Effect of swimming on bone metabolism in adolescents

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Physical activity has been shown to have a positive effect on bone metabolism among adolescents. The objective of this study was to determine the effect of swimming on bone metabolism during adolescence. Swimming, as a non-weight-bearing sport, has been considered to be insignificant in the maintenance of bone mass. We studied whether swimming is associated with a higher peak bone mass. Forty swimmers (males aged 10-17 years and females aged 9-16 years) were studied. The control group consisted of the same number of adolescents aged between 10-16 years who did not swim; distribution of male and female gender was similar in the non-swimming control group compared to the swimming group. Adolescents were matched for age, gender and pubertal stages based on Tanner staging. All subjects underwent combined measurement of bone mineral metabolism by dual-energy X-ray absorptiometry of total body calcium content, and specific biochemical markers of turnover including osteocalcin, calcium, phosphorus and alkaline phosphatase. Bone age (determined by Greulich and Pyle's Radiographic Atlas of Skeletal Development of the Hand and Wrist), weight, height, ideal body weight, ideal body weight ratio, body mass index, Tanner classification (rated by examiner), diet, history of tobacco and alcohol exposure, exercise, socioeconomic status and history of chronic illness and medications were recorded to evaluate potential mediators that would affect bone metabolism. Tanner staging was used to assess puberty, and diet was evaluated based on reported consumption of milk, yogurt and cheese and cola/caffeine beverage consumption daily. There was significant difference in bone mineral content between adolescent male swimmers and the control group males. Consumption of cola beverages were significantly higher among the control group compared with the swimmer group. Ideal body weight ratio was significantly high among the female control group compared with female swimmers. Milk consumption was significantly higher for both male and female swimmer groups, whereas yogurt consumption was only significantly higher in the male swimmer group compared with control group. These results indicate that a highly active nonimpact sport such as swimming may lead to increased bone mineral content only for male swimmers. However, dietary behaviors may be more important than swimming on bone metabolism among adolescents.

Key words: adolescents, bone metabolism, swimming.

Adolescence is a transitional period between the juvenile state and adulthood. During adolescence, young people reach 37% of the bone mineral density (BMD) of adults after completing pubertal development. Osteoporosis is characterized by low bone mass and volume. Prevention of osteoporosis through weight-bearing physical activity has gained more attention in recent years[1]. Sixty percent of cases with osteoporosis in adult life are related to low BMD in adolescence[2]. The skeletal system may be most responsive to the stimulus of weight-bearing physical activity during adolescence. Swimming represents a non-weight-bearing sport that affects bone metabolism by increased muscle contraction and strain on the skeleton, hence leading to increased mechanical loading[3]. This provides an active loading to skeletal structures, whereas weight-bearing sports influence skeletal structures by direct impact loading. Good swimming is an endurance sport with a great number of similar movements but lacks the ground impacts[4]. Many studies have shown that weight-bearing exercise can increase BMD, but it is controversial whether non-weight-bearing sports such as swimming improve bone structure. Dual energy X-ray absorptiometry (DEXA) is used for BMD measurement but not for bone structure. The risk of developing deficient BMD in later adulthood is reduced by maximizing BMD in adolescence[2]. Intense physical activity and exercise is known to increase BMD. Dietary calcium intake on BMD change must be evaluated for deficient bone structure. Calcium intake is relatively low among adolescents[2]. Among the implicated contributing factors is that during puberty, fast food is more popular among adolescents than adults[2]. In addition, young people prefer to consume drinks with cola and caffeine on a daily basis, and they have a tendency to skip meals to avoid weight gain[2]. Dieting is especially popular among girls[2]. Adolescents who smoke tobacco and drink alcohol during this critical period of skeletal development may also experience a negative impact on BMD. Nutrition influences bone mass, yet genetic background (heritability) is also suggested to be a main determinant of the variance in BMD in young people[2]. Therefore, evaluation of any adolescent's bone metabolism requires all parameters to be taken into consideration.

