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and Sport Sciences



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Physiotherapy

An Open Label Study on the Effects of a Prevention Protocol for Improving Knee Strength and Performance to Reduce the Anterior Cruciate Ligament Injuries

A Thesis Submitted in Partial Fulfillment of the Requirements for the
Master of Science Degree in Physiotherapy

Submitted by
Nowara Ebrahim Khalil
University ID: 20102440

Supervised by
Dr. Mohamed Abdulla Mohamed
(Assistant Professor)
University of Bahrain

Kingdom of Bahrain
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Defense Committee's Approval

University of Bahrain
Deanship of Graduate Studies and
Scientific Research



جامعة البحرين
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Thesis Discussion Committee Decision

Student Name: NOWARA EBRAHIM KHALIL EBRAHIM	Student ID: 20102440
Department: Physiotherapy	College: Health and Sport Sciences
Program: MSc Physiotherapy	
Thesis Title: An Open Label Study on the Effects of a Prevention Protocol in Reducing Anterior Cruciate Ligament Injuries Risk Factors Among Female Athletes	
Supervisor's name: Dr. Mohamed Abdulla Mohamed	Student's GPA: 3.60

The Discussion Committee met on 30th Oct 2022 online via Microsoft Teams. Upon discussing the student whose details are stated above in public, the discussion committee recommends the following:

The student is awarded a grade A- in the thesis subject.

- ☐ Without making any changes to the thesis.
- ☒ After making the modifications attached with this decision.

Discussion Committee Members Approval:

Name

- | | |
|------------------------|---------------------|
| 1. Dr. Mohamed Abdulla | (Advisor) |
| 2. Dr. Simone Perna | (Internal Examiner) |
| 3. Dr. Ali Alnahdi | (External Examiner) |

Signature


Simone Perna
Ali Alnahdi



Dissertation Deposit Form

Author Name:	Nowara Ebrahim Khalil Ebrahim Abdulla		
Email:	20102440@stu.uob.edu.bh	Contact No:	37113022
College:	Physical Education & Physiotherapy		
Department:	Physiotherapy		
Thesis Title:	An Open Label Study on the Effects of a Prevention Protocol in Reducing Anterior Cruciate Ligament Injuries Risk Factors Among Female Athletes		
Year:	2022		

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Abstract

Introduction: Anterior cruciate ligament (ACL) injury is one of the most common sports injuries. Recent studies connect ACL reconstruction with long-term complications, knee joint degeneration, and osteoarthritis. Therefore, this study aimed to assess the effect of the Knäkontroll ACL prevention protocol on the mechanical risk factors of developing non-contact ACL injuries among female athletes. **Methods:** Thirty females aged between 18 to 35 years playing different sports at an amateur level participated voluntarily. Tuck jump, static balance, dynamic balance, and hop tests were tested pre-intervention, 2 and 4 weeks after the intervention. The Knäkontroll ACL prevention program was performed thrice per week for four weeks. Instructions and videos were delivered via video calls (remotely) in the first session of each week, and the remaining two sessions were done as a home program. All data were analyzed using the Statistical Package for Social Science (SPSS), descriptive statics (mean and standard deviation), repeated-measures ANOVA, and means of difference were calculated. **Results:** The significant improvements for all the tests was shown after the fourth week, (static balance with eyes open (Mean $\pm$ standard deviation, 163 ± 42.50 sec, Mean of Difference (MD) = 114 sec, 95% CI [102.45, 125.60], $P < 0.001$), Cross over hop test (MD = 33.22 cm, 95% CI [29.73, 36.71], $P < 0.001$, $n_p^2 = 0.90$), and Y-balance posterolateral (103 ± 9.00 cm) (MD = 23.02 cm, 95% CI [21.64, 24.40], $P < 0.001$). Only in tuck jump test the biggest difference in scores was seen between the second and fourth weeks (MD = 5.47 points, 95% CI [4.80, 6.14], $P < 0.001$, $n_p^2 = 0.94$). **Conclusion:** The Knäkontroll ACL prevention protocol effectively reduces ACL injury risk factors by improving the static and dynamic balance, jump and hop abilities. It can also be applied to athletes remotely as a quick intervention before sporting events.

Dedication

To the women who stood with me in every struggle

For you and your sons, I dedicate my work

To my two aunties and uncle that we lost last year

For my dear parents

To my husband Ahmed

To my two angles Sara and Abdulla

To my beloved family and friends

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List of Abbreviations

ACL	Anterior Cruciate Ligament
ACLR	Anterior Cruciate Ligament Reconstruction
CG	Control Group
CI	Confidence Interval
COVID-19	Corona Virus 2019
FIFA	Federation International Football Association
FPS	Frame Per Second
GJH	Generalized Joint Hypermobility
ICCs	Interclass Correlation Coefficients
IG	Intervention Group
LEFS-Ar	Lower Extremity Functional Scale (Arabic)
LT	Left
MD	Mean Differences
PICO	Patient, Intervention, Comparison, Outcome
RT	Right
SD	Standard Deviation
SEM	Standard Errors of Measurement
TJA	Tuck Jump Assessment
YBT	Y-Balance Test

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Chapter One

Introduction to the Study

1.1 Introduction and short background

Anterior cruciate ligament (ACL) injuries are one of the recurrent sports injuries among young athletes (Amraee et al., 2017), which frequently require ligament reconstruction surgery, especially for athletes who want to go back to sport and competition (Joseph et al., 2008). However, the prolonged rehabilitation period after the reconstruction will delay the athletes' return to sport. Furthermore, recent studies connect ACL reconstruction with many long-term complications, especially knee joint degeneration and osteoarthritis (Oshima et al., 2018a). Therefore, ACL injury prevention is essential to avoid these complications (Swart et al., 2014).

Knowledge about the risk factors leading to ACL injuries is crucial for preventing and avoiding complications. The risk factors for ACL injury are divided into internal and external factors. External risk factors include the type of sport, footwear or surface interface, and the weather (Hashemi et al., 2011; Dai et al., 2012). On the other hand, the internal risk factors include lower extremity alignment, the femoral intercondylar notch, patella tendon-tibia shaft angle, hormonal changes, neuromuscular control, and biomechanical factors (Hashemi et al., 2011; Dai et al., 2012).

Female players have a higher chance of anterior cruciate ligament injuries. Women are four to six times more likely to have an ACL injury than men who play the same sport (Oshima et al., 2018a). Moreover, seventy percent of these injuries are non-contact ACL injuries that occur without direct contact (Wesley et al., 2015). The higher ACL injuries in females are that they have greater hip

adduction, hip internal rotation, knee valgus, and less knee flexion (Beese et al., 2015). The knee valgus and the limitation in knee flexion place an extra load on the ACL. On top of that, higher hip internal rotation and adduction are thought to increase the torque experienced at the knee joint (Beese et al., 2015).

ACL injury prevention can take many forms, including various training programs, athlete education, and bracing techniques (Alentorn-Geli et al., 2009). One of the most common prevention protocols is the Knäkontroll injury prevention program, a Swedish protocol for knee control injury prevention in English. It was developed by the Swedish Football Association and Swedish National Centre for Research in Sports. This program comprises the lower limb and core strength, neuromuscular control, balance, jumping, and landing technique with a good postural position. The Knäkontroll program was shown to be effective by many studies involving female players showing a significant reduction in the rate of non-contact ACL injuries (Häggglund et al., 2009a).

1.2 Research Problem

In the last few years, there was an increase in physical activity and sports participation among Bahraini females. As a result, sports injuries became more common and required more attention. The ACL injury is considered one of the most recurrent injuries among female athletes due to anatomical, mechanical, and neuromuscular factors. These injuries are not only costly, but they also affect the patients' functional activities and quality of life. A previous study showed that among patients with ACL injuries, 31% had moderate to severe overall disability in walking, 44% had moderate to severe general disability in routine daily functional activities, and 77% could not return to their sport at the same activity level as before the injury (Dai et al., 2012). Despite the importance of this topic, no published study in Bahrain or the Arabian Gulf area

has investigated the effect of prevention protocol on ACL risk factors among female athletes. Most ACL injury prevention research is limited to the United States, Australia, and Europe. More diversity in study locations and populations is needed (Arundale et al.,2021).

Moreover, despite the enormous preventive efforts introduced over the past decades, the rates of ACL injuries among athletes have not decreased (Agel et al., 2016). From 2004 to 2013, there was a statistically significant increase in the average annual number of ACL injuries reported for male and female basketball, ice hockey, field hockey, football, and volleyball players (Agel et al., 2016). The leading cause of this increase in ACL injury rates is low adherence (Warren, 2021).

1.3 Research questions

1. Is there any improvement in the female athlete's static and dynamic balance after applying the prevention protocol for two and four weeks?
3. Is there any improvement in the female athlete's functional performance after applying the prevention protocol for two and four weeks?
4. Is there any reduction in female athlete tuck jump score after applying the prevention protocol for two and four weeks?

1.4 Research Aim/Objectives

1.4.1 Aim

This research aims to assess the effect of the Knäkontroll prevention protocol on improving female athletes' static balance, dynamic balance, and

functional performance and reducing the most common ACL mechanical risk factors.

1.4.2 Objectives

1. To examine the effect of the Knäkontroll prevention protocol on female athletes static and dynamic balance after 2 and 4 weeks.
2. To examine the effect of the Knäkontroll prevention protocol on female athletes functional performance after 2 and 4 weeks.
3. To examine the effect of the Knäkontroll prevention protocol on female athletes Tuck Jump score after 2 and 4 weeks.

1.5 Research significance

Despite the variety of advanced scientific treatments for ACL injury, osteoarthritis occurs ten times more in individuals with ACL injury compared to healthy individuals regardless of the type of treatment, whether it is conservative management or surgical treatment (Myer et al., 2004). Also, it is worth mentioning that ACL injuries' side effects are not limited to the physical aspect only. It has a substantial psychological impact. Many athletes suffer from depression and anxiety due to reduced daily living activity and delayed participation in sports, especially if they are professional athletes (Palisch & Merritt, 2018). Finally, ACL rehabilitation or reconstruction costs are considered very high. The results of this study are supposed to generate a new body of knowledge about the effectiveness of the Knäkontroll ACL prevention program in reducing ACL risk factors related to neuromuscular control and biomechanical factors. The researcher believes that this prevention protocol will effectively reduce ACL risk factors, improve players' function in activities of

daily living, and improve players' functional performance. On top of that, it will reduce the costs of ACL reconstruction surgeries and rehabilitation programs and will reduce the chance of re-injury.

1.6 Definition of Terms

- Static balance: the ability of a person to keep his center of gravity within a stationary and immobile base of support such as standing (Mostafaei et al., 2017).
- Dynamic balance: the ability of a person to keep his center of gravity over a moving base of support, such as standing on a tilting board (Mostafaei et al., 2017).
- Noncontact Anterior Cruciate Ligament (ACL) injury: the injury that occurs without direct contact to the knee from another player, the floor, or an external element (Smith et al., 2012).
- Generalized Joint Hypermobility (GJH): The capacity of a person to passively or actively move their joints more than the normal range of movement. GJH is more common in females than males (Singh et al., 2017).
- Adherence: the degree of players' commitment to do their exercises and follow the instructions recommended by their coaches or physical therapists (Goddard et al., 2021).
- Dynamic knee valgus (DKV): is a series of movements that happens when there is adduction and internal rotation of the femur, abduction of the knee, anterior tibial translation, tibial external rotation, and eversion of the ankle (Dempsey et al., 2009).
- Osteoarthritis: a disease that occurs due to mechanical abnormalities that lead to degeneration of joints affecting the articular cartilage and subchondral bone (Glyn-Jones et al., 2015).

- Plyometric training: This type of exercise aims to develop power and speed; it is usually used as a part of ACL injury prevention protocols (Ramírez-Campillo et al., 2013).
- Kinetics: The mechanics section investigates the relationships between the forces and torques causing the motion of a body or system (Hewett et al., 2016).
- Kinematics: The mechanics section investigates a body's motion without any attention to the changes in its mass or the forces applying it (Hewett et al., 2016).
- Proprioceptive training exercises: the physical activities that improve the body's capability to discover the motion in the foot and make postural adjustments according to it (Leavey, 2006).
- Dominant Leg: the leg you prefer to use when you want to stand on one leg or kick a ball (Melick et al., 2017).
- Dynamic Postural Control: The potential to maintain stability when in a dynamic state such as running, walking, or jumping (DiStefano et al., 2009).

Chapter Two

Literature review

2.1 Introduction

Anterior cruciate ligament (ACL) injury is considered one of the most devastating injuries among young athletes, leading them to a temporary disability (Amraee et al., 2017). Treatment for ACL can be surgical or non-operative, depending on the players' goals and situations. In the United States alone, about 200,000 ACL reconstruction surgeries were performed annually, costing approximately \$20,000 per surgery, which is a very high cost annually (\$4 billion) (Brophy et al., 2009).

Furthermore, ACL surgeries are not only costly, and many studies connect ACL reconstruction with many complications in the long term, such as osteoarthritis, knee joint degeneration, and meniscus tears (Oshima et al., 2020). On top of that, one of the studies showed that among patients with ACL injuries, more than half of them couldn't regain the same activity level during sports activities (77%). A considerable number of them had moderate to severe disability in activities of daily living (44%), and some of them had moderate to severe disability in walking (31%) (Dai et al., 2012). Therefore, ACL injury prevention is critical to avoid these complications (Swart et al., 2014).

Knowing ACL risk factors is crucial for avoiding and preventing ACL injuries. The risk factors for an ACL injury can be divided into internal and external factors (Dai et al., 2012) or environmental, anatomic, neuromuscular, and hormonal (Laible & Sherman, 2014). Females have been reported to have a higher prevalence of ACL injury compared to males who play the same activity, and they are at risk of ACL injuries four to six times more than males (Oshima

et al., 2018b). The reasons behind the higher ACL injuries in females are that they have greater hip adduction, hip internal rotation, knee valgus, and less knee flexion during landing (Beese et al., 2015). About 72% of ACL injuries occur with a noncontact mechanism that is without direct contact with the knee when the ACL is injured (Wesley et al., 2015).

The literature review below was based on an electronic literature search conducted through the following search engines: Science Direct, Google Scholar, PubMed, Springer Link, and PEDro to get literature relevant to this study. The search was extended to include references cited in the retrieved studies and the suggested relevant studies. The literature search was limited to the studies in English only, and there was no restriction to any country. The primary keywords used in the search plan through the databases were: ‘Anterior cruciate ligament injuries,’ ‘mechanism of Anterior cruciate ligament injury,’ ‘Anterior cruciate ligament risk factors,’ ‘Anterior cruciate ligament intrinsic risk factors,’ ‘Anterior cruciate ligament,’ and ‘extrinsic risk factors.’ For the assessment part, the following terms were used: ‘static balance tests,’ ‘dynamic balance tests,’ ‘y balance test,’ ‘single-leg stance test,’ ‘modified star excursion balance test,’ ‘functional performance tests,’ ‘hop tests,’ ‘single-leg hop test,’ ‘triple hop test,’ ‘crossover hop tests,’ ‘tuck jump test,’ and ‘sport.’

2.2 Anterior cruciate ligament anatomy

Six ligaments control knee joint movement and stability. The anterior cruciate ligament (ACL) is one of them and is considered the most important ligament for knee support. The ACL is a thick band of connective tissues that originate from the posteromedial corner of the medial aspect of the lateral femoral condyle within the intercondylar notch and insert anterior to the inter-

condyloid eminence of the tibia. It merges with the anterior horn of the medial meniscus (Purnell et al., 2008).

The ACL is, on average, about 3 cm in length and 1 cm in diameter. Mechanoreceptors from the posterior articular branches of the tibial nerve nourish ACL, contributing to its proprioceptive role. The middle geniculate artery is considered the main blood supply of ACL (Biedert et al., 1992).

Functionally, the ACL consists of two bundles the anteromedial (AM) bundle and the posterolateral (PL) bundle. It has been shown that the AM bundle lengthens and tightens in flexion. In contrast, the PL bundle lengthens and tightens in extension. It restricts anterior tibial translation on the femur, secondary restriction to the knee external and internal rotation, and limiting valgus knee rotations (Nazario et al., 2019).

2.3 Anterior cruciate ligament injury

The mechanism of ACL injuries can be divided into two types: contact and non-contact ACL injuries. Over 70% of anterior cruciate ligament (ACL) injuries usually occur with a non-contact mechanism, meaning they occur without a direct blow to the knee or fall. The injury occurs when the running player changes the direction quickly or hyperextends the knee after landing from a jump. As a result, the knee goes into an abnormal position that causes injury or tear of one or more knee ligaments (Kiapour et al., 2015). Most knee joint motion occurs in the sagittal plane, like knee flexion and knee extension. Further motion not within the normal physiologic ranges in any plane might cause a ligamentous injury. This can directly impact the ACL, where most injuries occur during multi-planar movements rather than uni-planar movements (Hewett et al., 2016).

Descriptive video analysis was done by Olsen et al. (2004) to study the mechanism of ACL injuries among female handball players. Twenty videotapes of ACL injuries from international competitions were collected from 1988 to 2002. The videos were analyzed to study the injury mechanism by six professionals (3 medical doctors and three national team coaches). In addition, thirty-two players with a history of ACL injury from the Norwegian handball team were interviewed to compare players' recall of their injury characteristics and the video analysis results. The results showed that there were two main injury mechanisms for ACL injuries. The first is a plant-and-cut movement with a forceful valgus and external or internal rotation with the knee close to full extension in 12 out of 20 injuries. This position has been named the dynamic knee valgus or the position of no return (Figure 2.1) (Hewett et al., 2005). The second was a single-legged jump landing with a forceful valgus and external rotation with the knee close to full extension, as recorded in 4 out of 20 injuries. Furthermore, the results from the video analysis and players' interviews were identical (Olsen et al., 2004).

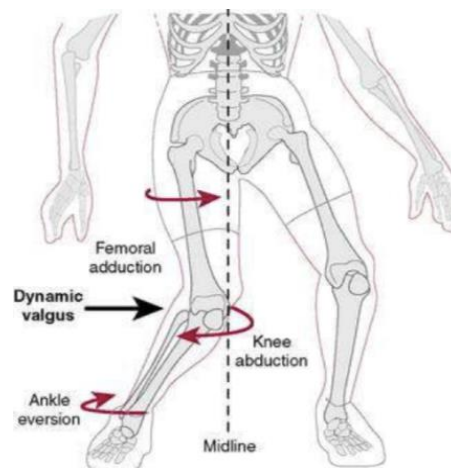


Figure (2.1): Mechanism of ACL injury (Hewett et al., 2005)

In the United States alone, approximately 200,000 anterior cruciate ligaments (ACL) injuries are diagnosed each year. The estimated annual cost of ACL rehabilitation and reconstruction can reach 3 billion dollars (Queen et al., 2021). Additionally, females are at higher risk of ACL injuries. It is reported that one from 29 female athletes, and one from 50 male athletes will have an ACL injury (Walker et al., 2021). Of all the knee ligamentous injuries, ACL-related injuries form around 25%–50%, and complete ACL tear represents 90%–73% of the total ACL injuries (Gupta et al., 2021). According to the National Collegiate Athletic Association (NCAA), the highest rate of injury in men occurred was reported in football (0.17 per 1000 Athlete-Exposures [AE]), while basketball and lacrosse had the highest reported ACL injuries among women (0.23 per 1000 AE) (Pfeifer et al., 2018).

