activities. The KOOS has shown good validity and demonstrated that it is responsive to ACL reconstruction and rehabilitation, it shows that it is a reliable instrument for patients undergoing ACL surgery and rehabilitation (Roos et al., 1998; Almangoush et al., 2013).

At present no Arabic speaking countries have access to a valid and tested version of KOOS. Therefore, these researchers aimed to cross-culturally adapt the English-American

version of the KOOS questionnaire into Arabic. The psychometric properties of the translated version were evaluated and found to be satisfactory. The rigorous testing for reliability and validity performed in this study demonstrated that the questionnaire could provide reliable results for other research studies for Egyptian patients with a variety of knee injuries.

The third study was an important addition to the current research and will enable other researchers and clinicians to use the qualitative scoring system of limb alignment during single leg squat test with confidence in order to identify movement patterns to determine lower extremity alignment. The single-leg squat (SLS) test is a cost-effective and simple movement carried out with a single camera in any setting, this procedure can visibly identify a valgus lower extremity alignment on landing, which is considered to be a potential risk factor for a possible noncontact ACL injury (Paterno et al., 2010). The SLS test has been described in a number of studies as a useful clinical measure to identify hip muscle function and dynamic knee control (Risberg et al., 1999). The objective of this study was to assess the inter and intraobserver reliability of the new assessment tool to determine if it shows similar reliability to other qualitative assessment methods of SLS tests. This reliability study was done before the main study started and showed this novel tool to be reliable.

Almangoush (2014a) claims that there is only one study has evaluated ACL patients qualitatively. This study by Trulsson et al (2010) based its findings on clinical

observations on 9 test movements. This procedure takes about 35 minutes on each test occasion, which could be considered too long for patients. Also, this assessment needs several tools such as: trampoline, treadmill and supported stands, which are not available everywhere for the clinical use or the researcher. The concurrent validity of TSP is not yet validated. To meet the demands of a test method evaluating qualitative aspects of function for both athletes and non-athletes before, during and after rehabilitation, the test-movements in the QASLS do not require running or jumping. Instead, postural position, a fundamental condition for any movement, is evaluated. This study was an important addition to the current research and will enable other researchers to easily identify undesirable movement patterns which determine lower extremity alignment in the coronal plane.

This thesis main emphasis was based on another observational study that had been performed on ACL reconstruction in Egypt. This is the first study which has investigated the QASLS and dynamic balance tested by modified SEBT used in the functional assessment of ACLR patients. This allowed indications of dynamic balance and quality of movements of functional performance tests to be attained; this is a factor not yet extensively studied for ACLR patients, although the performance of which has been regarded as significant in the outcomes from surgery.

This study has found improvements in the self reported questionnaire and all functional performance tests of the affected and contra lateral leg. The values found on assessment

did not reach the normality (typical values for asymptomatic individuals) even at 12 months post operation.

There have been few reports that have assessed the patients' reports on their opinions of their leg function during the set period which is: pre-op, 3, 6 and 12 months post op. which is the time of the most functional changes. This is also the time that involves some degree of imposed activity restrictions for the patient which could affect their reported scores. This present study's major finding is the low pre-operative KOOS and the greater improvement post operation in non-elite patients' KOOS score compared to the elite patients with ACLR (Beynnon et al., 2005) or healthy young athletes' score (Paradowski et al., 2006; Cameron et al., 2013). In this study the KOOS scores were higher by 10 points in most of the KOOS subscales, showing the greatest changes, over a longer period, in KOOS which was up to 30 points as seen in the ADL subscale. These results conformed to the UK National Ligament Registry Report (Gabr et al., 2015), demonstrating the similar improvement in the same time intervals after surgery, in all KOOS subscales except the Sports/Rec subscale. This study results presented lower scores, again the main reason for that is this study was limited to patients with low activity levels.

In the KOOS subscale "Function, sports and recreational activities" which includes 'Kneeling' it was shown that Egyptian patients presented the lowest score. This was also

the case in the “pain” subscale which involves a question on "Bending knee fully". The majority of the Egyptian population are relatively conservative and are practising Muslims, therefore attend prayers 5 times daily involving a minimum of 20 kneeling sessions which require a large range of movements. (see appendix 1).

Egyptian patients reported anterior knee pain and most of them complained of discomfort that occasionally caused difficulty in kneeling. It is well known that difficulty in kneeling may significantly affect some occupations and religious and/or recreational activities (Brosseau et al., 2001). An alternative graft choice might reduce the number of patients with these problems (Eriksson et al., 2001) although such a procedure is usually more expensive and the graft fixation is less secure.

The prospective study showed an improvement of the hop tests and LSI from 6 to 12 months postoperatively, compared with the preoperative performance. This present study demonstrated outcomes for the single hop distance which were below the “safe range” of LSI, and value of 85% was shown in less than 25% of patients at the 6 month check and less than 2/3rds at 12 months post-op check. Ageberg et al (2008) revealed that in a medium-term study of both ACL-deficient and ACL-reconstructed patients, two to five years after surgery, only 44-56% of patients had normal limb symmetry.

