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Review

Bone mineral density in pre-professional female ballet dancers: A systematic review and meta-analysis

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ABSTRACT

Objectives: To quantitatively compare bone mineral density (BMD) outcomes between pre-professional female adolescent ballet dancers and control populations.
Design: Systematic review and meta-analysis.
Methods: Six electronic databases and relevant journals were systematically searched up to August 2017. Included articles examined BMD in adolescent females undergoing pre-professional ballet training and healthy age-matched controls with an available English full text. Dancers were aged 15–19 years and trained in ballet at least 10 h per week. BMD data were analysed via standardized mean difference to account for differences in reporting methods
Results: From 3984 potential articles, 8 cross-sectional studies were accepted for inclusion, which compared 293 dancers (16.9 ± 0.8 years) to 333 controls (16.9 ± 0.9 years). No data were available from longitudinal studies. Dancers displayed lower BMD at the radius and higher BMD at the femoral neck, femoral trochanter and Ward's triangle. No significant differences were observed in the lumbar spine or tibia. The overall study quality was low and heterogeneity was present in some analyses.
Conclusions: This meta-analysis indicates that there may be a site-specific osteogenic effect of pre-professional classical ballet training in adolescent females, with a notable and concerning finding of reduced upper limb BMD compared to age-matched controls. Longitudinal cohort studies are required to confirm the effects of pre-professional ballet training on BMD during adolescence.

1. Introduction

The physiological and psychological benefits of recreational dance activities throughout adolescence are well-reported.[1] However, there is also concern for ballet dancers who undertake intensive pre-professional ballet programs during adolescence, especially as some training programs are becoming more intensive from a younger age. Adolescence is a key time point for bone development, as peak bone mass occurs around 19 years in women.[2] The concept of Relative Energy Deficiency in Sport (RED-S) describes an imbalance between daily energy intake and energy expended to support daily activities.[3] Chronic energy deficiency has a number of physiological consequences, one of which is a decline in bone health, which can increase the risk of stress fractures.[4] This condition is more often seen in "aesthetic" sports, like ballet, gymnastics or figure skating, where athletes are driven to fulfil a lean and gracile body shape.[5] Therefore, it is important for teachers and clinicians to have an awareness of the potential for this condition to occur in ballet dancers.[6]

Bone health issues, particularly low bone mineral density (BMD) in dancers are anecdotally common. However, the literature is inconclusive, especially in adolescents. Amorim et al. reported that prevalence of low BMD in pre-professional ballet dancers may be higher than for current and retired professionals, with low BMD occurring in up to 47.7% and 32.9% of pre-professional dancers in the lumbar spine and total body, respectively.[7] However, other reviews report a positive effect of ballet training on osteogenesis at load-bearing sites compared to non-athletic controls, where BMD values were higher in dancers in the femoral neck, lower in the upper limb and inconclusive at the lumbar spine.[8] Studies by Amorim et al. reported that before undergoing pre-professional training, first year vocational ballet students (mean age 10.9 years) had lower BMD than controls in weight-bearing (femoral neck and lumbar spine) and non-weight bearing (radius) sites.[9] However, during vocational training young adolescent ballet dancers (mean age 13.5 years) had lower BMD, but once adjusted for factors such as body composition, nutrition and physiological maturity, similar BMD values were found for vocational female dancers and con-

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Table 1
Characteristics of included studies.

Author	Country	Participants		Age (years)		BMI		Age at Menarche (years)		Ballet (hours/week)	GRADE quality
		Dance	Control	Dance	Control	Dance	Control	Dance	Control		
Foldes et al.[19]	Israel	27	27	15.6 ± 1.2	15.6 ± 0.8	19.7 ± 1.5	22.8 ± 3.0	NA	NA	18.2 ± 3.4	Low
Munoz et al.[20]	Spain	12	14	16.4 ± 2.0	16.9 ± 1.0	18.5 ± 1.5	21.2 ± 3.0	13.7 ± 1.0	12.8 ± 1.0	>20	Low
Pearce et al.[15]	Australia	41	46	17.6 ± 0.9	17.5 ± 1.4	NA	NA	15.0 ± 1.3	12.9 ± 0.2	NA	Low
Quintas et al.[21]	Spain	33	90	16.2 ± 2.0	16.7 ± 1.0	18.7 ± 1.5	21.0 ± 2.5	13.3 ± 1.1	12.8 ± 1.0	>20	Low
To and Wong[16]	Hong Kong	47	36	18.3 ± 0.7	18.3 ± 0.5	19.6 ± 1.6	22.1 ± 3.2	13.0 ± 1.5	12.0 ± 2.7	>18	Low
Tsai et al.[22]	Taiwan	29	20	16.3 ± 0.5	16.6 ± 0.8	20.2 ± 2.2	22.1 ± 2.3	NA	NA	NA	Low
Yang et al.[18]	China	60	77	16.5 ± 0.7	16.5 ± 0.6	18.3 ± 1.4	21.7 ± 3.1	14.0 ± 0.9	13.0 ± 1.3	26.5 ± 5.2	Low
Young et al.[17]	Australia	44	23	17.0 ± 0.2	16.7 ± 0.3	18.2 ± 1.7	21.6 ± 3.7	14.9 ± 1.2	12.9 ± 1.9	>32	Low

