

INTAKES OF SELECTED NUTRIENTS, BONE MINERALISATION AND DENSITY OF ADOLESCENT FEMALE SWIMMERS OVER A THREE-YEAR PERIOD

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ABSTRACT: The aim of this study was to conduct three-year monitoring of bone mineralization (BMC) and bone mineral density (BMD) of adolescent girls engaged in swimming at the time of attaining the peak bone mass and of their counterparts leading a rather sedentary life, considering the intakes of calcium, phosphorus and protein, as well as the proportions among those nutrients. Two groups of girls aged 11–13 years were studied 3 times at yearly intervals: untrained controls ($n = 20$) and those engaged in competitive swimming ($n = 20$). Bone density was determined by dual-energy X-ray absorptiometry (DXA) in the lumbar spine (L2 – L4). Nutrient intakes (energy, protein, calcium, phosphorus) were assessed from 24-h recalls. The group of swimmers had significantly lower BMI values than the control group. No systematic, significant between-group differences were found in nutrient intake or in bone mineralization variables. Calcium intake was below the recommended norm in all subjects but mean values of bone mineralization variables (BMC, BMD) steadily increased in both groups. The BMD z-scores proved negative throughout the three-year period of early adolescence in both groups of girls and that decrease was significant in swimmers. This could have been due to insufficient calcium intake as well as to inadequate calcium-to-phosphate and protein-to-calcium ratios and, when continued, might result in a decreased bone mass in adulthood.

KEY WORDS: swimmers, bone mineralization and density, calcium and phosphorus intake, adolescence

INTRODUCTION

Engagement of young subjects in sport activities is known to bring about beneficial effects in the bones [14,28]. For example, a high bone mineral density achieved by female gymnasts in the course of their sport career persisted after that career had been terminated [36]. Also, women who used to practice swimming had better backbone mineralization than their sedentary peers [23]. However, according to Fehling et al. [5] and Heinrich et al. [12], sport walking or volleyball are more effective in increasing bone density than swimming at low intensities, but the latter is by all means better than a sedentary lifestyle.

The appropriate development of the skeletal system is conditioned by adequate nutrition, especially calcium supply and correct proportions between the intakes of calcium, phosphorus and protein. Yet, many studies [15,26,27] have demonstrated a too low content of calcium in the diet of schoolchildren and that may be responsible for insufficient bone mineralization in adolescence and in adulthood.

The aim of this study was thus to conduct three-year monitoring of bone mineralization (BMC) and bone mineral density (BMD) of adolescent girls engaged in swimming at the time of attaining the peak bone mass and of their counterparts leading a rather sedentary

life, considering the intakes of calcium, phosphorus and protein, as well as the proportions among those nutrients.

MATERIALS AND METHODS

Two groups of girls aged 11–13 years volunteered to participate in the study approved by the local Committee of Ethics: swimmers ($n = 20$), attending Mastery Schools of Sports in Ożarów Mazowiecki and Międzyrzec Podlaski, engaged in competitive swimming for 2.3 ± 1.2 years, participants of Junior National Championships, and sedentary controls ($n = 20$). The examinations were conducted three times: in June and September 2008, in June 2009 and in June 2010.

Bone mineralization BMC (g) and bone density (BMD ($\text{g} \cdot \text{cm}^{-2}$)) were determined for the lumbar area (L2 – L4) by DXA absorptiometry using a Lunar DPX-L device (USA). All measurements were performed by a well-trained specialist. Individual results were expressed as z-scores based on the Pediatric Reference Database.

The nutrition was assessed from 24-h recalls on the eve of every examination. The intakes of energy, protein, calcium and phosphorus were computed using the reference national software [18]; the data

of energy, protein and phosphorus were related to the mean group requirements (EAR) and those of calcium to the recommended sufficient intake (AI), considering age, body mass and physical activity of subjects [13]. The calcium-to-protein and calcium-to-phosphorus ratios were related to the recommended normal values [13].

