Vitamin D Status and Musculoskeletal Health in Adolescent Male Ballet Dancers
A Pilot Study

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Abstract

Adequate vitamin D levels during growth are critical to ensuring optimal bone development. Vitamin D synthesis requires sun exposure; thus, athletes engaged in indoor activities such as ballet dancing may be at relatively high risk of vitamin D insufficiency. The objective of this study was to investigate the prevalence of low vitamin D levels in young male ballet dancers and its impact on musculoskeletal health. Eighteen male ballet dancers, aged 10 to 19 years and training for at least 6 hours per week, were recruited from the Australian Ballet School, Melbourne, Australia. Serum 25(OH)D and intact PTH were measured in winter (July) from a non-fasting blood sample. Pubertal stage was determined using self-assessed Tanner criteria. Body composition and areal bone mineral density (aBMD) at the whole body and lumbar spine were measured using dual-energy x-ray absorptiometry (DXA). Injury history and physical activity levels were assessed by questionnaire. Blood samples were obtained from 16 participants. Serum 25(OH)D levels ranged from 20.8 to 94.3 nmol/L, with a group mean of 50.5 nmol/L. Two participants (12.5%) showed vitamin D deficiency [serum 25(OH)D level < 25 nmol/L], seven dancers (44%) had vitamin D insufficiency (25 to 50 nmol/L), and the remaining seven dancers (44%) had normal levels (> 50 nmol/L). No relationship was found between vitamin D status, PTH levels, body composition, and aBMD. The most commonly reported injuries were muscle tears and back pain. The average number of injuries reported by each dancer was 1.9 ± 0.4 (range: 0 to 5). There was no difference in the frequency of reported injuries between subjects with vitamin D deficiency or insufficiency (2.1 ± 0.6 injuries) and those with normal vitamin D levels (1.4 ± 0.6 injuries). This pilot study showed that more than half of highly-trained young male ballet dancers presented with low levels of vitamin D in winter. Further investigations in larger samples of adolescent athletes are needed to determine if this could negatively impact bone growth and place them at higher risk for musculoskeletal injuries.

Vitamin D, the vitamin manufactured in the presence of sunshine, is recognized for its importance in brain development, differentiation of tissues, effect on cardiovascular and immune systems, glucose homeostasis, and muscle function, as well as being essential for bone health in children.[1-4] Severe vitamin D deficiency in children and adolescents causes rickets, a deforming bone disease that has had a recent resurgence,[5-7] which has been attributed to low sun exposure. Investigations conducted in different countries, including New Zealand and Australia, revealed that in wintertime 35% to 80% of children and adolescents presented with vitamin D insufficiency (serum 25[OH] D: 25-50 nmol/L).[3,8-13]

Concerns for vitamin D status in the general population have recently been extended to young athletes[14]; however, very little is known about vitamin D status and its impact on bone health in this population, particularly young males. Preliminary reports indicate a prevalence of vitamin D deficiency or insufficiency in young athletes similar to, or higher than, the general population.[9,15,16] Although it has long been assumed that all young individuals have good vitamin D levels in Australia,[17] when tested in 2007, 15 out of 18 female gymnasts from the Australian Institute of Sport in Canberra had serum vitamin D below 75 nmol/L, and one-third had vitamin D insufficiency (serum 25[OH]D < 50 nmol/L).[18] Therefore, vitamin D deficiency is an important issue even in countries with high sun exposure.

Indoor disciplines in general, and particularly those emphasizing a

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lean physique (with a greater risk of low energy intake and therefore low vitamin D intake), such as ballet dancing, place athletes at increased risk of vitamin D insufficiency. The lack of sun exposure and low dietary intake of vitamin D have both been shown to be significant predictors of vitamin D level in boys and girls.[8,10,11,16,19,20] Vitamin D regulates calcium levels in the body[21]; thus, an insufficiency could be detrimental to the growing skeleton. The greatest osteogenic effects of exercise are observed from pre-puberty to mid-puberty; therefore, this period is critical to maximizing bone mineralization.[22] If optimal bone accretion is compromised in young ballet dancers, it may place them at high risk for musculoskeletal injuries during their career (such as stress fractures) and osteoporotic fractures later in life.