2.3 Anterior cruciate ligament injury risk factors

To apply for an ACL prevention program, it is necessary to identify the expected risk factors and the groups that are at a higher risk. Hashemi et al. (2011) and Dai et al. (2012) divided ACL injury risk factors into internal and external threats, Sports type, playing surfaces, and shoes. The weather is considered an external risk factor. In contrast, lower limb position, hormonal changes, the femoral intercondylar notch, patella tendon-tibia shaft angle, neuromuscular control, and biomechanical factors consider internal risk factors. Among the previous internal risk factors, neuromuscular control and the biomechanical factors are the only factors that can be modified for ACL injury prevention by a well-designed training program (Dai et al., 2012; Hashemi et al., 2011)

Two years after that, Laible and Sherman (2014) divided ACL injury risk factors in their study into four parts: environmental, anatomic, neuromuscular,

and hormonal risk factors. They found that the most common playing situations that increase the chance of an ACL injury are a sudden change of direction or cutting maneuver associated with deceleration and landing from a jump in or near full extension. Furthermore, athletes with solid quadriceps and weak hamstrings cause anterior tibial translation putting the ACL under a lot of stress (Laible & Sherman, 2014).

2.3.1 Internal Risk Factors

Biomechanical and Neuromuscular Risk Factors

A study was done by Herrington et al. (2009) compared the dynamic balance between patients with ACL injury and the asymptomatic controls group. Twenty-five patients with ACL injury (17 male and eight female) with a mean age of 30 years and twenty-five matched controls were included in this study. The Star balance excursion test was applied to all the participants. Results showed significant differences between the two groups in limb movement for the anterior reach, lateral reach, posterior-medial reach, and medial reach. Furthermore, between the control limb and uninjured limb there were also significant differences in the directions of the medial reach and lateral reach only. Compared to normal healthy subjects, participants with ACL injury have a deficit in their dynamic postural control. The sample size of this study is considered small, and there are no detailed results for the males and females separately (Herrington et al., 2009).

A study done by Yasuda et al. (2016) aimed to assess the correlation between hip rotation and ACL injury prevalence among female handball players and show the relationship between hip rotation and knee valgus motion. Seventeen female players in the university handball team (8 with an ACL injury and nine uninjured) were recruited in this study. Results showed that smaller hip

external rotations ($P = 0.006$) (mean = 36.3, SD = 6.9) and greater hip internal rotation ($P = 0.012$) (mean = 55.6, SD = 9.0) were correlated with the incident of ACL injury in female handball players. Moreover, there is a significant connection between smaller hip external rotation range of motions and greater hip internal rotation with knee valgus induced by ACL injury screening tests ($P = 0.004$) (mean = 43.3, SD = 12.4). These study findings show the importance of a range of motion measurement of hip rotation to identify female athletes at risk for ACL injury (Yasuda et al., 2016). However, no random sampling was applied in this study; all the participants were volunteers, and the sample size was relatively small.

A retrospective study was done from May to October 2013 to show the predictor factors relevant to the lower limb position in non-contact (ACL) injuries among male athletes. Fifty-three males with a mean age of 25 years with complete non-contact ACL tear participated voluntarily in this study. The assessment was done for all the participants before the ACL reconstruction surgery and within twenty-one to eighty-four days after the reconstruction. Eight lower limbs measurements were conducted: the navicular drop, ankle dorsiflexion range of motion (ROM), internal tibial torsion, knee hyperextension, Q angle, hip internal rotation ROM, hip external rotation ROM and hip anteversion; each measure was repeated three times for the injured limb, and the mean of the three trials was used for data analysis. Results showed that from the eight lower limbs assessment tests only ankle dorsiflexion ROM (OR=0.62, 95% CI [0.45,0.86]) ($P = 0.004$, SD = 1.67), hip internal rotation ROM (OR=0.82, 95% CI [0.72,0.93]) ($P = 0.003$, SD = 4.51) and hip anteversion (OR=1.78, 95% CI [1.32,2.40]) ($P = 0.00$, SD = 2.73) were considered as accurate predictors of the ACL injury (Amraee et al., 2017). There is a demand for larger-scale retrospective studies with higher statistical power. On top of that, there is a need for interventional studies to correct the

ACL injury risk factors.

A prospective study was done by Oshima et al. (2018) to study the relationship between static balance and the incidence of noncontact ACL injury in female high school athletes. Two hundred seventy-six 15 years old high school female handball or basketball players were included in this study. Any participant with previous lower limb injuries or symptoms was excluded from the study. At the time of admission to the university, the static balance was measured for each athlete using a gravicorder, and the incidence of non-contact ACL injury was investigated for three years until the athletes graduated from high school. During the 3-years observational period, 27 players had an ACL injury, 24 injured players sustained a non-contact injury, and the other three suffered a contact injury. The 3 participants with contact injuries were excluded from the study. The comparison was made in the static balance between injured and uninjured players. The results showed that the ACL injured group had poor static balance compared to the uninjured group (mean =1.31, SD = 0.37) ($P = 0.046$). From this, the researcher concludes that poor static balance is one of the risk factors for non-contact ACL injury. The long observational period might be a limitation for this study, and there is a chance of injuries among the participants also the effect of the growth spurt among participants. Moreover, the researchers did not focus on one game but added two types of sport (handball and basketball).

A recent prospective study published in 2020 aimed to study the risk factors for noncontact ACL injury among high school females but only for basketball and handball teams. It included 317 high school female athletes aged 15 years, all of who underwent throw some examinations during their first year of high school. Their height, weight, navicular drop, general joint laxity, femoral anteversion angle, knee extensor/flexor muscle strength, hip abductor strength, and anterior laxity of the knee using the KT-1000 Knee Ligament

Arthrometer were measured. Thirty ACL tears occurred; three were contact injuries, while the remaining 27 were noncontact injuries. Greater body weight (95% CI, [1.030, 1.174], $P = 0.004$), a high hip abductor strength (95% CI, [1.462, 4.827], $P = 0.001$), and small femoral anteversion (95% CI, [0.746, 0.982], $P = 0.027$) were found to be risk factors for noncontact ACL injury in high school female basketball and handball players. However, several limitations exist in this study. First, it did not study the activity level of the players, and it is assumed that players with greater activity levels would be at a higher risk of injury. Also, the type of study, which is a prospective study, means that the data were collected prospectively from a single point in time, so weight and muscle strength might change over the years. Finally, the isokinetic testing machine will provide more accurate and reliable results than the hand-held dynamometer (Nakase et al., 2020).

Psychological factors

A prospective study was done to study the effect of psychological factors (personality, coping variables, and stress) on the risk of lower limb injuries. Forty-eight male soccer players aged between 16 to 36 years were included in the study. They were playing at a competitive level in three different teams in Sweden. Each participant completed five questionnaires to measure an athlete's competitive worry Football Worry Scale was used to study the personality factors Swedish universities Scales of Personality was used, the Life Events Survey for Collegiate Athletes was used to measure an athlete's life history stressors, and Daily Hassle Scale was used to measure athlete's level of daily hassles. Brief COPE was used to assess how players cope with the stressor.

Forty-eight participants completed the first four questionnaires (Football Worry Scale, Swedish universities Scales of Personality, Life Events Survey for

Collegiate Athletes, and Brief COPE), and only eighteen completed the daily hassles scale. Thirty percent of the participants reported missing one or more practice or competition sessions.

The result showed that the injured group had higher daily hassles before injury than the non-injured group, but this difference was not statistically significant ($F(1, 16) = 3.376$, $P = 0.085$). The group of non-injured players had significantly lower level of behavioral disengagement ($F(1,47) = 4.461$, $P = 0.040$) and self-blame ($F(1,47) = 4.264$, $P = 0.044$) compared to injured players. Additionally, the injured players had a significantly higher level of somatic trait anxiety ($F(1,43) = 5.432$, $P = 0.025$), psychic trait anxiety ($F(1,43) = 4.322$, $P = 0.044$), stress susceptibility ($F(1,43) = 6.285$, $P = 0.016$), and trait irritability ($F(1,43) = 5.517$, $P = 0.023$) (Ivarsson & Johnson, 2010). This study had a small sample size, and only one team out of the three had weekly followed up with the daily hassle score test.

2.3.2 External factors

Footwear and playing surface.

A control laboratory study was done to study the effect of playing surface and type of shoes on ACL injuries among soccer players. Four types of playing surfaces were examined gym turf, Kentucky, bluegrass, old artificial turf with rubber infill, and new artificial turf with rubber infill. Four soccer shoes were tested: soft ground, turf shoes, bladed studded, and round studded. Results showed that the natural grass with round studded cleats ($P = 0.028$) or turf shoes ($P = 0.029$) is the best in reducing the risk of ACL injury, followed by old artificial turf surfaces ($P = 0.0294$) (Mansfield & Bucinell, 2016). The study was done in the lab, and the result may change in actual playing or training situations.

Another controlled laboratory study was done by Villwock et al. (2009) to study the effect of footwear and play surfaces on rotational traction. Four playing surfaces were examined; two were artificial surfaces, and two were natural grass. Ten different shoes were tested on the four playing surfaces. The shoes were classified into five groups based on their properties: (1) cleated shoes, (2) moulded cleat shoes with 12 cleats, (3) moulded-cleat shoes with four cleats around the heel region, (4) cleat designs characterized by blade-style cleats (edge), and (5) shoes with a dense pattern of short elastomeric cleats distributed over the entire sole (turf). Results showed that both natural grass surfaces have significantly lower peak torque and rotational stiffness than the artificial surface ($P = 0.008$). There were no significant differences between the cleat patterns except for the turf-style cleat, which got the lowest torque ($P < .001$) (Villwock et al., 2009). There was a difference in the temperature while testing. There was a variation by 21°C in testing for the natural grass, while the artificial surfaces were tested at a similar temperature, which might affect the results.

Temperature

Laible et al. (2014) reported that ACL injuries are more likely to occur during hot and dry weather because the shoe-surface friction interaction increase in these weathers, so the ideal climate to reduce the chance of ACL injury is the cold and wet weather. Another study by Csapo et al. (2017) has different viewpoints, and the study was repeated measures study design (experimental); it was aimed to explore the causes for the increased likelihood of anterior cruciate ligament injuries under cold environmental conditions, the study investigated temperature effects on different neuro-muscular parameters. A sample of 10 healthy female subjects was included from the Department of Sport Science at the University of Innsbruck. Subjects suffering from acute

lower extremities injury and those who had previously injured their ACL were excluded from the study.

Infrared thermometry measured the body core temperature (IRT3020, Braun GmbH, Germany). In every case, the temperature was recorded three times: at baseline, after 20 minutes, and following the cold intervention. An arthrometer (GeNouRob, Laval, France) was used to measure the anterior displacement of the tibia (knee laxity). Motor neuron assessment was done using EMG, and surface EMG electrodes were applied over the rectus femoris, vastus lateralis, vastus medialis, semitendinosus muscles, and biceps femoris. A custom-built examination bed was used to measure the force; the load cell was connected to the lower leg proximal to the malleoli using a steel cable and a leather ankle cuff. The study concluded that knee laxity, force, and maximum voluntary contraction strength, were not affected by the decrease in the temperature.

On the other hand, there was a significant decrease in force generation of knee flexor muscles ($P = 0.016$). Also, there was a reduction of hamstring co-activation while knee extensors contracted. The study was conducted in a laboratory control environment. More studies with more sample size and in actual competition or training environment are needed (Csapo et al., 2017b).

Type of sport

An electronic literature review of 36 research was done through two databases, PubMed and EBSCOhost, from 1969 until 2017. No significant differences were found between male and female athletes' ACL injuries among the following sports groups: noncontact (IRR = 1.49) ($P = 0.22$), limited contact (IRR = 1.21) ($P = 0.77$), and collision ($P = 0.63$). Females had a higher risk of injury in both contacts (IRR = 3.00) ($P < .001$) and sports with high-impact

rotational landing (IRR = 5.51) ($P < .001$). However, sports with high-impact rotational landing had the highest rate of ACL injuries among all the groups (Montalvo et al., 2019). Unfortunately, this study did not clarify the mechanism of injury, whether ACL injuries were contact or non-contact. Also, the inclusion criteria were wide. They did not exclude the low-level studies with poor quality. There was an obvious difference in the number of females participating in collision sports, and fewer studies included female athletes.

A study was done to study the high school athletes ACL injury epidemiology among male and female athletes. Female were playing four different types of sport (soccer, volleyball, basketball, and softball), while male were playing five (football, soccer, basketball, baseball, and wrestling). One hundred schools were included in this study. The athletic trainer from each school assigned to record the injuries among player on a weekly basis from August 2007 until December 2012. During the study period they recorded 617 injuries. There was no difference between girls and boys in the ACL injury rates. Results showed that almost half of ACL injuries for females happened while playing soccer (53.2%), followed by basketball (26.5%), then softball (11.4%), and the lower injury rate was while playing volleyball (8.8%). On the other hand more than half of ACL injuries for males occurred while playing football (71.2%) , then soccer (17.2%), followed by basketball (5.5%), and wrestling (4.1%), while the lower was during playing baseball (2.0%) (Joseph et al., 2013) .

2.4 Prevention protocols

People might think of acute injuries as a state of bad luck or fate and do not realize that acute injuries are often predictable and preventable (Emery et al., 2006). A logical approach for reducing the chance of ACL injuries is to strengthen the ACL tissue to increase its ability to withstand the vast loads. Research has shown that collagen concentration and ligament force tolerance are significantly decreased post maturation, and training is ineffective in promoting collagen regeneration to strengthen ACL tissue. The keys to preventing ACL injuries are increasing the strength of muscles surrounding the knee and improving players' technique to reduce the external force effect (Donnelly, 2012).

Table (2.1): Summary of the prevention protocols

Author	Country	Sample	Type of exercise	Results
(Cochrane et al., 2010).	Australia	Male rugby athletes,	strength and balance training	Strengthening exercises are not effective in reducing the risk of ACL injuries when performing alone
(Herman et al., 2009)	USA	Recreational female athletes	Feedback with and without strength training	Programs that include both strength training and movement education through feedback is important to increase the effectiveness of anterior cruciate ligament prevention programs
(Pfeiffer et al., 2006).	USA	High-school female athletes aged between 13 to 18 years	Plyometric-based exercise program twice a week	Plyometric-based exercise program that performed twice a week throughout the season is not effective in reducing the rate of noncontact anterior cruciate ligament injuries
(Irmischer et al., 2004)	USA	Twenty-eight female athletes	Low-intensity plyometric based knee ligament injury prevention program	The results showed that there was a significant reduction in peak vertical impact forces ($p = 0.0004$) and rate of force development ($p = 0.0205$)

(Myer et al., 2008).	USA	Fifty-three female athletes aged between 13–17 years	Comprehensive neuromuscular training program.	Results showed that there is significant improvement in squat, bench press, single leg hop test, double leg vertical jump, sprint time.
(Steffen et al., 2008).	Norway	2092 female football players	FIFA 11+ exercises protocol for core stability, lower extremity strength, neuromuscular control, and agility.	No difference was observed in the overall injury rate between the intervention and control group
(Sugimoto et al., 2016).	USA	Female athletes	Neuromuscular training intervention	ACL prevention protocols are effective in reducing ACL rates among female athletes. Also, it is concluded that for getting the most effective results from the prevention protocol it should apply on young participants, longer than 20 min in duration and frequency greater than two times per week
(Daneshjoo et al., 2012).	Malaysia	Thirty-six soccer players aged between 17 and 20 years	FIFA 11+ and HarmoKnee	The two warm up programs turn out to be objectively effective in improving proprioception and balance, which in turn may improve performance and prevent lower injuries especially ACL

(Longo et al., 2012)	England	121 elite male basketball players	FIFA 11+	The warm-up program is effective in reducing the injury rate in male basketball players
(Sadigursky et al., 2017)	Brazil	6,344 soccer players	FIFA 11+	The program reduced injuries in soccer players by 30%
(Silvers et al., 2014)	USA	1525 collage male soccer players	Online FIFA 11+	The program is effective in reducing injuries in soccer players

2.4.1 Strengthening exercises

An experimental study examined the effect of 12 weeks of strength and balance training in male rugby athletes. Kinematic and kinetic variables were studied for each participant while performing side-stepping to 30 and 60 degrees, cross-over cutting to 30 degrees, and straight-line running. Fifty healthy males were included in the study and were divided into four treatment groups and a control group. The first group did a machine weights strength training only for leg curl and leg press exercises using pin-loaded isotonic resistance machines. The second group only did free weights strength training using leg curl and squat exercises with free weights. The third group did balance training only using balance instruments such as dura discs, wobble boards, tilt boards, mini trampolines, and Swiss balls. Balance exercises were progressed from double-legged to single-legged static balancing, double-legged to single-legged squats, and stability challenging exercises while maintaining balance on the various equipment. The fourth group was the combination group containing the machine-based exercises in the machine weights group and balance exercises in the balance training group. All training groups were doing the exercises for 30 minutes, three times per week for 12 weeks. Results showed that the peak internal rotation moment increased by 28% after free weights training, increasing from 0.13 to 0.16 after the training ($P < 0.001$). The balance training group decreased the peak internal rotation moments by 15%, from 0.19 to 0.16 ($P < 0.001$). However, there was a decrease in the peak internal rotation, but this decrease was not statically significant. Also, there was a substantial reduction in the peak valgus only in the balance group. This study shows that strengthening exercises are ineffective in lowering the risk of ACL injuries when performed alone. It's important to state that there were some limitations in this study. First, this study was done in a lab, so the results in the real world

might be different. Second, the strength training contained only two exercises and was done only in the sagittal plane while the balance training exercises were in three planes and might be similar to the strength program in time but not in volume (Cochrane et al., 2010).

Another controlled laboratory experimental study was done to study the impact of feedback with and without strength training on lower limb biomechanics. Fifty-eight recreational female athletes participated in this study. They were assigned into two groups: the first group did nine weeks of strengthening exercises with movement education feedback using illustrative video, and the second group was given only nine weeks of movement education feedback using illustrative videos. Knee and hip kinematic and kinetic were assessed for all the participants while performing three stop-jump tasks. Results showed that programs that contain both strength training and movement education through feedback are essential to improve the effectiveness of anterior cruciate ligament prevention programs. Also, there was an increase in the hip abduction angle ($P < 0.001$) in the group that performed strength training with feedback, but no increase was observed in the group that received feedback only. Also, the peak knee anterior shear force ($P = 0.015$) decreased in the group that performed strength training with feedback but increased in the group that received only feedback ($P = 0.009$) (Herman et al., 2009).

There is a contrast between the two previous studies' results. The finding might be due to several factors, such as the participant's gender and activity level characteristics. The study by Cochrane et al. (2010) consisted of male rugby competitive level players, while Herman et al. (2009) contained female recreational athletes. It is also possible that the participants in the Cochrane et al. (2010) study already had sufficient strength. Therefore, the strengthening program did not add a lot to their results. Moreover, there is also a difference in

the intervention program as one was combined with balance training while the other was combined with feedback training.

