Calcif Tissue Int (1996) 58:150–154

Calcified Tissue International

Total and Regional Bone Mineral Content in Spanish Professional Ballet Dancers

A. Cuesta, M. Revilla, L. F. Villa, E. R. Hernández, H. Rico

Department of Medicine, Alcalá de Henares University, 28801 Madrid, Spain

Received: 11 April 1995 / Accepted: 7 September 1995

Abstract. Total body bone mineral content (TBBMC) and regional bone mineral content (BMC) was measured in the members of the Spanish National Dance Company (15 female, mean age 25.1 ± 3.8 years, and 15 male, mean age 28.2 ± 2.1 years) and in 30 controls (15 women, mean age 26.1 ± 1.8 years, and 15 men, mean age 28.0 ± 1.5 years). Ca, P, and Mg intake were greater in the group of ballet dancers than in controls analysis of variance (ANOVA, all $P < 0.0001$). BMC was similar in the group of ballet dancers and controls except in the trunk without pelvis ($P < 0.001$). Both male and female dancers weighed less than controls ($P < 0.05$). The BMC of the male dancers was less than that of male controls only in the trunk ($P < 0.05$) and in the trunk without pelvis ($P < 0.005$); BMC was lower in female dancers than in female controls only in the arms and in the trunk without pelvis ($P < 0.05$ and $P < 0.005$, respectively). TBBMC, adjusted for weight and age, was correlated partially with caloric intake (kcal/day) and with Ca, P, Mg, and Zn intake (g/day), and yielded significant differences between the dancers and controls only in P intake ($P < 0.01$), and between male dancers and male controls only in caloric intake and in Ca, P, and Zn intake (all $P < 0.01$, except for Ca, $P < 0.05$). The lower trunk bone mass observed in the female dancers is a risk factor for eventual osteoporosis.

Key words: Ballet dancers — Bone mass — Total, regional bone mineral content.

Studies in humans [1, 2] and animals [3, 4] have shown that physical exercise can increase bone mineral content (BMC) and bone mineral density (BMD) in healthy bone. However, other studies show that some types of exercise may produce bone loss [5, 6], suggesting that the frequency, intensity, duration, and type of physical activity that delivers the maximum anabolic stimulus to bone is not certain [7–9]. Nonetheless, the effect of exercise on bone mass depends on the type of exercise [10] and whether or not the bones involved are load-bearing [11, 12]. On the other hand, continuous physical activity can produce different effects on the cortical and trabecular components of bone [13]. The level of exercise involved in professional ballet dancing is considered equivalent to that of elite athletes [14]. On the other hand, several studies have reported the existence of bone lesions in ballet dancers [15, 16].

Dual-energy X-ray absorptiometry (DXA) is considered to be a precise technique for measuring bone mass. It delivers a low radiation dose [17] and allows total body bone mineral content (TBBMC) and regional bone mineral content (RBMC) to be measured [18]. As the study of TBBMC and RBMC may reveal differences that occur in load-bearing and nonload-bearing bones as well as in bones constituted mainly by cortical bone (limbs) or trabecular bone (trunk), we used TBBMC and RBMC to evaluate the influence of dancing on the skeleton in members of the Spanish National Dance Company.

Correspondence to: H. Rico

Material and Methods

Subjects

The members of the Spanish National Dance Company, consisting of 15 female dancers (mean age 25.1 ± 3.8 years) and 15 male dancers (mean age 28.2 ± 2.1 years), were studied. The dancers trained 7–8 hours a day, 5–6 days a week. Fifteen normal women (mean age 26.1 ± 1.8 years) and 15 normal men (28.0 ± 1.5 years) also were studied.

Diet in terms of specific intakes and energy output was studied in both groups. A 7-day dietary survey was made in both groups [19]. The energy output of the ballet dancers was calculated at the end of two training sessions and two performances to get an idea of the physical effort expended. The energy outputs under each of these circumstances were compared with two measurements made in baseline conditions. The averages of each pair of measurements were compared. Energy output was calculated using the calorimetric system and a Schartzman instrument version 04 (Schartzman, Germany); the Wier formula was used [20].