Most studies of bone health in ballet dancers have been conducted in females and adults.[23-35] The objectives of this study were to determine the prevalence of vitamin D deficiency (serum 25[OH]D < 25 nmol/L) and insufficiency (serum 25[OH]D < 50 nmol/L) in young male ballet dancers, and to investigate the relationship between serum vitamin D and musculoskeletal health in this population. We hypothesized that a significant proportion (≥ 30%) of young male ballet dancers would present with serum vitamin D level below 50 nmol/L.

Material and Methods

Participants

All males participating in the vocational dance program at the Australian Ballet School in Melbourne, Australia, were invited to participate. Information on the project was also sent to young male ballet dancers attending the school for a short period of time coinciding with the time of the experiments. Inclusion criteria included age 10 to 19 years, training volume of 6 or more hours per week, and absence of chronic condition or treatment that affects bone metabolism. Melbourne is situated at latitude 37° S. All measurements were performed in July, which corresponds to wintertime in Australia. Ethics approval was obtained from the Deakin University ethics committee, and participation of students from the Australian Ballet School (ABS) was sought through the ABS board. All participants and their parent or guardian gave informed consent before taking part in the study.

Anthropometric Measurements

Body weight was measured without footwear to the nearest 0.1 kg with an electronic scale. Standing and sitting heights were measured to the nearest 0.1 cm with a stadiometer.

Pubertal Status and Maturity Offset

Pubertal status was assessed by self-reported pubertal stages using Tanner's criteria for pubic hair and testis development.[36] Participants were classified as pre-pubertal (pubertal stage I), peri-pubertal (pubertal stages II to IV), or post-pubertal (pubertal stage V). The maturity offset was calculated from standard anthropometric measures (height, weight, sitting height) and chronological age. This gives an estimation of where an adolescent is in relation to his growth spurt.[37]

Biochemistry

Non-fasting blood samples (10 mL) were taken from the participants on the day of the experiments at Deakin University. Blood samples were centrifuged within two hours of venipuncture and frozen at -80° C. They were then sent to the AusSun Research Lab (Brisbane, Australia), where assays were performed. Serum 25(OH)D level was measured using a commercial chemiluminescent immunoassay [LIAISON® 25(OH) Vitamin D TOTAL Assay, DiaSorin Inc, Stillwater, MN, USA]. This assay measures both 25-(OH)D_2 (ergocalciferol) and 25-(OH)D_3 (cholecalciferol). Participants with serum 25(OH)D below 25 nmol/L were referred to their medical doctor for treatment. Intact parathyroid hormone (PTH) level was also determined using a commercial chemiluminescent immunoassay (LIAISON® N-tact™ PTH Assay, DiaSorin Inc, Stillwater, MN, USA). Intra-assay variability was 3% to 6% and 1.4% to 4.8% for serum 25(OH)D and PTH respectively. Corresponding values for inter-assay variability were 6% to 11% and 3.5% to 6.9%.

Calcium and Vitamin D Intakes

Dietary calcium and vitamin D intakes were assessed with a validated food frequency questionnaire.[38] The questionnaire was administered on the phone, all by the same research staff member. Calcium and vitamin D intakes were calculated based on the calcium and vitamin D contents of food and beverages that were included in the questionnaire.[38]

Dual-Energy X-ray Absorptiometry (DXA)

Whole body composition was determined by DXA (Prodigy, Lunar Corp, Madison, WI, USA), with analysis software enCORE Multimedia version 12.10.027. Bone mineral content (BMC, g), areal bone mineral density (aBMD, g/cm^2) and bone area (cm^2) were determined at the lumbar spine (L1-L4). Estimated bone volume (cm^3) and bone mineral apparent density (BMAD, g/cm^3) were calculated using Carter's method,[39] which is based on the observation that vertebral BMC is scaled proportionately to projected bone area to the 1.5 power. Therefore, BMAD is defined as BMC/(bone area$^{1.5}$). Calculations were done for vertebrae L1-L4 as previously described.[40] Subjects were positioned for each scan according to standard procedures. The reproducibility of this technique was determined in our lab to be 0.9% to 1.5% for total and regional aBMD, 0.7% for total body soft tissue, 2.9% for total fat mass, and 1.6% for lean tissue mass. The effective radiation doses associated with DXA scans were 1.9 mSv for subjects under 40 kilograms and up to 3.75 mSv for subjects over 40 kilograms.