2.4.2 Plyometric exercise

A two-year prospective cohort study was done to evaluate the outcome of a knee prevention program that prevents knee ligamentous injuries on the prevalence of noncontact anterior cruciate ligament injuries among high-school female athletes aged between 13 to 18 years. A total of 1439 athletes playing three types of sports: basketball, volleyball, and soccer, from 15 schools (112 teams) were split into the control group (862 athletes) and treatment group (577 athletes) and were monitored for two consecutive seasons. The intervention group engaged in a plyometric exercise protocol twice weekly during the playing season. Exercises, games, and matches that were played and adherence to the exercise program were documented every week. Confirmation of possible noncontact anterior cruciate ligament injuries was done according to patient history, surgery time, and/or magnetic resonance imaging results. The results revealed six confirmed noncontact anterior cruciate ligament injuries: half of them in the treatment group and the other half in the control group. The prevalence of noncontact anterior cruciate ligament injuries per thousand exposures was 0.167 in the intervention group while it was 0.078 in the control group, showing an odds ratio of 2.05, which was not significant ($P > 0.05$). So this study's results showed that this 20 min prevention program containing plyometric exercises is ineffective in reducing the rate of non-contact ACL injuries. (Pfeiffer et al., 2006).

An experimental study was done to evaluate the peak vertical impact forces and rate of force development after nine weeks of low-intensity plyometric exercises designed to prevent knee ligament injury, composed of

simple jump landing tasks. Twenty-eight females participated in this study, and they were randomly assigned into two different groups. Treatment subjects attend the plyometric injury prevention program twice a week. Ground reaction forces generated during a step-land protocol (peak vertical impact forces and rate of force development) were assessed at the starting of the study and the end of the ninth week. The results showed that there was a significant reduction in peak vertical impact forces ($P = 0.0004$) and rate of force development ($P = 0.0205$) (Irmischer et al., 2004).

The possible explanation of the variation in the previous research results is that the movement pattern of the plyometric exercises in the study of Pfeiffer et al. (2006) might not be related to the ACL mechanism of injury. For this reason, it was not effective in preventing ACL injuries. Also, the difference in the volume and intensity of the exercise might cause the difference. One more explanation is that the first study studied the effect of plyometric exercises on the incidence rate of ACL injury. In contrast, the second study investigated the impact of some of the ACL injury risk factors.

2.4.3 Mixed methods

Myer et al. (2005) did a controlled experimental study to study the effects of a neuromuscular training program on female athletes' performance and biomechanics of the lower limbs. Fifty-three female athletes aged between 13–17 years were included in this study. A neuromuscular training protocol was applied for six weeks, containing plyometric, movement education, core strengthening, balance training, resistance training, and interval speed training. The training session lasted for approximately 90 minutes three times per week. The pretested assessment was done for both groups (Control and experimental)1

week before the training session. The post-test test assessment was done four days after the training session, approximately seven weeks after the pre-test.

Results showed that there is an improvement in the mean of the one repetitive maximum of the squat by 92% ($P = 0.001$), there was a 20% improvement in the bench press ($P = 0.001$), right single-leg hop increased by 10.4cm and the left single-leg hop distance increased by 8.5 cm ($P = 0.001$), there is improvement in double-leg vertical jump also it moved from 39.9 ± 0.9 cm to 43.2 ± 1.1 cm ($P = 0.001$), the average of the sprint time reduced in the intervention group significantly. The mean of 9.1-m sprint speed increased from 1.80 ± 0.02 sec to 1.73 ± 0.01 sec ($P = 0.001$). The internal valgus torque for the right knee was reduced by 28% ($P = 0.001$), while the internal varus torque for the right knee was reduced by 38% ($P = 0.001$). The control group demonstrated no significant improvement in any parameters after the study period. Unfortunately, this type of training protocol is considered exhaustive. It needs a lot of time and equipment, which might limit its applications in the real clinical practice, and a large segment of athletes won't be able to take advantage of this prevention program (Myer et al., 2008).

A Systematic review and meta-regression were done to determine the essential parts of neuromuscular training that optimize ACL injury reduction among female athletes. The results showed that the ACL prevention protocols are productive in reducing ACL incidence among female athletes. Also, it is concluded that for getting the most effective results from the prevention protocol, it should apply to young participants for more than 20 min, not less than three times per week, with more than one type of exercise, and it is better to be with the verbal feedback. Initially, this study was designed to assess compliance and adherence to the program as one of the factors wanted to study. However, most reviewed studies did not record the compliance/ adherence information in the original studies. Moreover, most of the studies included

female football players, and only six had handball, basketball, volleyball, and floorball female players. Additionally, of the 14 studies, only 4 included participants over 18 years (Sugimoto et al., 2016).

A cluster-randomized controlled trial was done to study the effect of the FIFA 11+ on the incidence of lower limb injuries among female football players. Teams were divided randomly into two groups, the intervention group included 1091 athletes from 559 teams, and the control group contained 1001 athletes from 544 teams. FIFA 11+ exercises protocol was applied to the intervention groups, and it has core stability exercises, lower limbs strengthening exercises, neuromuscular control, and agility training. The protocol was done over eight months for 15 min. Twenty percent of the athletes (396) had injuries. The rate of injury was the same in the control and intervention ($P = 0.94$) (Steffen et al., 2008). The limitations of this study are the low study statistical power and the low adherence to the program.

A cluster randomized control trial done by Longo et al. (2012) agreed with Steffen et al. (2008) results. It revealed no significant effect of FIFA11+ on ankles and knee injuries. It was done to study the impact of FIFA 11+ protocol among male basketball players. Eleven teams were randomized to the control and intervention groups. Eighty players from seven teams were placed in the intervention group, which underwent FIFA 11+ program, while forty-one players from four teams were placed in the control group and received their regular training. Results shows that the FIFA 11+ program is effective in lowering the injury incidence in elite male basketball players, the intervention group had statistically significant lower injury rates for trunk ($P = 0.013$), hip, and groin ($P = 0.023$). Still, there is no significant difference in knee and ankle injuries. The limitation of this study is that the control group performed their regular warm-up program there wasn't any standardized program of warmup, teams were not blinded to the exercise protocol, there is a difference in the two

groups' sample size, and because they used cluster randomization, the control group participants were older, taller, and heavier. So all these factors will affect the results (Longo et al., 2012).

A literature review and meta-analysis were done to assess the effectiveness of the FIFA 11+ injury prevention protocol for both genders of soccer players. The inclusion and exclusion criteria classified the research according to PICO, which stands for Patient, Intervention, Comparison, and Objectives. Only six investigations met the inclusion and exclusion criteria. The study included only randomized clinical trial studies investigating the relationship between the FIFA 11+ prevention protocol and injury prevention among soccer players. Only articles published between 2006 and 2016 in English, Portuguese, French, and Spanish were selected. Any study that doesn't contain randomization, studies with an inadequate description or missing data, participants not playing soccer, and those with any kind of injuries were excluded from the study. The sample size included 6,344 soccer players, of which 3,307 (52%) belonged to the intervention group and 3,037 (48%) belonged to the control group. Results showed that the FIFA 11+ protocol decreases the risk of injuries among soccer players by thirty percent, with a relative risk of (95% CI [0.52–0.93]) ($P = 0.01$). Twenty-four percent of the participants (779) in the intervention group had injuries, compared to forty percent in the control group (1219). The limitations of this study were the few literature references about this topic, only a few studies available in the literature, and almost all of them did not follow a standard protocol for the warm-up program. Some application errors may affect the results (Sadigursky et al., 2017).

The previous studies disagreed with Steffen et al. (2008) and Longo et al. (2012) results. They found that FIFA 11+ is an effective prevention protocol in reducing knee injuries, especially ACL. The variation of the results between the

studies may be due to the limitation in Steffen et al. (2008) study, as the participant's compliance with the prevention program was low. In the study by Longo et al. (2012), the control group performed their usual warm-up program. There wasn't any standardized program.

2.4.4 Online prevention protocols

A prospective randomized controlled trial was conducted to investigate the effectiveness of the FIFA 11+ injury prevention protocol among college male soccer players. Sixty-one collages were included in this study. Randomization was done to allocate the participants to the intervention or control groups. Eight hundred fifty participants were obtained from Thirty-four control collages, and six hundred seventy-five participants were obtained from twenty-seven intervention collages. To explain the FIFA 11+ prevention program, instructional DVDs and teaching manuals were given to the intervention group. The prevention program was done through the playing session twice or three times per week. Results showed that the intervention group had two hundred eighty-five injuries (mean= 10.56 ± 3.64).

In contrast, the control group had six hundred sixty-five Injuries (mean= 20.15 ± 11.01). The intervention group total days missed due to injury was 2824 (mean=9.94) compared to 8776 days (mean =13.20) in the control group. So the intervention group had lower injury rates and lower missed days

One of the limitations of this study is that the training was done online; due to the big geographical area of the study, there was no direct contact or training with each individual college or team, which might affect the performance of the exercises. Simultaneously, an online prevention program might be needed in some situations, like during the COVID-19 pandemic, when

the direct contact and meeting in the sports facilities are not safe (Silvers et al., 2014).

2.5 Other factors affecting the prevention protocols

2.5.1 Injury prevention adherence and motivation

Multielement ACL injury prevention training protocols have reached a range from 39% to 82% ACL injury risk reduction (Gagnier, Morgenstern, & Chess, 2013; Grindstaff, Hammill, Tuzson, & Hertel, 2006; Hewett, Ford, & Myer, 2006; Nessler et al., 2017; Sadoghi, von Keudell, & Vavken, 2012; Sugimoto, Myer, McKeon, & Hewett, 2012; Taylor, Waxman, Richter, & Shultz, 2015; Yoo et al., 2010). The cause for the variation in the range of reduction in injury rates between programs may be due to deviation in the prevention protocol adherence rate (Warren, 2021).

A meta-analysis was done to study the relation between adherence levels to ACL injury prevention programs and the decrease in ACL rates among young female athletes. Search was conducted through four different search engines in the period from 1995 until 2010. Any prospective and controlled research that contain female participants, mention the amount of ACL injuries, used a neuromuscular training protocol, and provided information about the adherence to the training program were included in this study. Only six studies out of two hundred five met the inclusion criteria. To calculate the overall rate of compliance, they calculated the attendance as the total number of athletes who finish each session converted into a percentage of the entire number of athletes, and the intervention completion was calculated as the total number of sessions done by the total number of athletes converted into a percentage of the entire number of training sessions. Sugimoto et al. (2012) divided the compliance into three levels: high (>66.6%), moderate (33.3-66.6%), and low (<33.3%). The

results showed that studies with lower and moderate levels of compliance rates have higher ACL injury incidence rates compared to studies with higher compliance rates (95% CI, [0.02-0.77], $P = 0.18$) (Sugimoto et al., 2012).

Several social psychological theories have been applied in the sports injury rehabilitation environment to increase athletes' adherence to prevention protocols and to improve the effectiveness of these programs. (Chan et al., 2017; Seeberg, 2016). Motivation is one of the most important factors that affect adherence to exercises that received early focus in sports psychology research. Motivation has been described as the action whereby goal-directed activities are started and sustained (Cook & Artino, 2016). However, the players adherence to a rehabilitation or prevention program is still not well-understood, this may be due to the deficiency of rich qualitative studies that are designed to investigate the adherence factors (Seeberg et al., 2016).

2.5.2 Injury prevention education

Practical and exercise approaches are not the exclusive procedures to improve biomechanical techniques and reduce the risk of lower limb injuries. One study showed that elevation of the level of knowledge and understanding of ACL injury can also contribute to improving landing strategies and leading to fewer chances of ACL injuries. One hundred thirty-three females that play basketball in high school and twelve coaches were included in this study. Knee anatomy and physiology were explained to the participants, also information about ACL, ACL injury risk factors, ACL injury prevention strategies, and instructions about safe landing techniques were explained to participants. At the beginning and end of the season, there was an evaluation to assess players' and coaches' knowledge about ACL, their behavior toward ACL injury prevention, as well as players' landing techniques. After the intervention, there was a

significant improvement in knowledge about ACL injury for players and coaches. In addition, the number of errors associated with landings significantly decreased (Iversen & Friden, 2009).

2.6 Outcomes measured

2.6.1 Static and dynamic balance tests

The Y-balance test is a functional outcome measure that helped to measure the dynamic balance. It was developed based on previous research suggesting a less time-consuming outcome measure because the Star Excursion Balance Test (SEBT) requires a lot of time to apply. The eight directions of the SEBT were developed into a more time-efficient test that contained only three directions (anterior, posteromedial, and posterolateral). There is proof in the evidence on the YBT results as an indicator for injuries. Studies showed that there is a chance to have 2.5 times increase in the possibility to get lower limbs injury if there is more than a four cm difference in the anterior, left or right YBT score between the two lower limbs results (Shaffer et al., 2013).

A study in a military setting was done using multiple raters to test the interrater test-retest reliability of the YBT. Sixty-four service members voluntarily participated in this study, 53 of them were males, and the remaining 11 were females, their age range from 18 to 35 years. Each participant was assessed by a different randomly assigned rater on the second day who was blinded to the first day results. The results showed that the YBT has good interrater test-retest reliability (ICC= 0.85 to 0.93), and the level of measurement error among multiple raters screening active service members are considered with an acceptable level. this study only included actively training service members and no randomization was done, so we can't generalize the results (Shaffer et al., 2013).

A prospective cohort study was done to assess the validity of the y-balance test in suspecting soft tissue injuries among professional soccer players. Seventy-four male professional football players were included in this study. The results showed that the YBT must be counted as a helpful assessment tool in identifying players with a higher risk for soft tissue injuries. The inter and intra-evaluator reliability of this test is high (95% CI, [0.88, 0.99], $P < .01$). Moreover, the YBT is considered helpful during pre-season assessment and before returning to play after injuries. According to Logistic regression models results, there was a 3.86% increase in the chance of lower extremity injury among players if they have a difference of four cm or more between lower extremities in posteromedial reach. ($P = 0.001$) (Gonell et al., 2015).

A cross-sectional study was done among healthy young adults in Saudi Arabia. It was designed to initiate YBT reference values according to gender, and to translate the Lower Extremity Functional Scale into Arabic (LEFS-Ar). Also, to compare between male and female YBT and LEFS-Ar results. Sixty-one males and females aged between 18–29 years old voluntarily participated in this study. The results indicated that males have better results than females in YBT ($P = 0.04$). Although, no difference was found between males and females in LEFS-Ar results ($P = 0.77$). Also, reference values for YBT and LEFS were established for young Saudi adults (Table 2.1) (Alnahdi et al., 2015; Maribo et al., 2009). There was no randomization in this study. Further studies are required to obtain reference values for the same outcome measures in other age groups and different populations like athletes.

Table (2.2): Reference values for the Y Balance Test (a percentage of the leg length [%LL]) and LEFS-Ar (Alnahdi et al., 2015).

Variable	Females		Males		Gender difference
	Mean $\pm$ SD	95% CI	Mean $\pm$ SD	95%CI	Mean difference (95% CI)
Anterior (%LL)					
Right	70.1 $\pm$ 4.1	68.6–71.6	73.1 $\pm$ 7.3	70.4–75.8	2.9 (–0.08 to 6.0)
Left	70.4 $\pm$ 4.3	68.8–71.9	73.5 $\pm$ 8.5	70.4–76.7	3.2 (–0.32 to 6.6)
Dominant	70.2 $\pm$ 4.3	68.6–71.7	73.0 $\pm$ 7.5	70.2–75.8	2.8 (–0.3 to 6.0)
Non-dominant	70.3 $\pm$ 4.1	68.8–71.9	73.6 $\pm$ 8.3	70.6–76.7	3.3 (–0.1 to 6.7)
Average ^a	70.3 $\pm$ 3.9	68.8–71.7	73.3 $\pm$ 7.0	70.7–75.9	3.1 (0.1 to 6.0)*
Posteromedial (%LL)					
Right	93.7 $\pm$ 7.3	91.0–96.4	104.2 $\pm$ 8.4	101.1–107.4	10.5 (6.5 to 14.6)*
Left	92.9 $\pm$ 7.8	90.0–95.8	107.0 $\pm$ 8.7	103.8–110.2	14.1 (9.8 to 18.3)*
Dominant	93.4 $\pm$ 7.4	90.7–96.1	104.3 $\pm$ 8.6	101.0–107.5	10.8 (6.7 to 14.9)*
Non-dominant	93.2 $\pm$ 7.9	90.3–96.1	107.0 $\pm$ 8.5	103.8–110.2	13.8 (9.6 to 18.0)*
Average	93.3 $\pm$ 7.3	90.6–96.0	105.6 $\pm$ 7.8	102.7–108.6	12.3 (8.4 to 16.2)*
Posterolateral (%LL)					
Right	92.3 $\pm$ 8.0	89.4–95.3	105.0 $\pm$ 10.0	101.3–108.8	12.6 (8.0 to 17.3)*
Left	92.8 $\pm$ 9.0	89.5–96.1	105.3 $\pm$ 11.6	101.0–109.7	12.5 (7.2 to 17.8)*
Dominant	92.3 $\pm$ 8.5	89.2–95.4	105.8 $\pm$ 10.5	101.9–109.7	13.5 (8.7 to 18.4)*
Non-dominant	92.9 $\pm$ 8.6	89.8–96.0	104.5 $\pm$ 11.2	100.4–108.7	11.6 (6.5 to 16.7)*
Average	92.6 $\pm$ 8.0	89.6–95.5	105.2 $\pm$ 10.3	101.3–109.0	12.6 (7.8 to 17.3)*
Composite (%LL)					
Right	85.4 $\pm$ 5.7	83.3–87.5	94.1 $\pm$ 7.2	91.4–96.8	8.7 (5.4 to 12.1)*
Left	85.4 $\pm$ 6.3	83.0–87.7	95.3 $\pm$ 7.4	92.5–98.1	9.9 (6.4 to 13.4)*
Dominant	85.3 $\pm$ 6.0	83.1–87.5	94.1 $\pm$ 7.0	91.5–96.8	8.8 (5.5 to 12.2)*
Non-dominant	85.5 $\pm$ 6.1	83.2–87.7	95.3 $\pm$ 7.6	92.5–98.1	9.8 (6.3 to 13.3)*
Average	85.4 $\pm$ 5.8	83.2–87.5	94.7 $\pm$ 7.0	92.1–97.3	9.3 (6.0 to 12.6)*
LEFS-Ar	74.3 $\pm$ 6.6	71.9–76.7	74.8 $\pm$ 5.2	72.8–76.7	0.44 (–2.6 to 3.5)

%LL: percentage of leg length; CI: confidence interval; LEFS-Ar: Arabic version of the Lower Extremity Functional Scale

^aAverage of both the legs; *Significant difference between males and females ($p < 0.05$)

A study was done to measure the absolute and relative reliability of intra-observer and inter-observer measurements of static balance using the one leg stand test among participants with low back pain. Patients were randomly

assigned to the groups. The study included 21 participants with lower back pain in the intra-observer group and they were tested by the same physiotherapist twice. On the other hand, twenty-seven patients were in the inter-observer group and they were tested by two different physiotherapists independently. Results showed that using this protocol in a population of patients with chronic low back pain, the reliability is acceptable with a standard error of measurement of 2.48 and 1.42 and a minimal detectable change of 6.88 and 3.95 for the intra-observer and inter-observer reliability respectively. The relative reliability of the one leg stand test seems to be like the computerized balance test that was performed on a force platform (ICC= 0.86). But the one leg stand test is much easier without complications and without the need for technical equipment (Maribo et al., 2009). The previous research was done only on patients with lower back pain, not on healthy or athletic populations, and the sample size was relatively small.