Material and Methods

Selection of Participants

Forty swimmers (20 males, 20 females) who were in training for a minimum of two hours/day and had been swimming more than three years were included. Forty non-swimmers (20 males, 20 females) who were not doing any weight-bearing or non-weight-bearing exercise regularly were recruited as a control group. The control group comprised pubertal stage-matched adolescents whose physical activity had not exceeded two hours per week in the previous year. Swimmers with a history of participating regularly in other forms of weight-bearing exercise were excluded. Participants were free of any chronic disease and of any medication that would affect bone metabolism. All participants were selected from similar socioeconomic status.

Evaluation of Diet and Exercise

All participants were evaluated for diet, tobacco and alcohol intake, and exercise. Evaluation of diet included daily consumption of calcium-containing foods (milk, cheese, and yogurt) and of cola beverages. Dietary information was obtained from food diaries or by extensive dietary interviews, which were conducted by the examiner. We recorded all supplementation use. All participants who were ranked according to the same pubertal stages were evaluated for calcium, phosphorus, alkaline phosphatase, osteocalcin, complete blood count, ideal body weight ratio, and body mass index. Serum concentrations of calcium, phosphorus, alkaline phosphatase and complete blood count were obtained by routine laboratory methods. Osteocalcin levels were measured by ELISA kits (Novo Calcin Metro Biosystems), and results were expressed as nanogram/millimeter (ng/ml).

Evaluation of Pubertal Stage

Tanner's classification was used for staging sexual maturation in both sexes[5]. Testicular volumes were evaluated by Prader's orchidometer in males and breast developmental staging was used for females by the examiner. Anthropometric measures (body weight and height) were determined using standard methods and undertaken by the same examiner. Ideal body weight was determined as 50^{th} percentile of weight and 50^{th} percentile of height. Ideal body weight ratio was calculated by dividing weight by ideal body weight. The body mass index was calculated by dividing the body mass by the square of height ($kg.m^{-2}$). Greulich and Pyle's Radiographic Atlas of Skeletal Development of the Hand and Wrist was used for determination of skeletal ages[6].

Evaluation of Bone Mineral Density

Bone measurement was measured with DEXA scans of total body calcium content since DEXA has become a widely used technique for BMD assessment due to its low radiation exposure (0.5 mRem per whole body scan), low burden and high in vitro precision ($<1.0\%$)[7].

Informed Consent

Each subject who volunteered for the study received an explanation of the purpose of the study. They signed an informed consent to participate in the study, in accordance with the Helsinki declaration. Parents also provided informed consent.

Statistics

The data were analyzed using SPSS 11.5 statistical software. Shapiro-Wilks test was used to determine normality or not of variable distribution. Independent sample t test were used to examine differences between groups for normally distributed variables and Mann-Whitney test was used for non-normally distributed variables. Level of significance was set at $p<0.05$. Data are reported as mean ± SD.

Results

Bone Mineral Density

All participants who enrolled completed the study. When the groups were assessed separately, adolescent male swimmers had higher level of BMD (Z score) compared with the control group, and the difference was significant ($p=0.05$), but there was no significant difference in BMD and bone mineral content in adolescent female swimmers compared with the respective control group ($p=0.08$, $p=0.10$, respectively).

Dietary Habits

Consumption of cola beverages was higher in the control group compared with swimmers among both males and females ($p=0.01$, $p=0.04$, respectively). Ideal body weight ratio was higher in females in the control group compared with female swimmers ($p=0.02$). Although milk and yogurt consumption was higher in male swimmers, only milk consumption was higher in female swimmers compared with the control group ($p=0.001$, $p=0.05$, $p=0.03$, respectively). Variables of specific biochemical markers of bone turnover such as osteocalcin, calcium, phosphorus and alkaline phosphatase and the measurements of bone age, weight, height, ideal body weight ratio, body mass index in addition to socioeconomic status were not significantly different by group ($p>0.05$).

No participants had a history of tobacco or alcohol intake in our study. Our results suggest that adverse changes in BMD do not occur in the swimmer group when compared with the sedentary control group.

