Tuesday 1:15-2:15 pm A/Professor Jacqueline Alderson, University of Western Australia, Perth, Australia. Sports Injury Prevention: Are we tilting at windmills? (KS)

Sports Injury Prevention: Are we tilting at windmills?

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Injury prevention frameworks (e.g. Translate Research into Injury Prevention Practice) are critical for reducing injury rates. However, their success relies heavily on the available information within each stage of the framework. Using anterior cruciate ligament injury prevention research as a working example; this paper presents a rationale for the cultivation of cross-disciplinary injury prevention research groups and highlights the role of biomechanics in informing each stage of the injury prevention framework.

KEY WORDS: sports injury model, injury prevention framework, anterior cruciate ligament injury.

INTRODUCTION:

Cervantes (1952) 'tilting at windmills' is one of many metaphors that might be used to describe the effectiveness of injury prevention models in reducing sports related injuries among community level athletes. In a scene from the novel, Don Quixote tilts (fights) windmills that he imagines to be giants, such that his course of action is based on incorrectly perceived adversaries. In the context of sports injury prevention frameworks, the lack of success in reducing lower limb injury rates among community level athletes may be in part attributed to the misinterpretation of the primary injury mechanism(s) (adversaries). Ultimately, the downstream effect of such a misinterpretation is the development and/or implementation of poorly designed training interventions that can at best be described as successful, despite a lack of the mechanistic understanding by which the intervention worked, and in a worst case scenario may unintentionally increase injury risk.

There is little doubt that sports injury prevention frameworks such as those proposed by van Mechelen et al. (1992) followed by Finch's (1996) to Translate Research into Injury Prevention Practice (TRIPP), are critical for the development and implementation of effective injury prevention training protocols. However, the success of such a framework relies heavily on the available information within each stage, and how this information is used to inform successive stages. That is, for an injury prevention framework to be effective, the information within each stage must be empirically verified, and appropriately employed, to inform or guide subsequent stages. In general, research within each stage of an injury prevention framework is undertaken by scientists across multiple disciplines (e.g. epidemiologists, bioengineers, biomechanists, physiotherapists, health promotion and public health experts) operating in silos, with minimal to no interdisciplinary collaboration.

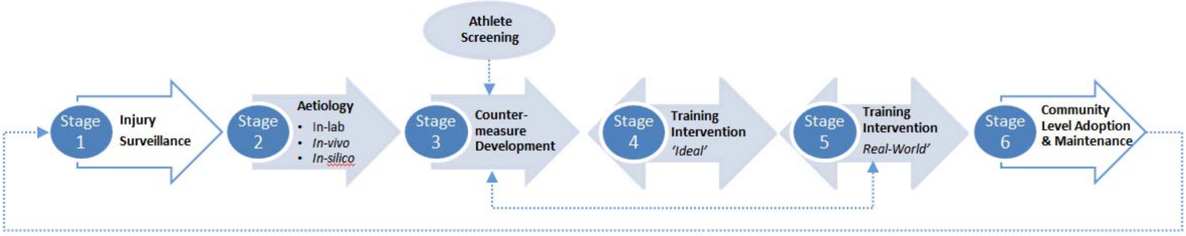

Figure 1: ACL injury prevention framework to translate ACL focused research into injury prevention practice (Donnelly et al., 2012a).

The purpose of this paper is to present a rationale and highlight the benefits of cultivating a cross-disciplinary injury prevention research setting, and to define the role of the biomechanist within this environment. Working examples, drawing upon anterior cruciate ligament (ACL) injury prevention research, across all stages of Finch's TRIPP model (adapted by Donnelly et al., 2012a) (Figure 1) is provided.

STAGE 1 OF 6: INJURY SURVEILLANCE

Despite significant advances in sports science and sports medicine, ACL injury estimates from the United States, Scandinavia, and Australia are increasing (Donnelly et al., 2012a). What we can be sure of is that; if injury prevention research was being effectively translated into injury prevention practice, ACL injury rates should be decreasing or at a minimum remaining constant. To guide researchers to better understand what sporting manoeuvres and phases of a movement are associated with ACL injury, we look to video analyses of athlete's rupturing their ACL and/or use surveys to retrospectively ascertain how athletes were injured. From these types of analysis we can direct our research focus to the analysis on non-contact single-leg landing or sidestepping sport tasks directly following initial foot contact (Cochrane et al., 2007; Krosshaug et al., 2007), as this represents how and when almost half of all ACL injuries occur (Cochrane et al., 2007; Gianotti et al., 2009).

STAGE 2 OF 6: MECHANICAL AETIOLOGY

Consistent with most injuries, an ACL rupture or partial rupture occurs when the forces applied to the tissue are greater than its ability to sustain the load (Lloyd, 2001). It is the role of the biomechanist to identify what loading patterns place the ACL at greatest risk of injury. *In-vivo* and cadaveric research has shown that it is the combination of tibio-femoral compression, anterior tibial translation, and valgus and/or internal rotation knee moments which elevate ACL strain and expose it to the greatest risk of injury (Markolf et al., 1995; Shin et al., 2011; (Meyer & Haut, 2008). Consistent with *in-vivo* findings (Cerulli et al., 2000), and aligning with video analysis research (Cochrane et al., 2007; Krosshaug et al., 2007), biomechanics based experimental investigations have revealed that the ACL risk is greatest during the weight acceptance (WA) phase of sidestepping (Besier et al., 2001; Dempsey et al., 2009) and single-leg landing (McLean et al., 2010).

