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## The effect of swimming and type of stroke on bone metabolism in competitive adolescent swimmers: a pilot study

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**Background/aim:** Physical activity plays a key role in increasing and preserving bone mineral density (BMD). Effects on bone development associated with various nonweight-bearing sporting activities, such as swimming, are controversial. Different strokes used in swimming may also present as another factor. The aim of this study was to evaluate the effect of swimming and type of stroke on BMD in competitive adolescent athletes.

**Materials and methods:** Seventy-nine swimmers between the ages of 10 and 21 years participated in this study. BMD was measured with dual-energy X-ray absorptiometry at the lumbar vertebrae and left proximal femur. Daily calorie intake and calcium consumption, and measurements of calcium, phosphorus, alkaline phosphates, 25-hydroxyvitamin D (25(OH) D), and osteocalcin were evaluated.

**Results:** Preliminary results revealed that the type of stroke had no effect on BMD ( $P = 0.79$ ). Additionally competitive swimmers did not have augmented bone mineral accretion, and in 13.9% of athletes low BMD was confirmed. Sixty percent of swimmers had either deficient or insufficient 25(OH) D levels and a low mean calorie ( $P = 0.542$ ) and calcium ( $P = 0.038$ ) intake was observed.

**Conclusion:** This was the first study to evaluate the effect of swimming stroke on BMD. Although no effect was statistically shown, further studies with a larger series may determine this effect.

**Key words:** Adolescent, bone mineral density, competitive athlete, swimming, swimming stroke

### 1. Introduction

During childhood and adolescence, bone mineral density (BMD) increases until peak bone mass is reached. Many factors have been shown to influence BMD such as age, weight, height, pubertal status, heredity, nutrition, and physical activity (1). There is a growing awareness of the importance of maximizing BMD in adolescence, as bone mass acquired during growth and development is a major determinant of the future risk of osteoporosis in later adulthood (2).

Osteoporosis is defined as low bone mineral density, leading to increased bone fragility and a greater risk of fracture (3). The World Health Organization (WHO) defines osteoporosis as a bone density (or bone mass) at least 2.5 standard deviations below peak bone mass. The most widely validated technique to measure BMD is dual-energy X-ray absorptiometry (DXA). DXA is expressed as absolute BMD ( $\text{g}/\text{cm}^2$ ) and standard deviation from the mean peak bone mass is termed the T score. Thus, a

T score of the lumbar spine or hip at least 2.5 standard deviations below the norm defines osteoporosis (4).

Although this definition is used for adults, the term osteoporosis does not have a widely recognized definition in pediatrics. As children and adolescents have not attained peak bone mass using this definition creates difficulties (5).

Current recommendations related to bone densitometry in the pediatric population stem from the First Pediatric Consensus Development Conference on the use and interpretation of bone density studies in children in 2007, which was sponsored by the International Society for Clinical Densitometry (6). Pediatric osteoporosis is defined as the presence of both a clinically significant fracture history and low bone mineral content or bone mineral density. Low BMD is defined as a Z-score less than or equal to 2.0, adjusted for age, sex, and body size, as appropriate (7).

The role of physical activity in increasing and also preserving BMD is supported by the literature. However,

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the type of exercise appears to be an important variable influencing the osteogenic adaptive response (8). The bone development associated with various sporting activities such as swimming, a nonweight-bearing sport, show controversial results that require greater attention. There are 4 main strokes involved in swimming: freestyle, backstroke, butterfly, and breaststroke. Most strokes involve rhythmic and coordinated movements of all major body parts but the biomechanics of each stroke vary (9). We argue whether the discrepancy of swimming stroke will have an effect on BMD.

For this reason, the objective of this study was to determine the effect of swimming on bone metabolism during adolescence in competitive adolescent swimmers and evaluate the effect of different strokes.

## 2. Materials and methods

### 2.1. Participants

This cross-sectional pilot study took place at the Division of Adolescent Medicine at Hacettepe University, İhsan Dogramacı Children's Hospital, Ankara, Turkey. Seventy-nine swimmers (38 female, 41 males) between the ages of 10 and 21 years (mean 12 years) were recruited to participate in this study. None of the subjects had a chronic disease or had ever used medication that might have affected bone metabolism.

Swimmers were selected from established athletic teams and were from teams who participated in regional age group competitions. Only teams who practiced all year round were approached. All swimmers had been engaged in a training program for at least 2 years. At the time of the study they were training a minimum of 3 times per week in water for a minimum of 90 min. Number of hours of training per week, type of swimming stroke (freestyle, backstroke, breast stroke, butterfly), and type of training (in water or on land) were noted. Measurements were obtained during the competitive season.

Written informed consent was obtained from the parents and adolescents. The Research Ethics Board of Hacettepe University approved this study.

