DOI: 10.7251/SSH1901034P
Short notice

UDC: 796.332:612.766.1
Kratko saopštenje

Lower Limbs Joint Loading – Case Study

Milos Petrovic
Research Centre of Movement Sciences, Faculty of Medicine, University of Iceland, Reykjavik, Iceland

Correspondence:
Dr Milos Petrovic
Research Centre of Movement Sciences, Faculty of Medicine,
University of Iceland, Reykjavik, Iceland
mpetrovic@hi.is

Abstract: *Injury prevention plays an important role in modern sport. The most commonly injured joint in male and female football players is the knee joint. It has been reported that approximately 60-85% of football injuries occur in the lower limbs. The aim of this study is to present the methods of biomechanical assessment of lower limbs joint loading during specific tasks (single leg squat (SLS) and single leg landing (SLL)). In this experimental setup, Qualisys Tracking Motion system synchronised with AMTII force plates embedded into the floor was used. The marker setup Salford Lower Limb model was used to track pelvis and lower body movements. By analysing biomechanical parameters (range of motion, internal moments, power, ground reaction forces) in all three planes it is possible to identify the structures and the imbalances of the lower extremity that need intervention and further decrease the possibility of injury to the knee and to evaluate an appropriate moment of return to play. This method showed a very high reproducibility and it can be considered as a reliable tool in assessing lower limb performance tasks.*

Keywords: *ACL, Lower Limbs, Biomechanics, Screening.*

Introduction

Football is the most popular sport worldwide. Football consists of the movements in three-dimensional space and they require speed, agility, power and endurance (Fraude et al., 2013). Most football players possess the athletic abilities to perform these movements, however the risk of injury, contact and non-contact, is constantly present. It has been reported that approximately 60-85% of football injuries occur in the lower limbs (Inklaar, 1994). The most commonly injured joint in male and female football players is the knee. There has been a lot of research regarding knee injuries in female football players but not as much on the male football players (Weiss & Whatman, 2015). By analysing the performance for a given task using biomechanics, it might be possible to identify the structures of the lower extremity that need intervention and further decrease the possibility of injury to the knee as the most common injured joint. FIFA conducted a survey in 2006 which concluded that about 265 million people were playing football worldwide. As suspected, that also comes with injuries although some aspects of playing football can be very beneficial to people's health both physically and psychologically. However, because the injury rate is so high, playing football could also have a negative impact on the quality of life of players as well as long term consequences (Lohmander et al., 2004). It has been found that knee injuries are thought to be more severe in nature as well as more costly in comparison to other injury sites (Weiss, & Whatman, 2015). Due to high number of people playing football, the demand of injury prevention programs is high. A lot of research has been done investigating football injuries and a few factors have been established, e.g. approximately half of the injuries occur during player-to-player contact and the other half occurs during running, shooting, turning and heading (Rahnama et al., 2002). However, there is still a lot of information missing from the field. The ACL's primary function is to prevent the tibia from moving too far in front of the femur (Volpi, 2006 & Friel & Chu, 2013). The ligament originates on the medial side posteriorly on the lateral epicondyle of the femur. Anterior cruciate ligament tears are one of the most serious injuries an athlete can be exposed to (Roos et al., 1995). ACL ligament tears in men have not been researched enough (Silvers-Granelli et al., 2017). Moreover, there has been a lot of research and there is an extensive knowledge on ACL ligament tears in the female population. Knee injuries are very common in football, specifically anterior cruciate ligament tears or ACL as well as Patellofemoral pain syndrome or PFPS are reported to be the most common knee injuries (Weiss & Whatman, 2015). The mechanisms of ACL injuries have been investigated quite a lot, however most of the research that has been carried out is regarding females since ACL tears are more common in females than males. In Weiss and Whatman's systematic review from 2015 it was found that increased abduction loading, and shallow knee flexion angles are the most common biomechanical variables associated with an ACL injury (Markolf et al., 1995; 1990). When an individual with excessive abduction movement in the knee performs a dynamic knee abduction, too much strain is put on the medial collateral ligament, medial patellofemoral ligament and the anterior cruciate ligament (Weiss & Whatman, 2015). Running, changes of direction, landing after a jump, pivoting on a planted foot, and cutting movements combined with deceleration are the movements that contribute most to ACL injuries. Small knee flexion during landing leads to a higher knee frontal plane loading and therefor increases the risk of injury to the ACL (Myer et al., 2011). It is possible that the biomechanics of the hip also contribute to ACL injuries (Weiss & Whatman, 2015). ACL injuries have been linked to excessive hip flexion among other factors. Since the hamstrings extend the hip and the quadriceps flexes the hip. It is possible that the hamstring strength decreases, and the activation of quadriceps increases the hip flexion and therefor decreases the flexion in the knee resulting in an increased risk of ACL injury. It aims to enhance lower limb alignment and landing techniques trying to avoid putting valgus load on the knee during movements.

