Is there a relationship between female ballet injuries and maturation? A review

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Abstract

Ballet dancers are a historically underrepresented cohort in the field of sports medicine. Although increasingly more research is being conducted on the dancing population, as of recent, many questions remain. Young, elite, female dancers have high rates of injury with longstanding adverse consequences though further research is required to better understand the etiology of injuries in this demographic. What is apparent is that the injury location is often the lower extremity and back, whereas the injury type is often stress fracture and overuse injury. Delays in menarche and menstrual irregularities are often present in female dancers which may impact skeletal development during the critical time of bone accrual and subsequently increase the risk of dancers acquiring injuries such as stress fractures. Issues of energy availability and training demands during adolescence may also influence injury patterns and require consideration. Determining the contributions of these various factors to the types of ballet injuries during adolescence is an important direction of future investigations. Furthermore, developing appropriate screening measures and effective treatment strategies is of value for maturing female ballet dancers.

Introduction

Evidence in the discipline of dance medicine is limited compared to sport science investigations of other athletic endeavours; however, the production of literature regarding ballet dancers is gradually expanding. The need for continued study of ballet–resultant injuries is warranted considering the high injury rates being documented in elite adolescent ballet dancers.[1-3] There remains a gap in the literature currently as to how a delay in the onset of menarche or menstrual dysfunction are related to a dancer's injury occurrence in the pre–pubescent and pubescent years, especially across different injury types acquired in ballet.[4] This review aims to present the impact of energy and hormonal imbalances, puberty, and skeletal maturation on the types and rates of injury within adolescent ballet dancers.

Injuries in adolescent ballerinas

As most ballet injury–based research has been conducted retrospectively in adult professional dance populations, there is less evidence as it relates to injuries sustained in the pre–adolescent and adolescent years.[4-6] Importantly, the impacts of injuries acquired during the early training years persist, often reappearing during one's professional career or leading to dropout prior to a professional career, and subsequently affect other forms of physical activity participation.[5,7] Musculoskeletal injury is a substantial risk for ballet dancers, whose athletic pursuits require training in extreme positions of joints.[1] Common injuries cited include those of the lower extremities and overuse injuries, particularly through the spine.[2,3] Overuse injuries consistently account for the majority of injuries, whereas fractures have been found to be responsible for the longest recovery time.[2,4] Although in–depth examinations of the different injury types presenting during ballet training are needed, it is difficult to do so without accounting for the multivariate underpinnings of ballet injuries. For example, time lost from practice cannot be relied on to classify injury prevalence or severity because most dancers will continue to train through an injury.[2]

Energy, availability, menstrual irregularity, and ballet training

Dancers tend to have a lower body mass index, shorter height, lower weight, and smaller breast circumference than non–dancers.[5] For example, both small stature and low height was found in 18% of adolescent dancers compared to 9% of controls in a study of adolescent dancers.[5] The relevance of an extremely lean body in classical ballet is its association to a delay in the onset of menarche and subsequently strong predictive nature for acute injury.[6–9] The delay of maturation and growth of female dancers may partially be due to selection and self–selection of those who genetically mature later, are lighter weight, and are shorter[10–12] rather than as an outcome of dancing itself.

In relation to leanness, inadequate eating patterns can arise from a combination of factors such as high intensity training or pressures to reach weights for performance or aesthetic enhancement that are unrealistic.[13] It is now believed that the relative energy deficiency between energy intake through diet and the body's various forms of energy expenditure, appears to be the driving cause of the phenomenon in athletes commonly known as "Female Athlete Triad," and now being referred to as "Relative Energy Deficiency in Sport."[14] Energy balance is cited as 45 kcal/kg of fat–free body mass,[15] and female dancers are recommended to intake 45-50 kcal/kg when heavily training.[16] Intake below the threshold of energy availability at 30 kcal/kg of fat–free body mass runs a risk of hormonal suppression[17] and the result of energy deficiency subsequently includes negative physiological impacts on systems such as menstrual functioning and bone health.[14] The older theory of 17% body fat being required for onset of menarche and 22% body fat required for maintaining menstrual cycles in adulthood may not represent truly accurate numbers;[18] however, the trend of adequate fat mass and energy availability being required for the female reproductive system to operate effectively, appears to hold true.

Menstrual disturbances from insufficient energy availability can include oligomenorrhoea, primary amenorrhoea, or secondary amenorrhoea, which are menstrual cycles longer than 36 days, no menstruation by 16 years of age, and a post–menarcheal absence of three consecutive menstrual cycles, respectively.[13,14] Female dancers show a greater prevalence and length of all of these menstrual abnormalities, with rates of stress fractures increasing alongside delayed or halted menstruation.[4,5,7,8,10,19,20] In addition, they exhibit higher incidences of

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delayed onset of menarche, delayed growth and maturation, and sexual immaturity, compared to non–dancers. [5,7,8,10,20] For example, Kadel et al.[21] found 80% of pre–professional dancers to have delayed onset of menarche, 56% of dancers with stress fractures and amenorrhoea, and most notably amenorrhoea corresponding to a 93 times greater chance of developing a fracture. Even so, the contributions of activity, body composition, and genetics to the maturation of young dancers[8] and how they relate to the various injuries seen around the time of puberty are not fully understood.