The data of nutrient intakes proved to be right-skewed and were transformed to logarithms. Then all data were subjected to two-way ANOVA with repeated measures. Whenever the years \times groups interaction was significant, the post-hoc Scheffé's test was applied; otherwise only the significances of main effects were reported. Since no differences were found between the ANOVA results for log-transformed or raw data, only the latter ones were shown. The level of $p \leq 0.05$ was considered significant.

RESULTS

The results are presented in Tables 1–3. There were no between-group differences in body height but the swimmers tended to be lighter than their untrained counterparts and this was significantly emphasised by BMI data ($p < 0.05$ – 0.001). Moreover, the difference

between groups was reflected by the declared weekly volumes of physical activity, namely about 13 and about 2 h \cdot week⁻¹ in swimmers and controls, respectively (Table 1).

As follows from Tables 2 and 3, no systematic, significant between-group differences were found either for nutrient intakes and proportions or for bone density variables. As far as the changes in time are concerned, only energy intake significantly ($p < 0.001$) increased every year, other variables showing only occasional time-related differences within groups (Table 2).

Compared with untrained girls, more swimmers exhibited an insufficient energy intake (48 vs. 23%; $p < 0.01$) when all data collected in the study period were considered. Protein intake was within recommended limits in both groups. The frequencies of insufficient phosphorus intake were similar in both groups, at about 33%, while calcium intake was in all girls below the recommended minimum throughout the study. Bone mineral density was similar in both groups but when mean z-scores were computed for the entire study period, they amounted to -0.30 ± 0.93 ($p < 0.05$) and -0.15 ± 1.58 in the swimmer and control groups, respectively.

TABLE 1. MEAN VALUES (\pm SD) OF SOMATIC VARIABLES AND OF SELF-REPORTED PHYSICAL ACTIVITY (PA) OF ADOLESCENT FEMALE SWIMMERS AND CONTROLS

| Variable | Swimmers (n = 20) | | | Controls (n = 20) | | | Years | Groups | Y. x Gr. |
|----------------------------------|-----------------------------|-------------------------------|-------------------------------|-------------------|-----------------|-----------------|-------|--------|----------|
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 | | | |
| Age (years) | 11.6 \pm 0.9 | | | 12.2 \pm 0.8 | | | | | |
| Body height (cm) | 154.1 \pm 8.3 | 159.6 \pm 7.8 | 165.9 \pm 9.6 | 154.9 \pm 9.8 | 157.3 \pm 9.6 | 162.3 \pm 9.5 | *** | | |
| Body mass (kg) | 41.5 \pm 7.9 | 47.0 \pm 8.1 ^{oo} | 53.4 \pm 9.6 | 46.7 \pm 10.3 | 54.8 \pm 9.9 | 56.3 \pm 5.1 | ** | | *** |
| BMI | 17.3 \pm 2.1 ^o | 18.3 \pm 2.1 ^{ooo} | 19.6 \pm 2.7 ^{ooo} | 19.4 \pm 3.5 | 22.1 \pm 3.5 | 23.6 \pm 2.8 | *** | *** | *** |
| PA (h \cdot wk ⁻¹) | 11.9 \pm 3.7 | 12.5 \pm 2.5 | 13.5 \pm 2.9 | 2.2 \pm 2.2 | 1.9 \pm 1.1 | 1.9 \pm 1.0 | | *** | |

Note: BMI: body mass index; PA: physical activity; Y:x Gr.: interaction effect of years and group; significance of main effects: ** $p < 0.01$; *** $p < 0.001$; significantly different from the respective value in the control group: ^o $p < 0.05$; ^{oo} $p < 0.01$; ^{ooo} $p < 0.001$.