The single leg squat (SLS) and single leg landing (SLL) manoeuvres are frequently used tasks to assess lower alignment (Herrington, 2014, Nakagawa et al., 2012, Willy and Davis, 2011). Both tests have biomechanical and neuromuscular similarities to a wide range of athletic movements and thus are involved in rehabilitation programmes of different sports designed to prevent injuries and enhance athletic performance (Alenezia et al., 2014, 2016). Development of the technology and use of motion capture systems in everyday clinical and sport scientific practise help to use different tests as the screening tools. The main difference between these two tests is that the SLL involves flight phase and provides better understanding of dynamic control of the movement. These tests were developed predominantly as the tests for the knee screening assessment in different groups with pathological symptoms, mostly linked to the patellofemoral pain (Carry et al., 2017; Herrington 2014; Levinger et al., 2017; Nakagawa et al., 2012).

The aim of this paper is to provide better understanding and rationale of biomechanical test as a successful tool for investigating asymmetries in lower limbs loading as a reliable measurement for the injury prevention screening and return-to-play estimation time. For the purpose of presenting this research, presented trials are collected from one semi-professional football player.

Methods

A twelve-camera motion analysis system (Qualisys, Sweden), sampling at 200 Hz, and a force platform embedded into the floor (AMTI, USA), sampling at 1000 Hz, were synchronised to collect kinematic and kinetic data during the support phase of SLS and SLL task. Where possible markers were placed directly onto the skin; to minimise movement artefacts resulting from loose clothing all participants wore tight-fitting shorts and tops. Before a session, participant was allowed to practise each of the four tasks until he felt comfortable; this was typically two to three trials. Participant started with five minutes of low intensity warm-up on a cycle ergometer. After familiarisation, participant was required to complete five successful repetitions of each task.

