Material

Relationships between physique and bone strength of tibia in junior high school soccer players

Masashi WATANABE[*1] and Masaru KAGA[*2]

*1 Department of Early Childhood Education, Niimi College
1263-2 Nishigata, Niimi, Okayama 718-8585 Japan
watanabe@niimi-c.ac.jp
*2 Graduate School of Education, Okayama University

Received April 26, 2010 ; Accepted October 18, 2010

The purpose of this study was to clarify the relationship between the physique and bone strength of tibia in 19 junior high school male soccer players. The bone strength was measured by the speed of sound of the tibia (t-SOS, m/sec) using a SoundScan 2000 Compact (Myriad Ultrasound System Ltd., Israel). We enrolled 45 junior high school boys who did not exercise other than physical education classes as a control group. There were no significant differences between the soccer players and the control group in the height, body weight and calcium intake from dairy products. The length of tibia in the soccer players (40.5±1.9 cm) was significantly longer than in the control group (38.4±2.2 cm) ($p < 0.05$). The length of tibia / height in the soccer players (24.8±0.9 %) was significantly higher than in the control group (23.9±1.1 %) ($p < 0.05$). t-SOS in the soccer players (3720±71 m/sec) was significantly lower than in the control group (3778±113 m/sec) ($p < 0.05$). The value of t-SOS demonstrated a positive correlation with calcium intake from dairy products in the soccer players ($r = 0.63$ $p < 0.05$).

These results suggest the possibility that the lower t-SOS values in the junior high school soccer players were affected by the longer length of tibia. Therefore, instruction for soccer players should reflect an understanding of these physical features. It is speculated that the effects of calcium intake on bone formation are greater in the soccer players than in the non-players. The optimal amount of calcium to be taken should be determined according to individual amount of physical activity.

Key words : Physical characteristics, bone strength of tibia, soccer

Human Performance Measurement Vol. 7, 7-13 (2010)

1. Introduction

Puberty is the spurt phase of physical development in which longitudinal growth of bone and bone mass and strength rapidly increase (Boot et al., 1997; Kaga et al., 1999). Bone formation is promoted by physique, exercise, and nutrition (Slemenda et al., 1994; Merrilees et al., 2000) and determined by the interaction these factors. In fact, physique and bone formation are related to weight (Kardinaal, 2000) and weight load stimulates bone growth and enhances the acquisition of mass and strength. In addition, it has been reported that the greater the number of steps taken by male junior high school students per day, the greater bone strength becomes (Matsueda et al., 2001), and that individuals involved in sports activities that have enough load show high bone mass (Nichols et al., 1995). Therefore, physique and exercise are important factors that influence on the acquisition of bone mass and strength.

Average height and weight, both factors in physique, of junior high school students now are higher than those of 25 to 30 years ago (Ministry of Education, Culture, Sports, Science and Technology, 2008). Furthermore, the frequency of exercise of male junior high school students in 2000 has increased compared to 1970 (Kaga et al., 2004). In other words, students have become larger and are actively engaged in exercise. In Japan, children in their teens are more involved in soccer than any other

sport (Sasakawa Sports Foundation, 2010). It has been reported that bone mineral density in the lumbar spine and calcaneal bone of soccer players is higher than in non-exercise control group (Madic et al., 2010; Fredericson et al., 2007). However, these reports are often based on the measurement of regions whose cancellous bone ratio is high. There is a lack of research that measures strength of tibia, which are high in cortical bone that supports the load of body weight and physical exercise. There is also a lack of research examining the relationship between physique and strength of tibia in soccer players. Therefore, an examination of the relationship between physique and exercise, and acquisition of bone mass and strength in soccer players in their physical growth and development phase are significant is considered an effective means of acquiring new findings that contribute to the promotion of sound growth in children.

This sutdy aimed to clarify the relationship between physique and strength of tibia in junior high school soccer players using the speed of sound of tibia as an index.

2. Methods

2.1. Subjects

Subjects were 19 male junior high school soccer players (hereinafter referred to as soccer players). Information on average number of activities per week, average hours used per activity, and years of playing soccer was obtained through individual interview. Results revealed that the average hours of activity per week was 14.6±3.8 hours/ week (average value±SD), and the average number of practice sessions was 6.5±0.4 times/ week. The average of years playing soccer was 7.1±1.6 years. The average age of the soccer players was 14.4±0.6 years. Meanwhile, The control group consisted of 45 male students enrolled at T. Junior High School in O. city, who participated in no regular sports activities except for gymnastics classes required by the school curriculum. The average age of the control group was 14.4±0.4 years. The purpose and method of this study were explained to subjects and their consent for participation in the study was obtained before measurements and investigations were carried out.