This study's results showed that at 3 months post-operation there was no improvement. Most of the studies in the literature evaluate the hop tests before surgery and at 1 or 2 years post surgery (Laxdal et al., 2007). There were very few studies that evaluated functional performance at 3 or 6 months post surgery. Risberg et al. (2007) showed worse values at 6 months post operation than the preoperative assessment for strength training and neuromuscular training groups when assessed by the one leg hop test. Hohmann et al. (2011) showed low LSI scores at 3, 6 and 9 months post operation (56.3, 73.9 & 75.9) respectively, before reaching some improvement to approximately 82% at 12 months postoperatively, although the preoperative LSI score was 75.8% for the same patients. Jong et al. (2007) evaluated the LSI of crossover hop for distance preoperatively, and at 6, 9 and 12 months postoperatively the mean values were: 87, 83, 89 and 93 and this also showed a decreased LSI value at 6 months.

Unfortunately many patients refused to perform the hop test, or were not permitted to perform it pre operatively or at the 3 or 6 months check post surgery. The reasons given for not performing the hop test were: poor dynamic stability, marked quadriceps weakness and sometimes appointments having been missed. However the fear of re-injury was cited as the most common reason for not performing the hop test or returning to less involvement in sports activities (Ardern et al., 2011).

In this prospective study many patients received their ACL rehabilitation from their preferred physiotherapists. However few patients were prepared to attend professionally supervised physiotherapy sessions or to follow prescribed guidelines prepared by these physiotherapists. One explanation for the successful return to full pre-operation activity after an isolated ACL reconstruction could depend on the motivation of the individual patient (Hohmann, Tetsworth & Bryant, 2011). Or it might be argued that patients who are unsupervised are more prepared to take control of their own rehabilitation therefore exercise more (Hohmann, et al., 2011). Whatever the cause, non-compliance or lack of physiotherapy does not appear to affect the better outcomes, which then begs the question as to whether it is necessary to re-evaluate the current physiotherapy protocols to establish which interventions produce the best results (Treacy, Barron, Brunet & Barrack, 1997; Feller, Webster, Taylor, Payne & Pizzari, 2004).

This thesis offered a comparison study between two different countries of patients with reconstructed ACLs. Twenty four patients from the UK were evaluated 6 to 9 months post surgery, then matched to similar patients from Egypt at 6 and 12 months time intervals following surgery. The Egyptian ACLR group had KOOS and hop performance scores below those reported for ACLR UK patients 6-9 months post surgery. The UK patients 6 to 9 months post operation showed good improvements and reached normality at KOOS scores and appropriate values in LSI during the single leg hop for distance.

The retrospective audit study made an interesting finding in that the QALS scores were almost equivalent in both the UK and Egyptian patients. This could be attributed to the fact that the Egyptian patients had practised the task many times before recording this improved score. Different rehabilitation programmes could have created differences in outcomes of the hop; however some outcomes remained the same because the lower level of achievement for functions such as OASLS and KOOS was assessed.

The results of this study should be interpreted with caution, one reason being that the cohort of Egyptian patients are not representative of the general Egyptian population of ACLR patients. The Egyptian patients had to be matched to the UK group which was selected first. Moreover the epidemiology of ACL in Egypt and clinical characteristics of the Egyptian patients, their QoL and culture differ considerably from those in the UK.

Finally, although the cultural difference between Egypt and the UK was one of the primary reasons for this study, the educational differences may have also limited the comparability of the results. Because many Egyptian patients were illiterate, questionnaires were administered in a face-to-face interview with an investigator, whereas the UK questionnaires were generally self-completed. The presence of an investigator may have affected the patients' reporting of pain or physical functioning.

## **7.1 Limitations of the work undertaken**

This thesis has several limitations that should be acknowledged. For instance in chapter two, the systematic review utilised very specific inclusion/exclusion criteria for selection of functional performance tests. Therefore, it is possible some functional performance tests were not identified.

The main study of this thesis was a prospective and observational study and did not include comparison groups. Knee laxity was not evaluated with an arthrometer (KT 1000) due to its unavailability. However, knee laxity does not correlate with functional results in most studies as discussed by Hurd et al. (2008) and Herrington & Fowler, (2006).

A weakness of this prospective study is that the participant group were male patients due only to the cultural considerations of the Egyptian population. Therefore, these findings cannot be generalized to all ACLR patients in Egypt. There would appear to be no gender differences in outcome after ACL reconstruction with hamstring tendon autograft (Salmon et al., 2006), but this cannot be stated for Egyptian women. Patients who had hamstring tendon grafts only were included in this project. A prospective comparison study of bone-patellar tendon-bone and hamstring tendon grafts for ACLR in male patients displayed no significant differences between the two study groups in terms of functional outcome and knee laxity at the 2-year follow-up (Laxdal et al., 2007).

Another limitation is that kinetic data were not included in this study due to lack of availability of any facility to collect this kind of data for example a force plates and 3D cameras, and these could have provided important information about the forces and

moments during the hop tests. However this lack of data was compensated by using a multiple validated outcome measurements of functional recovery including qualitative assessments. A final limitation of the main study of this thesis is due to the different modes used for rehabilitation which could have affected the outcomes. It was not possible have control over the rehabilitation program because patients had come from different areas of Egypt. The questionnaire offered a range of photos which explained each exercise for the patients to follow post ACL surgery in order to present uniformed rehabilitation, but there is no way to confirm if these exercises were performed.