2.6.2 Hop Tests:

A test-retest reliability study was constructed to assess four types of hop tests, three of them for distance (single hop, triple hop, and crossover hop), and one for time (6 meters time hop test). Two testing sessions were done, and the second one was done 4 weeks apart from the first one. Eighteen men without any medical problems were included in this study. Repeated measures analysis of variance was used to test the reliability of the four hop tests. The results reveal that the previous hop tests are reliable techniques to assess horizontal jumping abilities for healthy men with 4 weeks intervals between the first and second sessions. The intraclass correlation coefficients (ICCs) for the 4 hop tests were 0.92 to 0.97. Moreover, the standard errors of measurement (SEMs) for the single hop, triple hop, and crossover hop tests that evaluate the jump distance ranged between 4.61 to 17.74 cm. The SEM for the 6-meter time hop

test which evaluate the time was 0.06 seconds. No clinically significant changes were noted between the repeated measures analysis of variance when the mean scores of the 2 test trials were compared by a repeated measures analysis of variance for any of the single leg hop tests.

2.6.3 Tuck jump

The Tuck Jump Test (TJT) is a clinician examining tool that was designed to help the coaches and the physical therapists in identifying the most common neuromuscular deficits that lead to a higher chance of anterior cruciate ligament injury (Dudley et al., 2013).

Attention was focused by many experts in the field on finding clinical tools that are easy, less complicated, and with minimum cost to screen the lower limbs biomechanical compared to the laboratory methods (Crossley et al., 2011; Fox et al., 2016; McCunn et al., 2016; Padua et al., 2011). One of the most popular tests are the single-leg squat, single-leg, and bilateral drop vertical jump. There are some limitations in the previous assessment tools, the single leg squat is a low intensity test not like the high intensity actions and sport specific movements that lead to lower limbs injuries. Both the single-leg and two-leg vertical drop jump are not designed to assess repeated sequent jumps it only evaluates the landing phase of one single land. On the other hand, the repeated nature of the tuck jump test mimics the sport specific movements with high intensity actions it examines the landing process errors during a maximum repeated plyometric action (Herrington et al., 2013).

A study was done to investigate the tuck jump test interrater and interrater reliability by raters of different educational qualifications and different clinical conditions. Forty participants were included in this study, they were video recorded while applying a tuck jump test based on approved published protocol.

The videos were scored again one month after the first records by 3 raters. The results showed that there is poor interrater reliability by 5 raters (95% CI, [0.33–0.62], $P=0.47$). However, the inter-rater reliability was improved between the 3 raters who completed the two scoring sessions. It jumped from 95% CI, [0.35–0.68], (MEAN= 0.52) for the first session to 95% CI [0.55, 0.81], (MEAN= 0.69) for the second session. There was poor to moderate Intra-rater reliability extending from 95% CI [0.22, 0.68] (MEAN= 0.44) to 95% CI [0.55, 0.84] (MEAN= 0.72) (Dudley et al., 2013).

Another study was done to measure the inter-tester and intra-tester reliability of the tuck jump test (TJT). Ten participants were involved in the study (5 male and 5 female athletes). The participants perform the tuck jump test, and two independent examiners calculated the scores at two different times. The results showed that when comparing the two assessor scores of the tuck jump, the study showed very good–excellent intra-tester and inter-tester reliability for both examiners. There was a complete agreement in 5 out of 10 participants for the entire grading criteria. There was good reliability for the test, the score of the kappa measure of agreement was 0.88. The intra-tester ranged from 87.2% to 100%, with kappa values of 0.86–1.0 (Herrington et al., 2013).

The results of Dudley et al. (2013) contrast with Herrington et al. (2013) results. The difference in the results might be due to different factors. For instance, the small sample size in the Herrington et al. (2013) study may cause a bias because the raters might have remembered the previous scores of the participants. Moreover, in the study by Dudley et al. (2013), the raters were from different educational and experience levels and that may lead to the difference in the results. Educated raters with more experience might be more accurate in scoring the TJT than raters with lower educational and experience levels.

2.7 Summary

Most of the previous studies contained a lot of methodological errors such as lack of randomization, low sample sizes, low study power, and high dropout rates. There is a serious demand for larger scale studies that investigate the relationship between lower limb alignments and ACL injuries with larger sample sizes and more statistical power. As well as that, interventional studies that aim to correct the hip, knees, and ankle biomechanical risk factors to reduce the risk of ACL injuries are required (Amraee et al., 2017). Overall, the results indicated that most female players are at high risk for knee injuries, due to the abnormal movement in their mechanics. Such findings spot the light on the need for greater application of prevention protocols to reduce female injury rates (Beese et al., 2015).

Chapter 3

Methods and Procedure

3.1 Study design and sampling

The study is an open label study where both the investigator and trial participants are fully aware of the prevention protocol. A convenience sampling method involving thirty female athletes was followed.

3.2 The study setting:

This study involves players from two different clubs in Bahrain.

3.3 Ethical Approval

The ethical approval to start the study was obtained from the Research and Ethics Committee at the College of Health and Sport Sciences, University of Bahrain (Rec. No. 11/2020-21, 23 February 2021). The study protocol was also approved by the University of Bahrain Council (Decision 683/2020).

3.4 Participants and recruitment

3.4.1 Eligibility

To be eligible to participate in the study, the participants should have met the following inclusion criteria:

- Female athlete
- Their age is between 18 to 35 years

- Had a minimum of 6 months of training experience in amateur competitive level, training at least 3 days per week (García-Luna et al., 2020)

The following criteria were applied to exclude participants before starting the study:

- Musculoskeletal injuries to the hips, knees, and ankles in the last three months.
- Surgeries in the lower extremities.

Postural abnormalities in the lower limbs such as knee genu valgus (knee Q angle > 20) or knee genu varum (knee Q angle < 10).

- General body hypermobility with Beighton score equal to or more than five (Figure 3.1).
- Cardiac or respiratory problems such as asthma, arrhythmia, pneumonia, chronic obstructive pulmonary disease
- Participation in any lower limb injury prevention protocol in the last 6 months.

Moreover, the participants were excluded from the study after the start of the protocol if:

- The participant is not correctly applying the program
- Any injuries occurred during the study period

3.4.2 Recruitment

Female athletes aged between eighteen to thirty-five years old were recruited for this study in the period between March and September 2021. Advertisements were sent by WhatsApp. Also, three sports clubs were contacted to encourage their players to voluntarily participate in this study.

Once the participants showed interest in the study, a clear information sheet was given to the participants in hard or soft copies if they were interested in participating (Appendix 1). Next, they were sent an eligibility questionnaire via WhatsApp or email (Appendix 2). The participants' posture and general joint mobility were tested through video calls. Those who are eligible and accept to participate in this study read and signed an informed-consent form (Appendix 3). They were also told that they can ask any question at any time they want, and they can withdraw from the study at any level without explaining any reasons or clarifications.

3.5 Potential risk and safety

The study protocol, procedures, and the potential risks were explained to the participants. Also, they were informed that they have the right to withdraw at any stage of the study.

The procedures done in this study are non-invasive. However, the participants might experience mild muscle soreness and fatigue. To reduce the impact of these side effects, a stretching exercises protocol was given at the end of the sessions and there was a gradual increase in the intensity and repetition of the exercises (Appendix 5). The participants were told to use ice and rest if they complained of any soreness or fatigue. Moreover, the participant was asked to contact the researcher if there were any concerns.

Due to the Corona Virus 2019 (COVID-19) pandemic, some additional precautions were taken to ensure participant safety based on recommendations by the National Collegiate Athletic Association (NCAA). Education was the first step in which information about COVID-19 signs and symptoms and the way of spreading the virus were provided. Before entering the training facility, a screening assessment was done to check if the participants have any signs or

symptoms and to measure their temperature. Any participant who showed any signs or symptoms or had fever had to have a COVID-19 rapid test before entering the facility. Moreover, everyone had to wear a mask inside the facility during the testing protocol, and disinfectants and sanitizers were provided. On top of that, the COVID-19 rapid test was done to all participants twice per week. The study procedures were modified to ensure a social distance of 1.8 meters. Additionally, the prevention protocol was done online using WhatsApp video call and one part of the prevention protocol was removed because it contained an exercise that required training with a partner.

3.6 Testing

3.6.1 Mobility and Postural Assessment

General body mobility

The researcher, who is a physiotherapist, performed all tests in this study. General body hypermobility was tested online by video call by using the Beighton score (Figure 3.1). It is a numerical mobility score ranging from 0 to 9, and one point is given for the ability to perform one of the following tests:

- 1) Taking the small finger back more than 90 degrees (1 point on each side)
- 2) Taking the thumb back to reach the front of the forearm (1 point on each side)
- 3) Bending the elbow more than straight line (1 point on each side)

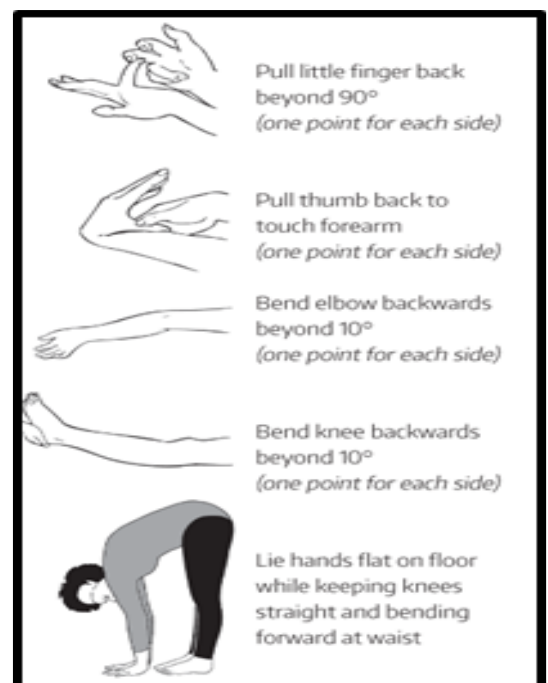


Figure (3.1): Beighton score (Clinch et al., 2011)

- 4) Bending the knee beyond a straight line (1 point on each side)
- 5) Resting the hands flat on the ground without flexing the knees (1 point)

Interpretability: A positive Beighton score for adults is 5 out of the 9 possible points indicating general body hypermobility. The intra-rater [ICC: 0.71–0.82] and the inter-rater [ICC: 0.72–0.80] reliability of the Beighton Score are very high (Singh et al., 2017).

Postural assessment

The postural assessment was completed online by video call. The participants were barefoot and were standing in a relaxed position. The various components of the postural assessment were evaluated anteriorly, posteriorly, and laterally (sideways). Moreover, a dynamic postural assessment while walking was also conducted. Participants with postural deformities to the knees like genu varum and genu valgum or other lower limb deformities were excluded. The postural assessment was done the second time in the presence after signing the consent form to make sure that there are no postural deformities.

Reliability: Basic musculoskeletal postural assessment is sufficiently reliable when performed by trained clinicians. Posture, mobility, and movement can be assessed with adequate reliability (Singla & Veqar, 2014).

Leg length was measured during the first session for all the participants using tape measurement, they were asked to lay in a supine position and the measurement was done from the anterior superior iliac spine (ASIS) to the distal tip of the medial malleolus (Munro & Herrington, 2011).

3.7.2 Outcomes measured

General Procedure

All the measurements were done by the researcher who is a physiotherapist with 8 years of experience. Hop tests, y-balance test, static balance test and tuck jump test were applied for the first time pre intervention, then they were repeated after 2 and 4 weeks from the prevention protocol.

The tests and measurements for each leg were done individually for all the participants except for the tuck jump test. For the single leg stance test and Y-balance test, the participants were asked to remove their shoes and socks to eliminate the effect of the support and stability from the shoes (Markström et al., 2018). For the tuck jump and hop test, the participants were asked to wear sports shoes and to wear the same shoes for all the remaining tests. Also, they were told to wear shorts or comfortable sport leggings.

All participants in the study were asked to perform three practice trials to be familiar with the test and to reduce the learning effect. Two minutes rest period was given between each test and 30 seconds between each trial were also given to reduce fatigue (Phillips & van Deursen, 2008). Each test was enhanced with verbal feedback during the familiarization period and visual demonstration by a video showing each test.

Hop Tests

The aim of the Hop Tests is to test the functional performance of the participants. They are measured using a normal metric tape measurement. Three types of hop tests were used in this study (single hop, triple hop, and crossover hop) (Figure 3.2).

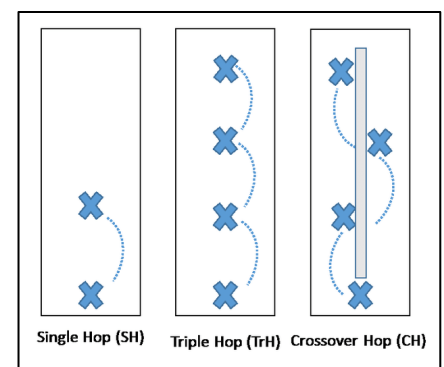


Figure (3.2): Hop tests (Greenberg et al., 2019)

The Hop Tests procedures were conducted according to the protocol by Ross et al. (2002). An eight-meter line was made using masking tape, and another line of 0.3 meters was applied perpendicular to the first line as an indicator for the starting point. Each participant performed 3 practice trials in the following order: single hop for distance, triple hop for distance, and crossover hop for distance. The participants should jump and land on one leg and maintain stability for 3 seconds. If the participant jumped and touched the floor with the non-weight bearing leg during landing, landed with both legs, or did not maintain stability for 3 seconds, it was considered an error and another jump should be performed. All tests were performed after completing the practice trials and the average of the three trials was used in data analysis.

- *Single hop test:* At the beginning of the test, the participants stand on one leg with their toes on the marked starting point. They were asked to jump as far as possible horizontally on a single leg without losing balance and landing firmly on the same leg. The distance from the starting point to the heel was measured, and the same procedure was done to the other leg.
- *Triple hop test:* The same procedure as the single hop test is followed. However, the participants are asked to jump as far as possible on a single leg, three consecutive times and land firmly without losing balance. The distance from the starting point to the heel were measured, and the same procedure was done to the other leg.
- *Crossover hop test:* In this test, the participants are asked to jump horizontally as far as possible on a single leg three consecutive times and land firmly without losing balance. During each hop, the participant will jump across midline and land on the same limb. The distance from the starting point to the heel was measured, and the same procedure was done to the other leg.

Interpretability: The distance was measured from the starting line to the heel of the landing leg, and the results were compared pre-and post-intervention. The Hop Tests demonstrated strong intra-rater reliability for dominant and non-dominant legs (ICC =0.85) (Ross et al., 2002).

Single leg stance test

The single leg stance test is an uncomplicated test for measuring static balance that can be used in various settings and requires minimal equipment and training (Springer et al., 2007). The players were tested without shoes and socks, they were asked to fix their eyes on a point 1.5 m away, to put their upper limb on their chest crossed, and elevate one leg 10 cm and place it behind the weight-bearing leg. Two training trials were done before testing.

The timing was measured to the participants from elevating their legs and was stopped if they were not able to maintain the position. For both lower limbs, the average result with eyes closed and eyes open was recorded. Measurements were taken 3 times for the players with their eyes open and eyes closed and standing on each lower limb. Next, the average of the measurements was taken. If one or more of these situations occurs, then the participant should repeat the test:

if the lifted foot touched the floor, the arms are removed from their position, the legs touch each other, and the weight bearing foot moves from its place (Lynn et al., 2012). The relative reliability of the one leg stand test seems to be like the computerized balance test performed on the force platform. But the one leg stand test is much easier without complications and without the need for technical equipment (Maribo et al., 2009).

Y-Balance Test (YBT)

The test is used to assess the dynamic balance of the participants (Guo et al., 2021). To prepare for the test, a Y-shape white masking tape was applied on the playing ground floor. The degrees between the anterior stripe and both posterior lines is 135 degrees, and the degrees between the two posterior lines is 90 degrees (Willis et al., 2017) (Figure 3.3).

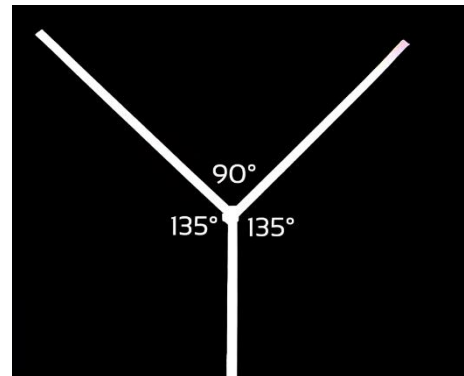


Figure (3.3) : Y-Balance test (Willis et al., 2017)

Before testing (Plisky et al., 2006):

1. Instructions were given to the participants about the correct procedures to apply the test.
2. An instructional video was played to the participants to get a general idea about the test procedures.
3. The participants were asked to apply four practice trials for the two legs in all the six test directions. The practice trials will help in reducing the learning effect without causing fatigue that might affect the ability to perform the test (Robinson & Gribble, 2008). They were conducted in the following order (Figure 3.4):

- a. Right anterior reach
- b. Left anterior reach
- c. Right posteromedial reach
- d. Left posteromedial reach
- e. Right posterolateral reach
- f. Left posterolateral reach

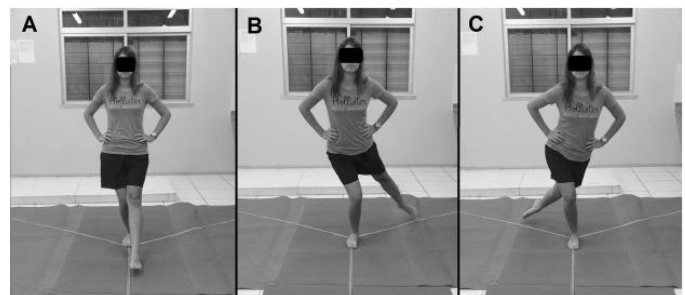


Figure (3.4): Y-balance reach

4. Two minutes of rest was given to the participants after completing the practice trials (Coughlan et al., 2012).

Testing protocol: The participants were told to take off their shoes before starting the test, and applying the test barefoot is important to remove the additional support and stability from the shoes (Coughlan et al., 2012). The participants were standing on only one leg at the starting point with the toes of the foot at the center of the three connecting lines they were asked to put their hands on their hips, then they were instructed to slide their foot forward as much as they can with their left foot and return to the starting upright position. They should repeat this three times with the same foot (Figure 3.4). After completing three successful reaches with their right foot, they repeated the process with their left foot, then they progressed to the next test direction as mentioned in the pre-testing above. Reach distances were recorded to the nearest 0.5 cm (Guo et al., 2021).