2.2. Measurements

1) Strength of tibia

In this study, the speed of sound of tibia (hereinafter referred to as t-SOS m/sec) was measured by SoundScan2000Compact (Myriad Ultrasound System Ltd., Israel). The measurement was performed at the exact half point on the anterior surface of the tibia (from the proximal to the distal end of the medial malleolus), moving the measurement probe in the horizontal direction to set the t-SOS value (m/ sec.) as the maximum speed of the ultrasonic pulse passing through the cortical lamina. This method is mobile and poses no risk of radiation exposure. The amount of time required for measurement is as short as 3-5 minutes per subject. The coefficient of variation (CV) in the three measurements (measured twice on the same day and once on a different day) for adults was 0.24 % and the CV in five measurements on the same day for Japanese elementary school students was 0.37 %. Therefore, it is suitable for bone strength assessment and bone metabolic disorder screening for children and adolescents. (Kaga et al., 1998; Foldes et al., 1995).

2) Physique

Height, weight, and length of tibia were measured. The length of tibia were measured in subjects from the rough surface on the upper end of the tibia to the lower end of medial malleolus based on palpation of the front of the tibia of seated subjects with the knee joint angle at 90 degrees. All measurements were performed by the same person. For comparison of bone development processes, the ratio of tibial length to height (%) was used as an index.

3) Calcium intake from milk and other dairy products

Using the calcium intake from milk and other dairy products as an index, we surveyed the weekly intake of milk and other dairy products through direct interview. Based on the Standard Tables of Food Composition in Japan, calcium intake from 200cc of milk was set as 200mg and calcium intake from one portion of dairy products, such as a slice of cheese (20 g) or a cup of yogurt (120 g), as 130mg. (Ministry of Education, Culture, Sports, Science and Technology, 2005).

2.3. Statistical processing

Stat View 5.0 was used as the statistical software and t-test was used for the comparison between the

soccer players and control group. The level of statistical significance was set at less than 5%.

3. Results

3.1. Physical characteristics

The results of the physical characteristics are shown in Figure 1 to 4. There were no significant differences in height and weight between the soccer players (163.3±7.3 cm/ 51.1±7.9 kg) and the control group (160.9±6.7 cm/ 51.5±9.5 kg). According to nation statistics, the average height of junior high school 1st year students is 152.5±8.06 cm, 2nd year students is 159.7±7.75 cm, and 3rd year students is 165.2±6.73 cm. The average weight of junior high school 1st year students is 44.2±9.92 kg, 2nd year students is 49.1±10.18 kg, and 3rd year students is 54.3±10.18 kg (Ministry of Education, Culture, Sports, Science and Technology, 2010). It was confirmed that the height and weight of both the soccer players and