## **7.2 The remaining questions and ideas for future research**

After the successful completion of his PhD the researcher is planning to continue his work in research, expecting to be able to use these present findings and add to them through his advancing knowledge. There is a need to focus on items that have been uncovered in this study which would benefit from further research, for instance there is a need to compare outcomes of the surgery between genders. Then there needs to be more research into the difference controlled “supervised” rehabilitation makes on patients with different levels of physical activity. More kinematic and kinetic data from force platforms and 3D motion capture cameras would help provide important detailed information on studies using this equipment. Moreover further research is needed to compare outcomes from ACLR patients all of whom have a similar cultural background but are from different Arabic countries.

### **7.3 Dissemination of results**

The findings from this study will be disseminated in as many ways as is possible. Without the new knowledge herein being available to the health profession the work on this study would be wasted. Therefore the author will send out the findings to known colleagues and specialist orthopaedic surgeons. He will publish articles in relevant journals. The information will be presented at relevant conferences both in Europe and throughout the rest of the world.

### **7.4 General conclusions**

This thesis conducted the first study to culturally adopt an Arabic-version of KOOS and investigate its validity and reliability for Egyptian patients with various knee injuries. This Arabic-version of KOOS could be used for all Arabic knee patients anywhere, because it is understandable language for any Arabic people due to public and common use in the TV and media (Almangoush et al., 2013).

Also, this thesis conducted the first reliability study of the QASLS test which is feasible and easy to administer in the clinical setting and in research to address lower extremity movement quality. However, both intra-rater and inter-rater reliability of the qualitative scale measures successfully exceeded levels necessary for application of this measurement method in the clinical setting and research (Almangoush et al., 2014b).

Overall, this is the first study to investigate the quantitative and qualitative functional performance, dynamic balance and self reported outcome of Egyptian patients with ACL reconstruction preoperatively and 3, 6 and 12 months postoperatively. This thesis will therefore add much to the knowledge of both experimenters and clinicians within the knee ligaments injury field.

In the present study, there was a general trend for slight improvements in raw performance scores for the injured and uninjured limbs when assessed quantitatively and qualitatively over the 4 test occasions, particularly at 6 and 12 months. This trend may perhaps reflect a lack of confidence in performing functional tests, or a detraining effect of the injured limb secondary to reduced physical activity. The used QASLS measure ensure that the clinician can confidently attribute differences in performance scores to actual changes in limb function, rather than to inconsistencies or variability in measurement of ACL patients following surgery.

Useful data on an early recovery of limb function are presented from the measurements of the scores at 3 and 6 months. This data will give information to the rehabilitation teams so they can review the changes the rehabilitation programs and highlight it's potential benefits for patients in Egypt. The strength of this present study lies in the prospective repeated measurement methodology and the use of the multi-validated outcome measures. This pragmatic trial permitted the patient to choose both a physiotherapist and the amount

and intensity of the rehabilitation. This means that this study reflects reality and is applicable for use in daily practice. It should be accepted that although all the patients would have improved postoperatively without rehabilitation, they would not have reached the same level of normal mobility as those who received rehabilitation. UK patients showed better results than Egyptian patients at similar conditions in KOOS score or single hop test. But it could be due to the differences in the activity levels between them, skilled surgeons and rehabilitation compliance. The frequency of postoperative anterior knee pain should be under consideration in patients who are required to kneel for religious or occupational activities, and alternative grafts may be considered in these cases.

