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Are maturation, growth and lower extremity alignment associated with overuse injury in elite adolescent ballet dancers?

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ABSTRACT

Objective: To identify growth, maturation and biomechanical risk factors for overuse injury in elite adolescent ballet dancers.
Methods: Maturation (Tanner scale), growth (foot length change) and age at onset of menarche were recorded in elite adolescent ballet dancers. A modified knee valgus angle and lateral tilt of the pelvis were measured using 2D video during two dance movements (*fondu, temps levé)* to quantify lower extremity alignment. Overuse dance injuries were recorded by a physiotherapist. The injury rate ratio (RR) associated with each variable was estimated using over-dispersed Poisson regression modelling.
Results: Changes in right foot length (RR = 1.41, CI = 0.93–2.13), right knee angles during the *fondu* (RR = 0.68, CI = 0.45–1.03) and *temps levé* (RR = 0.72, CI = 0.53–0.98), and pelvic angles during the *temps levé* on the left (RR = 0.52, CI = 0.30–0.90) and *fondu* on the right (RR = 1.28, CI = 0.91–1.80) were associated with substantial changes in injury risk.
Conclusions: Rate of growth in elite adolescent ballet dancers is likely associated with an increase in risk of lower extremity overuse injury and better right lower extremity alignment is likely associated with a reduction in risk of right lower extremity overuse injury.

1. Introduction

It is well documented that there is a high incidence of injury among elite adolescent and professional ballet dancers. Overuse injuries of the spine and lower extremities are particularly common in this population (Allen, Nevill, Brooks, Koutedakis, & Wyon, 2012; Bowling, 1989; Ekegren, Quested, & Brodrick, 2011; Gamboa, Roberts, Maring, & Fergus, 2008; Garrick, 1999; Krasnow, Mainwaring, & Kerr, 1999; Leanderson, Leanderson, Wykman, Strender, Johansson, & Sundquist, 2011; Nilsson, Leanderson, Wykman, & Strender, 2001; Steinberg et al., 2011). Recent research has begun to highlight key risk factors for these injuries with particular reference to adolescent dancer populations (Fournier, Rizzoli, Slosman, Theintz, & Bonjour, 1997; Gamboa et al., 2008; Phillips, 1999a; Steinberg et al., 2011) due to a sharp increase in the incidence of injuries observed at the onset of, and during pubertal development. The adolescent growth spurt and the period of maturation that follows, including the age at onset of menarche in females, have been suggested as two key risk factors for injury in elite adolescent dancers and athletes (Ford, Shapiro, Myer, Van den Bogert, & Hewett, 2010; Hewett, Myer, & Ford, 2004; Matthews et al., 2006; Poggini, Losasso, & Iannone, 1999; Steinberg, Sivan, Peleg, Dar, Masharawi, & Hershkovitz, 2008).

Maturation, or the development of secondary sexual characteristics, occurs during adolescence with significant variation between individuals in the timing and tempo of growth (Matthews et al., 2006; Phillips, 1999a). Several studies of female athletes have highlighted how maturation can lead to an increased risk of injury. Following the onset of maturation, female athletes demonstrated increased peak knee abduction angle when landing from a vertical drop jump (Ford et al., 2010; Hewett et al., 2004). A number of studies have highlighted a relationship between poor dynamic alignment of the lower extremity on landing and increased risk of lower extremity injury (Levinger, Gilleard, & Coleman, 2007; Willson & Davis, 2008). Poor alignment is commonly reported as the appearance of excessive knee valgus (femur angle inward, tibia angle outward) likely resulting from various combinations of altered hip and knee transverse and frontal plane kinematics (Willson & Davis, 2008). Currently, no

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research has assessed this period of maturation as a risk factor for injury in elite adolescent ballet dancers, nor specifically the possible link with poor dynamic lower extremity alignment.

Due to the variation in timing of maturation, chronological age is not necessarily an accurate indicator of the level of injury risk for a young dancer exposed to high levels of training (Helsen, Van Winckel, & Williams, 2005; Matthews et al., 2006). Instead, measures of maturation such as the Tanner scale (Marshall & Tanner, 1969) may offer a more accurate guide, and therefore provide guidance when determining desirable training loads during certain growth and maturation phases. Although the use of Tanner scales may improve specificity in training loads and assist in reducing injuries, few studies with adolescent dancers have used them. Age at onset of menarche is further associated with the period of maturation, although there is general agreement among the literature that this milestone is often delayed among female ballet dancers putting them at greater risk for injury (Brooks-Gunn, Burrow, & Warren, 1988; Kadel, Donaldson–Fletcher, Gerberg, & Micheli, 2005; Kadel, Teitz, & Kronmal, 1992; Klentrou & Plyley, 2003; Torstveit & Sundgot-Borgen, 2005; Vadocz, Siegel, & Malina, 2002; Warren, Brooks-Gunn, Hamilton, Warren, & Hamilton, 1986). While numerous studies have demonstrated a link between delayed onset of menarche or menstrual irregularity with high volume advanced dancers (Brooks-Gunn et al., 1988; Kadel et al., 2005; Steinberg et al., 2008; Torstveit & Sundgot-Borgen, 2005), this delay has not been successfully demonstrated to coincide with an increase in injuries aside from stress fractures, specifically in elite adolescent populations.