### 2.2. Anthropometric determinations and evaluation of pubertal stage

Measurements of weight (kg) were obtained using electronic scales (Scale-Seca 220, Hamburg, Germany), and measurements of height (m) were obtained using the Harpenden stadiometer.

Tanner's classification was used for staging sexual maturation in both sexes and evaluated by the same physician (10). Bone age was assessed by left wrist radiographs of all the subjects, and analyzed, using Greulich and Pyle tables (11).

### 2.3. Dietary evaluation and calcium intake

Dietary information was obtained from a 3-day food diary. Daily calorie intake and calcium consumption was estimated from the approximate quantity of food and calcium rich products consumed daily. A dietitian from our hospital analyzed this data.

### 2.4. Evaluation of bone mineral metabolism

All subjects underwent measurement of BMD by dual-energy X-ray absorptiometry (DXA). BMD was measured at the following sites: lumbar vertebrae (L1–4) and left proximal femur (including femoral neck, trochanter, and Ward's triangle) (DXA, Lunar Prodigy with fan beam of X-ray). The intraassay coefficient of variation with this method is 1% in lumbar spine and 1% in femoral neck. The DXA results are valid for Turkish adolescents with adjustment for age, height, and weight. Results were reported as absolute BMD values (g/cm<sup>2</sup>) and also as standardized Z-scores. Osteoporosis and low bone mineral density was defined according to the International Society for Clinical Densitometry guidelines (6). Serum calcium (mg/dL), phosphate (mg/dL), and alkaline phosphatase (IU/L) obtained by venipuncture were determined with standard methods. Osteocalcin (ng/mL) levels were measured by enzyme-linked immunosorbent assay kits (Novo Calcin Metro Biosystems). Vitamin D status was defined according to clinical practice guidelines defined by the Endocrine Society (12). 25-Hydroxyvitamin D (25(OH) D) level (ng/mL) was determined with radioimmunoassay. Vitamin D deficiency was defined as a 25(OH) D below 20 ng/mL and vitamin D insufficiency as a 25(OH) D of 21–29 ng/mL.

### 2.5. Statistical analysis

The data were analyzed using SPSS 16. The Mann–Whitney U test and Kruskal–Wallis test were used for nonnormally distributed variables to compare the difference among two groups and more than two groups, respectively. Medians (min–max) were used to summarize quantitative data. Level of significance was set at  $P < 0.05$ .

## 3. Results

All swimmers had been training for at least 2 years, the mean time being 5 years (2–12 years). The mean number of training sessions per week in water and on land was 6 (2–10) and 1 (0–7) respectively. Each training session lasted at least 90 min.

The bone mineral density of 68 subjects (86%) was normal. Two of the subjects (2.5%) were found to have osteoporosis, one in the lumbar region ( $Z = 2.5$ ) and the other in the proximal femur region ( $Z = 2.5$ ). One had a stress fracture at the calcaneus and the other at the tibia. A total of 9 subjects (11.4%) were found to have low bone mineral density.

The majority of subjects, 40 (50.9%), swam a combination of strokes, 8 (10%) swam freestyle, 6 (7.6%) swam backstroke, 17 (21.5%) swam breaststroke, and 8 (10%) swam butterfly exclusively. Although both subjects with osteoporosis swam breaststroke there was no statistically significant effect of stroke on BMD ( $P = 0.79$ ).

All subjects with normal BMD and those with low bone mineral density were compared, by evaluating for sex, age, weight, height, BMI, daily calorie and calcium intake, amount of hours training in water and on land, and number of years of training. The only statistically significant finding was a higher calcium intake was found in the group with normal BMD ( $P = 0.038$ ) (Table).

Another important finding was the low calorie and calcium intake of the swimmers. The median calorie intake was 1900 kcal (min–max: 900–2850) and median daily calcium intake 685 mg (min–max 250–1700) (Table). Even though the calorie and calcium intake was low, none of the subjects were malnourished; two of the female swimmers, both 12 years old, had a height and weight percentile between 3 and 10 percent and BMI close to the fifth percentile (BMI: 15.3 kg/m<sup>2</sup> and 14.8 kg/m<sup>2</sup>). Only two subjects, one male and one female, were obese with a BMI greater than the 95th percentile (13-year-old female BMI 28.5 kg/m<sup>2</sup> and 12-year-old male BMI 28.1 kg/m<sup>2</sup>).

Measurements of calcium, phosphorus, and alkaline phosphatase and osteocalcin were at a normal range for all the swimmers. There was no statistical significance between levels of calcium, phosphorus, alkaline phosphates, osteocalcin, and the development of low BMD in these swimmers ( $P > 0.05$ ).