Trials were excluded if the players touch the floor with their foot before returning to the starting position, lost their balance while performing the task, place their foot heavily on top of the line in order to gain support during the reach, lifted the stance leg (Willis et al., 2017).

The YBT has good interrater test–retest reliability and small degrees of measurement error for both the maximal reach and the mean of 3 reaches. The measurement error was reduced and interrater test–retest reliability was better when the average of 3 reach trials was used. Interrater test–retest reliability of the maximal reach had ICC of 0.80 to 0.85 with a standard error of measurement ranging from 3.1 to 4.2 cm for all the three reach directions (anterior, posteromedial, and posterolateral). Interrater test–retest reliability of

the average reach of 3 trials had an ICC range of 0.85 to 0.93 with an associated standard error of measurement ranging from 2.0 to 3.5 cm (Shaffer et al., 2013).

Results of the YBT are computed as a composite score. The absolute reach distance and relative reach distance were calculated using these equations:

- ❖ Absolute reach distance (cm) = (Reach 1 + Reach 2 + Reach 3) / 3.
- ❖ Relative (normalized) reach distance (%) = Absolute reach distance / limb length * 100.
- ❖ Composite reach distance (%) = total of the 3 reach directions / 3 times the limb length * 100

Tuck jump

The Tuck Jump Test (TJT) is an assessment tool that was designed to support practitioners with the identification of neuromuscular deficits related to an ACL injury, in addition, the tuck jump can also be used as an assessment for the level of improvement in the player's performance (Fort-Vanmeret al., 2017b).

Participants will stand in a normal anatomical position; their feet will be apart opening at shoulder width. They will start the jump with a slight bend downward while their upper limbs will be extended behind their back. Then, they will sway their upper limbs forward as they concurrently jump up straight elevating their knees up. Their thighs should be parallel to the floor when they reach the highest point of the jump. Direct after landing the participants must start the next tuck jump. The participants were encouraged to land softly, using a toe to mid-foot rocker landing. If the participants land with a knock knee or they are unable to control high landing force they must stop jumping (Myer et al., 2008a). Three training jumps were done to make the participants familiar with the test and the fourth jump was recorded for assessment. Two

smartphones (Apple's iPhone 12 pro max (30 frame per second (FPS) and iPhone 8 max (30 FPS)) were placed in the frontal and sagittal planes to record the jump at the height of 0.7 m and 5.0 m from the jumping area. A dichotomous grading scale was used according to ten criteria to assess the jump landing errors (Appendix 4) (Robles-Palazón et al., 2021).

There are 10 practical errors that can be measured as either having the apparent deficit or not through the tuck jump assessment. It has been recommended that participants should take more technique training if their scores of tuck jump are 6 or more to avoid ACL injuries (Lininger et al., 2017a).

3.7 Intervention

During the COVID-19 and the lockdown period, it was important to find an easily applicable prevention protocol that the participant can apply at home safely to ensure their safety. The Knäkontroll prevention program was applied to the participant who passed the inclusion and the exclusion criteria (Appendix 6). It was developed by the Swedish Football Association in cooperation with a group of experts. It is an easy, and time-efficient prevention program. No equipment is needed in this protocol other than a ball (Waldén et al., 2012).

The purpose of the Knäkontroll prevention program is to develop a movement pattern through simple exercises during training that reduces the chances of knee injuries, Also, to strengthen the knees and core muscles by focusing on neuromuscular knee control (Häggglund et al., 2009b). The program consists of six exercises: one-legged knee squat, pelvic lift, two-legged knee squat, the bench, the lunge, and jump landing. There are four subdivisions to each exercise ranging in its difficulty from an easy level in the first week and progressing to the next level each week (Häggglund et al., 2009b).

The participants were asked to apply the Knäkontroll prevention program three times per week for four weeks. Completing the exercises took between ten to fifteen minutes. The first session of every week was given online by video call, and each exercise was explained by the examiner to the participants. An illustrative video was sent to each participant with detailed steps of the exercises. After that, each participant stood in front of the camera and applied the exercise while the examiner is watching. The remaining two sessions of each week were performed as a home program, reminder messages were sent to each participant by WhatsApp to do the exercises. Moreover, an exercises checklist with a QR code for the exercises was given for follow up reasons (Appendix 7). Stretching exercises of the major muscle groups were performed before and after the prevention protocol to reduce the chance of injuries and muscle soreness (Appendix 5).

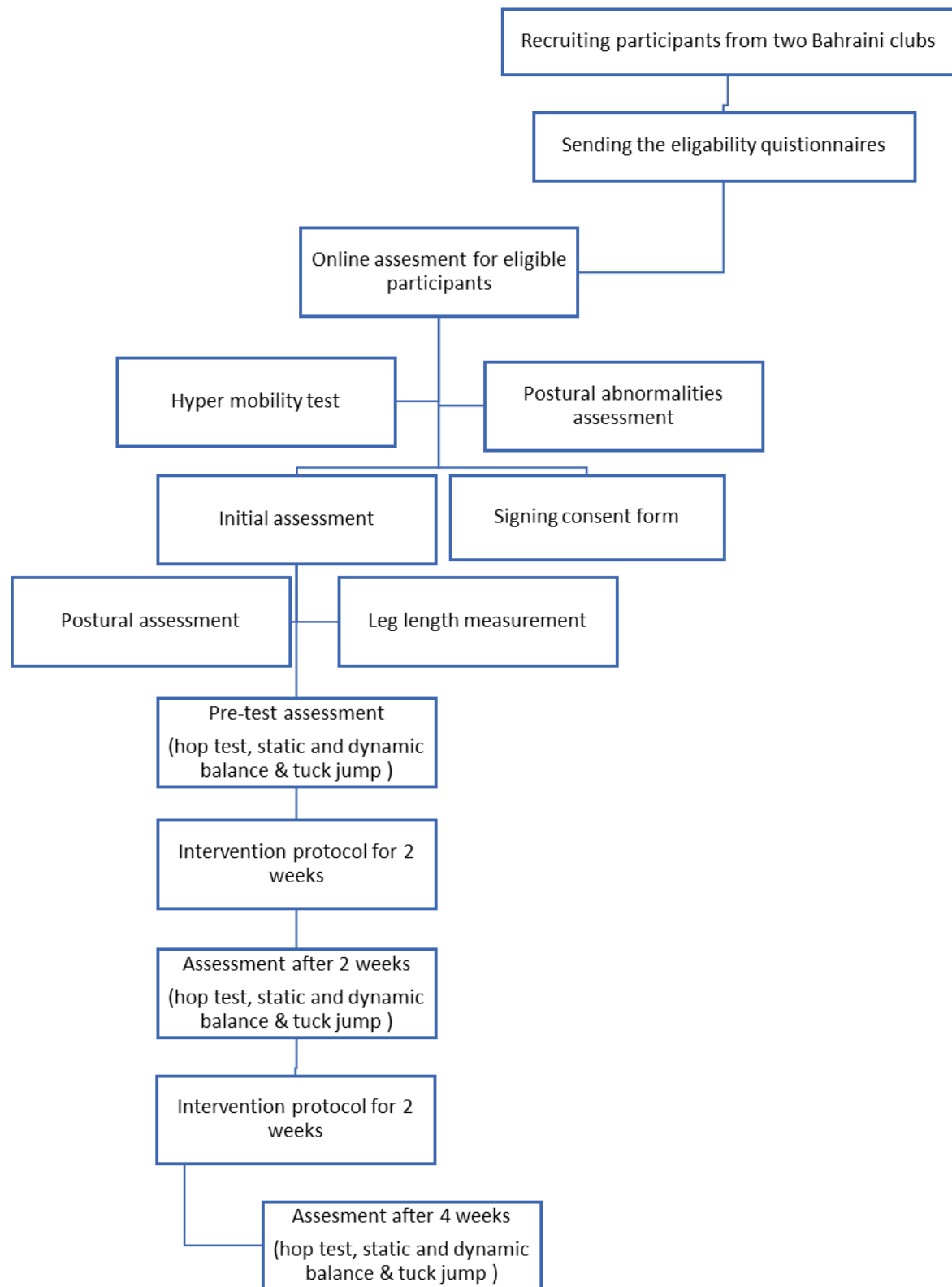


Figure (3.5): Study protocol

3.8 Variables

Variables of the study were identified as:

Independent variable:

- Knäkontroll injury prevention program

Dependent variable:

- Risk of ACL injury
- Static balance
- Dynamic balance
- Functional performance

Confounding variables:

- Participation in other sports
- Daily activities

3.9 Statistical Analysis

The Statistical Package for Social Science (SPSS) of Windows 16.0 (IBM Inc, Chicago, IL) was utilized for statistical analysis. Descriptive analysis (Means and standard deviation) was done for participants' age, weight, and leg length. In addition, it was done for the measurements at the pre-protocol, after 2 weeks, and after 4 weeks for the all-assessment tests (tuck jump, hop test, static balance test, and Y-balance test). Repeated measures analysis of variance (ANOVA) was performed with post-hoc Bonferroni test to all assessment test protocols after 2 weeks, between 2 and 4 weeks and after 4 weeks. Eta squared (η^2) was used to estimate the effect size of the difference between two measurements. Because there was no statically significant difference between the left and the right lower limbs, the average between them was used for analysis.

Chapter 4

Results

4.1 Descriptive results

Out of the 88 participants who were eligible to participate, 33 were excluded for the following reasons: 19 were having injuries in the lower limbs, 1 was having surgery in the right lower limb, 2 were having deformities in the lower limbs (flat feet and genu valgum), and one was not in Bahrain. Six participants did not agree to sign the consent form. The remaining forty-nine participants started with the prevention program. Four of them were excluded because they were not committed to doing the exercises, nineteen did not want to continue due to the increase in COVID-19 rates, three of them traveled and one participant had a car accident. The thirty participants who complete the program were 21.4 ± 2.7 years, weighed 58.3 ± 11.2 kg, and had an average leg length measurement of 76.3 ± 4.2 cm. A flowchart of participant recruitment is provided in Figure (4.1).

There is no significant difference between the results of the right and left lower limbs for the hop test, static balance and dynamic balance. The overall results showed general improvements in the means of all test results after 2 weeks, after 4 weeks and from the second to fourth week (Tables 4.1, 4.2, 4.3, and 4.4).

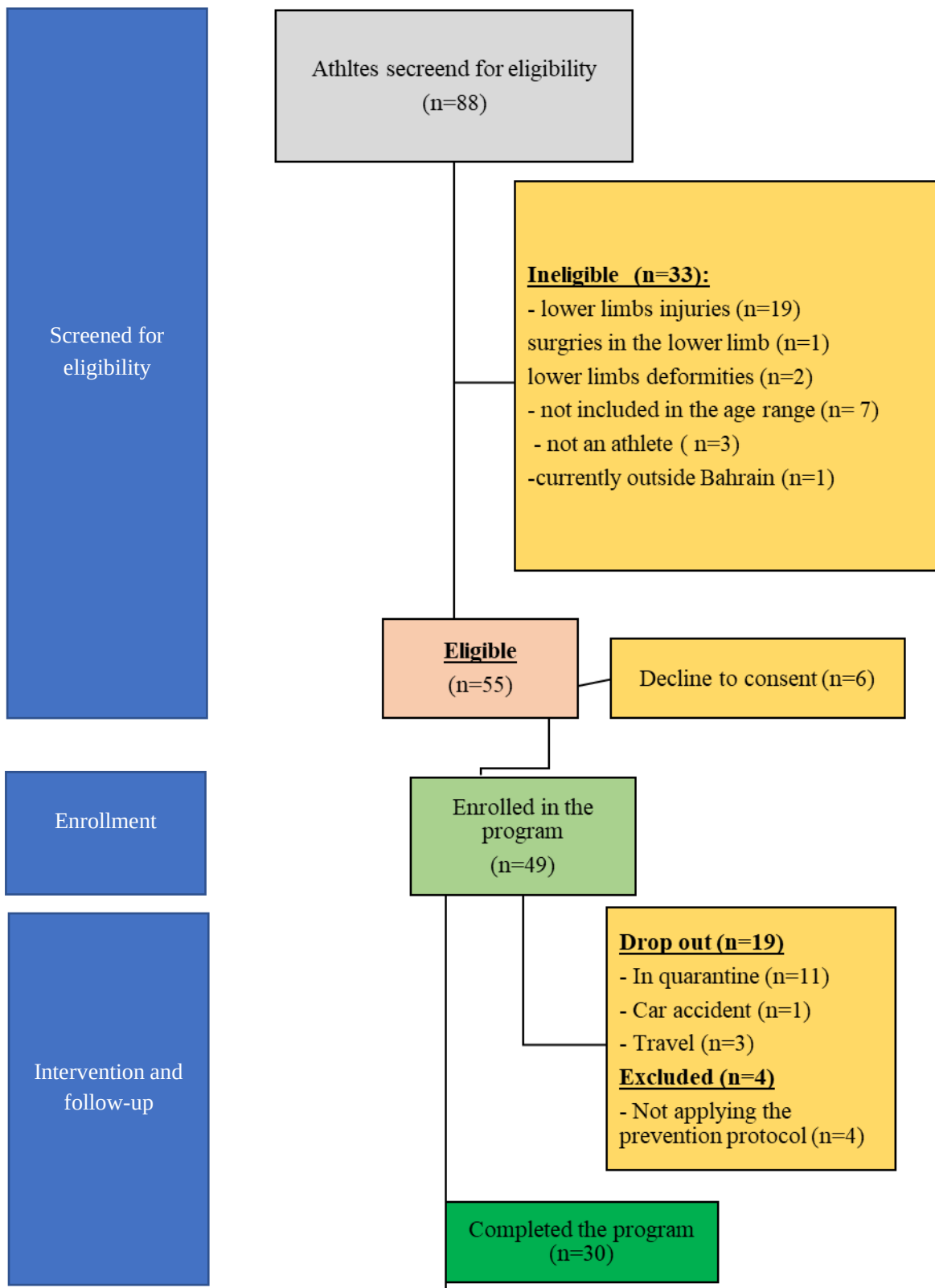


Figure (4.1): Study flow and Participants Recruitment

4.2 Hop tests results

There is a significant improvement in all the hop tests scores after 2 weeks, 4 weeks from the prevention program ($P < 0.001$). Moreover, there is a significant improvement between the results of the second and fourth weeks ($P < 0.001$). The following Table (4.1) show the repeated measures ANOVA with, mean of difference, and confidence interval results for all the three hop tests (single hop, triple hop, cross over hop).

- 1) Single hop test: The most significant improvements in single hop test score were observed after 4 weeks of prevention program (Mean $\pm$ SD) (130 ± 14.61 cm) (MD = 30.75 cm, 95% CI [27.54, 34.05], $P < 0.001$), with a large effect size ($\eta_p^2 = 0.91$). There were also significant improvements after 2 weeks of the prevention program (117 ± 19.42 cm) (MD = 17.11 cm, 95% CI [13.98, 20.26], $P < 0.001$), and between 2 and 4 weeks (MD = 13.63, 95% CI [9.54, 17.72], $P < 0.001$) but to a lesser extent (Table 4.1).
- 2) Triple hop test: Similar findings were observed for the triple hop test after 4 weeks of prevention program (323 ± 44.19 cm) (MD = 32.55 cm, 95% CI [27.06, 38.04], $P < 0.001$), also with a large effect size ($\eta_p^2 = 0.79$). The results also improved after 2 weeks (310 ± 45.52 cm) (MD = 19.28 cm, 95% CI [15.61, 22.96], $P < 0.001$), and between the second and fourth weeks (MD = 13.27 cm, 95% CI [9.72, 16.82], $P < 0.001$) (Table 4.1).
- 3) Cross over test: The biggest improvements for the cross over test were also seen after 4 weeks of prevention program (307 ± 49.82 cm) (MD = 33.22 cm, 95% CI [29.73, 36.71], $P < 0.001$, $\eta_p^2 = 0.90$). Scores after 2 weeks also improved (292 ± 51.64 cm) (MD = 18.22 cm, 95% CI [15.90,

20.53], $P < 0.001$) and between 2 to 4 weeks (MD = 15.00 cm, 95% CI [12.37, 17.63], $P < 0.001$) (Table 4.1).

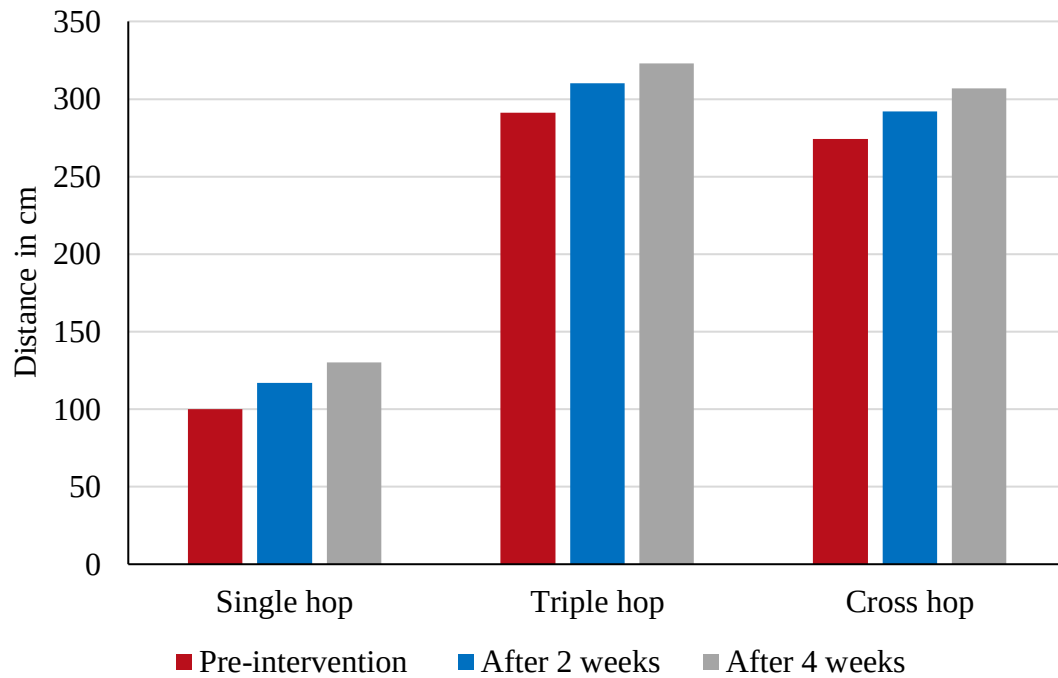


Figure (4.2): Mean of hop test results (Average right and left lower limbs)

Table (4.1): Repeated measures ANOVA results with Post-hoc Bonferroni for hop test (Average right and left lower limbs)

Test	Timeline (1)	Timeline (2)	Timeline (1) M ± SD (cm)	Timeline (2) M ± SD (cm)	MD (1-2)	P	95% CI		F	n ²
							Lower Bound	Upper Bound		
Single Hop	After 2 weeks	Pre-intervention	117±19.42	100±16.45	17.11	< 0.001	13.98	20.26	301	0.91
	After 4 weeks	Pre-intervention	130±14.61	100±16.45	30.75	< 0.001	27.45	34.05		
	After 4 weeks	After 2 weeks	130±14.61	117±19.42	13.63	< 0.001	9.54	17.72		
Triple Hop	After 2 weeks	Pre-intervention	310±45.52	291±49.15	19.28	< 0.001	15.61	22.96	108	0.79
	After 4 weeks	Pre-intervention	323±44.19	291±49.15	32.55	< 0.001	27.06	38.04		
	After 4 weeks	After 2 weeks	323±44.19	310±45.52	13.27	< 0.001	9.72	16.82		
Crossover Hop	After 2 weeks	Pre-intervention	292±51.64	274±52.45	18.22	< 0.001	15.90	20.53	284	0.90
	After 4 weeks	Pre-intervention	307±49.82	274±52.45	33.22	< 0.001	29.73	36.71		
	After 4 weeks	After 2 weeks	307±49.82	292±51.64	15.00	< 0.001	12.37	17.63		

Notes: M, mean; SD, standard deviation; MD, mean of difference; CI, Confidence Interval for Difference; n², Eta Squared; cm, Centimeter

4.3 Static balance test results

The repeated measures ANOVA showed a significant improvement in static balance test results with eyes open and eyes close scores after 2 and 4 weeks from the prevention program ($P < 0.001$). Moreover, there is a significant improvement between the results of the second and fourth week ($P < 0.001$) (Table 4.3, 4.4).