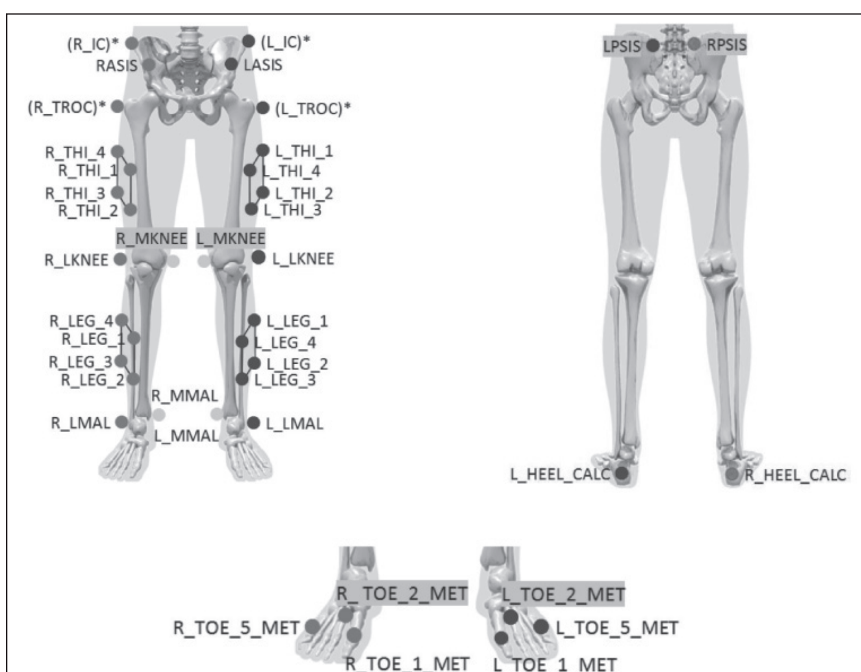

Figure 1. *Salford lower body marker set up*

Data analysis

Biomechanical parameters (range of motion, internal moments, power, ground reaction forces) were calculated from the kinematic data using Visual 3D software. Joint kinematic angles were processed using an X–Y–Z Euler rotation sequence, where X equals flexion extension, Y abduction-adduction, varus-valgus and Z internal-external rotation. Joint kinetic data were calculated using three-dimensional inverse dynamics, and joint moment data were normalised to body mass and presented as external moments referenced to the proximal segment (Alenezia et al., 2014). Initial contact was defined as the instant after ground contact, when the vertical ground reaction force (GRF) was higher than 15 N, while the end of contact was defined as the point when the knee joint reaches its maximal flexion.

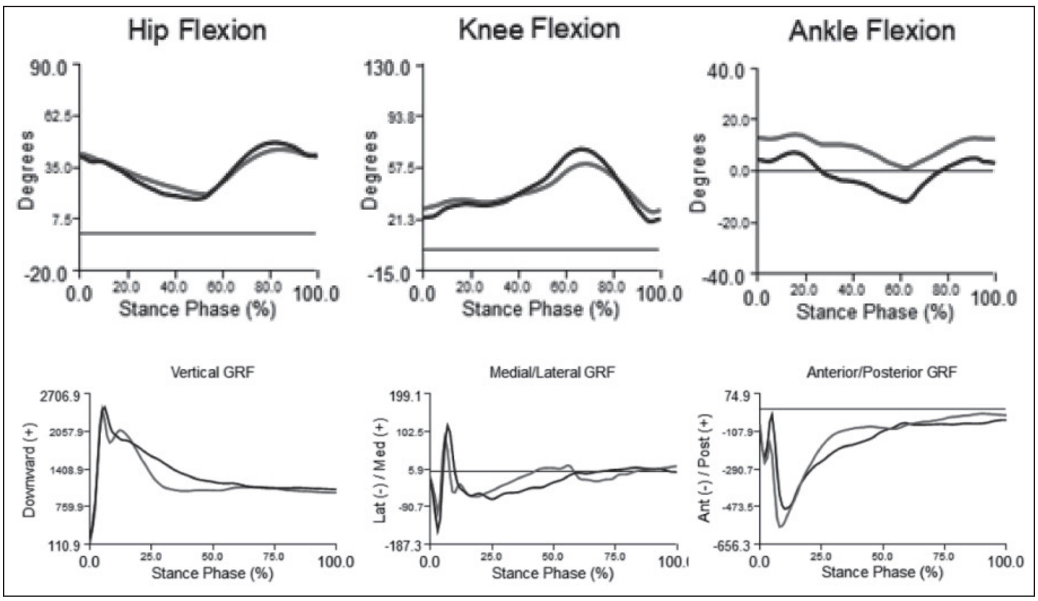

Figure 2. *Kinematic and kinetic data from single leg landing.*

Discussion and conclusion

In this paper, we have shown a rationale and a novel method of using biomechanical, functional tests in order to provide a current profile of musculo-skeletal system and its adaptation during loading of the lower limbs. The presented results showed significant differences in ankle flexion between left and right limb during single leg landing. The reason for this might be decreased ability of ankle joint to sustain GRF upon landing. In the preliminary data analysis, this pattern was observed in athletes with previous history of ankle injuries or reduced strength of plantar flexors. Participant in this study displayed an altered, stiffer kinematic landing strategy and related alterations in landing kinetics, which might predispose for episodes of giving way and actual ankle sprains. Observing results from each individual player can help physical therapists and strength and conditioning coaches to understand the nature of the movement and to work on segmental development that are weak and unstable. This protocol has the advantage of offering improved anatomical relevance as it attempts to reduce skin movement artefacts by attaching cluster markers to the centre of segments rather than single markers on the joints, as in the Helen Hayes model (Alenezia et al., 2016). These results can only apply to certain laboratory settings and models, along with an individual's ability to place markers, which could affect the results obtained in other laboratories. It must be acknowledged that there may be differences between the laboratory environment and the actual performance of study tasks. The novelty of this research is that these tests can be used in both clinical and sport population in order to investigate potential asymmetries within limbs in dynamic and static activities and a chronic ankle and knee stability. Including EMG in this setup allows to investigate muscle activity and muscle activation pattern. Data obtained with EMG can indicate certain pattern how the muscles trigger during different phases of the movement and might show the differences during the rehabilitation process or implementation of new methods for developing strength and joint stability.