An increase in injury incidence has reportedly been observed in dancers both at the beginning, and throughout the adolescent growth spurt (Burckhardt, Wynn, Krieg, Bagutti, & Faouzi, 2011; Daniels, Rist, Rijven, Phillips, Shenton, & Posey, 2001; Krasnow et al., 1999; Leanderson et al., 2011; Phillips, 1999b; Stacey, 1999; Steinberg et al., 2011). However it is difficult to ascertain the exact cause for this observed increase given adolescence is often when students also begin to increase the intensity of dance training (Daniels et al., 2001). Several studies assessing injury incidence have reported a higher injury frequency in adolescent dancers (Leanderson et al., 2011; Steinberg et al., 2011), noting that the observed increase could be explained by an amplified rate of bone growth in comparison to the ligaments and tendons, thereby exposing the soft tissue to a higher risk of injury (Hamilton, Hamilton, Marshall, & Molnar, 1992). However, there was no clear evidence for this being the cause of injury as opposed to increased exposure. Although there are some biomechanical and physiological underpinnings suggesting a rapid increase in growth may lead to an increased risk of injury (Daniels et al., 2001; Phillips, 1999b; Stacey, 1999), there is currently a lack of evidence supporting this cause–effect relationship, specifically in elite adolescent dancers.

Poor alignment of the hip, knee and ankle has been identified as a further risk factor for lower extremity injury (Murphy, Connolly, & Beynnon, 2003; Poggini et al., 1999; Whatman, Hume, & Hing, 2012; Willson, Ireland, & Davis, 2006). In athletes, poor frontal and/or transverse plane control of the pelvis, hip, knee and foot is considered less than ideal, and it is thought that identifying this may help detect those athletes most at risk for injury (Stensrud, Myklebust, Kristianslund, Bahr, & Krosshaug, 2011; Whatman et al., 2012). This pattern of lower extremity dynamic alignment is also considered important in dancers (Clippinger, 2007). A number of studies have been conducted in athlete populations to assess for poor lower extremity alignment with several studies demonstrating a link between poor dynamic alignment and injury (Levinger et al., 2007; Willson & Davis, 2008). However, to date no research has assessed elite adolescent ballet dancers for lower extremity alignment during functional dance movement with regard to injury risk.

Currently a paucity of information exists around key risk factors for injury, including growth, maturation and lower extremity alignment in elite adolescent dancers. To date, little research supports the cause–effect relationship between rapid growth and injury, while there is also no evidence assessing the effects of maturation on dance technique and its potential risk for injury. Furthermore, lower extremity alignment in dancers has yet to be assessed during dance movement with regard to injury risk. Therefore the aim of this study was to identify growth, maturation and biomechanical risk factors for overuse injury in elite adolescent ballet dancers.

2. Methods

Forty-six (Female = 30, Male = 16) adolescent ballet dancers (mean ± SD, age 16 ± 1.58 years) were recruited from the Australian Ballet School (ABS) in Melbourne and prospectively followed over six months. All dancers were full-time ballet students at the school. Ethical consent was granted for the study by the AUT University Ethics Committee (AUTEC) and the Australian Catholic University Ethics Committee. The dancers and their guardians provided written assent/consent prior to participation. Due to leaving the school, a total of four participants (Female = 1, Male = 3) dropped out of the study over the six month period.

Maturation, growth, height and body mass were recorded in all dancers. All dancers also completed a survey to assess their stage of maturation using the Tanner scale. The Tanner scale consisted of a series of images of female and male reproductive organs depicting development at each of the five stages of sexual maturity from a pre-pubescent child through to post-pubescent adult (Kadel et al., 2005). Tanner stages one to five were recoded to create two groups of sufficient number as well as a dichotomous classification of maturation for subsequent analysis. No dancers identified themselves as Tanner stage one. Tanner stages two and three were re-classified as maturation level one or a less mature group, and Tanner stages four and five as maturation level two, a more mature group. Age at onset of menarche was also included in the survey for female participants. Growth was assessed by change in foot length (Aml, Peker, Turgut, & Ulukent, 1997; Krishan & Sharma, 2007). Kinovea video analysis software (v 8.15) was used to measure foot length at baseline and six months (Fig. 1). Foot length was defined as the distance between the tip of the longest toe (first or second distal phalanx) to the most posterior point on the heel (calcaneus). The dancer stood with full body weight on the foot being assessed during all photographs. All height and body mass data were collected by the ABS physician.

Lower extremity alignment was also measured in all dancers. Each dancer was asked to perform two functional dance

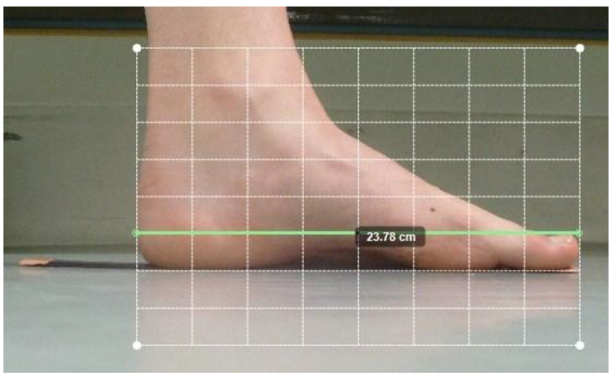

Fig. 1. Foot length measure.