Knee joint posture during WA has recently been verified as an important factor associated with ACL injury risk. This was shown by Wu and colleagues (2010), who successfully imaged the ACL during low velocity gait. They showed that peak elongation of both functional bundles of the ACL occurred when the knee is near full knee extension (0-15°). While further work concerning the aetiology of ACL injury is still warranted, we are provided with a sound foundation for the development of countermeasures to reduce ACL injury risk. Subsequently, it is generally accepted that during sidestepping and single-leg landing, effective countermeasures to reduce ACL injury risk should be focussed upon reducing peak valgus and internal rotation knee loading during WA, and that athletes should aim to increase their knee flexion angle at, and immediately following, foot contact.

STAGE 3 OF 6: COUNTERMEASURE DEVELOPMENT

There are effectively two available avenues to reduce ACL injury risk. These are; 1) change an athlete's technique to reduce external joint loading that could compromise the ACL and/or 2) improve the response of the musculature supporting the knee and ACL, when loading is high.

To date, biomechanically based research has primarily focused on external joint loading. Experimental literature has shown that an athlete's hip neuromuscular control during sidestepping and single-leg landing is a critical variable associated with peak frontal and transverse plane knee moments during sidestepping and single-leg landing (McLean et al., 2005; (Kipp et al., 2011). Trunk lateral flexion, away from an athlete's direction of travel (Dempsey et al., 2007) and restraining an athlete's arms to their midline (Chaudhari et al., 2007) have also been shown to elevate peak valgus knee loading during sidestepping. Solutions to reduce valgus knee loading during this manoeuvre include, but are not limited to, placing an athlete's foot stance foot closer to the body's midline while keeping their torso upright and rotated towards the desired direction of travel (Dempsey et al., 2009). From these experimental findings it is clear there is a complex, multifaceted interplay between an athlete's available kinematic degrees of freedom and the manner in which an athlete can reduce peak joint loading and injury risk during sporting tasks.

Recent *in-silico* work by Donnelly et al., (2012b), employed an optimisation approach to identify a simplified generalised kinematic solution from this seemingly complex, multifaceted kinematic problem. This group found that to significantly reduce valgus knee loading and ACL injury risk during sidestepping, a generalised kinematic strategy of redirecting the whole-body centre of mass medially towards the desired direction of travel was a consistent solution adopted by all simulations tested (n=9). A notable outcome from this simulation work is that athletes have the ability to develop their own unique motor control strategies in order to medialise their centre of mass during sidestepping tasks. More importantly, these findings show that simulation based research can play an integral role in identifying causal links between an athlete's technique and injury risk, as well as providing additional direction toward the development of effective injury prevention training protocols.

STAGE 4 OF 6: ACL FOCUSED TRAINING INTERVENTIONS

It is in the intervention stages where the bulk of the research within the ACL injury prevention framework currently resides, and this may be attributed to our limited mechanistic understanding by which training reduces ACL injury risk. This incomplete understanding is likely why training interventions studies have been met such with varied success, with more published studies reporting inconclusive (n=7) rather than conclusive (n =3) findings following a training intervention programme (Donnelly et al., 2012a). As a disciplinary field, biomechanists must begin identifying the mechanisms by which training protocols act, before we can repeatedly and effectively target the risk factors associated with ACL injury risk. This is necessary if we are to confidently progress to stage 5 of the ACL injury prevention framework.

What is common among most training interventions focused on reducing ACL injury predisposition is the type of training each programme adopts (i.e. combination of; technique, plyometric, balance and/or resistance training). However, the specific focus of these training interventions is not always apparent, and may go some way to explain why some training programmes are deemed unsuccessful. As such, it is unlikely the focus of a given training intervention will effectively target the biomechanical factors shown to influence knee joint loading or muscular support and in turn ACL injury risk (Stage 3). Simply stated, the root of a successful training protocol is not the type of exercises used, but the intended focus of the training programme employed. For example, given that simulations involving the redirection of an athlete's whole-body centre of mass medially, towards the desired direction of travel has theoretically been shown to reduce knee joint loading and ACL injury risk (Donnelly et al., 2012b), the focus of a training protocol should be to increase the neuromuscular control of the hip and trunk to allow an athlete to achieve this technique modification. Consequently, the type of training adopted in the intervention programme should be that which most effectively facilitates this goal. Therefore, we will likely remain in stage 4 until such time as biomechanists begin working with, and are accepted by, clinical and allied health researchers and trainers to bridge this gap.

DISCUSSION

In order to avoid a path similar to Cervante's character Don Quixote (1952), researchers embedded in the injury prevention framework must ensure that the correct adversary responsible for ACL injury is identified. This understanding is essential for the design and implementation of intervention prevention training programmes geared toward addressing the primary mechanism(s) of injury, which is a necessary outcome, if we are to move forward to stages 5 and 6 in the ACL injury prevention framework proposed by Donnelly et al., (2012a). Although the biomechanist is not central to the application of stages 5 and 6, which are focused on testing the efficacy of training interventions in 'real-world' settings and evaluating the challenges associated with their implementation, the preceding stages (1 to 4) should be used as a foundation for which these studies are based. From stage 1 we know that the majority of non-contact ACL injures occur during sidestepping and single-leg landing. From stage 2 it is known that combined loading, specifically valgus and internal rotation knee moments during the WA phase of sidestepping and single-leg landing with the knee near full extension, is the likely mechanism of non-contact ACL injuries. From stage 3 we know we can reduce external knee loading by altering an athlete's technique, and that the trunk and hip musculature play an important role in this process. Lastly, in stage 4 it is evident that the root of a successful training protocol is not the type of exercises adopted, but the intended focus of the training protocol employed; for example, to increase an athlete's hip and trunk neuromuscular control to assist in the mediatisation of their whole body centre of mass. It is through this rigor that injury prevention frameworks can be effectively translated into injury prevention practice in the context of the community level athlete.

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