The single leg squat is often used as a tool to assess movement due to its perceived relationship to functional movement, yet the relationship between it and more dynamic tasks must be explored and considered (Warner et al., 2019)

Fast development of sport science and physiotherapy provides a massive base of different screening/functional tests and return-to-play test. Practice has shown that the single leg squat and single leg landing can be used as a reliable method to estimate loading of lower limbs. Limitation of this research is that more advanced biomechanical setup is needed for conducting these measurements.

References

Alenezia, F., Herrington, L., Jones, P., Jones, R. (2014). The reliability of biomechanical variables collected during single leg squat and landing tasks. *Journal of Electromyography and Kinesiology.* 24(5), 718-721.

Alenezia, F., Herrington, L., Jones, P., Jones, R. (2016). How reliable are lower limb biomechanical variables during running and cutting tasks? *Journal of Electromyography and Kinesiology.* 24, 137-142.

Faude, O., Rößler, R., Junge, A. (2013). Football injuries in children and adolescent players: are there clues for prevention? *Sports medicine.* 43(9), 819-837.

Herrington L, Munro A. (2014). A preliminary investigation to establish the criterion validity of a qualitative scoring system of limb alignment during single-leg squat and landing. *J Exerc Sports Orthop*. 1(2):1–6.

Inklaar, H. (1994). Soccer injuries. *Sports medicine.* 18(1), 55-73.

Lohmander, L.S., Östenberg, A., Englund, M., Roos, H. (2004). High prevalence of knee osteoarthritis, pain, and functional limitations in female soccer players twelve years after anterior cruciate ligament injury. *Arthritis & Rheumatism: Official Journal of the American College of Rheumatology.* 50(10), 3145-3152.

Markolf, K.L., Burchfield, D.M., Shapiro, M.M., Shepard, M.F., Finerman, G.A., Slauterbeck, J.L. (1995). Combined knee loading states that generate high anterior cruciate ligament forces. *Journal of Orthopaedic Research.* 13(6), 930-935.

Markolf, K.L., Gorek, J.F., Kabo, J., Shapiro, M.S. (1990). Direct measurement of resultant forces in the anterior cruciate ligament. An in vitro study performed with a new experimental technique. *Journal of bone and joint surgery.* 72(4), 557-567.

Myer, G.D., Ford, K.R., Khoury, J., Succop, P., Hewett, T.E. (2011). Biomechanics laboratory-based prediction algorithm to identify female athletes with high knee loads that increase risk of ACL injury. *British journal of sports medicine.* 45(4), 245-252.

Nakagawa, T.H., Moriya, E.T., Maciel, C.D., Serrao, F.V. (2012). Trunk pelvis, hip, and knee kinematics hip strength, and gluteal muscle activation during a single-leg squat in males and females with and without patellofemoral pain syndrome. *Journal of Orthopaedic & Sports Physical Therapy.* 42:491-501

Rahnama, N., Reilly T., Lees, A. (2002). Injury risk associated with playing actions during competitive soccer. *British journal of sports medicine.* 36(5), 354-359

Roos, H., Ornell, M., Gärdsell, P., Lohmander, L., Lindstrand, A. (1995). Soccer after anterior cruciate ligament injury-an incompatible combination? A national survey of incidence and risk factors and a 7 year follow-up of 310 players. *Acta Orthopaedica Scandinavia.* 66(2), 107-112.

Silvers-Granelli, H.J., Bizzini, M., Arundale, A., Mandelbaum, B. R., Snyder-Mackler, L. (2017). Does the FIFA 11+ injury prevention program reduce the incidence of ACL injury in male soccer players. *Clinical Orthopaedics and Related Research*, 475(10), 2447-2455

Weiss, K., Whatman, C. (2015). Biomechanics associated with patellofemoral pain and ACL injuries in sports. *Sports medicine*. 45(9), 1325-1337.

Willy, R.W., Davis, I.S. (2011). The effect of a hip-strengthening program on mechanics during running and during a single-leg squat. *Journal of Orthopaedic & Sports Physical Therapy.* 41(9):625-32.

Primljen: 06. april 2019. / Received: April 06, 2019.
Prihvaćen: 13. jun 2019. / Accepted: June 13 , 2019.