TABLE 2. MEAN VALUES (\pm SD) OF DAILY PROTEIN AND MINERAL INTAKES BY ADOLESCENT FEMALE SWIMMERS AND CONTROLS

| Variable | Swimmers (n = 20) | | | Controls (n = 20) | | | Years | Groups | Y. x Gr. |
|----------------------|------------------------------|------------------------------|------------------------------|------------------------------|-----------------------------|-----------------|-------|--------|----------|
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 | | | |
| Energy intake (kcal) | 2227 \pm 470 | 2513 \pm 531 | 2604 \pm 548 | 2047 \pm 406 | 2355 \pm 459 | 2489 \pm 435 | *** | | |
| Protein (g) | 70.7 \pm 16.8 | 71.6 \pm 17.6 | 75.4 \pm 18.9 [^] | 63.8 \pm 13.9 [^] | 71.7 \pm 15.6 | 69.8 \pm 16.0 | | | ** |
| Calcium (mg) | 527 \pm 201 [^] | 770 \pm 258 [^] | 649 \pm 247 [^] | 414 \pm 197 [^] | 751 \pm 357 | 746 \pm 304 | | | *** |
| Phosphorus (mg) | 1193 \pm 366 | 1170 \pm 346 | 1302 \pm 368 [^] | 1016 \pm 254 [^] | 1268 \pm 317 [^] | 1169 \pm 273 | | | *** |
| Ca:P | 2.45 \pm 0.84 [^] | 1.66 \pm 0.67 [^] | 2.17 \pm 0.68 [^] | 2.82 \pm 0.99 [^] | 1.94 \pm 0.68 | 1.73 \pm 0.56 | | | *** |
| Ca:Protein | 7.6 \pm 2.9 [^] | 11.2 \pm 4.5 [^] | 8.8 \pm 3.4 [^] | 6.4 \pm 2.5 [^] | 10.4 \pm 4.0 | 10.7 \pm 3.9 | | | *** |

Note: Ca:P: calcium: phosphorus ratio; Ca:Protein: calcium: protein ratio; Y:x Gr.: interaction effect of years and group; Significance of main effects: ** $p < 0.01$; *** $p < 0.001$; [^] Significantly ($p < 0.05$) different from the respective values in other years (within group)

TABLE 3. MEAN VALUES (\pm SD) OF BONE DENSITY VARIABLES IN ADOLESCENT FEMALE SWIMMERS AND CONTROLS

| Variable | Swimmers (n = 20) | | | Controls (n = 20) | | | Years | Groups | Y. x Gr. |
|-----------------------------------|-------------------|------------------|-------------------------------|-------------------|------------------|------------------|-------|--------|----------|
| | 2008 | 2009 | 2010 | 2008 | 2009 | 2010 | | | |
| BMC (g) | 27.4 \pm 7.7 | 32.1 \pm 8.4 | 36.8 \pm 5.6 | 30.8 \pm 11.3 | 36.4 \pm 13.3 | 39.8 \pm 9.3 | *** | | |
| BMD (g \cdot cm ⁻²) | 0.88 \pm 0.12 | 0.95 \pm 0.12 | 1.15 \pm 0.10 ^{oo} | 0.93 \pm 0.19 | 1.01 \pm 0.21 | 1.25 \pm 0.12 | *** | | ** |
| BMD (%) | 96.9 \pm 9.9 | 97.2 \pm 8.3 | 98.3 \pm 26.8 | 97.9 \pm 17.1 | 98.7 \pm 17.0 | 98.7 \pm 13.2 | * | | |
| BMD (Z-score) | -0.29 \pm 0.90 | -0.42 \pm 1.13 | -0.25 \pm 0.83 | -0.16 \pm 1.60 | -0.15 \pm 1.81 | -0.18 \pm 1.17 | | | |

Note: BMC: bone mineralization; BMD: bone mineral density; Y:x Gr.: interaction effect of years and group; Significance of main effects: * $p < 0.05$; *** $p < 0.001$; ^{oo} Significantly ($p < 0.01$) different from the respective value in the control group

DISCUSSION

Adequate accretion of bone at an early age and, in consequence, of peak bone mass depend on both genetic and environmental factors; among the latter, appropriate nutrition and, especially, daily intakes of calcium and phosphorus [25, 26] and physical activity [3,32] are of prime importance. Positive effects of physical activity practiced in the adolescence period were conclusively demonstrated [14,22,17].

No such effect was found in this study despite high volumes of swimming training. This could have been due to the fact that swimming reduced the effect of gravitational forces [31], which are considered essential for shaping bone density [16], as was demonstrated for young women aged 16–21 years [16] or for pre- and post-menopausal women [19]. Nonetheless, BMC and BMD values significantly ($p < 0.001$) increased every year.