- 1) Eyes opened: Improvements in static balance were the biggest after 4 weeks of applying the prevention program (163 ± 42.50 sec) (MD = 114.03 sec, 95% CI [102.45, 125.60], $P < 0.001$, $n_p^2 = 0.91$). There were also significant improvements after 2 weeks (102 ± 40.58 sec) (MD = 53.36 sec, 95% CI [43.76, 62.96], $P < 0.001$) and between 2 to 4 weeks (MD = 60.67 sec, 95% CI [53.29, 68.05], $P < 0.001$) (Table 4.2).
- 2) Eyes closed: Similar improvements were seen with the eyes closed after 4 weeks of prevention program (94 ± 36.96 sec) (MD = 79.97 sec, 95% CI [68.80, 91.14], $P < 0.001$, $n_p^2 = 0.85$), after 2 weeks (53.36 ± 28.24 sec) (MD = 38.67 sec, 95% CI [30.74, 46.60], $P < 0.001$) and between 2 and 4 weeks (MD = 41.30 sec, 95% CI [34.76, 47.85], $P < 0.001$) (Table 4.2).

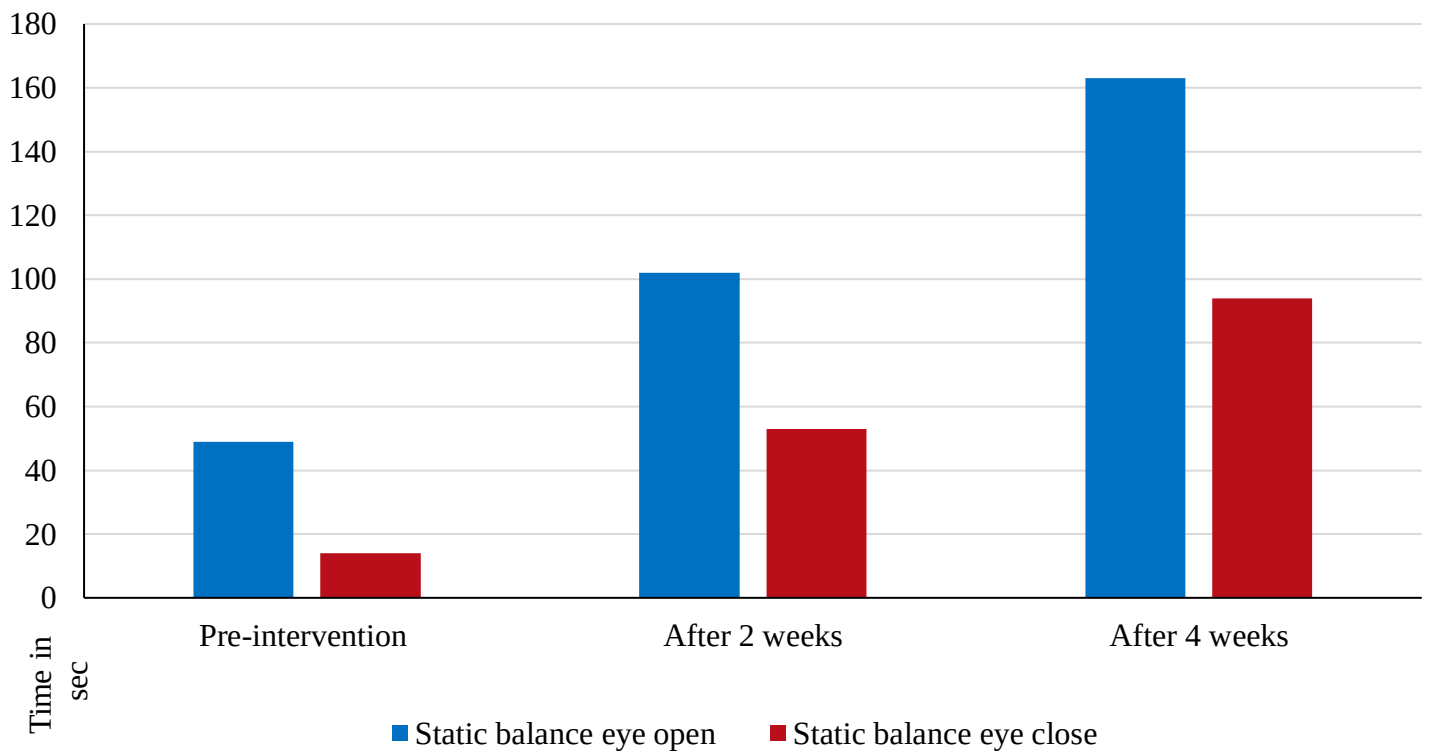


Figure (4.3): Mean of static balance results (Average right and left lower limbs).

Table (4.2): Repeated measures ANOVA results with Post-hoc Bonferroni for static balance (Average right and left lower limbs).

Static balance	Timeline (1)	Timeline (2)	Timeline (1) M ± SD (sec)	Timeline (2) M ± SD (sec)	MD (1-2)	P	95% CI		F	n ²
							Lower Bound	Upper Bound		
eyes open	After 2 weeks	Pre-intervention	102±40.58	49±25.43	53.36	< 0.001	43.76	62.96	321	0.92
	After 4 weeks	Pre-intervention	163±42.50	49±25.43	114.03	< 0.001	102.45	125.60		
	After 4 weeks	After 2 weeks	163±42.50	102±40.58	60.67	< 0.001	53.29	68.05		
eyes close	After 2 weeks	Pre-intervention	53±28.24	14±11.86	38.67	< 0.001	30.74	46.60	162	0.85
	After 4 weeks	Pre-intervention	94±36.96	14±11.86	79.97	< 0.001	68.80	91.14		
	After 4 weeks	After 2 weeks	94±36.96	52±28.24	41.30	< 0.001	34.76	47.85		

Notes: M, mean; SD, standard deviation; MD, mean of difference; CI, Confidence Interval for Difference; n², Eta Squared; sec, Second

4.4 Y-balance test results

Results showed significant improvements in all the reaches for the Y-balance test for both lower limbs in all directions after 2 and 4 weeks from the prevention program ($P < 0.001$). Moreover, there is a significant improvement between the results of the second and fourth week ($P < 0.001$). (Tables 4.3).

- 1) Posteromedial: The most significant improvements in the posteromedial Y-balance test were noticed after 4 weeks of prevention program (105 ± 9.46 cm) (MD = 18.17 cm, 95% CI [16.50, 19.84], $P < 0.001$), followed by the scores after 2 weeks (96 ± 8.64 cm) (MD = 8.94 cm, 95% CI [7.91, 9.97], $P < 0.001$). Moreover, there was a significant improvement in the results between the second- and fourth weeks following the intervention (MD = 9.23 cm, 95% CI [8.23, 10.22], $P < 0.001$). The effect size of the difference was large ($\eta_p^2 = 0.93$) (Table 4.3).
- 2) Posterolateral: Like the posteromedial results, changes for the posterolateral Y-balance test were the greatest after 4 weeks of the prevention program (103 ± 9.00 cm) (MD = 23.02 cm, 95% CI [21.64, 24.40], $P < 0.001$), followed by a significant improvement after 2 weeks of the prevention program (91 ± 8.08 cm) (MD = 11.62 cm, 95% CI [10.82, 12.42], $P < 0.001$). The changes were the lowest between the second and fourth weeks (MD = 11.40 cm, 95% CI [10.55, 12.25], $P < 0.001$, $\eta_p^2 = 0.97$) (Table 4.3).
- 3) Anterior: Anterior reach test also showed marked improvements after 4 weeks (92 ± 7.27 cm) (MD = 22.71 cm, 95% CI [21.40, 24.03], $P < 0.001$), and after 2 weeks of prevention program (81 ± 7.03) (MD = 11.66 cm, 95% CI [10.73, 12.59], $P < 0.001$). Similar to posterolateral reach, the changes between the second and fourth weeks were the lowest (MD = 11.06 cm, 95% CI [10.16, 11.95], $P < 0.001$, , $\eta_p^2 = 0.97$) (Table 4.3).

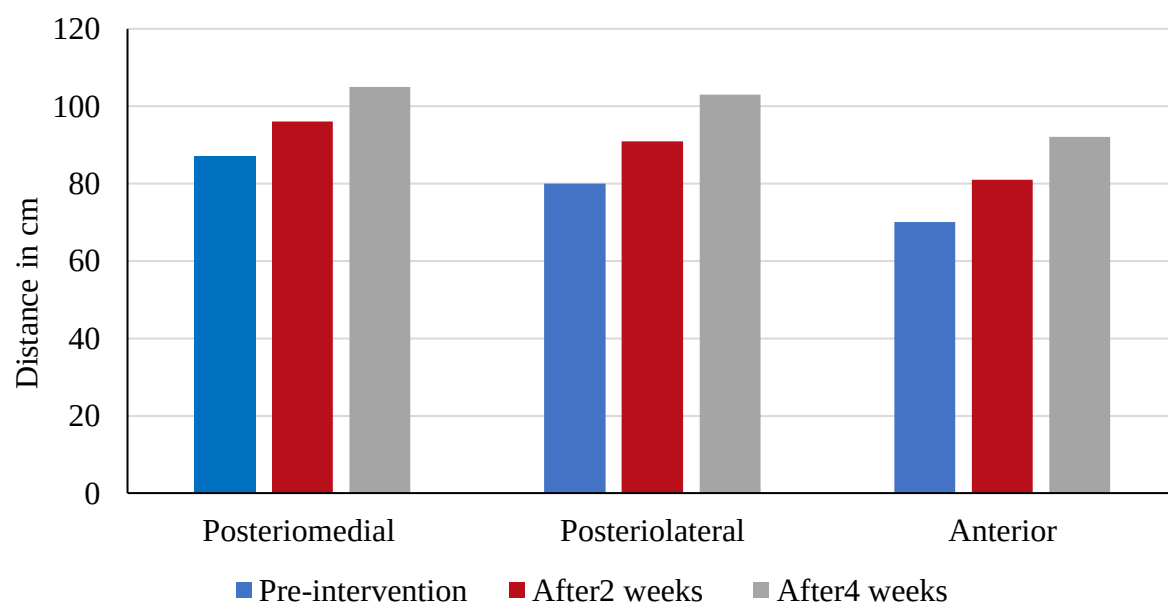


Figure (4.4): Mean of Y- balance results (Average right and left lower limbs)

Y-balance	Timeline (1)	Timeline (2)	Timeline (1) M ± SD (cm)	Timeline (2) M ± SD (cm)	MD (1-2)	P	95% CI		F	n ²
							Lower Bound	Upper Bound		
Posteromedial	After 2 weeks	Pre-intervention	96±8.64	87±8.87	8.94	< 0.001	7.91	9.97	354	0.93
	After 4 weeks	Pre-intervention	105±9.46	87±8.87	18.17	< 0.001	16.50	19.84		
	After 4 weeks	After 2 weeks	105±9.46	96±8.64	9.23	< 0.001	8.23	10.22		
Lateral	After 2 weeks	Pre-intervention	91±8.08	79±8.29	11.62	< 0.001	10.82	12.42	840	0.97
	After 4 weeks	Pre-intervention	103±9.00	79±8.29	23.02	< 0.001	21.64	24.40		
	After 4 weeks	After 2 weeks	103±9.00	91±8.08	11.40	< 0.001	10.55	12.25		
Anterior	After 2 weeks	Pre-intervention	81±7.03	69±7.53	11.66	< 0.001	10.73	12.59	885	0.97
	After 4 weeks	Pre-intervention	92±7.27	69±7.53	22.71	< 0.001	21.40	24.03		
	After 4 weeks	After 2 weeks	92±7.27	81±7.03	11.06	< 0.001	10.16	11.95		

Notes: M, mean; SD, standard deviation; MD, mean of difference; CI, Confidence Interval for Difference, n², Eta Squared; cm, Centimeter

Table (4.3): Repeated measures ANOVA results with Post-hoc Bonferroni for Y-balance (Average right and left lower limbs).

4.5 Tuck jump test results

There is a significant improvement in tuck jump test score after 2 weeks (8.1 ± 1.22 points) (MD = 1.30 points, 95% CI [0.82, 1.77], $P < 0.001$), and between the second and fourth weeks (MD = 4.16 points, 95% CI [4.80, 6.14], $P < 0.001$, $n_p^2 = 0.94$). However, the biggest difference in scores was seen after 4 weeks of the prevention program (3.9 ± 1.59 points) (MD = 5.47 points, 95% CI [3.39, 4.95], $P < 0.001$) (Table 4.4).

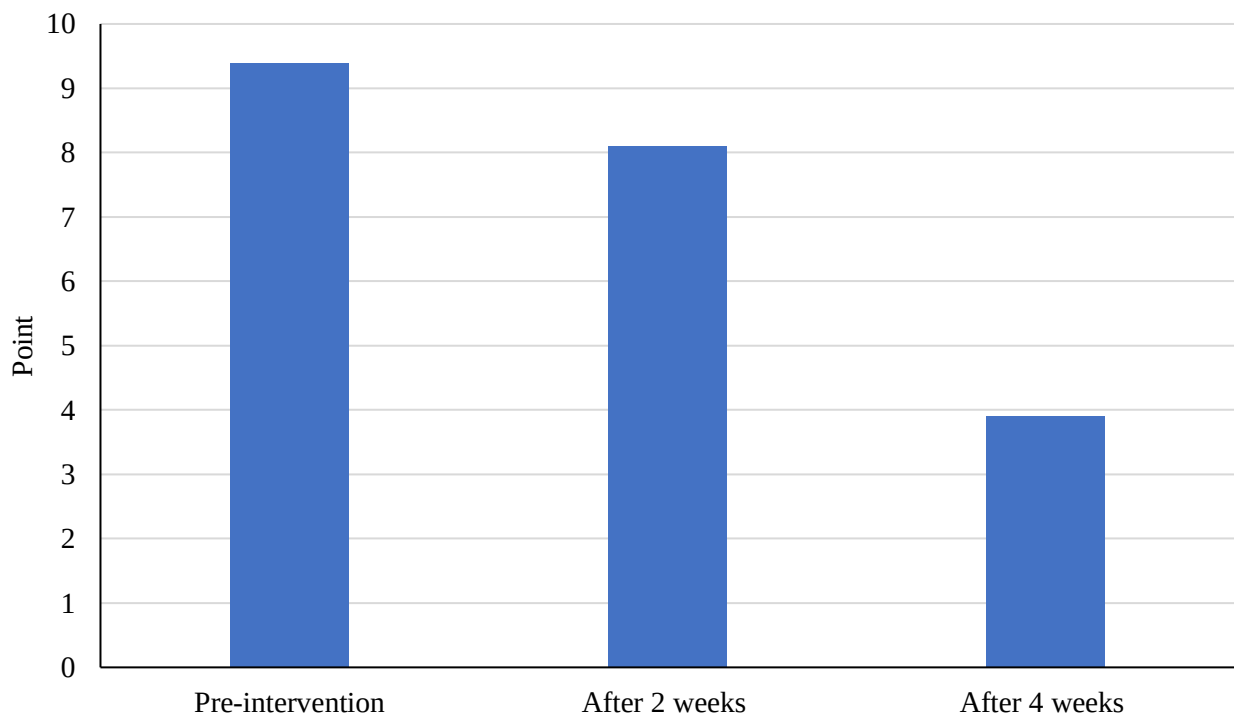


Figure (4.5): Mean of Tuck jump results

Table (4.4): Repeated measures ANOVA results with Post-hoc Bonferroni for Tuck jump

Y-balance	Timeline (1)	Timeline (2)	Timeline (1) M ± SD point	Timeline (2) M ± SD point	MD (1-2)	P	95% CI		F	n ²
							Lower Bound	Upper Bound		
Tuck Jump	After 2 weeks	Pre-intervention	8.1 ±1.22	9.4 ± 0.73	1.30	< 0.001	0.82	1.77	245	0.94
	After 4 weeks	Pre-intervention	3.9 ±1.59	9.4 ± 0.73	5.47	< 0.001	3.39	4.95		
	After 4 weeks	After 2 weeks	3.9 ±1.59	8.1 ±1.22	4.16	< 0.001	4.80	6.14		

Notes: M, mean; SD, standard deviation; MD, mean of difference; CI, Confidence Interval for Difference n², Eta Squared

4.6 Adherence rate

The total number of participants that started the prevention protocol were 49 and only 30 of them complete the program so the percentage of the participants that complete the program was 61.2 %. The rate of exercise adherence for the 30 participants that finished the protocol was 100% because all the participants complete their exercises with the required repetitions 3 times per week for 4 weeks.

Chapter 5

Discussion

This research aimed to assess the efficiency of the Knäkontroll prevention program in diminishing some non-contact ACL injury risk factors (static balance, dynamic balance, landing technique, and functional performance) among female athletes. The result of this study showed that the prevention program was effective in improving static balance, dynamic balance, and functional performance. Also, it reduces the landing errors that have proven to cause ACL injuries.

5.1 Static and Dynamic Balance

This study results support the results of Oshima et al. (2020). They did a case series to study the efficiency of a 6-month training program (part 2 of the FIFA 11 prevention program) on the activation and strength of the core and lower limb muscles and balance performance (static and dynamic). The study's results align with this study results, which found that the FIFA11 prevention protocol effectively improves static and dynamic balance. Despite the difference in the two prevention protocols, both contain neuromuscular knee control and core stability exercises.