## *Chapter eight*

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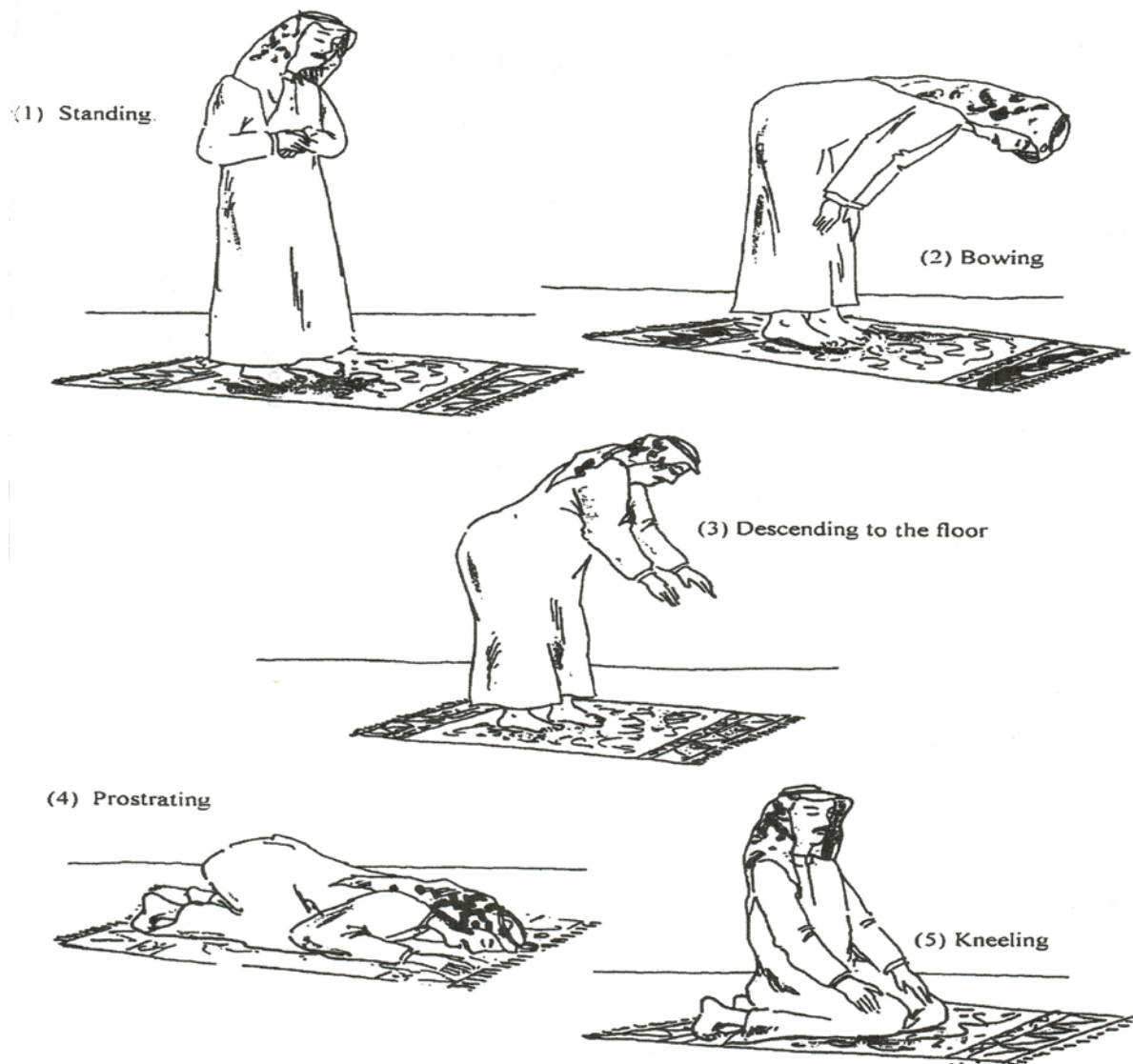
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## Chapter nine

### Appendix 1



## Appendix 2

العلاج الطبيعي والتمارين العلاجية التي قد يجريها مريض الرباط الصليبي من تاريخ إجراء العملية إلى فترة ثلاثة شهور  
 أي من التمارين الآتية التي قد تكون قمت بها خلال الثلاث شهور الماضية وكم مرة في الأسبوع؟  
 \* الرجاء إختيار الإجابة المناسبة بوضع علامة ( / ) داخل المربع.  
 اسم المريض.....  
 الرقم.....

رقم	نوع التمرين	أبدا لم أقوم بهذا التمرين	فترة من 0-2 أسبوعين بعد العملية	فترة من 3 إلى 6 أسابيع بعد العملية	فترة من 7 إلى 12 أسبوع بعد العملية
1	 بسط الركبة مساكنا أي بدون حركة	<input type="checkbox"/>	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
2	 رفع الساق بالتكامل من وضععية النوم على الظهر	<input type="checkbox"/>	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
3	 بسط الركبة بمساعدة المتشفة	<input type="checkbox"/>	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
4	 قبض مفاصل للركبة يتمح للجلدية لتقي الركبة إلى 90 درجة	<input type="checkbox"/>	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
5	 بسط و تمديد الركبة تدريجيا على الجدار بمساعدة القدم الأخرى	<input type="checkbox"/>	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> مرة في الأسبوع <input type="checkbox"/> مرتين في الأسبوع <input type="checkbox"/> 3 مرات أو أكثر في الأسبوع

6		بمنط (تمنيد) سليمي للركبة بدون حركة	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
7		ثني للركبة من وضع التوم علي البطن فوق السرير	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
8		منحني ومد الساق بوحلة مؤخرة القدم علي السرير	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
9		ثني الركبة بمنحني القدم علي السرير تدريجيا	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
10		تمارين تقوية للمعضلة الرباعية	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
11		الضغط علي الكرة بواسطة المفصلات الخلقية للساق	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع
12		رفع القدم علي إستقامتها من وضع الجلوس	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الاسبوع	مرة في الاسبوع	مرة في الاسبوع
				مرتين في الاسبوع	مرتين في الاسبوع	مرتين في الاسبوع
				3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع	3 مرات أو أكثر في الاسبوع

13		تثبيط لركبة بمساعدة الرجل الأخرى	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
14		النوم على البطن وإخراج القديمن من المريز مع وضع أنقل	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
15		تثبيط للركبتين من وضع الوقوف	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
16		تثبيط إلى أقصى درجة للركبتين مع مد الذراعين إلى الأمام	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
17		تثبيط إلى أقصى درجة للركبة المصابة مع مد الذراعين إلى الأمام	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
18		تثبيط للركبة بالتكامل (وضعية الجلوس في الصلاة)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع
19		الوقوف على الرجل المصابة مع وضع اليدين في الوسط	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				مرة في الأسبوع	مرة في الأسبوع	مرة في الأسبوع
				مرتين في الأسبوع	مرتين في الأسبوع	مرتين في الأسبوع
				3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع	3 مرات أو أكثر في الأسبوع