Calcium requirement is highest during the growth spurt, when it is $1500 \text{ mg} \cdot \text{d}^{-1}$, and it should not fall below $1000 \text{ mg} \cdot \text{d}^{-1}$ in other periods [1]. Yet, Matkovic [20] recommended the daily intake of $1500 \text{ mg} \cdot \text{d}^{-1}$ to be maintained throughout the entire growth period. Mean calcium supply to children aged 4–17 years did not, however, exceed $1000 \text{ mg} \cdot \text{d}^{-1}$ in many European countries and was lowest in Poland and in Great Britain [8]. The actual recommendation for Polish girls aged 11–15 years is $1500 \text{ mg} \cdot \text{d}^{-1}$ [13].

Many authors have reported common dietary irregularities concerning schoolchildren. Ustynowicz-Fabiszewska et al. [33] and Zagórecka et al. [35] found insufficient calcium intakes in 70% of girls from diverse schools. A study of Stefańska et al. [29] conducted 10 years later demonstrated that 77 and 87% of diets consumed by boys and girls, respectively, aged 10–13 years, did not meet the recommended minimum calcium intakes; in addition, 30 and 20%, respectively, of those diets contained excessive amounts of phosphorus. Those results were confirmed by Błaszczuk et al. [4], who found insufficient calcium intake in 81 and 93% of boys and girls from Łódź schools, respectively, aged 10–13 years and excessive phosphorus intake by 80% of them. Also in schoolgirls attending Mastery Schools of Sports, the daily intake calcium was low (855 mg) and 88% of girls were at risk of calcium deficiency; on the other hand, phosphorus intake was high (1164 mg) and the Ca:P ratio amounted to 1:1.4 [30]. Those reports are consistent with the results presented in this paper.

The adverse effects of low calcium intake on bone mineralization may be seriously enhanced by high phosphorus intake. The Ca:P ratio should range from 2:1 to 1:1 and this can be attained by consuming natural dairy products; milk and its products, apart from containing both elements in the right proportions, also contain substances facilitating the intestinal absorption of calcium [9]. When

the Ca:P ratio is shifted towards the predominance of phosphorus, the secretion of parathormone is stimulated, which, in turn, intensifies calcium resorption from bones. The importance of milk products as the basic source of calcium was demonstrated in a longitudinal study on children by Fiorito et al. [7], by Moore et al. [21], and by Kalkwarf et al. [15], who studied adult women. An excessive phosphorus intake results from consuming highly processed foods (meat products, concentrates, cheese, beverages) which contain phosphates and polyphosphates added to improve the shelf-life. On the other hand, a meta-analysis of reports (Fenton et al. [6]) did not reveal increased urinary calcium excretion or bone demineralization; this may call for a re-evaluation of our views on hazards related to consuming phosphates contained in milk, meat or leguminous products.

The consumption of proteins was in this study fairly high in both groups; no case of insufficient or excessive protein intake was noted. According to Barzel [2], excessive protein intake may affect calcium metabolism. A different view was presented by Heaney [11]; according to him, protein intake correlates with that of calcium and does not affect calcium metabolism except when calcium intake falls below $500 \text{ mg} \cdot \text{day}^{-1}$. That view was supported by Vatanparast et al. [34], who demonstrated in adolescent females that increased protein consumption brought about favourable effects on bone mass when calcium intake was adequate.

The recommended protein-to-calcium ratio, equal to 16:1, enables a good metabolic balance of calcium and minimises its excretion (Heaney [10,11]) while an excess of protein in the diet increases diuresis and, thus, calcium excretion [24]. In this study, the protein-to-calcium ratio was, however, far lower than the recommended one. Yet, mean values of bone mineralization variables (BMC, BMD) steadily increased although the average BMD z-scores were slightly negative throughout the study.

CONCLUSIONS

In conclusion, the BMD z-scores proved negative throughout the three-year period of early adolescence in both groups of girls and that decrease was significant in swimmers. This could have been due to insufficient calcium intake as well as to inadequate calcium-to-phosphate and protein-to-calcium ratios and, when continued, might result in decreased bone mass in adulthood.

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