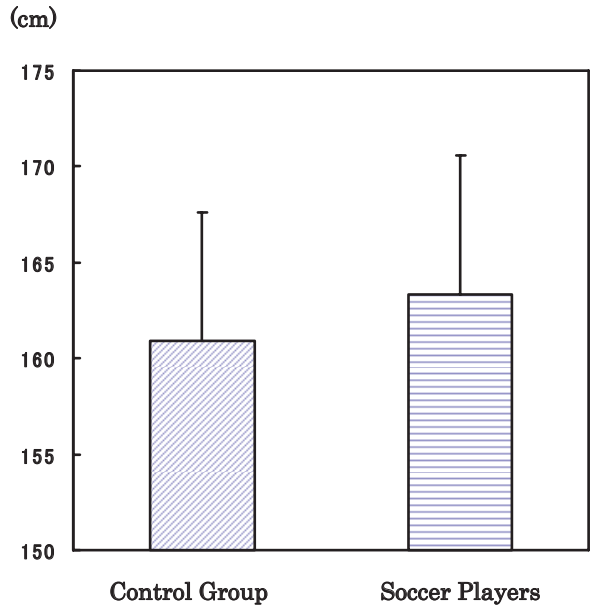

Figure 1. Comparison of height

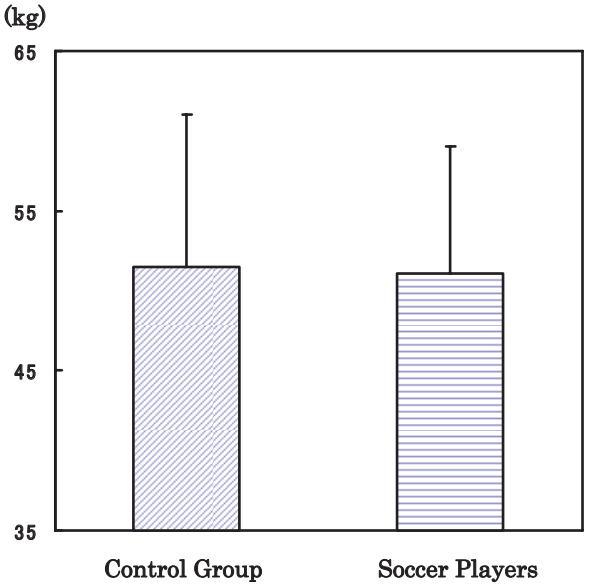

Figure 2. Comparison of weight

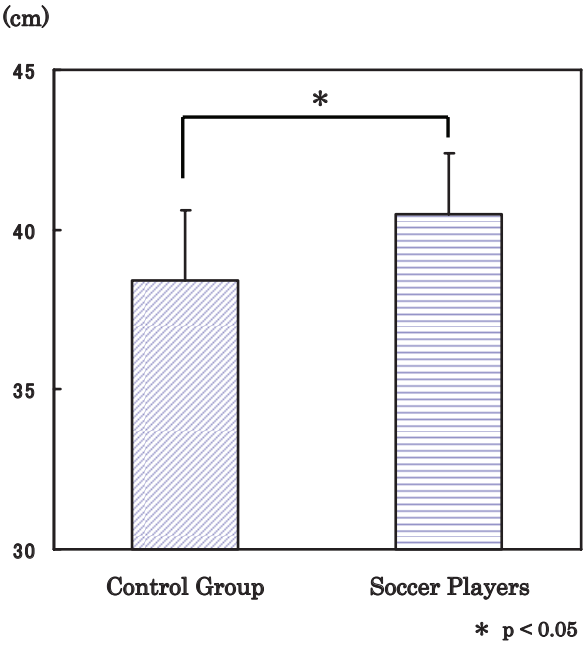

Figure 3. Comparison of length of tibia

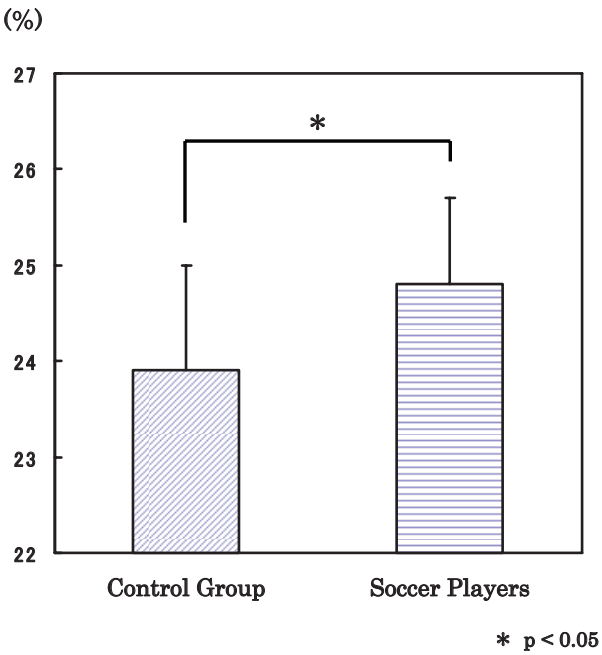

Figure 4. Comparison of length of tibia / height

the control group in this study were within the national average for 2nd and 3rd year students. The length of tibia in soccer players (40.5±1.9 cm) was significantly longer than that in the control group (38.4±2.2) ($t(62) = 3{,}400$, $p < 0.05$). The ratio of tibial length to height in soccer players (24.8±0.9%) was significantly higher than that in the control group (23.9±1.1 %) ($t(62) = 3.016$, $p < 0.05$).

3.2. Strength of tibia

The results of t-SOS are shown in Figure 5. The soccer players (3720±71 m/ sec.) showed significantly lower values than control group (3778±113 m/ sec.) ($t(62) = 2.069$, $p < 0.05$). Table 1 shows the correlation coefficient between t-SOS and measurement items by group. As a whole, t-SOS and weight showed weak positive correlation ($r = 0.38$, $p < 0.05$). In the control group, t-SOS and weight showed weak positive correlation ($r = 0.39$, $p < 0.05$). No correlation was observed between t-SOS and height, length of tibia, and ratio of tibial length to height.