20		الوقوف علي مقعد التوازن	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
21		الوقوف علي أصابع الرجل المصابة فقط بمساعدة الحائط	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
22		رفع الجسم و الإرتكاز علي أصابع القدمين مع الإستناد علي الحائط	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
23		ثني الركبة المصابة إلي أقصى درجة من وضع الوقوف في الوسط	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
24		الجلوس علي الكرة و محاولة التثبيت بالرجل المصابة	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
25		الضغط علي الكرة بواسطة الركبتين	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع
26		مقاومة إبعاد الجانبى لمفصل الخصر	<input type="checkbox"/>	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع	<input type="checkbox"/>	مرة في الأسبوع
				<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع	<input type="checkbox"/>	مرتين في الأسبوع
				<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع	<input type="checkbox"/>	3 مرات أو أكثر في الأسبوع

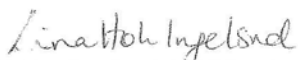
27		مقاومة بسيط الفخذ للخلف	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
28		صعود الدرج (السلالم)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
29		صعود درجة واحدة للأمام	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
30		صعود درجة واحدة من الجنب	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
31		النزول درجة واحدة	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
32		الإنفعال إلى الأمام	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع
33		تشدّد (تمطيط) عضلة الفخذ الأمامية (الرباعية)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
				<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع	<input type="checkbox"/> مرة في الأسبوع
				<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع	<input type="checkbox"/> مرتين في الأسبوع
				<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع	<input type="checkbox"/> 3 مرات أو أكثر في الأسبوع

## Appendices 3

### **The Knee injury and Osteoarthritis Outcome Score - KOOS**

#### **Permission to translate**

Adel Almangoush has received permission to translate and validate the KOOS to Arabic (Egypt).



18.04.12 Lina Ingelsrud, KOOS web manager, on behalf of Professor Ewa Roos

Code (       )

*Information Gathering Sheet of Star Excursion Tests, ROM and Single- Leg Squat*

Name.....

D.O.B..... /...../.....

Dominant Foot.....

Height.....

Leg Length.....

Weight .....

The injured knee is: **R / L**

Position	Practice Circuit 1		Practice Circuit 2		Practice Circuit 3		PracticeCircuit 4	
	Date...../...../.....		Date...../...../.....		Date...../...../.....		Date...../...../.....	
	(R) ROM ...../.....		(R) ROM ...../.....		(R) ROM ...../.....		(R) ROM ...../.....	
	(L) ROM ...../.....		(L) ROM ...../.....		(L) ROM ...../.....		(L) ROM ...../.....	
	(R) SLS (   )		(R) SLS (   )		(R) SLS (   )		(R) SLS (   )	
	(L) SLS (   )		(L) SLS (   )		(L) SLS (   )		(L) SLS (   )	
	R	L	R	L	R	L	R	L
Anterior 1								
Anterior 2								
Anterior 3								
Medial 1								
Medial 2								
Medial 3								
Lateral 1								
Lateral 2								
Lateral 3								

*Information Gathering Sheet of hop Tests*

**1- Single hop for distance**

The Trial	The distance M/cm							
	Practice Circuit 1		Practice Circuit 2		Practice Circuit 3		Practice Circuit 4	
	Date...../...../.....		Date...../...../.....		Date...../...../.....		Date...../...../.....	
	R	L	R	L	R	L	R	L
Frist trial								
Second trial								
Third trial								

**2- Crossover hop for distance**

The Trial	The distance M/cm							
	Practice Circuit 1		Practice Circuit 2		Practice Circuit 3		Practice Circuit 4	
	Date...../...../.....		Date...../...../.....		Date...../...../.....		Date...../...../.....	
	R	L	R	L	R	L	R	L
Frist trial								
Second trial								
Third trial								

**Appendix 4**

24 May 2012

Dear Adel,

**RE: ETHICS APPLICATION HSCR12/16 – Validation of an Arabic version of the Knee Injury and OA Outcome Score (KOOS) in Arabic patients with a reconstruction of an Anterior Cruciate Ligament (ACL)**

Following your responses to the Panel's queries, based on the information you provided, I am pleased to inform you that application HSCR12/16 has now been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible.

Yours sincerely,

*Rachel Shuttleworth*

Rachel Shuttleworth  
College Support Officer (R&I)

16 May 2012

Dear Adel,

**RE: ETHICS APPLICATION HSCR12/21 – Outcomes of Anterior Cruciate Ligament Reconstructions and Rehabilitation of people with knee Injuries in Egypt: a prospective study**

Following your responses to the Panel's queries, based on the information you provided, I am pleased to inform you that application HSCR12/21 has now been approved, on the condition that a copy of the formal local (Egypt) ethical approval is submitted to us before the study starts.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible.

Yours sincerely,

*Rachel Shuttleworth*

Rachel Shuttleworth  
College Support Officer (R&I)

7 August 2014

Dear Adel,

**RE: ETHICS APPLICATION HSCR14/39** – An audit outcomes of anterior cruciate ligament reconstruction ACL and rehabilitation of people with knee injuries in the UK: a retrospective study

Based on the information you provided, I am pleased to inform you that application HSCR14/39 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible.