Injury History

Each participant was asked about occurrence of injuries, including fractures (with a distinction between acute fracture and stress fracture). General information was collected regarding known risk factors for stress fractures, such as smoking[41] and family history of osteoporosis.[42]

Physical Activity

The characteristics of training (age when began dancing, number of sessions per week, duration of the sessions, and frequency of competitions) were documented using a short questionnaire developed by the research team.

Statistical Analysis

Data were presented as mean ± standard error of the mean (SEM). The Gaussian distribution of the parameters was tested by the Kolmogorov–Smirnov test. Z-scores in aBMD at the whole body and lumbar spine were compared between subjects who were vitamin D deficient or insufficient and those who had normal vitamin D level using an independent t-test. The same test was used to compare the average number of reported injuries between the two groups. Associations between serum vitamin D levels, PTH, vitamin D intake, calcium intake, and aBMD were investigated using the Pearson's correlation coefficient. The alpha level for statistical significance was set at 0.05. All statistical procedures were performed with the software SPSS for Windows, version 17.0.1 (SPSS Inc., Chicago, Illinois, USA, 2008).

Results

Eighteen male ballet dancers agreed to participate in the study. A blood sample could not be obtained in two subjects (one was not comfortable with venipuncture, the other missed his appointment). Therefore, the final sample includes 16 participants. Descriptive characteristics of the group are given in Table 1. The proportion of participants in each pubertal stage was: 6% pre-pubertal (n = 1), 56% peri-pubertal (pubertal stage II, n = 2; pubertal stage IV, n = 7), 38% post-pubertal (n = 6). Only six participants agreed to do the food frequency questionnaire by phone.

One dancer took a multivitamin supplement, but none indicated taking vitamin D or calcium supplements. Vitamin D levels ranged from 20.8 to 94.3 nmol/L, with a group mean of 50.5 nmol/L. Two participants (12.5%) showed moderate vitamin D deficiency (serum 25(OH) D level < 25 nmol/L). Seven dancers (44%) had serum 25(OH)D level between 25 and 50 nmol/L (insufficiency). The remaining seven dancers (44% of the sample) had serum 25(OH)D level above 50 nmol/L, and only three had a value between 75 nmol/L and 100 nmol/L (Fig. 1). Mean PTH level was 53.6 ± 3.5 pg/mL (range: 19.5 to 81.4 pg/mL). PTH level was not correlated to serum 25(OH)D (r = -0.095, p = 0.727).

Unadjusted data for body composition and areal bone mineral density at the whole body and lumbar spine are presented in Table 2. Due to the fact that there were only two subjects with vitamin D deficiency, major outcomes were compared between those who were either vitamin D deficient or insufficient (n = 9) and those with normal vitamin D level (n = 7). No difference in percent body fat and aBMD was found between the two groups after adjustment for maturity offset.

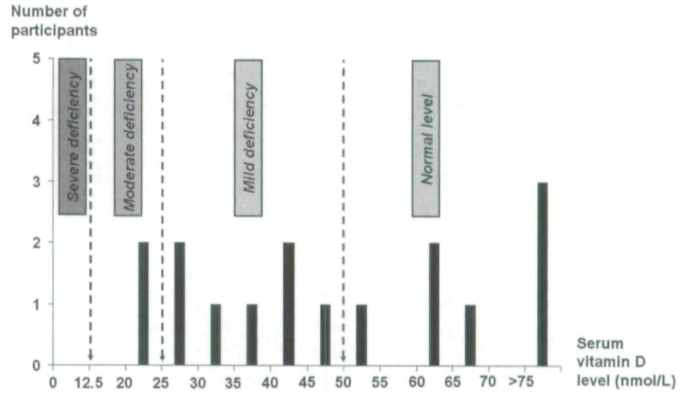

Figure 1 Serum 25(OH)D level in young male ballet dancers (n = 16).