Thirty-one (39.2%) subjects had vitamin D deficiency, 16 (20.2%) had vitamin D insufficiency, and 32 (40.5%) had a normal vitamin D level. The lumbar and femur neck BMD of swimmers with lower 25(OH) D levels did not differ from those with adequate vitamin D levels ( $P = 0.522$ ). One of the subjects with osteoporosis had an insufficient vitamin D level and the other had a normal vitamin D level. Four subjects with low bone mineral density had a deficient 25(OH) D level, 1 had an insufficient 25(OH) D level, and 4 had a normal 25(OH) D level.

#### 4. Discussion

The primary outcome of the study shows that no single stroke has a higher incidence of low bone mineral density. To our knowledge our study is the first to report the effect of the type of swimming stroke on BMD.

Changes in muscle function are seen as a response to the demands of the action. In many sports there are considerable differences in the demands across the body and between agonists and antagonists involved in the actions, which will in turn have a different impact on bone. This is most obvious in sports in which there are specific and different roles for different limbs and muscles such as swimming (13). Although all muscle groups are used in swimming each stroke uses the muscles differently and to varying degrees; thus different strokes will have more impact on particular muscle groups and will isolate and work out different muscle groups harder.

Although our study did not show a statistically significant effect of type of stroke on BMD, both subjects with osteoporosis were breaststroke swimmers. The

**Table.** Characteristics of swimmers with normal and low BMD.

	Normal BMD median (min–max)	Low BMD median (min–max)	Total median (min–max)	P value
Number of patients	68	11	79	
Age (years)	12 (10–21)	12 (10–17)	12.1 (10–21)	0.703
Weight (kg)	50 (24–82)	44 (28–58)	47.7 (24–82)	0.154
Height (m)	153 (126–189)	153(121–181)	153 (121–189)	0.513
BMI (kg/m <sup>2</sup> )	20 (15.1–28.5)	18.8(15.6–22.2)	19.65 (15.1–28.5)	0.156
Bone age	12 (8–18)	11 (8–14)	12 (8–18)	0.303
Daily calorie intake (kcal)	1900 (900–2850)	1850 (1500–2100)	1900 (900–2850)	0.542
Daily calcium intake (mg)	700 (250–1700)	600 (340–650)	685 (250–1700)	0.038
Years of swimming	5 (2–12)	4 (3–6)	5 (2–12)	0.304
Number of training in water/week	6 (2–10)	6(4–8)	6 (2–10)	0.721
Number of training on land/week	1 (0–7)	1(0–2)	1 (0–7)	0.973

breaststroke is a swimming stroke in which the swimmer is on his or her chest and the torso does not rotate. Although it is the slowest of the four competitive strokes, it is commonly agreed that it is by far the most difficult to do correctly (14).

While the swimming stroke was shown to have no effect on BMD, we do think the cause of this may be the small amount of exclusive swimming strokes as over half of the study population swam a combination of strokes.

Our study did not show individuals engaged in high-intensity chronic training for swimming to have augmented bone mineral accretion, and in 13.9% of athletes' osteoporosis or low bone mineral density was confirmed. Literature on this subject is contentious; some authors would argue that swimming represents a nonweight-bearing sport leading to increased muscle contraction and strain on the skeleton, thereby increasing mechanical loading, which will in turn have a positive effect on bone density (15). A similar study from our clinic performed on noncompetitive swimmers showed a significant difference in BMD between adolescent male swimmers and the control group males; the difference of the study was that the swimmers were not competitive athletes (16).

A study by Harumia et al. (17) evaluated 74 female swimmers between the ages of 40 and 60 years that swam for 1–2 h/week for the past 7 years, and showed that the swimmers had higher bone mass at baseline than controls, and that those with the longest swimming history had the highest values. However, these subjects were noncompetitive postmenopausal individuals. Furthermore, animal studies have shown that swimming of sufficient intensity and duration will sufficiently increase mechanical stimuli causing an increased bone density in rats (18,19).

Other research shows that part of the type of physical activity necessary to build and maintain bone density must be weight bearing and that activities with a higher magnitude of skeletal loading and repetitive impact will in turn result in a greater BMD (20). Some authors would even argue that even high muscle forces may not be able to compensate for a lack of impact loading, as studies on competitive cyclists have shown these athletes to have low BMD even though they train intensively (21). A study by Andreoli et al. (22) evaluated BMD in athletes performing 3 different types of sports, and the total BMD of the control group was significantly lower than either judo or karate athletes but not different from the group of water polo athletes. Another study by Courteix et al. (23) evaluating prepubertal girls also showed the BMD measurements for swimmers were not significantly different from the control group for all the BMD measurements, even though the swimmers had performed intensive training for 3 years,

whereas mean BMD in gymnasts was significantly higher than in the control group. Fehling et al. (8) showed that female college students who participated in athletics classified as impact loading (volleyball and gymnastics) had greater BMD than those who participated in an active, loading sport such as swimming. In fact the swimmers were no different to the control group.