Yours sincerely,

*Rachel Shuttleworth*

Rachel Shuttleworth  
College Support Officer (R&I)

Jun 18, 2012

Salford University  
Manchester  
UK

To Whom It May Concern

**Re: Outcomes of Anterior Cruciate Ligament Reconstructions and Rehabilitation of people with knee Injuries in Egypt: a prospective study**

This is to inform that we have approved the above mentioned research project to be carried out at Alex Knee Centre, under the supervision of Mr. Adel Almangoush, Dr. Lee Herrington , Dr. Ahmed Waly and Dr. Akram Al-Dawoudy.

Sincerely

Shokry Ramadan  
Adminstrative Manager


0 شارع فوزى معاذ  
سموحة - الإسكندرية  
تليفون: ٤٢٥٨٤٧٠ - ٤٢٥٨٤٧١  
٠١٩٢٢٢٠٦٦٠ - ٠١٠١٧٦٩٧٢١  
5 Fawzy Moaaz St.  
Smouha - Alexandria  
Tel : 4258471 - 4258470  
0101769721 - 0192220660  
info@alexknee.com  
[www.alexknee.com](http://www.alexknee.com)

May 28, 2012

Salford University  
Manchester  
UK

To Whom It May Concern

Re: Validation of an Arabic version of the Knee injury and Osteoarthritis Outcome Score (KOOS) in Egypton patients with knee injuries

This is to inform that we have approved the above mentioned research project to be carried out at Alex Knee Centre , under the supervision of Mr. Adel Almangoush, Dr. Lee Herrington, Dr. Ahmed Waly and Dr.Akram Al-dawoudy.

Sincerely

Shokry Ramadan  
Adminstrative Manager



0 شارع فوزى معاذ  
سموحة - الإسكندرية  
تليفون: ٤٢٥٨٤٧١ - ٤٢٥٨٤٧٠  
٠١٩٢٢٢٠٦٦٠ - ٠١٠١٧٦٩٧٢١

5 Fawzy Moaaz St.  
Smouha - Alexandria  
Tel : 4258471 - 4258470  
0101769721 - 0192220660  
info@alexknee.com  
[www.alexknee.com](http://www.alexknee.com)



الإسم.....

الرقم.....

### (KOOS) إستبيان لتقييم الحالة الصحية للركبة

هذه المعلومات سوف تساعدنا لمعرفة كيف تشعر بركبتك و كذلك كيف ستكون قادر على إنجاز نشاطاتك الاعتيادية.

أجب كل سؤال بوضع دائرة واحدة على الإجابة المناسبة أمام كل سؤال، وإذا كنت غير متأكد من الإجابة الرجاء إختيار أقرب إجابة ممكنة.

الألم (الوجع)						
1	كم مرة تحس بوجع في ركبتيك عادة؟	ماحصلش (4)	كل شهر (3)	كل أسبوع (2)	كل يوم (1)	دائما (0)
ماهي شدة الوجع التي قد تكون شعرت بها الأسبوع الماضي خلال أدائك للنشاطات الآتية...؟						
2	القف و الإستعداد (الإرتكاز) على الركبة المصابة	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
3	فرد الركبة بالكامل	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
4	ثني الركبة بالكامل (وضع الجلوس في الصلاة مثلا...)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
5	المشي على الأرض المستوية	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
6	طولوع أو نزول السلالم	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
7	في الليل، أثناء وجونك في السرير للقوم	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
8	وضع الجلوس أو وضع القوم (الاستلقاء)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
9	عند وقوفك في الوضع الطبيعي	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
أعراض المرض						
1	ما هي شدة صعوبة فرد الركبة عند إستيقاظك في الصباح ؟	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
2	ما هي شدة صعوبة فرد الركبة بعد وضع الجلوس، التمدد أو الإسترخاء في وقت لاحق من نفس اليوم؟	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
3	هل يوجد تورم في ركبتيك؟	ماحصلش (4)	ناردا (3)	أحيانا (2)	غالبا (1)	دائما (0)
4	هل تشعر بأي خمششة أو سماع فرقة، أو أي نوع آخر من الأصوات عندما تحرك ركبتيك؟	ماحصلش (4)	ناردا (3)	أحيانا (2)	غالبا (1)	دائما (0)
5	هل ركبتيك تنقف فجأة أو يتعلق عندما تقوم بالحركة ؟	ماحصلش (4)	ناردا (3)	أحيانا (2)	غالبا (1)	دائما (0)
6	هل يمكنك فرد ركبتيك بالكامل (على الآخر)؟	دائما (4)	غالبا (3)	أحيانا (2)	ناردا (1)	ماحصلش (0)
7	هل يمكنك ثني ركبتيك بشكل كامل (على الآخر)؟	دائما (4)	غالبا (3)	أحيانا (2)	ناردا (1)	ماحصلش (0)
أنشطة الحياة اليومية						
ما الصعوبات التي قابلتها في الركبة الأسبوع الماضي...؟						
1	في نزول السلالم	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
2	في صعود (طولوع) السلالم	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)