Table 1 Anthropometric Data, Maturity Offset, and Training History in Young Male Ballet Dancers by Vitamin D Status*

	Serum 25(OH)D < 50 nmol/L (n = 9)	Serum 25(OH)D ≥ 50 nmol/L (n = 7)	Whole Group (n = 16)	
	Mean ± SEM	Mean ± SEM	Mean ± SEM	Range
Age (yrs)	16.4 ± 1.0	15.6 ± 1.0	16.0 ± 0.7	10.6; 19.6
Height (cm)	172.1 ± 4.1	168.1 ± 4.9	170.3 ± 3.1	143.5; 187.3
Weight (kg)	64.3 ± 5.5	58.1 ± 5.5	61.6 ± 3.9	36.2; 86.2
Sitting height (cm)	86.4 ± 4.4	87.4 ± 3.0	86.9 ± 2.7	55.5; 95.9
Maturity offset (yrs)	1.7 ± 1.0	1.3 ± 0.9	1.5 ± 0.6	-3.4; +4.4
History of training				
Age when began dancing (yrs)	6.9 ± 1.0	6.9 ± 0.9	6.9 ± 0.7	3.0; 12.0
Training volume (hrs/wk)	25.6 ± 5.8	21.0 ± 4.9	23.6 ± 3.8	4.7; 52.0
Years of training (yrs)	9.5 ± 0.5	8.7 ± 1.2	9.1 ± 0.6	2.3; 11.6

*Vitamin D deficiency/insufficiency: serum 25(OH)D level < 50 nmol/L. No difference was found between groups.

Table 2 Unadjusted DXA-Derived Body Composition at the Whole Body and DXA-Derived Areal Bone Mineral Density at the Lumbar Spine in Young Male Ballet Dancers by Vitamin D Status1 (n = 16)

	Serum 25(OH)D < 50 nmol/L (n = 9)	Serum 25(OH)D ≥ 50 nmol/L (n = 7)	Whole Group (n = 16)	
	Mean ± SEM	Mean ± SEM	Mean ± SEM	Range
Body composition				
Lean Tissue Mass (kg)	54.1 ± 3.7	48.5 ± 5.1	51.6 ± 3.0	28.7 ; 65.1
Percent body fat (%)	11.7 ± 1.4	12.5 ± 2.3	12.0 ± 9.4	5.9 ; 25.1
Bone densitometry at the whole body				
BMC (kg)	2.86 ± 0.23	2.54 ± 0.32	2.71 ± 0.19	1.45 ; 3.67
BMD (g/cm²)	1.202 ± 0.048	1.134 ± 0.053	1.172 ± 0.036	0.945 ; 1.346
Z-score whole body BMD (SD)	+0.8 ± 0.3	+0.6 ± 0.2	+0.7 ± 0.17	-0.7 ; +1.9
Bone densitometry at the lumbar spine (L1-L4)				
BMC (g)	63.96 ± 5.38	54.97 ± 8.13	60.02 ± 4.64	27.80 ; 84.20
BMD (g/cm²)	1.164 ± 0.061	1.016 ± 0.080	1.010 ± 0.051	0.720 ; 1.370
Z-score L1-L4 BMD (SD)	+0.4 ± 0.3	-0.26 ± +0.24	+0.1 ± 0.2	-1.4 ; +1.7
BMAD (g/cm³)	0.158 ± 0.006	0.140 ± 0.006	0.150 ± 0.005	0.115 ; 0.190

*Vitamin D deficiency/insufficiency: serum 25(OH)D level < 50 nmol/L. No difference was found between groups after adjustment for maturity offset.

Z-scores for aBMD at the whole body and lumbar spine are presented in Figure 2. In 87% of the dancers (14/16), Z-score for aBMD at the whole body was greater than Z-score for aBMD at the lumbar spine. Only two subjects presented with a negative Z-score for aBMD at both the whole body and lumbar spine. One of these suffered from asthma and had been treated with salbutamol (ventolin™, GSK) since the age of three years. The potential cause of low aBMD in the other subject is unclear.

Injuries reported by the dancers are given in Table 3. The most common injuries were muscle tears and back pain. Fractures, stress reactions, Sever's disease and ankle sprains were also reported by several participants.

