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The impact of previous knee injury on force plate and field-based measures of balance

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ABSTRACT

Background: Individuals with post-traumatic osteoarthritis demonstrate increased sway during quiet stance. The prospective association between balance and disease onset is unknown. Improved understanding of balance in the period between joint injury and disease onset could inform secondary prevention strategies to prevent or delay the disease. This study examines the association between youth sport-related knee injury and balance, 3–10 years post-injury.
Methods: Participants included 50 individuals (ages 15–26 years) with a sport-related intra-articular knee injury sustained 3–10 years previously and 50 uninjured age-, sex- and sport-matched controls. Force-plate measures during single-limb stance (center-of-pressure 95% ellipse-area, path length, excursion, entropic half-life) and field-based balance scores (triple single-leg hop, star-excursion, unipedal dynamic balance) were collected. Descriptive statistics (mean within-pair difference; 95% confidence intervals) were used to compare groups. Linear regression (adjusted for injury history) was used to assess the relationship between ellipse-area and field-based scores.
Findings: Injured participants on average demonstrated greater medio-lateral excursion [mean within-pair difference (95% confidence interval); 2.8 mm (1.0, 4.5)], more regular medio-lateral position [10 ms (2, 18)], and shorter triple single-leg hop distances [−30.9% (−8.1, −53.7)] than controls, while no between group differences existed for the remaining outcomes. After taking into consideration injury history, triple single leg hop scores demonstrated a linear association with ellipse area ($\beta = 0.52$, 95% confidence interval 0.01, 1.01).
Interpretation: On average the injured participants adjusted their position less frequently and demonstrated a larger magnitude of movement during single-limb stance compared to controls. These findings support the evaluation of balance outcomes in the period between knee injury and post-traumatic osteoarthritis onset.

1. Introduction

Knee osteoarthritis (OA) is characterized by articular cartilage degeneration and is associated with pain, functional impairments and increased rates of comorbidity (e.g. obesity, diabetes and heart disease) (Lohmander et al., 2007; Suri et al., 2012). While idiopathic OA typically develops in older adults, evidence suggests that youth and younger adults develop post-traumatic osteoarthritis (PTOA) prematurely as a result of a sport-related knee injury (Ajuied et al., 2014; Lohmander et al., 2004; Richmond et al., 2013; Roos, 2005; Roos et al., 1998). For instance, a recent meta-analysis identified previous joint injury and history of meniscectomy as significant risk factors for knee OA [odds ratio (OR) 3.8 (95% CI) 2.0, 7.2 and 7.4 (95% CI) 4.0, 13.7 respectively] (Richmond et al., 2013). This is consistent with other reports in which radiographic PTOA was identified in approximately 50% of male athletes 14–21 years following meniscectomy (Roos et al., 1998; Von Porat, 2004). Similarly, in individuals that have suffered an anterior cruciate ligament (ACL) rupture, regardless of conservative or surgical treatment, the relative risk of developing minimal OA (Kellgren Lawrence radiographic grade II) is estimated at 3.89 (95% CI; 2.72, 5.57) and moderate to severe OA (Kellgren Lawrence radiographic grade III or IV) at 3.84 (95% CI; 1.84, 8.01) compared to an uninjured population (Ajuied et al., 2014). Given the potential long-term health impact of joint injury, it is a priority to identify modifiable potential risk factors that can be targeted with secondary prevention strategies aimed at halting or slowing progression to PTOA.

The pathogenesis of PTOA is multifaceted and thought to result from the interplay of a variety of etiological factors including joint injury and

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obesity (Andriacchi et al., 2004). It is plausible that the biological pathways by which intra-articular joint injury leads to PTOA may be mediated by reduced balance, through mechanisms associated with impaired proprioception, reduced muscular strength and increased co-contraction of the muscles that cross the knee joint which result in altered joint loading (Al-Dadah et al., 2011; Hubley-Kozey et al., 2008; Ingersoll et al., 2008; Jerosch et al., 1996; Magyar et al., 2012; Nagai et al., 2011). While balance abilities have been measured in the months following injury (Herrington et al., 2009; Ingersoll et al., 2008; Magyar et al., 2012) and in patients with OA (Hinman et al., 2002), there is a lack of research quantifying balance in the interval between joint injury and PTOA onset. Improved understanding over this interval could shed light on the prospective relationship between balance ability and PTOA onset in individuals at high risk of developing PTOA due to previous intra-articular knee injury and inform secondary prevention strategies aimed at preventing and/or delaying PTOA onset.