However, Oshima et al.'s (2020) study period was very long (6 months) compared to this study (4 weeks). Another study was done by Leavy (2006) with a relatively comparable intervention period to this study (6 weeks) to study the effect of gluteus medius strengthening exercises and proprioception training on dynamic postural control. Results showed that there are differences found for pre-test or post-test values between groups for gluteus medius strength but it is not considering significant ($F_{3,47} = 1.454$, $P = .240$, $ES = .090$, $\beta = .358$), on the other

hand there was significant improvement in dynamic balance post-intervention for all the groups ($F_{3,47} = 6.145$, $P = .001$, $ES = .295$, $\beta = .946$) (Leavey, 2006)

Our study results showed a significant difference between static balance with eyes opened and eyes closed, whereas static balance was lower. Giagazoglou et al. (2009) did a study to compare static balance and lower limbs strength between blind and sighted women. Twenty women volunteered to participate in this study (ten blind and ten with normal vision). The result showed that the ability to control balance in both anterior/posterior and medial/lateral directions was superior in sight women than in blind women. There were no differences in concentric, eccentric, and isometric strength measurements of the lower limb muscles between the blind and sighted individuals. Despite similar levels of strength in both groups, sighted individuals performed significantly better in all balance tests than blind individuals. The difference in the results with eyes open and eyes close was explained in some studies, in which they found that vision plays a more prominent role than the coding in processing other sensory information and in the absence of vision. There is an increase in postural sway because visual input affects neural control of body sway (Nougier et al., 1998).

Several theories tried to explain the effect of balance on postural control. Balance training will stimulate the activity of vestibular and cerebellar systems, which in turn lead to automatic postural control. It will activate the muscles that respond in maintaining posture and gait from conscious to subconscious control. Also, spinal reflex excitability will be suppressed due to the task-specific neural adaptation gained from balance training, like muscle stretch reflex during postural tasks. Reducing spinal reflex excitability will lead to less destabilizing movement and better balance. On top of that, the neural adaptation will affect motor response and might explain the improvement in knee proprioception (Daneshjoo et al., 2012).

5.2 Tuck jump and hop tests

The results of the present study showed that there was a significant change in the tuck jump results at 2 and 4 weeks after the prevention protocol. Moreover, there was a significant improvement in all three hop tests after 2 and 4 weeks of the intervention. The differences found in the hop tests and tuck jump results are due to the nature of the tests. Every test examines different constructs; the tuck jump test examines the quality of movement while the hop test measures the distance.

A prospective cohort study was conducted by Arundale (2020) to study the connection between tuck jump score ≥ 6 and hop test among female soccer players who performed ACL reconstruction and healthy individuals without ACL injuries. Results showed that forty percent of the female soccer players in this study had a tuck jump score of ≥ 6 . Although players with ACL reconstructions had slightly more scores, that is ≥ 6 , than uninjured players, the difference was not considered statistically significant ($P=0.43$). Also, there were no statistically significant correlations between single-legged hop and limb symmetry index (Spearman's rho = -0.06, $p = 0.35$).

The total score of the tuck jump test was used in this study. Tuck jump scores of ≥ 6 out of 10 were considered poor and a sign of a high risk of ACL injuries. Even though Lininger et al. (2017) argue that the tuck jump test assesses three primary constructs. First is fatigue, which can be shown as lacking the strength or endurance to maintain proper landing form for 10 seconds. Second, a distal landing pattern can be revealed as decreased knee flexion and dorsiflexion during landing. Finally, it assesses proximal control, which is the core and glute strength deficits leading to a difficulty controlling the knees and feet during landing

(Lininger et al., 2017b). Thus, using the tuck jump test to identify particular areas of the deficit will be clinically more valuable when the separate tuck jump assessments are conducted than assessing the total score.

A retrospective cohort study was done to study the effect of ACL prevention programs as a postoperative ACL reconstruction (ACLR) tool. It aimed to evaluate its effect on improving the hop tests and limb symmetry and compare the prevention protocol results among different age groups. Results showed that an intensive 6-week neuromuscular prevention protocol improved the hop test results in patients post ACLR. Moreover, there was an improvement in the mean limb symmetry results in all hop tests, but the improvement was insignificant except for the single-leg hop test (87% pretest to 92% posttest). Lastly, the participants who were younger than 18 years got better results (Meierbachtol et al., 2016).

The explanation of the improvement in the tuck jump score after the prevention program is mainly due to the core strength gained from core strengthening exercises. The core muscles play an essential role in the stability of the spine and pelvis; a strong core will help in improving postural stability and the quality of tuck jump by preventing the lateral movements of the trunk during jump landing tasks, helping in gaining support to land in the same place every time, reducing the pause between jumps and helping in elevation the thighs (Saber et al., 2021).

5.3 Compliance with the prevention program

The results of the study by Steffen et al. (2008) oppose this study's results. They aimed to assess the effectiveness of FIFA 11+ on reducing the lower limb injury rate. Even though their study was done over a more extended period (8 months), the rate of players' commitment to the exercise was low. On the contrary, the commission rate in the current study was maintained by distributing

checklists to the participant to fill as a method of encouragement, and they were reminded to perform the exercises via WhatsApp messages. Moreover, participants who did not commit to doing the exercises were excluded. Myklebust et al. (2003) also faced participants' poor compliance. Consequently, the prevention exercise showed no significant reduction in the injury rate. However, when data from the sub-group of the participants that committed to doing exercises were separately analyzed, lower injury rates following the prevention protocol were observed.

In their study, Thein-Nissenbaum and Brooks (2016) tried to identify the barriers that affect high school basketball players' compliance with home-based ACL injury prevention programs. They found that the two main reasons explaining low compliance among players are lack of time to do the exercise and forgetting to do them. Sending reminder messages was effective in increasing participant commitment to our study. This solution applies in the experimental setting because of the small sample size. However, it might be challenging to implement in real-world settings or studies with higher participant numbers.

Another factor that might affect the participant's compliance is the time of the prevention protocol. Sugimoto et al. (2016) did a literature review to get the key components that can improve the effectiveness of ACL injury prevention programs. The literature review results found that the prevention protocol should be longer than 20 minutes in duration and frequency greater than two times per week. Even though the previous questionnaire results were done by Thein-Nissenbaum and Brooks (2016) showed that 50% of participants said that the exercise program was too long. However, the prevention program was only 15 minutes long. In our study, the prevention program took 10 to 15 minutes and showed promising results.

To increase players' adherence to the prevention protocols, coaches' awareness should increase the effectiveness and importance of the prevention

protocols in reducing injuries. Also, it is necessary to provide them with an effective prevention program requiring minimal time, place, and equipment. In a cluster randomized controlled trial by LaBella et al. (2011), the study results showed a significant reduction in lower limb injury rate (noncontact ankle sprains, noncontact knee sprains, and noncontact anterior cruciate ligament injuries) after the application of 20 minutes of neuromuscular prevention program by the coaches.

McGuine et al. (2013) conducted a cross-sectional survey to determine the high school basketball coaches' use of prevention programs. More than 50% of the coaches reported that lack of awareness and knowledge about the importance and effectiveness were the leading cause that limited them from applying the prevention protocol. In addition, it should be noted that providing knowledge about the prevention program might not be enough to encourage the coaches to perform them with their player's other factors like availability of time and place play an important role. Many coaches reported that they only have 100 to 120 minutes with each team because the court is shared with different levels of teams, and it is difficult to take 10 to 20 min to apply the prevention protocol (McGuine et al., 2013).

5.4 Age

Age is one of the critical factors that can affect the prevention protocol results. Sugimoto et al. (2012) reported that although the risk of ACL injury among female athletes is during their end-teen, it is better to start the prevention program with the players from their mid-teens. Two studies used similar neuromuscular training programs to reduce the risk of lower limb injuries. The injury prevention program consisted of four components: running techniques, balance and body control, plyometric, and strengthening exercises. The difference

between the two studies is the age group. Pasanen et al. (2008) included participants in their late teens (19-24 years old), while Olsen et al. (2005) included participants in their mid-teens (14-18 years old). Results showed that participants in their mid-teens showed significant reductions in ACL injuries throughout the study, which is two years. Conversely, no significant reduction was observed in the ACL injury rate among participants in their late teens. Other factors that might contribute to the late-teens players' group results are the participant's adherence to the prevention program and performing the exercises with correct techniques.

In this study, the participants range between 18 and 35 years old. The participants were older than 18 due to ethical approval as they were considered adults and did not need their parents' approval at any stage of the study. Moreover, most participants were driving, which also positively impacted their commitment to attending the sessions.

Chapter 6

Conclusion and Recommendations

6.1 Conclusion

Prevention is better than cure; this study's outcomes showed that the Knäkontroll prevention protocol effectively reduces ACL injury risk factors. Applying this prevention protocol in Bahrain clubs and national teams will reduce the risk of injuries among players, the withdrawal period after surgeries and rehabilitation, and the costs of surgeries.

Online prevention protocol played an essential role in reducing the risks of ACL injuries, especially in an unusual situation like the COVID-19 pandemic. Also, it could reduce time and effort and increase player adherence to home programs.

6.2 Limitations

There are some limitations in this study that might affect the interpretation of the study results. There was no control group in this study so this might affect the internal validity of the study, due to the COVID-19 pandemic, it was difficult to recruit participants. Thus, no random sampling was applied convenience sampling was used in the study to get more significant numbers of participants. Moreover, there was a high withdrawal rate which affected the sample size. There were no specific criteria to increase the intensity of the exercises. Due to time limitations, the participants had to shift to the next level every week. Moreover, the part of the

protocol requiring a partner was removed due to the lockdown period and maintaining participants' safety.

The sample size was not calculated because there is no accurate information about the exact number of female athletes in Bahrain clubs. But according to central limit theorem sample size of 30 or more is considered acceptable (Chang et al., 2006).

6.3 Recommendations

To generalize the results on a broad scale, it is preferable to conduct the study based on bigger sample size, with the control group and following a randomization technique are needed. Moreover, Studies including participants from different age groups, especially young athletes less than 18 years, are required, as it was recommended by Sugimoto et al. (2012) to start the prevention programs in the mid-teens.

It will be better to apply the prevention protocol for a more extended period and gradually increase the intensity of the exercises according to the individual athlete's progression level.

To save time and effort and prevent participants' fatigue from many examination tests, future studies can employ 2-Dimensional (2D) video analysis techniques to measure the knee valgus angles (frontal plane projection angle; FPPA) while landing and while performing the crossover hop test. This test has strong reliability and relatively low standard error of measure (SEM) in measuring lower limb functional performance and the valgus angle of the knee (Alshemimary & Herrington, 2016).

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Appendices

Appendix 1: Information Sheet.

Information sheet

Study title: Application of a Prevention Protocol to Reduce ACL Injuries Risk Factors Among Female Athletes.

Overview:

The aim of this research is to study the effect of Knäkontroll prevention protocol on improving balance, and functional performance of female athletes and reducing the most common ACL mechanical risk factors. Assessment will be done at the baseline and will be repeated twice after 2weeks and after 4 weeks.

Why are we doing this research?

The results of this study are supposed to generate a new body of knowledge about the effectiveness of the Knäkontroll prevention program in reducing ACL risk factors among female athletes in Bahrain. The researcher believes that the prevention protocol will be effective in reducing ACL risk factors, improve the players' performance, on top of that it will reduce the costs of ACL reconstruction surgeries and rehabilitation programs.

What will happened if I agreed to participate in this study?

You will be asked to sign a consent form then your height, weight, leg length will be measured also your posture will be examined. Ten to fifteen minutes injury prevention protocol will be added to your training program three times per week for four weeks. In the first day, second week and fourth week you will be asked to do some functional tests to test your functional performance, balance, and jump landing errors.

What are the possible benefits of taking part in this study?

Players who will participate in this study will have a chance to get assessment for their landing biomechanics. On top of that an exercise protocol will be provided, it is expected to improve their performance and reduce their chance of getting ACL injuries.

What are the possible disadvantages and risks of taking part?

There might be a mild side effects such as: muscle soreness and fatigue and in rare cases there might be muscular strains and ligaments sprain. To reduce the chance of these side effects a warmup protocol and stretching exercises will be given in the beginning of the sessions.

Who is eligible to participate?

Female athletes, aged between eighteen to thirty-five years old and. Without Musculoskeletal injuries to the lower extremities, history of hip or knee joint injuries, general body hyper mobility with Beighton score equal or more than four and clear from Cardiac or respiratory problems.

Will my taking part in this project be kept confidential?

All the information obtained in this study will be kept as confidential as possible. Names and contact details will not be mentioned to maintain participants anonymity, photographic and video tape records will be taken as needed. However, the researcher will maintain your confidentiality by not showing your face, the images and video records may be published in an appropriate journal or present in a lectures.

What will happened if I don't want to continue participating in this study?

Your decision to participate in this study or not is voluntary, it will not affect your relationship with University of Bahrain or the researcher. Also, you have the right to withdrawal at any point of the study, just inform the researcher no need for giving any reasons or clarifications.

What happens if something was not wright?

If you have any enquiries or complaints about the project in the first instance you can contact Nowara Abdulla as soon as possible to address and deal with the issue. If you feel your complaint has not been handled to your satisfaction, you can contact with Dr Mhammed Abdulla. All the details are shown below.

Contact details:

For further information, please do not hesitate to contact with any one of the researchers below:

Principal researcher

Nowara Ebrahim

Master student

Mobile 37113022

Email: Nowaraek@gmail.com

Course supervisor

Dr Mohammed Abdulla

Assistant Professor, Physiotherapy Department, University of
Bahrain

Email: moabdulla@uob.edu.bh

عنوان الدراسة: تطبيق بروتوكول وقائي لتقليل عوامل الخطر لإصابات الرباط الصليبي الأمامي بين الفتيات الرياضيات

نظرة عامة:

الهدف من هذا البحث هو دراسة تأثير بروتوكول الوقاية Knäkontroll على تحسين التوازن والأداء الوظيفي للفتيات الرياضيات، وتقليل عوامل الخطر الميكانيكية الأكثر شيوعاً في الرباط الصليبي الأمامي. سيتم إجراء تقييم قبل بدء البرنامج وسيتم تكراره مرتين، المرة الأولى بعد أسبوعين والمرة الثانية بعد أربع أسابيع من بداية البرنامج.

لماذا نقوم بهذا البحث؟

لنتبين فعالية برنامج الوقاية Knäkontroll في الحد من عوامل خطر الإصابة بالرباط الصليبي الأمامي بين اللاعبات.

يعتقد الباحث أن بروتوكول الوقاية سيكون فعالاً في الحد من عوامل خطر الرباط الصليبي الأمامي ، وتحسين أداء اللاعبات ، علاوة على أنه سيقبل من تكاليف عمليات إعادة بناء الرباط الصليبي الأمامي وبرامج إعادة التأهيل.

ماذا سيحدث إذا وافقت على المشاركة في هذه الدراسة؟

سيطلب منك التوقيع على نموذج موافقة ، كما سيتم فحصك من قبل الاختصاصية الباحثة لترى مدى مناسبة وضعك للاختبار. ستتم إضافة بروتوكول منع الإصابات من عشر إلى خمس عشرة دقيقة إلى برنامج التدريب الخاص بك ثلاث مرات في الأسبوع لمدة أربعة أسابيع. سيطلب منك إجراء بعض الاختبارات الوظيفية لاختبار أدائك الوظيفي والتوازن وأخطاء الهبوط السريع في اليوم الأول والأسبوع الثاني والأسبوع الرابع من الدراسة.

ما هي الفوائد المحتملة للمشاركة في هذه الدراسة؟

ستتاح للمشاركات اللاتي سيشاركن في هذه الدراسة فرصة للحصول على فحص لميكانيكا الهبوط لديهن . علاوة على ذلك سيتم توفير بروتوكول تمارين وقائية من المتوقع أن يحسن أدائهن ويقلل من فرص إصابتهن بإصابات الرباط الصليبي الأمامي

ما هي المخاطر المحتملة للمشاركة في الدراسة ؟

قد تكون هناك آثار جانبية خفيفة مثل: ألم خفيف في العضلات و التعب الناتج عن اداء المجهود ، و في الحالات النادرة التواء في الأربطة وإجهاد العضلات. لتقليل فرصة حدوث هذه الآثار الجانبية ، سيتم إعطاء بروتوكول إحماء وتمارين إطالة في بداية الجلسات.

من هو المؤهل للمشاركة؟

الفتيات الرياضيات اللاتي تتراوح أعمارهن بين ثمانية عشر وخمسة وثلاثين سنة ويمارسن النشاط الرياضي و لا يعانون من اي مشاكل في القلب او الجهاز التنفسي و بدون اصابات او تاريخ اصابات في الاطراف السفلية. كما انهن لايعانين من زيادة في المرونة.

هل ستبقى مشاركتي في هذا المشروع سرية؟

سيتم الحفاظ على سرية جميع المعلومات التي تم الحصول عليها في هذه الدراسة قدر الإمكان. لن يتم ذكر الأسماء وتفاصيل الاتصال للحفاظ على سرية هوية المشاركين ، وسيتم أخذ التسجيلات الفوتوغرافية وشرائط الفيديو حسب الحاجة. ومع ذلك ، سيحافظ الباحث على سريتك من خلال عدم إظهار وجهك ، وقد يتم نشر الصور ومقاطع الفيديو في مجلة مناسبة أو تقديمه في محاضرات .

ماذا سيحدث إذا لم أرغب في مواصلة المشاركة في هذه الدراسة؟

إن قرارك بالمشاركة في هذه الدراسة من عدمه طوعي ولن يؤثر على علاقتك بجامعة البحرين أو الباحث. كما يحق لك الانسحاب في أي وقت من الدراسة ، فقط أبلغ الباحث بعدم الرغبة بالمشاركة من دون الحاجة لإبداء أي أسباب أو توضيحات.

إذا كان لديك أي استفسار أو مشكلة حول المشروع يمكنك الاتصال بنورة عبد الله في أقرب وقت ممكن لمعالجة المشكلة والتعامل معها. إذا شعرت أنه لم يتم التعامل مع استفسارك أو شكواك بشكل يرضيك ، يمكنك الاتصال بالدكتور محمد عبد الله كل تفاصيل التواصل موضحة أدناه.

معلومات التواصل:

لمزيد من المعلومات ، لا تتردد في الاتصال بأي من الباحثين أدناه:

الباحث الرئيسي

نورة ابراهيم

طالبة ماجستير

هاتف: 37113022

البريد الإلكتروني: Nowaraek@gmail.com

المشرف على البحث

الدكتور محمد عبدالله

أستاذ مساعد ، قسم العلاج الطبيعي ، جامعة البحرين

بريد إلكتروني: moabdulla@uob.edu.bh

Appendix 2: Eligibility questionnaire

ACL prevention

Im Nowara Abdulla , a physiotherapist and a master student in the university of Bahrain. I invite you to participate in my master research project with the title of : Application of an online Prevention Protocol to Reduce Anterior Cruciate ligament Injuries Risk Factors among female athletes.

The aim of this research is to study the effect of a prevention protocol on improving static balance, and functional performance of female athletes and reducing the most common ACL mechanical risk factors.

*Required

1. Email address *

Personal information

2. Name *

3. Age *

4. sex

Mark only one oval.

☐ female

☐ male

5. Occupation

6. contact number *

7. Email *

Medical information

8. Do you have any medical problems? *

Mark only one oval.

☐ YES

☐ No

9. If yes mention your medical problems

10. Have you done any surgeries in your lower limbs (hips ,knees or ankles) in the last 6 months?

Mark only one oval.

☐ yes

☐ NO

11. If yes mention your previous surgeries

12. Do you have any injuries in your lower limbs (hips ,knees or ankles) ? *

Mark only one oval.