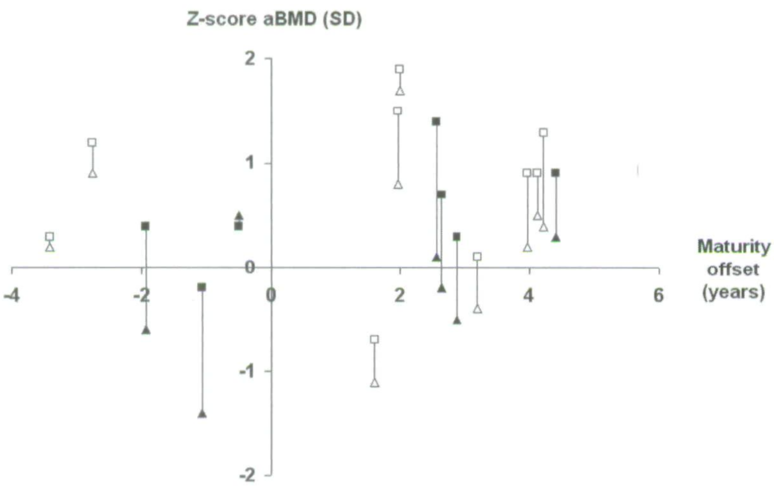

Figure 2 Z-scores in areal bone mineral density (aBMD) at the whole-body (squares) and lumbar spine (triangles) in young male ballet dancers who had low level of vitamin D (open symbols) or normal level of vitamin D (filled symbols). Low vitamin D level was defined as serum 25(OH)D below 50 nmol/L. The horizontal axis represents the estimated number of years before/after the growth spurt (maturity offset). The maturity offset was calculated according to Mirwald's equations.[37] The Z-scores were provided by the DXA software enCORE Multimedia version 12.10.027 (Lunar Corp, Madison, WI, USA). Any data point below the horizontal axis (negative Z-score) indicates the participant's aBMD was below the norm for his age.

As is the case in virtually all previous studies, the back and lower limbs were more frequently injured through the practice of ballet dancing than the upper limbs. The average number of injuries reported by each dancer was 1.9 ± 0.4 (range: 0 to 5). There was no difference in the frequency of reported injuries between subjects with vitamin D deficiency and insufficiency (2.1 ± 0.6 injuries) and those with normal vitamin D levels (1.4 ± 0.6 injuries). The two dancers who were vitamin D deficient reported 0 and 4 injuries.

Data on calcium and vitamin D intakes could only be collected in six participants. Inter-individual variations were high, with dietary calcium intakes ranging from 194 mg up to 1660 mg/day, and vitamin D intakes ranging from 55 to 505 IU/day.

Discussion

The study showed that in a small group of highly-trained young male ballet dancers more than half presented with low levels of vitamin D in winter. The prevalence of vitamin D deficiency (i.e., serum 25[OH]D < 25 nmol/L, 12.5%) or insufficiency (serum 25[OH]D < 50 nmol/L, 44%) was consistent with the prevalence previously reported in other groups of young male athletes. A study conducted in 175 male adolescents

Table 3 Injuries in Young Male Ballet Dancers by Vitamin D Status*

	Serum 25(OH)D < 50 nmol/L (n = 9)		Serum 25(OH)D ≥ 50 nmol/L (n = 7)		Whole Group (n = 16)	
	Due to ballet dancing	Not due to ballet dancing	Due to ballet dancing	Not due to ballet dancing	Due to ballet dancing	Not due to ballet dancing
Type of injuries						
Muscle injury (tear)	2	0	2	0	4	0
Back pain	2	0	2	0	4	0
Fracture	2	1	1	2	3	3
Stress reactions	1	0	2	0	3	0
Ankle sprain	2	0	1	0	3	0
Sever's disease (apophysitis Achilles tendon insertion on calcaneum)	3	0	0	0	3	0
Tendon injury (tear)	1	0	1	1	2	1
Dislocation	0	0	1	0	1	0
Cartilage injuries	1	0	0	0	1	0
Other injury (unspecified)	3	0	2	0	5	0
Number reported injuries/dancer†	2.1 ± 0.6	0.2 ± 0.2	1.4 ± 0.6	0.2 ± 0.4	1.9 ± 0.4	0.2 ± 0.3
Injury sites						
Upper limbs	2	1	3	1	5	2
Lower limbs						
Leg	7	0	3	0	10	0
Ankle	2	0	1	0	3	0
Foot	5	0	2	1	7	1
Back	2	0	2	0	4	0
Other	0	0	0	1	0	1 (skull fracture)

*Vitamin D deficiency or insufficiency: serum 25(OH)D level < 50 nmol/L. †Mean ± standard deviation. No difference was found between groups.