The normality of the ballet dancers and control subjects was established on the basis of an interview and biochemical measurements of blood glucose, transaminases, GGT, creatinine, calcium, phosphorus, total proteins, bilirubin, alkaline phosphatase, tartrate-resistant acid phosphatase, gonadal hormones, gonadotropins, and a coagulation study. Calcium was corrected for proteins in all cases. A biochemical study was made of 24-hour urine to confirm the normality of calcium excretion and tubular phosphate resorption. All control subjects were from the health district of the Príncipe de Asturias University Hospital (Alcalá de Henares, Madrid, Spain). The control subjects had visited the clinic of the Rheumatology Department for nonspecific pain for which no organic cause was found. All subjects gave written informed consent. The investigation was approved by the Office for Protection from Research Risks of the Alcalá de Henares University Medical School.

The study subjects were not taking any medication that could

Table 1. Number of subjects and characteristics of the two groups of men studied

	Males		
	Controls	Dancers	
N	15	15	
Age yr	28.3 ± 2.5	28.2 ± 2.1	ns
Weight kg	71.9 ± 9.2	65.5 ± 5.7	<0.05
Height m	1.74 ± 5.0	1.73 ± 4.8	ns
BMI kg/m^2	23.8 ± 3.0	21.7 ± 2.1	ns
TBBMC g	3222 ± 310	3068 ± 240	ns
TBBMC/W g/kg	44.8 ± 4.3	46.8 ± 3.6	ns
Head g	545 ± 89	535 ± 67	ns
Trunk g	1117 ± 135	1017 ± 109	<0.05
Trunk-Pelvis g	629 ± 74	546 ± 68	<0.005
Pelvis g	488 ± 94	470 ± 68	ns
Arms g	483 ± 75	452 ± 57	ns
Legs g	1077 ± 94	1064 ± 86	ns

BMI = body mass index; total body bone mineral content (TBBMC), TBBMC adjusted for weight (TBBMC/W). Regional BMC values are designated by region; Trunk-Pelvis = trunk without pelvis. *P* according to ANOVA

interfere with calcium metabolism. All women's menstrual histories indicated both current and prior history of menstrual regularity (11–13 cycles/year). All the control subjects had active lives but did not practice sports. Only 6% of the control subjects smoked, but none smoked more than 10 cigarettes a day. In all cases, alcohol intake was sporadic and coffee intake did not exceed 100 ml/day. Height was measured using a Harpenden stadiometer. Weight was the total body densitometric weight.

Densitometric Studies

The measurements of TBBMC and RBMC were done as described previously [18]. TBBMC was measured with a Norland XR-26 densitometer (Norland Co., Fort Atkinson, Wisconsin, USA) provided with dual-energy X-ray absorptiometry (DXA). Average 21-minute assessments were made on all subjects in supine position and at periods of time far from meals. When the scan was completed, the BMC of each measured point, based on the attenuation of the X-ray beam and known bone and soft-tissue absorption characteristics for each energy documented with a calibration standard (Norland), was calculated with an XR-26 IBM PS-2 computer. Our group has found a coefficient of variation (CV) for this procedure of 1.2% *in vivo* for TBBMC, 1.3% for trunk, and 1.2% for arms, legs, head, and pelvis. Bone measurements were reported in ten normal males and females at intervals ranging from 1 to 16 weeks to assess the reliability of repeated measurements. The XR-26 was calibrated weekly with a calibrator supplied by Norland. TBBMC was divided by body weight to obtain a corrected measurement.

Statistical Studies

The parameters studied (continuous variables) in the groups (nominal variables) were compared using one-way analysis of variance (ANOVA). A partial correlation study was made of TBBMC and RBMC, adjusted for weight and age, against daily calories, calcium (CA), phosphorus (P), magnesium (Mg), and zinc (Zn) intake. A multiple regression study was made between TBBMC and Ca intake and energy output. All studies were made with the Statview 4.02 program (Abacus Concepts, Inc., Berkeley, CA, USA) on a Macintosh computer.

Results

The ballet dancers' energy output was 1691 ± 290 kcal/24 hours in baseline conditions, 2096 ± 502 kcal/24 hours after practice ($P < 0.01$ versus baseline), and 2712 ± 453 kcal/24 hours after performance ($P < 0.001$ versus baseline and post-practice) (all values expressed as mean ± SD).