Variables of BMD, dietary habits and ideal body weight ratio in both groups are summarized in Table I. There was no significant difference in BMD except that high level BMD (Z score) was significantly different between the control group and male swimmers (Figs. 1-3).

Table I. Bone Mineral Density, Dietary Habits and Ideal Body Weight of Participants

Variables	Gender	Sedentary $\bar{X}\pm SD$	Swimming $\bar{X}\pm SD$	P
Bone mineral density (Z score)	Male	-1.26±1.17	-0.58±0.91	0.05
	Female	-0.11±0.94	-0.21±0.80	0.75
Bone mineral content (g)	Male	41.44±12.97	46.22±15.96	0.35
	Female	41.96±11.23	50.07±8.19	0.08
Bone mineral density (g/cm^2)	Male	0.75±0.16	0.80±0.18	0.40
	Female	0.83±0.13	0.92±0.12	0.10
Coke consumption	Male	5.25±5.65	2.55±4.25	0.01
	Female	3.65±4.80	1.25±1.12	0.04
Milk consumption	Male	4.2±3.97	9.85±5.91	0.001
	Female	5.80±5.15	9.40±6.13	0.03
Yogurt consumption	Male	2.85±3.32	6.25±6.61	0.05
	Female	6.45±3.82	4.60±2.04	0.17
Ideal body weight ratio	Male	52.89±8.81	51.46±10.52	0.89
	Female	48.96±7.39	44.16±6.66	0.02

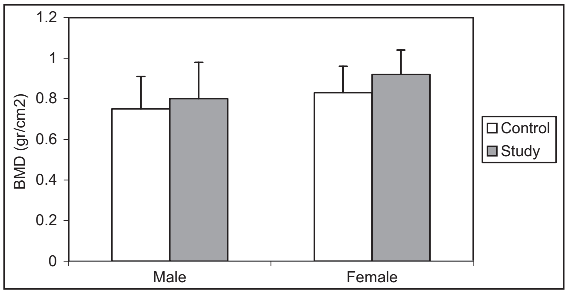

Fig. 1. Bone mineral density (g/cm²) of adolescent male swimmers compared with the control group, and bone mineral density of adolescent female swimmers compared with the control group ($p=0.40$, $p=0.10$, respectively).

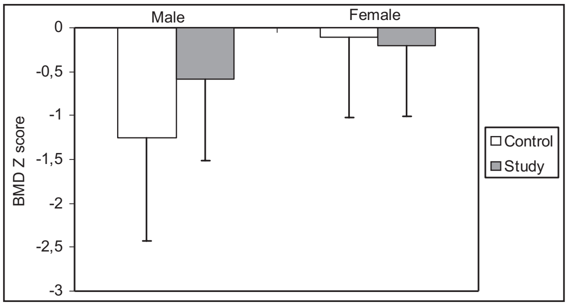

Fig. 2. Bone mineral density (Z score) in adolescent male swimmers compared with the control group, and bone mineral density in adolescent female swimmers compared with the control group ($p=0.05$, $p=0.75$, respectively).

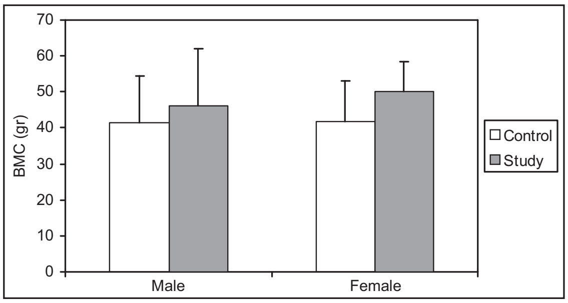

Fig. 3. Bone mineral content (g) in adolescent male swimmers compared with the control group, and bone mineral content in adolescent female swimmers compared with the control group ($p=0.35$, $p=0.08$, respectively).