from a jockey training center located near Paris (49° N) showed that the average serum vitamin D had fallen to 20 nmol/L at the end of winter.[15] An 18-month follow-up in one-third of them indicated that 70% had vitamin D levels below 25 nmol/L during winter time.[9] More recently, 58% of a cohort of Middle Eastern male sportsmen (n = 93), aged 13 to 45 years, were found to be vitamin D deficient (serum 25[OH]D < 10 ng/mL or 25 nmol/L), with another 33% being insufficient (< 50 nmol/L).[43] Our data are also consistent with what has been found in non-athletic boys at similar latitudes. In Tasmania, 68% of adolescent males had serum vitamin D levels below 50 nmol/L in winter,[11] and in New Zealand 28% of the comparable population had serum vitamin D below 37.5 nmol/L.[12]

In addition to the lack of sun exposure and low vitamin D intake that ballet dancers might be exposed to, leanness could be a risk factor. It has been suggested that athletes with extremely low body fat might be at increased risk during the winter months because of their decreased ability to store vitamin D in subcutaneous tissues.[14,44] Vitamin D is predominantly stored in adipose tissue,[45] and seasonal variation of serum 25(OH)D has been shown to be greater in lean subjects.[46] In the present study, no relationship was found between percent body fat and vitamin D status, but our sample size was small.

Although 14 out of 16 participants showed whole body aBMD above the norm for age, six displayed a spinal aBMD below the norm for age (Fig. 1). While low levels of spinal aBMD have been consistently reported in female ballet dancers (partly because of the negative effect of menstrual dysfunction on trabecular bone[23,28,30]), there is limited data on spinal aBMD in male ballet dancers. Previous studies of bone health in male dancers have suggested that aBMD tends to be lower at non-weight-bearing sites (e.g., trunk and skull).[47,48] As noted earlier, we did not find differences in aBMD between dancers who were vitamin D deficient or insufficient and those who had normal level of vitamin D. Although low vitamin D levels have been shown to be associated with lower aBMD in girls (below a threshold varying from 20 nmol/L to 46 nmol/L),[19,49-51] such an association has not been reported in boys. A cross-sectional study of 166 female adolescents (including 54 ballet dancers) showed that recent physical activity (in hours/week) was positively correlated with aBMD, particularly in the young women who were in the lowest tertile of serum 25(OH)D levels (< 28 nmol/ml).[35] However, past physical activity was not accounted for in this study. Longitudinal investigations would be required to confirm that physical activity might counteract the detrimental effect of vitamin D deficiency on bone health.

Concerns for the dancers' musculoskeletal health arise from epidemiological data regarding the incidence of injuries in adult professional dancers. Over a 12-month period, almost 50% of a large sample of professional dancers reported 1 to 6 days of restricted activity due to a musculoskeletal injury.[52] In our study, the participants reported an average of 1.9 injuries since they started dancing. This seems lower than what has previously been reported in young ballet dancers, with five injuries per 1,000 hours of participation.[53] However, a direct comparison of the prevalence and incidence of dance injuries between studies is difficult since data are expressed in different ways. We found that the back and lower limbs were the most frequent sites of injury, which is consistent with previous reports in professional dancers.[52]

Whether or not vitamin D deficiency could play a role in the etiology of musculoskeletal injuries, and more specifically stress fractures, is open to debate. A correlation between low levels of vitamin D and high incidence of stress fractures has been found in Finnish male military recruits.[54] In a study of over 2,500 Israeli soldiers, several factors were found to distinguish soldiers with high-grade stress fractures from those who were fracture-free, including lower levels of vitamin D.[55] More recently, calcium and vitamin D supplementation was shown to reduce the incidence of stress fractures by 20% in a large cohort of female military recruits.[56] At approximately the same time, in the female gymnasts enrolled at the Australian Institute of Sport, the high incidence of stress fractures (1 in 18 gymnasts) or bone stress reactions (12 in 18 gymnasts) over 12 months led the teams' physicians to investigate possible causes, including vitamin D deficiency. It was determined that 6 out of 18 of the gymnasts had serum vitamin D below 50 nmol/L.[18] Since then, all gymnasts with low vitamin D level (< 75 nmol/L) are being supplemented with oral vitamin D_3 (1,000 IU per day).[18]