3	القيام من وضع الجلوس	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
4	الوقوف	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
5	إنحناء الجسم أو توضع لإلقاء الأشياء (الحاجات) من علي الأرض	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
6	المشي على أرض مستوية	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
7	الصعود و النزول من السيارة (العربية)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
8	الذهاب للتسوق	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
9	لبس الثياب القصيرة أو الطويلة	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
10	القيام (النهوض) من السرير	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
11	خلع الثياب القصيرة أو الطويلة	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
12	اقوم في السرير (القلب علي أحد الجانبين أو الحفاظ علي وضع ثابت للركبة)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
13	عند قيامك بالاستحمام	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
14	وضع الجلوس	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
15	عند قيامك بقضاء الحاجة (قياما و قعودا من علي التواليف)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
16	الأعمال المنزلية المعقدة (تحريك و نقل الصناديق الثقيلة، شطف البلاط، ... الخ)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
17	الأعمال المنزلية الخفيفة (الطبخ، و مسح العراء، ... الخ)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
<b>النشاط الرياضي و المهارات اللازمة لممارسة الهوايات</b>						
<b>ما الصعوبات التي قابلتها في الركبة الأسبوع الماضي ؟</b>						
1	ثني الركبتين من وضع الوقوف	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
2	الجرى	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
3	القفز (القط)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
4	اللف و الإمتداد (الإرتكاز) علي الركبة المصابة	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
5	الفرز و الإرتكاز علي الركبتين (كالنزول للسجود في الصلاة مثلا...)	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)
<b>الركبة المصابة و علاقتها بنمط الحياة</b>						
1	إلي أي مدى تشغلك مشاكل ركبتك أو تمثل مساحة من ذهنك أو تفكيرك ؟	ماحصل (4)	شعبيا (3)	أسبوعيا (2)	يومي (1)	دائما (0)
2	هل قمت بتعديل أسلوب حياتك لتجنب الأنشطة التي قد تسبب نلقا في ركبتك؟	ماحصل (4)	قليل (3)	باعتدال (2)	بشدة (1)	كثيرا (0)
3	ما مدى قلقك من عدم ثقتك بكفاءة أداء ركبتك ؟	ماحصل (4)	قليل (3)	معتدل (2)	بشدة (1)	بشدة كبيرة (0)
4	بشكل عام، ما مدى الصعوبات التي تقابلها عند ممارسة حياتك الطبيعية بسبب مشاكل ركبتك ؟	لاشي (4)	خفيف (3)	معتدل (2)	شديد (1)	شديد جدا (0)

الرجاء التأكد من الإجابة على جميع الأسئلة  
شكرا لحسن تعاونكم

**CONSENT FORM**

Title of Project: **Knee functional outcome and postural stability following anterior cruciate ligament reconstructions: a prospective study**

Name of Researcher: **Adel Almangoush**

**Please initial in the box below**

1. I confirm that I have read and understand the patient information sheet for the above study. I have had the opportunity to consider the information questions and have had these answered satisfactory. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that members of the University of Salford research staff/student who are working on the project will only look at my answers of the questionnaire/data outcomes including video records of my test and I give permission for these individuals to have access to my records. ☐
4. I agree to take part in the above study. ☐

..... Name of patient	..... Date	..... Signature
..... Name of person taking consent	..... Date	..... Signature
..... Researcher	..... Date	..... Signature

Appendix:1

Date (to be updated)

Dear Sir/Madam,

**Invitation to participate in research study**

My name is Adel Almangoush and I am currently studying for my PhD at the University of Salford. I am writing to invite you to participate in my study.

To be eligible in the study, you must:

- Age 18-50 years
- You must be diagnosed with ACL rupture and underwent an ACL reconstruction about 6 months ago.
- 

Your involvement would require you to fill in a questionnaire and undertake a number of Knee function tests (hop, balance and squat ) which approximately takes 30 minutes to complete, and requires two visits to the Salford University at 6 and 12 months after the operation.

The university's ethical has been given approval for this study. All the information about your participants in this study will be kept confidential, and now I am seeking your help to conduct the study.

If you are interested, please feel free to contact me on by the email address below and I will provide you with further details of the study.

**Your help would be greatly appreciated**

Yours sincerely

Adel Almangoush

a.a.almangoush@edu.salford.ac.uk

## **Participants Information Sheet**

### **Part 1**

#### **1. Project Title.**

#### **Outcomes of Anterior Cruciate Ligament Reconstruction and Rehabilitation of people with knee Injuries In the UK**

#### **2. Invitation**

I would like to invite you to take part in a research study that will be conducted by Mr. Adel a postgraduate researcher at Salford University. Before you decide to participate, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Feel free to talk to others about the study if you wish.

- Part 1 tells you the purpose of this study and what will happen to you if you take part.
- Part 2 gives you more detailed information about the conduct of the study.

#### **3. What is the purpose of the study?**

The main purpose of this research is to look at what happens when injured patients who have had ACL reconstruction operations. The objectives of this postoperative study is to explore and evaluate ACL reconstruction and rehabilitation in the UK over two session of measurements; one will be just after 6 months and also at 12 months later as a follow-up. We are interested how these affect function performance, balance, range of motion.