Discussion

Physical exercise alters BMD, and muscular strength is correlated with bone mass[8]. Swimming was considered to represent a repetitive, non-impact loading sport. Swimmers typically perform a lot of pulley training with small weights and a high number of repetitions, a fact that may underline the role of muscle performance and modulate the skeletal response to incident loading[3,4]. The positive effect on bone metabolism in men is greater than in women, resulting in a greater effect on bone remodeling[9]. Results of our study indicate that swimming is not effective in increasing bone mineral development in females; however, only bone mineral content in male swimmers was higher compared with the control group. Other studies with similar results have been reported[9,10]. Swimming is not a weight-bearing mode of exercise, yet has been proposed to provide skeletal benefits, at least in men. Orwoll et al.[9] reported that the difference between the genders might be due to more forceful contractions on the skeleton generated by males, and suggested that swimming might be an osteogenic mode of exercise in men. Taaffe[10] reported that individuals engaged in high-intensity chronic training for swimming do not have augmented bone mineral even though they have a more favorable body composition, with increased lean mass and decreased fat mass, compared to their peers. Therefore, swimming among adolescents, regardless of gender, is not considered to have an osteogenic effect. High volumes of exercise can have deleterious effects on bone[11-13]. Swimming is an active loading sport that has been shown in several studies to be associated with decreased BMD[11-13]. Although these studies explain the negative effect of doing high volumes of swimming on bone mineral density, we did not determine any deleterious effects on bone for the swimmers group. Falk et al.[14] reported that possible effects of swimming exercise on bone, other than density, such as elasticity and microstructure, may not be reflected by DEXA yet could be detected by quantitative ultrasound method (QUS). In the current study, the data is limited to DEXA findings because the focus was on BMD; therefore, we are not able to comment on the value of QUS over DEXA. All of our swimmer participants were involved in competitive swimming for more than three years. As bone formation generally takes more than 12 weeks and bone mineralization requires another 3-4 months, changes in all body bone mass may not have been apparent before 24 weeks[15]. Diet, specifically calcium intake, may influence bone changes in association with exercise. We evaluated diet for calcium intake for all participants in our study. Consumption of cola beverages has a negative impact on the development of bone mass due to increased osteoporosis[16,17]. The trend towards a replacement of milk with cola and other soft drinks, which results in a low calcium intake, may negatively affect bone health[16,17]. Drinking cola beverages, which contain phosphoric acid and often caffeine, may increase the fragility of bones in adolescents through interactions with the bone mineral content[18]. High calcium content nutrients like cheese, yogurt and milk result in a greater effect on bone remodeling. We observed that swimmers have better dietary habits than the control group. They drank less cola beverages than the control group. In addition, adolescent male swimmers had higher consumption of milk and yogurt compared to the control group; we also found significantly higher milk consumption among female swimmers. We therefore conclude that diet is more important than regular exercise. Other factors that act on bone metabolism, such as dietary and hormonal status, should be taken into account given the low osteogenic effect of activities like swimming[19]. A parent-offspring study has demonstrated that heritability is an important determinant of the variation in bone density[20]. However, Karlsson et al.[21] reported that the higher BMD was due to the training program, and not to heredity. Haapasalo[22] reported that the accumulation of bone mass due to physical activity seems to be most effective if the activity is started no later than the growth spurt, for weight-bearing sports. However, in contrast to the impact sports, the endurance sports such as swimming result in no compatible increase in BMD if sport-specific training was started before growth spurt[22]. We selected participants at 17 years of age who had just reached their growth spurt; therefore, we cannot comment on this aspect of bone changes. In conclusion, we emphasize the role of swimming in the promotion of skeletal health among adolescents. Further studies with long-term follow-up and larger series are necessary to determine the effect of swimming on bone metabolism during adolescence.