To date, activities such as swimming that provide minimal skeletal load have more commonly shown no differences in the BMD of athletes when compared to inactive subjects (8,22–24). A study by Bellew et al. (20) compared the BMD of adolescent female soccer players, weightlifters, and swimmers between the ages of 10 and 17 years with the World Health Organization's normative BMD values for adult females. Results revealed that, compared to normative data from the WHO group, the soccer group was the only sport with BMD significantly greater than the norm, while those of the swimmers were significantly less than the norm ( $P < 0.001$ ), and the weight-lifters were not different from the norm, although in Bellew's study the results of adolescents were compared with those of adults and not an age appropriate control group. A study by Risser et al. (25) evaluated bone density in eumenorrheic female college athletes. They also showed that swimmers had a significantly lower mean density in the lumbar spine than all other groups, including the control group of nonathletes.

The competitive swimmers in our study were immersed in water for long periods. This creates a decreased gravitational component, leading to a reduction in the load on weight bearing

bones. This situation will in turn cause a relatively weightless situation for the athletes,

which is a well-known cause of significant loss of bone mineral (26). Although we were not able to statistically show the effect of the type of training program on BMD, we do think the reason for the high rate of low BMD was the minimal amount of training on land. In our study the ratio of training on land to water were 1:6 h per week. The recommended amount of water and land training for swimmers, per week, according to chronological age is; 4–7 h pool, and 1–2 h land training for 8–11 years of age female swimmers and 9–12 years of age male; 12–24 h pool and 2–3 h land training for 11–14 years of age female and 12–16 years of age male; 12–24 h pool and 3–4 h land training for 14–16 years of age female and 16–18 years of age male; 12–24 h pool and 3–6 h land training for 16+ years of age female and 18+ years of age male swimmers (27). We stress the importance of the fact that swimmers performed sufficient weight bearing and high impact exercise outside of the pool to maintain bone structure. The training programs of all athletes were reevaluated and reorganized with the team coach after the study.

Another important finding was that, according to the criteria defined by the Endocrine Society, close to 60% of all swimmers had either a deficient or insufficient 25(OH) D level. Similar observations were reported from other studies in adolescents in Turkey. A study by Hatun et al. (28) demonstrated that vitamin D insufficiency occurred in 43.8% and deficiency in 21% of Turkish adolescent girls. In Turkey there is no fortification of food with vitamin D and supplementation is only recommended for the first year of life, the reason for this being adequate sunlight exposure in many regions of Turkey. Although we accepted the guidelines proposed by the Endocrine Society, the blood level of 25(OH) D that is defined as vitamin D deficiency remains controversial and is still a cause for debate. In our study, similarly to the study by Hatun et al., we observed no relation between serum 25(OH) D levels and BMD (28). All blood samples in our study were obtained in winter. For this reason we argue that the threshold of vitamin D insufficiency should vary according to the population depending on seasonal variation. Those subjects with low BMD or low 25 OH Vitamin D level were reevaluated and were treated with calcium and vitamin D supplementation, and are currently being followed up.

Another important finding was the low calorie and calcium intake of the swimmers; although all trained at least 3 times a week the mean calorie intake was 1900 kcal (min–max: 900–2850) and the mean daily calcium intake was 685 mg (min–max 250–1700). Both these intakes are extremely low for competitive swimmers. The recommended daily allowance of calcium for an adolescent is 1300 mg/day (29). The mean calcium intake was less than half this amount in the study group. Those swimmers with low calorie and calcium intake were reevaluated and nutritional counseling was given.

There were two main limitations to this pilot study. The first was that we had no control group to compare the results of BMD, and instead evaluated each group separately for those with low BMD and those without. The Z-score values are expressed as the number of standard deviations above or below the mean reference value for adolescents of the same age, sex, and body size. For this reason, we did not think it would be ethical to measure BMD in healthy adolescents when the normative databases utilized for generation of the Z-score are already provided by the DXA manufacturer. The second was that more than half of the participants swam a combination of strokes, leaving the number of participants in each stroke group very small. The reason for this is that adolescent swimmers will begin competitive swimming with a combination strokes, and then exclusively swim with one style as they get older.

Another potential criticism that we are also aware of is that a variety of other factors may be responsible for the results observed in the present study, such as genetic predisposition to osteoporosis, environmental factors such as childhood illnesses, lack of exposure to sunshine, previous physical activity, and dietary intake.

In conclusion we think the importance of this study is that it shows sports such as swimming that do not involve impact loading do not seem to be effective in increasing BMD, especially when the nonweight-bearing exercise is not supported by weight-bearing exercise such as training on land. We stress the importance of additional training on land to promote healthy bone structure and the close monitoring of the nutritional habits of competitive swimmers. Although this study did not produce results showing any effect on BMD among any single stroke, future research with a larger population can be conducted to further clarify this issue during adolescence.

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