#### **4. Why have I been chosen?**

You have been chosen because you have had an anterior cruciate ligament reconstruction ACLR operation. The volunteers who take part in this study will be screened and selected carefully by the investigator, it is anticipated that up to 25 volunteers will participate in this study. During the study there is no need to stop any type of treatment or rehabilitation prescribed by your doctor or physiotherapist.

#### **5. Do I have to take part?**

Participation in the research is entirely voluntary. If you decide to participate you will be given the information sheets to read and keep, and will be asked to sign a consent form. You are still free to withdraw at any time and without giving a reason. A decision to withdraw at any time, or a decision not to take part, will not affect the standard of care you receive.

#### **6. What will happen to me if I take part?**

If you have decided to take part, then please read the following guidelines carefully:

- The study will take place at the University of Salford.
- The study is non-invasive.
- The research will last up to a maximum of 12 months.
- The duration of the study will include a number of sessions, which require 2 sessions: one at 6 months and other at 12 months post-operation. Each session will last approximately 30 minutes.
- These procedures are measurements taking and self-reported questionnaire which are well established in evaluation and treatment of patients.
- Adequate training will be given, such that you will be familiar with star excursion, hop tests and single leg squat before starting the trial.
- To maintain your privacy, only the lab team from the Salford University and me will be present during the trial.

#### **7. What do I have to do?**

During the trial, you will be guided throughout the procedures. A thorough explanation will be given at each session attended. It is recommended to wear suitable comfortable and sporting clothing (shorts and t-shirt) as well as sport footwear (running or training shoes).

## **8. What is the device or procedure that is being tested?**

The nature of the trial will involve standing and move the leg to 3 directions and 2 hops; single hop of distance and crossover hop of distance and single leg squat . These tests evaluates the functional performance and the dynamic balance after the ACL reconstruction operation and during/after rehabilitation.

## **9. What are the possible disadvantages and risks of taking part?**

As this study is non invasive, there will be no disadvantages. Hence the risks of taking part can be concluded as follow:

- Fatigue- the patient will be allowed to stop and rest whenever they feel it is necessary.
- In case of emergency, the individual hospitals' emergency protocol will be adopted; these are practiced weekly, for example: testing of the emergency alarm.

## **10. What are the possible benefits of taking part?**

As explained earlier, this study is of an observational nature, and we cannot promise the study will help you but the results and information we get may help clinicians and physiotherapists to improve the treatment regime and rehabilitation of people with ACL and reconstruction in the UK.

## **11. What if there is a problem?**

If you a concern a bout any aspects of the study, you should ask to speak to the researchers who will do their best to answer your questions (the contact number will be updated). If you remain unhappy or in the event that something dose go wrong and you are harmed during the research study there are no special compensation arrangements. But if you wish to complain formally, you can do this through the Salford University. Details can be obtained from the university of Salford

## **12. Will my taking part in the study be kept confidential?**

All the information about your participation in this study will be kept confidential. Only researchers involved in the study will have access to your information and details will not be passed on to a third party. All names will be replaced with codes so that individuals cannot be identified. We intend to publish the results of the study, that is, which treatment and rehabilitation was the most successful, but names or details of individuals will not be published.

The data will be transferred securely to Salford University and will be stored securely in a lockable filing cabinet at Salford University. Whereas I have personal computer with code and password that I will be using during the data collection. All the information collected and hand data (paper) will be kept in confidential locked bag. In addition, all the data will be transformed directly to SPSS software.

### **13. Contact Details:**

**For more information, please refer to:**

Adel Almangoush

Salford University

M5 4WT

United Kingdom

Tel: (To be updated)

Email; [A.A.Almangoush@edu.salford.ac.uk](mailto:A.A.Almangoush@edu.salford.ac.uk)

This completes Part 1 of the information Sheet.

If the information in Part 1 has interested you and you are considering participation, please continue to read the additional information in Part 2 before making any decision.

## **Part 2**

### **1. What if relevant new information becomes available?**

A letter explaining such information, when it becomes available would be given to the subjects and they would be encouraged to discuss the implications of such with the research team if they so wished. If new data becomes available that would affect the patients' participation in the study they will be asked to re-consent.

### **2. What will happen if I don't want to carry on with the study?**

You are free to withdraw or any information that you have provided for this project at any time prior to completion of data collection, without giving any reason, without being disadvantaged in any way.

### **3. What will happen to the results of the study?**

The findings will be written up in the form of a report, which will be included in a thesis that forms part of a post-graduate student's PhD research degree. Furthermore, it is also likely that this post-graduate student will write a paper based on our findings, and this paper will be published in a professional, peer-reviewed journal. However, your identity will be kept confidential.

### **4. Who is organising and funding the study?**

The research is based on self funding from the chief investigator.

ar parking at the university can be paid for and some refreshments will be provided but travel expenses will not be available.

### **5. Who has reviewed the study?**

The postgraduate researcher supervisor have reviewed all aspects of this study and before any research goes ahead, this study has to be checked by an Ethics Committee, they make sure that the research is OK to do.

## **Finally**

Thank you for the time you spent reading this information sheet. We are looking forward to your reply, and if you have any further queries, please do not hesitate to contact us.

Your sincerely, Adel Almangous