Mean Ca, P, and Mg intakes were greater in ballet dancers than in controls ($P < 0.0001$ for all), but there were no significant differences in Zn intake. The TBBMC, TBBMC/W, (adjusted for weight) and RBMC of the ballet dancers differed from those of controls only in the RBMC of the trunk without the pelvis, which was lower in the ballet dancers (530 ± 52 versus 594 ± 72 g, $P < 0.001$). Weight, height, and bone mineral index (BMI) did not vary between dancers and controls (all *P* ns).

When males and females were analyzed separately, the ballet dancers weighed less than controls (both sexes $P < 0.05$) (Tables 1 and 2). The RBMC of the trunk (1017 ± 109 versus 1117 ± 135 g, $P < 0.05$) and of the trunk without pelvis (546 ± 68 versus 629 ± 74, $P < 0.0005$) were lower in male dancers than in male controls. The RBMC of the trunk without the pelvis (511 ± 69 versus 568 ± 72 g, $P < 0.05$) and of the arms (295 ± 49 versus 333 ± 55 g, $P < 0.05$) were lower in female dancers than in female controls.

The partial correlation between TBBMC adjusted for weight and age and dietary intake (kcal/day), and Ca, P, Mg, and Zn intake (g/day) (Table 3) of the ballet dancers showed no correlation with dietary intake or with Ca, Mg, and Zn, and a positive correlation with P ($P < 0.01$). The same partial correlation in ballet dancers separated by sex showed no correlation between TBBMC and any of the variables in the female dancers and a positive correlation between TBBMC and dietary intake (kcal/day), Ca ($P < 0.05$), P ($P < 0.01$), and Zn ($P < 0.01$), but not Mg, in male dancers.

In the ballet dancers, TBBMC as a dependent variable correlated significantly with daily calcium intake and energy output on the day of physical activity (multiple regression analysis: $r = 0.87$, $P < 0.0001$; regression coefficients for caloric intake 0.81, $P < 0.0001$, and for calcium intake, 0.38, $P = 0.0174$). In the dancers separated by sex, this

Table 2. Number of members and characteristics of the two groups of women studied

	Females		
	Controls	Dancers	
N	15	15	
Age yr	26.0 ± 2.8	25.1 ± 3.8	ns
Weight kg	55.0 ± 7.4	52.6 ± 5.8	<0.05
Height m	1.62 ± 0.61	1.62 ± 0.40	ns
BMI kg/m^2	20.9 ± 2.8	19.9 ± 1.8	ns
TBBMC g	2610 ± 344	2521 ± 245	ns
TBBMC/W g/kg	47.4 ± 6.2	47.9 ± 4.6	ns
Head g	505 ± 62	488 ± 47	ns
Trunk g	954 ± 129	925 ± 104	ns
Trunk-Pelvis g	568 ± 72	511 ± 69	<0.05
Pelvis g	386 ± 64	414 ± 52	ns
Arms g	333 ± 55	295 ± 49	<0.05
Legs g	818 ± 106	813 ± 85	ns

Same as Table 1

Table 3. Partial correlation, adjusted for weight and age, between TBBMC with the intake of kcal/day, Ca, P, Mg, and Zinc in g/day

	kcal/d	Ca g/d	P g/d	Mg g/d	Zn g/d
TBBMC (all)	0.400	0.337	0.544[b]	0.342	0.471
Women	0.075	0.217	0.324	0.281	0.108
Men	0.587[b]	0.484[a]	0.652[b]	0.345	0.613[b]

[a] $P < 0.05$; [b] $P < 0.01$, others ns

relation remained significant (for women, r = 0.78, regression coefficient 0.37, $P = 0.003$; for men, r = 0.65, regression coefficient 0.35, $P = 0.037$).

Discussion

Ballet dancers are unique professionals in that they must satisfy both aesthetic and athletic demands. As professional performers, male and female dancers must maintain an exceptionally thin, sylph-like body that has been a requirement of the art. At the same time, they maintain high standards of technical proficiency and strength, similar to those required of high-performance athletes [21]. The significant increase in energy output observed after practice sessions and performances reflects the high level of daily effort in the group of ballet dancers studied.