REFERENCES

1. Bass S, Pearce G, Bradney M, et al. Exercise before puberty may confer residual benefits in bone density in adulthood: studies in active prepubertal and retired female gymnasts. J Bone Miner Res 1998; 13: 500-507.
2. Saggese G, Barancelli GI, Bertelloni S. Osteoporosis in children and adolescents: diagnosis, risk factors and prevention. JPEM 2001; 14: 833-859.
3. Cassell C, Benedict M, Specker B. Bone mineral density in elite 7- to 9-yr-old female gymnasts and swimmers. Med Sci Sports Exerc 1996; 28: 1243-1246.
4. Nikander R, Sievanen H, Uusi-Rasi K, Heinonen A, Kannus P. Loading modalities and bone structures at nonweight-bearing upper extremity and weight-bearing lower extremity: A pQCT study of adult female athletes. Bone 2006; 39: 886-894.
5. Tanner JM, Whitehouse RH, Takaishi M. Standards from birth to maturity for height, weight, height velocity and weight velocity: British children, 1965. Arch Dis Child 1966; 41: 454-471.
6. Greulich WW, Pyle SI. Radiographic Atlas of Skeletal Development of the Hand and Wrist (2nd ed). Stanford, CA: Stanford University Press; 1959.
7. Going SB, Massett MP, Hall MC, et al. Detection of small changes in body composition by dual energy X-ray absorptiometry. Am J Clin Nutr 1993; 57: 1699-1702.
8. Doyle F, Brown J, LaChance D. Relation between bone mass and muscle weight. Lancet 1970; 322: 391-393.
9. Orwoll ES, Ferar J, Oviatt SK, McClung MR, Huntington K. The relationship of swimming exercise to bone mass in men and women. Arch Intern Med 1989; 149: 2197-2200.
10. Taaffe DR, Marcus R. Regional and total body bone mineral density in elite collegiate male swimmers. J Sports Med Phys Fitness 1999; 39: 154-159.
11. Fehling PC, Alekel L, Clasey J, Rector A, Stillman RJ. A comparison of bone mineral densities among female athletes in impact loading and active loading sports. Bone 1995; 17: 205-210.
12. Nichols JF, Spindler AA, LaFave KL, Sartoris DJ. A comparison of bone mineral density and hormone status of periadolescent gymnasts, swimmers, and controls. Med Exerc Nutr Health 1995; 4: 101-106.
13. Grimston SK, Willows ND, Hanley DA. Mechanical loading regime and its relationship to bone mineral density in children. Med Sci Sports Exerc 1993; 25: 1203-1210.
14. Falk B, Bronshtein Z, Zigel L, Constantini N, Eliakim A. Higher tibial quantitative ultrasound in young female swimmers. Br J Sports Med 2004; 38: 461-465.
15. Dalsky GP, Stocke KS, Ehsani A, Slatopolsky E, Lee WC, Birge S. Weight-bearing exercise training and lumbar bone mineral content in postmenopausal women. Ann Intern Med 1988; 108: 824-828.
16. Kristesen M, Jensen M, Kudsk J, Henriksen M, Molgaard C. Short-term effects on bone turnover of replacing milk with cola beverages: a 10-day interventional study in young men. Osteoporos Int 2005; 16: 1803-1808.
17. Kinney MA. Does consumption of cola beverages cause bone fractures in children? Mayo Clin Proc 2002; 77: 1005-1006.
18. Wyshak G, Frisch RE. Carbonated beverages, dietary calcium, the dietary calcium/phosphorus ratio, and bone fractures in girls and boys. J Adolesc Health 1994; 15: 210-215.

19. Maimoun L, Mariano-Goulart D, Couret I, et al. Effects of physical activities that induce moderate external loading on bone metabolism in male athletes. J Sports Sci 2004; 22: 875-883.

20. Nordström P, Lorentzon R. Influence of heredity and environment on bone density in adolescent boys. A parent-offspring study. Osteoporos Int 1999; 10: 271-277.

21. Karlsson MK, Johnell O, Obrant KJ. Bone mineral density in weight lifter. Calcif Tissue Int 1993; 52: 212-215.

22. Haapasalo H, Kannus P, Sievanen H, Heinonen A, Oja P, Vuori I. Long-term unilateral loading and bone mineral density and content in female squash players. Calcif Tissue Int 1994; 24: 1190-1194.