Data presented as mean ± standard deviation; BMI: body mass index; GRADE: Grading of Recommendations, Assessment, Development and Evaluation; NA: not available.

trols at weight-bearing sites.[10] Over 50% of the female vocational dancers in this study were in Tanner stages I or II, compared to 50% of controls in stages IV or V, suggesting that differences between the groups in actual BMD values could be attributed to vocational dancers being late to mature compared to controls. Female professional ballet dancers have been reported to have higher BMD at weight-bearing sites, but to still have lower BMD at non-weight bearing sites, compared to controls.[10]

Given the impact that physiological maturity appears to have on BMD during the early adolescent years,[10] we were interested to evaluate BMD of pre-professional ballet dancers during later adolescence, when physiological maturity may be less varied and therefore may be less influential on BMD. This systematic review and meta-analysis aimed to quantitatively analyse and compare BMD in pre-professional female ballet dancers and age-matched controls.

2. Methods

This review followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[11] Six electronic databases (CINAHL, EMBASE, PubMed, Scopus, SportDiscus and Web of Science) were systematically searched up to August 2017 using the following terms: "adolesc* OR pre-professional OR preprofessional" AND "ballet OR dance". In addition, the *Journal of Dance Medicine and Science* was searched for recent publications. Following duplicate removal, both authors independently screened articles by title/abstract, and then by manuscript for potentially eligible studies. Discrepancies were resolved through discussion.

English-language studies were included if they reported BMD data for both adolescent females undertaking pre-professional ballet training and age-matched controls. Adolescence is considered to be the phase between 10 and 19 years,[12] however due to the variability in physiological maturity often seen in the early adolescent years,[10] we chose to assess BMD in the later adolescent years and only included studies with a mean participant age between 15 and 19 years. We based this decision on the fact that 'primary amenorrhea' is defined as an absence of menarche by 14 years of age in the absence of secondary sexual characteristics or absence of menses by 16 years in the presence of normal growth and secondary sexual characteristics,[13] suggesting that a more consistent level of physiological maturity may be reached by the time adolescents reach 15 years. All dancers were undertaking pre-professional ballet training, which included a minimum of 10 h of ballet per week. Excluded articles were those that did not compare dancers to a control group, combined males and females, or were published as conference abstracts or case reports.

Data for all BMD sites were extracted in duplicate by the authors and stored in a database, along with age at menarche, body mass index (BMI), participant demographics and training details. BMD data were analysed in Review Manager 5.3 (RevMan; Nordic Cochrane, Denmark). The standardized mean difference (SMD) was calculated in a random effects inverse variance model for BMD to account for potential differences in testing methodologies, which included one study using computerized topography to estimate BMD at the radius (reported in mg/cm^3). Inconsistency between groups was calculated using Higgins I^2 and heterogeneity was quantified using the Cochran Q test. Level of significance was set at $p < 0.05$ and 95% confidence intervals.

The quality of included studies was assessed using the Grading of Recommendations, Assessment, Development and Evaluation (GRADE) system[14] (Table 1). The GRADE system classifies the quality of evidence into one of four levels — high, moderate, low, and very low. RCTs start at a high-quality level, while non-RCT studies, i.e. observational studies, start at a low-quality level. Individual studies can be decreased to a lower category according to five criteria: study limitations; inconsistency of results; indirectness of evidence; imprecision; and reporting bias. Studies may be upgraded according to three criteria: effect size; dose-response relationship; and all plausible residual bias. If rated up for one, two or three of these items, observational studies can be classified as 'low plus one', 'low plus two' or 'low plus three', respectively.

3. Results

A total of 9532 records were captured during the initial search. Following duplicate removal, 3984 abstracts were screened and 112 full-text manuscripts were examined. Finally, 8 cross-sectional studies were included in the meta-analysis (Fig. 1). No longitudinal studies were identified in this population. Two studies disaggregated dancers according to duration of oligomenorrhea[15] or the presence of the athlete triad.[16] For each of these studies, we combined the dance groups to create a single pair-wise comparison against the control. For each study, we weighted the disaggregated group's values relative to the entire population.

A total of 8 studies were included, comprising 293 dancers (16.9 ± 0.8 years) to 333 controls (16.9 ± 0.9 years). The dancers' training load varied between studies, but several studies lacked clarity in reporting exact loads and no studies outlined the specific composition regarding the inclusion of any supplementary strength and conditioning activities. Dancers were enrolled in vocational academies in their respective countries, including Australia,[15,17] China,[18] Hong Kong,[16] Israel,[19] Portugal,[10] Spain[20,21] and Taiwan.[22] All included studies were rated as 'low' due to their observational design.

BMD was compared using reported data across 6 anatomical sites (Fig. 2). Dancers displayed lower BMD values in the radius (SMD = −0.77) and higher BMD values in the femoral neck (SMD = 0.42), femoral trochanter (SMD = 0.44) and Ward's triangle (SMD = 0.38). No significant difference was observed in the lumbar spine or tibia. Significant heterogeneity was apparent in the analyses of the radius and tibia, and publication bias was evident.

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