There are numerous outcome measurements that can be used to quantify balance ability. Generally speaking these measurements can be classified as laboratory or field-based. Laboratory measurements have traditionally utilized a force platform to quantify the movement of the center of pressure (COP) during bipedal or unipedal standing using specific spatial and temporal variables. Spatial variables provide information regarding the amount of movement while temporal variables provide information regarding the dynamic structure of the COP signal. In combination these variables allow for an assessment of the regularity of postural corrections (e.g. more or less regular COP signal) (Baltich et al., 2014). In contrast to laboratory methods, which require expensive equipment and skilled operators, several field-based screening tests have been developed to help coaches, sport scientists and rehabilitation practitioners assess balance in clinical and field-based environments (Cavanaugh et al., 2005; Kinzey and Armstrong, 1998). Three commonly used field-based balance tests that have demonstrated reliability and have been validated to identify injury risk in athletes include the triple single leg hop test (TSLH), star excursion balance test (SEBT), and unipedal dynamic balance test (UPDB) (Emery et al., 2005a; Kinzey and Armstrong, 1998; Plisky et al., 2006). These approaches require very little specialized equipment or skilled operators making them amenable for use with larger epidemiological studies. Additionally, field-based measures are more applicable to athletes, coaches, and the general public when trying to advocate for changes in training or rehabilitation protocols.

The combination of force plate and field-based measures to quantify balance provides a broad assessment of balance abilities in the time period between joint injury and PTOA onset. However, for settings where force plate measures are not plausible (e.g. in a medical practitioners office or on the playing field), it is important to determine the relationship between the force plate and field-based measures of balance. While the parameters measured in field-based and force plate assessments are different, it is plausible that they are correlated and quantify similar aspects or constructs of balance. Understanding the relationship between the two forms of measurements would inform which aspects of balance can be captured in settings where only field-based measures are utilized and would bridge the communication between biomechanical researchers and clinicians. To date, there is a paucity of literature assessing the relationship between force plate and field-based balance measures in populations at high-risk of developing PTOA.

The primary objective of this research was to compare force plate and field-based balance measures between individuals who sustained a sport-related intra-articular knee injury in youth, 3–10 years previously, and age, sex and sport matched controls. The secondary objective was to develop a more comprehensive understanding of the relationship between field-based and force plate measures of balance in these two populations. As balance deficits have been identified 1 year following injury, it was hypothesized that balance deficits would exist in the period 3–10 years following injury in those with a history of knee joint injury including increased magnitudes of COP movement (H1), increased COP regularity (H2) and reduced performance scores on the TSLH, SEBT, and UPDB tests (H3). Furthermore, that there would be a linear association between the COP ellipse area and performance scores from the field-based balance tests (H4)

2. Methods

2.1. Participants

Participants included 100 youth/young adults (aged 15 to 26 years); 50 with a history of sport-related intra-articular knee injury and 50 healthy matched controls (age, sex and sport). These participants represent the first 50 matched pairs recruited in year 1 (2013) of an ongoing longitudinal historical cohort study [The Alberta Youth Prevention of Early OA Study (AB Pre-OA Study)] (Whittaker et al., 2015). Participants were recruited by telephone contact after identifying them from one of three sources; previous cohort studies conducted by the Sport Injury Prevention Research Centre, University of Calgary that examined injury risk factors in various youth sports (both injured and uninjured participants) (Emery and Meeuwisse, 2006a, 2006b, 2010; Emery et al., 2005b, 2007, 2010), the University of Calgary Sport Medicine Centre (SMC) database (injured participants only) or, through personal distribution of study information by study co-investigators, collaborators and participants (uninjured participants only). The injured group included individuals who sustained an intra-articular knee joint injury during a previous cohort study (contact was attempted for all individuals from these previous studies that had sustained an intra-articular knee injury) or who had presented to the SMC with a sport-related intra-articular knee injury 3–10 years previously (contact was based on a computer generated random list). In contrast, the uninjured group included individuals that had not experienced an intra-articular knee injury. For the purposes of this study, knee injury was defined as a clinical diagnosis of knee ligament, meniscal or other intra-articular tibio-femoral or patella-femoral injury (e.g. osteochondral, fractures, etc.) that required both medical consultation (physician or physiotherapist), and resulted in disruption of regular sport participation in the past 3–10 years. Exclusion criteria included pregnancy, non-steroidal anti-inflammatory use or cortisone injection within 3 months prior to testing, a musculoskeletal injury within 3 months prior to testing that resulted in time loss (work, school or sport), diagnosis of other arthritides, or any current medical problem that prevents participation in the functional testing aspect of the study (e.g. neurological). As this was an exploratory analysis embedded in a larger historical cohort study no a priori power based sample size calculation was undertaken. Ethics approval was granted from the Conjoint Health Research Ethics Board at the University of Calgary, Canada and all participants provide signed consent/assent and completed a Physical Activity Readiness questionnaire (PAR-Q, 2002) prior to testing.

2.2. Testing procedures

All data were collected during one testing session for each participant at the University of Calgary, Sport Medicine Centre. After completing a study questionnaire regarding demographic details, knee injury and medical history, participants rotated through testing stations that measured anthropometric details (height, weight), force plate measures of balance and dynamic clinical measures of balance. Outcomes were gathered bilaterally with participants barefoot. The dominant limb was identified as the leg the participant would use to kick a ball as far as they could. For the purpose of this investigation, the index leg refers to the injured leg of the injured participants and corresponding leg of the matched control. Comparisons between groups were made using the indexed leg.