



Perspective

Measurement of movement patterns to enhance ACL injury prevention — A dead end?

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Received 30 April 2016; revised 27 June 2016; accepted 29 June 2016

Available online 20 July 2016

Abstract

Vertical drop jump has been suggested to be an effective movement screening task for ACL injury risk, but recent studies have questioned the ability of such tasks to accurately identify players with increased risk of injury. In this paper, we discuss the usefulness of movement screening tests from an injury prevention perspective.

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Keywords: sport injury; anterior cruciate ligament; screening task; injury prediction; vertical drop jump

Introduction

Anterior cruciate ligament (ACL) injuries in sports are common and require significant time to recover.^{1–4} Female athletes are reported to be two to six times more likely than males to sustain an ACL injury.^{4–6} In the short-term perspective, the injured athletes are likely to go through orthopaedic surgery, setting the athlete on the sideline for approximately 6 to 12 months. Although the anatomy of ACL can be reconstructed by surgery, the majority of ACL-injured athletes experience reduced ability to perform daily function activities and fail to return to the pre-injury competition level of their sport.⁷ Furthermore, ACL injury is a major risk factor for knee osteoarthritis.^{8,9} Regardless of treatment, injured athletes are highly likely to develop knee osteoarthritis within fifteen to twenty years.^{9,10}

Research on preventing ACL injuries has been a hot topic in the past decades. Understanding the injury mechanisms and

identifying risk factors are critical for designing preventive measures.¹¹ Previous studies have showed that over 70% of ACL injuries happen in non-contact situations.^{2,12,13} Moreover, these studies reported that most of the injury cases occur when the athletes are performing jump-landing, sidestep cutting and other sudden deceleration motions. Knee valgus and internal tibial rotation are important components of the injury mechanism as found by advanced video analysis technique.¹⁴

Research on risk factors for injury is advocated for two reasons: (1) to help understand why injuries happen and (2) to predict who is at risk for injury.¹⁵ Numerous risk factors have been investigated such as type of competition,² type of surface,^{16,17} knee anatomical geometry^{18,19} and neuromuscular factors.^{20,21} More importantly, neuromuscular factors has the potential to be modified through appropriate screening methods and training programmes.²² Hence, by improving the neuromuscular control of knee, the ACL injury risk could be reduced.

Movement screening task

A movement screening task is often introduced with the aim to identify the high risk athletes, similar to the concept of diagnostic tests. It can be regarded as a binary classification

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system which classifies the observations into two groups based on specific property. Thus, a screening task for ACL injury is expected to be able to classify athletes into high and low risk of suffering ACL injury as illustrated in Figure 1.

Vertical drop jumping was suggested to be a successful movement screening task to predict ACL injury. Hewett et al.²⁰ tested 205 American high school female players by using a 3D motion analysis technique to capture the joint kinematics and kinetics during a vertical drop jump task. They recorded nine non-contact ACL injuries and reported that knee valgus angles at initial contact and peak value, as well as peak knee abduction moments, were associated with ACL injury. Knee abduction moments had a sensitivity of 78% and a specificity of 73% in predicting an ACL injury status. However, the findings were based on nine injury cases only, which is far less than the suggested minimum number of injury cases (20–50) for detecting moderate to strong association between the risk factor and injury.²³ Nevertheless, the vertical drop jump task was used to develop a clinic-based nomogram to estimate the peak knee abduction moment in order to identify high ACL injury risk in female athletes.^{24–26} The clinic-based nomogram employs the clinically obtainable measures of knee valgus motion, knee flexion range of motion, body mass, tibia length and quadriceps-to-hamstrings ratio. This clinical technique was reported to predict high knee abduction moments (>25.25 Nm) in female athletes with high sensitivity of 85% and specificity of 93%.²⁵

Goetschius et al.²⁷ applied the same nomogram on 1855 female high school and college athletes of which 20 injuries occurred during the study period. They found no relationship between estimated peak knee abduction moments and ACL injury, and they concluded that the clinic-based nomogram cannot identify athletes with increased ACL injury risk. In response, Myer et al.²⁸ argued that their differing results could be explained by methodological variations. For instance, in the study by Goetschius et al.,²⁷ the jump involved horizontal movement and foot separation was not standardized before drop down. Myer et al.²⁸ claimed that this would reduce the effect of provoking knee valgus collapse. The validity of nomogram is easily affected by small methodological variations. In addition, the prediction ability of peak knee abduction moment is in doubt.

Recently, Krosshaug et al.²⁹ reported the result of using vertical drop jump to assess the ACL injury risk in Norwegian elite female football and handball players. A total of 782 players were tested from 2007 to 2014, with 42 new noncontact ACL injuries recorded. The study reported the associations between the injury and five hypothesis-driven variables including knee valgus at initial contact, peak knee abduction moment, peak knee flexion angle, peak vertical

ground-reaction force and medial knee displacement. In contrast to the study by Hewett et al.,²⁰ knee abduction moments and valgus angles at initial contact could not identify players with increased risk of ACL injury. Instead, medial knee displacement was the only variable having an association with increased risk for ACL injury. This indicates that the “kissing knees motion” seen in vertical drop jump do imply higher risk for ACL injury.