Stress fractures are a common injury in ballet dancing, with a prevalence ranging from 31% to 42% in female dancers, and some dancers sustain multiple stress fractures.[29,57] Literature documenting the incidence of stress fractures in male dancers[58] and adolescents in general[59,60] is scarce, however. In the present study, we were not able to provide evidence that vitamin D deficiency increased the risk of sustaining a stress fracture. However, again, the sample size was small. To support or allay concerns that low vitamin D status might be linked to musculoskeletal pain, suboptimal athletic performance,[61] and low muscle power and force,[62] further studies conducted with larger samples of athletes and controlled for the influence of factors such as training volume and diet are warranted.

Potential strategies to ensure healthy vitamin D levels throughout the year include vitamin D supplementation. A previous randomized controlled trial in 54 adolescent male jockeys indicated that vitamin D_3 supplementation from the end of summer throughout winter could prevent hypovitaminosis D in winter and a rise in PTH.[9] In a double-blind six-month study, a daily intake of vitamin D in the range of 17.5 to 20 µg (700 to 800 IU) seemed to be required to prevent winter seasonal increases in PTH and maintain stable bone turnover in young, healthy white men.[63] However, there is also a lack of evidence for a beneficial effect of vitamin D supplementation, with or without additional calcium, on bone mineralization in children and adolescents. The annual increase in bone mass was augmented by 17% at the femur and 12% at the spine in girls supplemented with 10 µg/day of vitamin D_3 compared to the placebo group,[64] while other trials showed smaller effects[65,66] or no effects at all.[67] Stronger evidence was recently obtained in a randomized controlled trial that was conducted in 20 pairs of peri-pubertal female identical twins age 9 to 13 years to assess the impact of a six-month daily calcium (800 mg) and vitamin D (400 IU of vitamin D_3) supplementation on bone acquisition. Bone structural properties were measured at the tibia and radius using peripheral quantitative computed tomography (pQCT), a three-dimensional imaging technique that allows for investigating trabecular and cortical bone separately. The supplemented twins showed greater gains in trabecular density (+ 3.3% to 5.2%) and bone strength (+ 5.7% to 6.6%) at the distal tibia and radius, as well as greater gain in cortical area at the tibial shaft (+ 6%) than the twins on placebo.[68] These preliminary findings would have to be confirmed in males, as all of the aforementioned trials were conducted in girls.

Limitations of this pilot study include the cross-sectional nature of the experiments. Seasonal variations in vitamin D levels could not be investigated, more specifically, whether or not the dancers recover normal vitamin D levels in summer. The sample size was small and the study did not include a control group, which limits interpretation of the impact of vitamin D status on bone health. Our study was underpowered to detect any effect of vitamin D deficiency on aBMD and musculoskeletal injury. Although calcium and vitamin D intake were included in the investigations, not all participants agreed to fill out the dietary questionnaire on the phone. Furthermore, this questionnaire has not been validated in children and adolescents. This information would have been very important because the 1995 Australian survey showed that the average estimated dietary intake of vitamin D for men was 2.6 to 3.0 µg/day and for women was 2.0 to 2.2 µg/day.[21] This is lower than the current recommended adequate intake of 5.0 µg/day (200 IU),[69] and low vitamin D intake has been shown to be a significant predictor of vitamin D level in boys and girls.[10,16,20,70]

Finally, although this study aimed at addressing the lack of research in male athletes, girls are more at risk of vitamin D deficiency than boys[71] and are less efficient at retaining calcium at a given calcium intake.[71] Late menarche as well as menstrual dysfunction (which are common in female ballet dancers) are also known to affect bone health negatively.[32,33] Clearly the issue of vitamin D deficiency also matters to female ballet dancers; recent experiments in Israel showed that among 54 young female ballet dancers recruited from ballet dance schools, all had vitamin D levels below 37.5 nmol/L.[35]

This pilot study showed that more than half of a small group of young male ballet dancers had vitamin D insufficiency in winter. Whether vitamin D insufficiency and deficiency can influence the rate of musculoskeletal injuries in ballet dancers remains unknown. These preliminary findings call for further research on vitamin D status and its impact on the health of dancers. This population is at risk partly due to the lack of sun exposure associated with its discipline.

Acknowledgments

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