Puberty, skeletal development, and injury

Injury prevalence in dancers corresponds with increasing age of the dancer and amount of dance exposure, which in pre–professional training increases concurrently with the beginning of the adolescent growth spurt.[10] Bone mass acquisition, modeling, and remodeling are highly influenced by the female reproductive system throughout puberty,[22,23] a period of time in which there is an asynchrony between the growth rate of one's stature and the rate at which the accumulation of bone mass occurs.[10] The hypothalamic–pituitary–gonadal system is interrelated to both puberty and skeletal maturation in a variety of ways.[24] The complex interactions of hormones such as sex hormones, growth hormone, and insulin–like growth factor I (IGF–I), that increase at the onset of menarche, also regulate osteoblastic lineage cells, thereby stimulating radial and longitudinal bone growth in addition to the rapid acquisition of skeletal mineralization.[22,23,25] For example, plasma levels of IGF–I rise during puberty and stimulate osteoblasts to differentiate and proliferate thus enhancing osteoblastic activity to form the extracellular matrix and increase the size of a bone.[26] Estrogen appears to play a protective role for conserving bone mass and inhibiting bone loss by extending the lifespan of the cells through increased osteoclast death and decreased osteoblast and osteocyte death.[22,26]

Bone mass acquisition peaks in females at menarche,[22] with one third of peak bone mineral density gained within the four years surrounding menarche's onset.[23] During the time of skeletal development, bone is relatively fragile for one's body size and has less resistance to mechanical stress, explaining why the highest incidence of fractures are recorded during the adolescent period.[3,22,24] Bone mineral density is known to be highly influenced by genetics,[27] with differences in bone mass measurements found between those with earlier and later age of menarche potentially already present before pubertal maturation or introduction to professional dance training.[11,12,24] However, with hormonal and menstrual pattern abnormalities and energy deficiency comes the negative effects on bone mineralization including osteoporosis and stress fractures.[10,13,28] This may be amplified when intensive or elite ballet training is initiated prior to puberty, since hypothalamic–pituitary function may be altered and cause a delay in menarche.[13] Delayed menarche has further been shown to correspond with lower bone mineral density in locations such as the spine, as well as with the high incidence of stress fractures, scoliosis, and other injuries seen in young ballet dancers.[4,10,21,24,26,31] For example, dancers with stress fractures have experienced a higher age of menarcheal onset at 15.2 years as compared to 13.5 years in dancers without stress fractures,[29] and 83% of dancers with scoliosis have had delayed onset of menarche, with 44% of dancers with scoliosis experiencing secondary amenorrhea.[19]

There are opposing views in regards to whether dancing has a harmful or protective effect on bone health, given that the findings on dancers' bone mineral density are unclear.[20] Research suggests that bone–forming cells may be stimulated by activities of dancing including jumping and weight–bearing, which require high levels of muscular strength.[20] Professional female ballerinas have reported higher bone mineral density at impact sites when compared to controls;[20] however, such findings are not consistent since low bone mineral density at non–impact sites, the lumbar spine, and throughout the whole body, have been found across available studies of dancers' bone mineral density. [27] The intensity, volume, and frequency thresholds of dancing to produce enough gain in bone mass to classify it as an osteogenic activity remain unknown and the negative effects of issues such as amenorrhea and low energy availability on the skeletal system are likely not fully offset by the weight–bearing nature of dance training.[27]

Identification of dancers at–risk

With high injury rates being seen in the training years, continued investigation into injury prevention strategies are needed along with the identification of major risk factors. Risk factors found for professional dancers cannot necessarily be assumed to be accurate for younger dancers[4,6] given the structural and physiological changes occurring during puberty and adolescence. Therefore, it would be of benefit to determine feasible screening and monitoring procedures for at–risk dancers during this time of skeletal immaturity, when the risk of overuse injuries is high.[10] With the onset of menarche being a prominent sexual developmental milestone,[24] using timing of onset of menarche as a marker for tracking maturation may be a possibility in such strategies. Addressing the complex interactions of training parameters, nutrition, pubertal status, and genetic predispositions on the musculoskeletal development of elite female ballet dancers in pre–adolescent and adolescent years appears to be a promising direction for further investigations.[7,11,30] In addition, it is of benefit to better determine puberty's effects on non–skeletal injuries in the adolescent elite dancing population. Health care professionals, dance teachers, and parents should all be cognisant of the time surrounding puberty when physical changes are occurring, as anatomical limitations may be present for female dancers and excessive volumes of intensive training and stretching may need to be adjusted.[31]

Conclusion

There is growing attention for the field of dance medicine that recognizes the athleticism and complexities involved with ballet and its training. Understanding the injuries of adolescent elite ballet dancers requires attention, as overuse injuries, stress fractures, and lower extremity injuries are prominent. The timing around puberty appears to be of particular interest for injury, due to its importance in skeletal development. Since dancers may exhibit issues with menstrual functioning and energy availability, the impacts of such factors on various injury types also require consideration. Due to the nature of ballet training and its desired aesthetics, a delay in sexual maturation and its subsequent effects on the skeleton are likely to make dancers vulnerable to injury during the skeleton's period of growth. Further research is encouraged to better understand these interactions and develop effective screening and injury prevention strategies.

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