There are clear differences in the influence of the type and intensity of exercise on bone mass [10, 22, 23]. For example, Hamdy et al. [23] report that, in the upper limb, BMD was highest in weight lifters and lowest in runners. Tommerup et al. [24] have reported that exercise does not increase bone mass in nonload-bearing bones.

Our findings in the group of ballet dancers did not indicate changes in TBBMC, TBBMC/W, and most RBMC compared with age- and sex-matched controls, except for RBMC in the trunk without the pelvis. In the ballet dancers separated by sex, the male dancers had a lower RBMC in the trunk and in the trunk without pelvis than age- and sex-matched controls, and the female dancers had lower RBMC in the arms and in the trunk without pelvis than age- and sex-matched controls. In a study of 44 female ballet dancers of an elite ballet school, Young et al. [25] reported a decreased bone mass in skull and arms. In a group of professional ballet dancers including 17 men and 25 women, Karlsson et al. [26] found decreased bone mass in the men's heads and in the women's arms. The decreased bone mass in female dancers' arms observed in the latter two studies and our own is attributed to the lower effect of exercise on nonload-bearing bones, as recently demonstrated by Tommerup et al. [24]. Trunk bone mass was lower in our male dancers than in controls, but the difference was only marginally significant ($P < 0.05$); bone mass continued to be lower in the trunk without pelvis. The trunk bone mass without pelvis also was decreased in our female dancers. Decreased spinal bone mass has been reported in female ballet dancers by Young et al. [25]. The minimal differences observed between our study and those previously commented on may be related to the differing age groups: 26.7 ± 3.4 years in our study versus 17.0 ± 0.2 years and 40 years in those by Young et al. and Karlsson et al., respectively. Also, the women studied by us were professional dancers; in the study by Young et al. they were ballet students, and 14 of those studied by Karlsson et al. had retired from dancing several years before.

In our ballet dancers, mean Ca, P, Mg magnesium intake was significantly greater than in the control group; Zn intake, which has a clear influence on bone [27], did not differ between the dancers and controls. On the other hand, the Ca intake of the group of ballet dancers was greater than the mean intake of the general Spanish population [28]. The influence of diet on bone mass has been confirmed repeatedly [29–31]. In a group of women whose age was similar to that of our women, Metz et al. [32] recently reported that bone mass correlated significantly with Ca intake. In contrast, in the female ballet dancers, bone mass adjusted for age and weight did not correlate (partial correlation) with Ca intake, but correlated significantly in male dancers. A significant correlation was found between bone mass and P and Zn in male ballet dancers but not in female ballet dancers. The differences in our findings and those of Metz et al. may be due to the use of different bone densitometric measurements (radial versus TBBMC and RBMC), study subjects (normal women versus professional female ballet dancers), and statistical studies (multiple regression versus partial correlation, adjusted for weight and age in our study). The differences between sexes that we observed in our study may derive from the subjects' age (men 28.2 ± 2.1 years and women 25. ± 3.8 years). There is a clear difference in the age at which peak bone mass is attained: 15–19 years in women [33], with peak bone mass continuing throughout fertility [34], and 25–29 years in men [33]. This difference would account for the relation observed between RBMC and mineral intake in the male dancers, and the absence of such a relation in the female dancers. In addition, the greater diet intake of dancers, especially of Ca, may explain why there are no greater differences between them and normal controls.

When the two most important factors related to bone mass, daily Ca intake, and daily energy output (an indicator of physical activity) were analyzed by multiple regression analysis as independent variables against TBBMC as the dependent variable, a significant relation was found in the group of ballet dancers ($P < 0.0001$). This relation persisted when the ballet dancers were analyzed by sex. The same conclusions were reached by Tylavsky et al. [35] and Recker et al. (36) in women of different characteristics.

We conclude that the members of the Spanish National Dance Company have a high calcium, phosphorus, and magnesium intake and intense, but not extenuating, daily physical activity. In the overall group of ballet dancers and in each sex group, the bone mass without the pelvis was decreased. In the female dancers the bone mass of the arms was significantly lower. This decreased bone mass may predispose ballet dancers of both sexes [15, 16] to the bone lesions that have been described in these professionals, and in female ballet dancers, to postmenopausal vertebral osteoporosis.

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