Although the ‘kissing knees motion’ in a vertical drop jump was identified as an injury risk factor in the form of knee valgus angle and medial knee displacement,^{20,29} it cannot be used as a movement screening task to predict ACL injury risk. As illustrated by Bahr,¹⁵ the medial knee displacement measurements of injury and control group are largely overlapped. As a consequence, the receiver operating characteristic analysis in the study by Krosshaug et al.²⁴ indicated a poor sensitivity. In other words, even if the results demonstrated that increased medial knee displacement is a risk factor for ACL injury, it is not sufficient to make a clear cut-off between injury and control group. A much higher between-groups discrepancy would be required to serve the purpose of cutting off the ‘safety zone’. The idea of movement patterns as an accurate injury predictor seems impossible, but does that mean measurement of movement patterns has come to a dead end?

Alternative use?

Even if we cannot accurately identify athletes with high risk, movement screening tasks may still be important for reducing injury rates. The movement screening task can serve two functions: (1) to identify risk factors of the injury, which can provide a better understanding of which components are important in preventive methods; (2) to evaluate interventions without redoing an entire prospective cohort study.

A valid movement screening task can be used to evaluate the effect of the injury prevention exercises or programmes, since the task can deduce the chance of ACL injury risk. The task can potentially characterize athletes with poor knee control. After implementing the injury prevention programme, those target athletes will be reassessed and monitored for the change of injury risk. In this case, the screening task will serve as an evaluator of the intervention training effect. Neuromuscular and movement technique training can reduce half of the ACL injuries but is generally time-consuming and low compliance.³⁰ In addition, we have very little knowledge of which components are important in the programme. Therefore, there is a need to further evaluate the ACL injury prevention programme.

We need to determine factors that are affected by injury prevention interventions. For instance, the change on the movement patterns and muscle activations are of great interest after exposure to neuromuscular and movement technique training. Since the injury risk in match is 20-fold higher than training,³¹ the movement task should be close to the real-game situation in order to reveal the poor knee control of athletes. The movement task can be more challenging and match-like intensive by introducing un-anticipation and visual

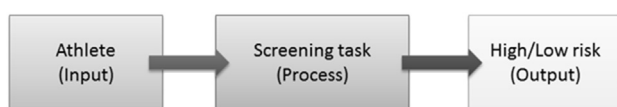


Figure 1. Model of a screening task, as a binary classification system, for sport injury.

distraction, such as an unanticipated ball-catching task.³² A more challenging and intensive task can potentially provoke a greater degree of poor knee control. Previous study has shown that a sport-specific sidestep cutting task induce knee joint loading approximately five times higher than vertical drop jumps.³³ The future task can include match-like elements such as jump-landing or single-leg support in an unanticipated situation.

If the test is reliable, we can detect movement pattern changes from injury prevention training, and also the enhancement on their knee controls. The knee biomechanical measurements can be reliably produced from the vertical drop jump task.^{34–37} The ultimate results of the movement screening task is injury risk, which indicates that the reliability of predicting injury is more important than the biomechanical variables themselves. However, none of the reliability studies used injury risk as a measurable outcome. The reliability of the task has yet been fully investigated, and it should be established based on injury case. Nevertheless, it is difficult to carry out a large scale prospective cohort, which costs a high amount of resources, to study reliability. Therefore, the breakthrough of reliability concept is needed for movement screening task.

The movement task has to be well-standardized with consistent intensity and stimulation. Virtual reality has great potential since athletes can be stimulated with pre-programmed scenarios. At the other end of movement detection, we need a breakthrough on the technology on measuring the knee biomechanics. It is well-known that the soft-tissue artifact has limited the validity of knee biomechanical measurements from the skin-marker-based motion analysis.³⁸ The incapability of measuring the true knee valgus and rotation hampered the usefulness of movement task's results. Lastly, muscle activation during movement task has never been investigated in large scale prospective cohort studies, while only pilot data were available.³⁹ The uninvestigated area of movement patterns in combination with muscle activations could provide a better understanding of ACL injury.

Summary

This article discusses the validity issue of movement screening task in predicting ACL injury risk, using vertical drop jump as an example. Measurement of movement patterns can still be valuable to detect important associations between knee biomechanics and ACL injury, which can help develop better injury prevention programmes. The use of ACL biomechanical risk model should shift to a role of evaluating the ACL injury prevention interventions, rather than aiming to identify high risk athlete. Ultimately, we hope the further development of movement task into clinical practice will be able to assess the effectiveness of injury prevention measures.

Conflicts of interest

The authors have no conflicts of interest relevant to this article to declare.

Funding/support

No financial or material support of any kind was received for the work described in this article.

Acknowledgements

The authors thank Dr. Tron Krosshaug of the Oslo Sports Trauma Research Center for proof-reading and valuable discussion.

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