☐ yes

☐ No

13. If yes mention your injuries

14. Do you have any history of injuries in your lower limbs (hips ,knees or ankles) in the last 3 months ?

Mark only one oval.

☐ Yes

☐ No

15. If yes mention your injuries *

Physical Activity

16. How many hours do you practice weekly

Mark only one oval.

☐ 1-3 hours

☐ 3-6hours

☐ 6-9

☐ 9-12

☐ more than 12

17. what type of sport you are practicing ? *

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Google Forms

Appendix 3: Consent form

Informed consent form

Name:

I hereby give my consent to participate in the study titled: Application of a Prevention Protocol on Reducing ACL Injuries Risk Factors Among Female Athletess

Researcher name: Nowara Ebrahim

Course title: Applied Research Project

Student No: 20102440

supervisor name: DR. Mohammed Abdulla

I, the undersigned, confirm that: (please tick as appropriate)

Statement	yes	No
1. I have read and understood the information regarding the study procedures, requirements and possible side affects as provided in the information sheet		
2. I voluntarily agree to participate in the all stages of the project		
3. I understand that I have the right to withdraw in any time without being ask for clarifications.		
4. The procedures regarding confidentiality have been clearly explained to me (use of names, pictures, anonymisation of data, etc),		
5. The use of the data in research, publications, sharing and archiving has been explained to me		
6. I understand that other researcher will be able to access the data only if they agree to preserve the confidentiality of the data and if they agree to the terms, I have specified in this form		
7. I understand that, if there is any concern about the appropriateness of my continuing in this research, I may be asked to withdraw my involvement at any stage.		
8. I have been given the opportunity to ask questions about the project and my participation. I have the right to ask further questions in the future		
9. All the information that I gave to the researcher are true and accurate to the best of my knowledge and I understand that I must notify if there are any changes to the information.		
I along with the Researcher agree to sign date this informed consent form		

Participant Name	Signature	Date
Investigator Name	Signature	Date

استمارة موافقة على المشاركة في الدراسة

الاسم----- :

أمنح بهذا موافقتي على المشاركة في هذه الدراسة بعنوان: تطبيق برنامج وقائي لتقليل عوامل الخطر المرتبطة بالرباط الصليبي الامامي بين الفتيات الرياضيات
اسم الباحثة : نورة ابراهيم خليل
رقم الطلابي: 20102440
عنوان المقرر: مشروع البحث التطبيقي
أنا الموقع أدناه، أؤكد هذا

(يرجى وضع صح في الخانة المناسبة)	نعم	لا
لقد قرأت وفهمت المعلومات المتعلقة بإجراءات الدراسة, المتطلبات, الاعراض الجانبية المتوقعة الموضحة جيداً في ورقة المعلومات		
انا اتطوع بكامل ارادتي للمشاركة في جميع مراحل الدراسة		
انا اعلم انه يحق لي الانسحاب من الدراسة في أي وقت دون طلب اي تبرير توضيح او		
لقد تم شرح الإجراءات المتعلقة بالسرية بوضوح (استخدام الاسم والصورة وإخفاء البيانات الشخصية ، وما إلى ذلك)		
لقد تم الشرح عن استخدام البيانات في البحوث والمنشورات و المشاركات		
اعلم انه قد يطلع بعض الباحثين على البيانات مع مراعاة الخصوصية و الشروط الموجودة في الموافقة		
اعلم انه قد يطلب مني الانسحاب من المشاركة في اي مرحلة من مراحل الدراسة إذا كان هناك أي قلق بشأن عدم ملاءمة استمراري فيها		
لقد تم السماح لي بطرح الأسئلة. واعلم ان لدي الحق في طرح المزيد من الاسئلة في اي وقت مستقبلا		
أنا اعلم بانه قد يكون هناك بعض الآثار الجانبية للمشاركة في برنامج التمارين ولقد تم شرح الخطر المحتمل جيداً لي.		
جميع المعلومات التي قدمتها للباحث صحيحة ودقيقة على حد علمي وأعلم أنه يجب اخباره إذا كان هناك أي تغيير في المعلومات		
أوافق مع الباحث على توقيع هذه الموافقة في التاريخ المذكور		

Participant Name	Signature	Date
Investigator Name	Signature	Date

Appendix 4: Tuck Jump Scoring Sheet

Tuck Jump Assessment	Pre	Mid	Post	Comments
<u>Knee and Thigh Motion</u>				
① Lower extremity valgus at landing	☐	☐	☐	
② Thighs do not reach parallel (peak of jump)	☐	☐	☐	
③ Thighs not equal side-to-side (during flight)	☐	☐	☐	
<u>Foot Position During Landing</u>				
④ Foot placement not shoulder width apart	☐	☐	☐	
⑤ Foot placement not parallel (front to back)	☐	☐	☐	
⑥ Foot contact timing not equal	☐	☐	☐	
7. Excessive landing contact noise	☐	☐	☐	
<u>Plyometric Technique</u>				
8. Pause between jumps	☐	☐	☐	
9. Technique declines prior to 10 seconds	☐	☐	☐	
10. Does not land in same footprint (excessive in-flight motion)	☐	☐	☐	
Total _____	Total _____	Total _____		

1


2


3


4


5


6


Section 1 : Before and After Exercise

Stretching Exercises

Warm up/pre-exercise stretches should be held for eight to 15 seconds and should be done two to three times.

Cool down/post-exercise stretches should be held for 45 to 60 seconds and should be done two to three times.

In a flexibility session each stretch should be held for 45 to 60 seconds and should be repeated three to five times at least.

Where stretches can be done on both sides of the body only one side is shown. Ensure that you stretch both sides equally.



Neck extensors - flex the chin to the chest.



Scalenes - facing forwards, bring the ear towards the shoulder taking care not to lift the shoulder.



Upper Trapezius - turn the head to look over the shoulder, take care not to turn the body.



Triceps - place your right hand behind your neck. Use the left hand to apply pressure to the elbow, drawing the elbow behind the head. Ensure shoulders are relaxed.

Before and After Exercise : Section 1

Section 1



Deltoids - reach across the front of the body, using the other arm to draw the arm across. Ensure that the shoulders are kept low.



Pectorals/Biceps - stretch both arms behind you, keeping the elbows straight and the thumbs pointing upwards. Ensure that you do not bend forwards.



Wrist flexors - with the elbow straight, use the left hand to apply the stretch by drawing the palm away from the floor, keeping the fingers straight.



Wrist extensors - with the elbow straight, use the left hand to apply the stretch by bending the wrist, bringing the palm towards the floor, keeping the fingers straight.



Trunk stretch - standing with feet shoulder width apart, stretch right arm up towards the ceiling and over to the left, keeping the body in one plane.



Rhomboids - standing with feet shoulder width apart, hold your left hand with your right hand out in front of you, keeping your arms horizontal. Reach forwards, keeping the body upright, until you feel a stretch between your shoulder blades.

Section 1 : Before and After Exercise



Gastrocnemius and Soleus - stand astride, stretch forward over the front leg, keeping the knee over the foot. Keep the back knee straight, keep both heels in contact with the floor.



Achilles - as for the Gastrocnemius and Soleus but bend the back leg bringing the knee towards the floor, keeping the heels on the floor.



Hip flexors Psoas/Quadriceps - stand astride, stretch forwards, dropping the left knee towards the floor, allowing the heel to raise. Keep the body upright.



Abductors - stand astride, with feet parallel, keep the left leg straight, bend the right knee and stretch until the knee is over the right foot.



Quads - keeping your inner thighs and knees together push your left foot into your hand and push the hips forwards.



Hamstrings, Gastrocnemius (straight leg) and Soleus (bent leg) - stand astride with your front foot resting on your heel with your toes pointing upwards. Stretch forward over the front leg bending your back knee, keeping the heel in contact with the floor. Use your arms to support your weight on your bent knee. Keep your back flat and head up.

Before and After Exercise : Section 1

Section 1



Hamstrings - sit on the floor, bend the left knee and slide heel towards the right inner thigh. Keep your back straight and flex from the hip, moving your torso towards the right thigh.



Hamstrings - lie flat on the floor, lift the left leg with the knee bent until the thigh is at a right angle to your body. Holding around the thigh, gently straighten the leg until you feel the stretch. The right leg should be bent with foot flat on the floor.



Hamstrings - keeping the back flat, reach over towards the right foot, feeling the stretch in the back of the right thigh.



Glutes/Piriformis - lie flat on your back with the right knee bent. Place the left heel on the right knee. Take hold around the right thigh and draw up towards your chest.



Rhomboids and Latissimus Dorsii - kneel on all fours, arms straight in front and spread slightly apart. Lower your chest to the floor, keeping the pelvis still.



Erector Spinae - lie on your back with knees bent; feet on the floor, grasp around your knees and pull your thighs towards your chest.

Section 1 : Before and After Exercise



Pectorals, Obliques & Hamstrings - lie on your back with your arms out to the sides. Bend the right knee and move it to the left. Gently straighten the right knee until you reach the point of tension. Keep the head, shoulders and arms flat on the floor.



Pectorals, Obliques & Glutes - as previous stretch but grasp the right knee with the left hand and gently let it rotate across the body and onto the floor. Keep the head, shoulders and arms flat on the floor.



Rectus Abdominus - lie face down, place your hands under your shoulders, fingers pointing forwards. Straighten your arms gently until you feel resistance. Stretch your shoulders and chin forward.



Piriformis, Buttock & Lateral Torso - sit upright, place your left foot flat on the floor and place the right elbow behind the left knee. The left hand should provide support behind the body. Twist your upper body towards the left hand.

Knäkontroll ACL prevention protocol

Only 4 levels will be applied.

Strength:

3 sets, 8-15 repetitions. Each exercise with 4 levels of difficulty

- Level 1: double-leg squat
- Level 2: double-leg squat with heel raise
- Level 3: double-leg squat with ball over head
- Level 4: double-leg squat with ball held in front of body
- Level 1: forward walking lunge
- Level 2: forward lunge with ball, lateral trunk rotation
- Level 3: forward lunge with ball over head
- Level 4: lateral lunge
- forward lunge while making throw-in with ball
- Level 1: single-leg squat
- Level 2: single-leg squat with overhead ball
- Level 3: single-leg squat with off leg at differing positions
- Level 4: single-leg Romanian deadlift

pressed between lateral sides of feet of non-supporting legs

Core stability:

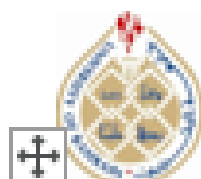
- **Level 1: prone plank on knees**
- **Level 2: prone plank on toes**
- **Level 3: prone plank on toes with lateral step**
- **Level 4: side plank**
- **Level 1: bridge, double leg**
- **Level 2: bridge, single leg**
- **Level 3: bridge, single leg on ball**
- **Level 4: bridge, single leg with hop**

Plyometrics

Level 1: single leg forward/backward hops

- **Level 2: double-leg lateral jumps, landing on single leg**
- **Level 3: take a few quick steps on same spot and make short jump straight forward, landing on 1 foot**
- **Level 4: take a few quick steps on same spot and make short jump, but change direction and jump to 1 side (90° turn); alternate sides**

Appendix 7: Exercises checklist



University of Bahrain
College of Health and Sport Science
Department of Physiotherapy

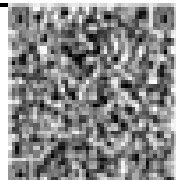
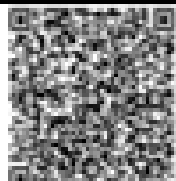
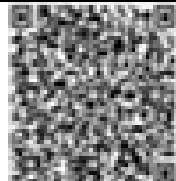
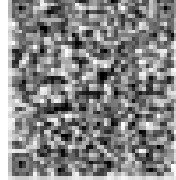
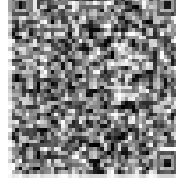
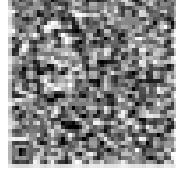
week 1
Participant:

strength		Repetitions			QR Code
		Day 1	Day 2	Day3	
Double leg squat	3 sets, 8-15 rep				
Forward walking lunges	3 sets, 8-15 rep				
Single leg squat	3 sets, 8-15 rep				
Prone plank on knees	15-30 sec (10-15)				
Bridge double leg	15-30 sec (<u>10-15</u>)				
Single leg backward forward hops	3 sets, 5-15 rep				



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College of Health and Sport Science
Department of Physiotherapy

Week 2
Participant:

strength		Repetitions			QR Code
		Day 1	Day 2	Day 3	
double-leg squat with heel raise	3 sets, 8-15 rep				
forward lunge with ball, lateral trunk rotation	3 sets, 8-15 rep				
single-leg squat with overhead ball	3 sets, 8-15 rep				
prone plank on toes	15-30 sec				
bridge, single leg	15-30 sec				
double-leg lateral jumps, landing on single leg	3 sets, 5-15 rep				

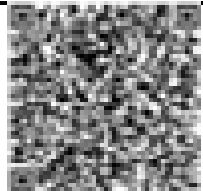
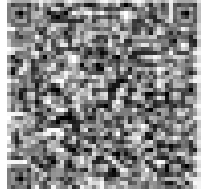
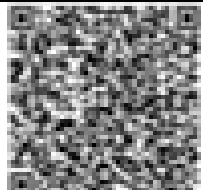
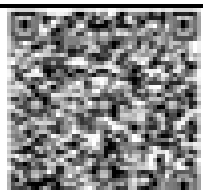
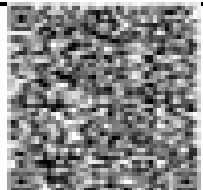
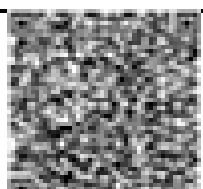


strength		Repetitions			QR Code
		Day 1	Day 2	Day 1	
double-leg squat with ball over head	3 sets, 8-15 rep				
forward lunge with ball over head	3 sets, 8-15 rep				
single-leg squat with off leg at differing positions	3 sets, 8-15 rep				
prone plank on toes with lateral step	15-30 sec				
bridge, single leg on ball	15-30 sec				
take a few quick steps on same spot and make short jump straight forward, landing on 1 foot	3 sets, 5-15 rep				



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Department of Physiotherapy

Week 4
Participant name:

strength		Repetitions			QR Code
		Day 1	Day2	Day 3	
double-leg squat with ball held in front of body	3 sets, 8-15 rep				
lateral lunge	3 sets, 8-15 rep				
single-leg Romanian deadlift	3 sets, 8-15 rep				
side plank	15-30 sec				
bridge, single leg with hop	15-30 sec				
take a few quick steps on same spot and make short jump, but change direction and jump to 1 side (90° turn); alternate sides	3 sets, 5-15 rep				

Appendix 8: Evaluation sheet



University of Bahrain
College of Health and Sport Sciences
Allied Health Department

Participant:

Phone #:

Date:

Evaluation sheet

Dominant side:

Static balance

	Eye open			average	Eye close			average
Right side								
Left side								

Hop tests

	Right side			average	Left side			average
Single Hop Test								
Triple Hop Test								
Crossover Hop Test								

Tuck jump

Tuck Jump Assessment	Pre	Mid	Post	Comments
<u>Knee and Thigh Motion</u>				
① Lower extremity valgus at landing	☐	☐	☐	
② Thighs do not reach parallel (peak of jump)	☐	☐	☐	
③ Thighs not equal side-to-side (during flight)	☐	☐	☐	
<u>Foot Position During Landing</u>				
④ Foot placement not shoulder width apart	☐	☐	☐	
⑤ Foot placement not parallel (front to back)	☐	☐	☐	
⑥ Foot contact timing not equal	☐	☐	☐	
7. Excessive landing contact noise	☐	☐	☐	
<u>Plyometric Technique</u>				
8. Pause between jumps	☐	☐	☐	
9. Technique declines prior to 10 seconds	☐	☐	☐	
10. Does not land in same footprint (excessive in-flight motion)	☐	☐	☐	
Total _____	Total _____	Total _____		

خلاصة البحث

المقدمة: تعد إصابة الرباط الصليبي الأمامي (ACL) من أكثر الإصابات الرياضية شيوعًا . تربط الدراسات الحديثة عملية إعادة بناء الرباط الصليبي الأمامي بالمضاعفات الجانبية طويلة المدى ، تآكل مفصل الركبة ، بالإضافة الى التهاب المفاصل. لذلك ، هدفت هذه الدراسة إلى دراسة تأثير بروتوكول الوقاية من الرباط الصليبي الأمامي Knäkontroll على ابرز عوامل الخطر الميكانيكية التي تزيد من فرصة الإصابة باصابة الرباط الصليبي الأمامي غير المتصلة بين الفتيات الرياضيات. **الطريقة:** ثلاثون أنثى تتراوح اعمارهن بين 18 و 35 سنة, يمارسون رياضات مختلفة على مستوى الهواة تطوعن للمشاركة في هذه الدراسة. تم اجراء اختبار القفز والية الهبوط ، والتوازن الثابت ، والتوازن الديناميكي ، واختبارات القفز قبل تطبيق البرنامج الوقائي ، بعد 2 و 4 أسابيع من التطبيق. تم تنفيذ برنامج الوقاية Knäkontroll ثلاث مرات في الأسبوع لمدة أربعة أسابيع. تم تسليم التعليمات ومقاطع الفيديو عبر مكالمات الفيديو في الجلسة الأولى من كل أسبوع ، وتم تنفيذ الجلستين المتبقيتين كبرنامج منزلي. تم تحليل جميع البيانات باستخدام الحزمة الإحصائية للعلوم الاجتماعية (SPSS) ، والإحصاءات الوصفية (المتوسط والانحراف المعياري) ، والقياسات المتكررة ANOVA **النتائج:** كان هناك تطور كبير في نتائج اختبار التوازن الثابت مع عيون مفتوحة بعد 4 أسابيع (Mean Difference(MD) = 114, (Mean 163 ± SD 42.50) (P < 0.001). CI [102.45, 125.60], 95% كانت هناك أيضًا تحسينات ذات دلالة إحصائية في جميع مقاييس النتائج الأخرى بعد 2 و 4 أسابيع من بروتوكول الوقاية (P < 0.001). **الخلاصة:** يقلل بروتوكول الوقاية من الرباط الصليبي الأمامي Knäkontroll بشكل فعال من عوامل خطر إصابات الرباط الصليبي الأمامي من خلال تحسين التوازن الثابت والديناميكي وقدرات القفز. كما يمكن أيضًا تطبيقه على الرياضيين عن بُعد ك تدخل سريع قبل المباريات الرياضية.

جامعة البحرين

كلية العلوم الصحية والرياضية



قسم العلاج الطبيعي

دراسة مفتوحة حول تأثير برنامج وقائي لتحسين القوة العضلية و الأداء لتقليل فرصة إصابة الرباط الصليبي الأمامي

اطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير في العلاج الطبيعي

اعداد

نورة ابراهيم خليل

20102440

اشراف

الدكتور محمد عبدالله محمد عبدالله

استاذ مساعد

جامعة البحرين

مملكة البحرين

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