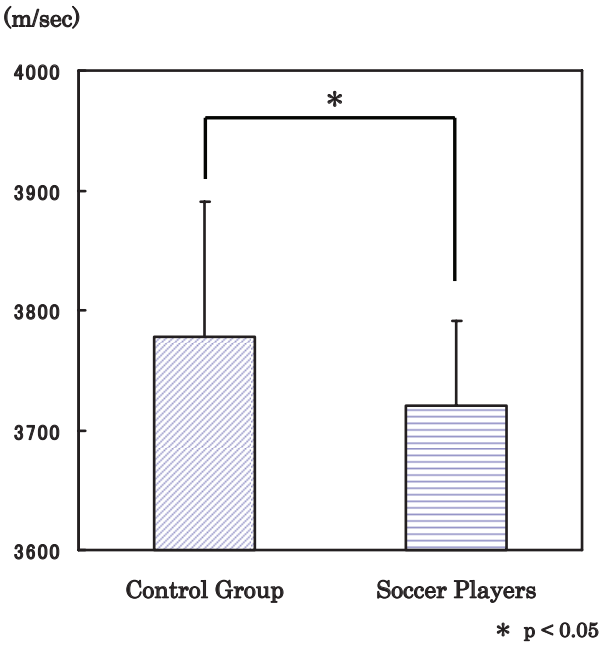

Figure 5. Comparison of t-SOS

Table 1. Correlation between t-SOS and measurement items by group

Measurement Items	t-SOS		
	Total (n=64)	Soccer Players (n=19)	Control Group (n=45)
Height	0.13	0.11	0.21
Weight	0.38*	0.39	0.39*
Length of tibia	−0.06	−0.08	0.07
Length of tibia / height	−0.19	−0.25	−0.09
Calcium Intake	0.20	0.63*	0.17

3.3. Calcium intake from milk and other dairy products

There was no significant difference in the calcium intake from milk and other dairy products between soccer players (3753±1787 mg/ week) and the control group (3108±2185 mg/ week). Table 1 shows the correlation coefficient between t-SOS and calcium intake from milk and other dairy products by group. In soccer players, t-SOS and calcium intake from milk and other dairy products showed a slightly strong correlation ($r = 0.63$, $p < 0.05$). However, in the control group, no correlation was observed between t-SOS and calcium intake from milk and other dairy products.

4. Discussion

Kaga et al., (1999) have reported age-related change in the t-SOS of Japanese children and adolescents. According to the report, male students reach peak height velocity (PHV) at 13 years of age and rapid increase of tibial strength at 14 years of age. The soccer players and control group in this study are considered to be in the stage of rapid increase of tibial strength after PHV. It has been reported that bone mineral density in individuals who play soccer is higher than control group not engaged in physical exercise (Kalai et al., 2007). However, certain physique factors in soccer players were revealed in this study, including longer tibia and higher ratio of tibial length to height compared with the control group, and significantly lower t-SOS values in the soccer players than in the control group. Furthermore, this study did not show significant differences in calcium intake from milk and other dairy products between the soccer players and the control group. This indicates that the nutrition factor had a small influence on the comparison of t-SOS values in these two groups.

In regard to longitudinal growth of bone, it was reported that mice that were engaged in appropriate exercise showed significantly longer tibia compared with non-exercise control group (Plochocki et al., 2008), suggesting that appropriate exercise promotes longitudinal growth of bone. Hormone is considered one of the important factors in bone development, and exercise accelerates the production of growth hormone (Roth et al., 1963). According to Soya (1997), rats engaged in running exercise, which exerts a sufficient effect on bone and muscle development, showed an increase in growth hormone production, which means that growth hormone acts on both bone and muscle in the growing stage and contributes to the interactive promotion of growth, including the promotion of bone development. In other words, the subjects of this study were engaged in sports activity which promoted the production of growth hormone and led to the longitudinal growth of bone. In addition, long bones first grow longitudinal derection, then in width increasing density (Garn, 1972). In regard to the relationship between sports and bone formation in the growing stage, participants in sports activities performed on-land, in which the full effect of gravity is experienced, showed higher bone density and strength values than sports that reduce load in water (Risser, 1990; Okano et al., 2003). Furthermore, in this study, only a weak correlation between weight and t-SOS was found. In other words, weight itself did not affect load significantly, however, the load in on-land sports activity associated with movement was thought to exert effect on strength of tibia. Therefore, soccer players in this study are considered to apply significant stress on the tibia which contributes to the promotion of bone formation; however, t-SOS results, indicate soccer players were in the process of growth in width.

Meanwhile, long bones of humans develop from the periphery in the lower rather than upper extremities (Roche, 1974). Soccer players showed high ratio of tibial length to height, which suggests a higher final height than the control group and that the individuals are in the stage of developing peripheral bones of the lower extremity. Briefly, there is a possibility that bone development in soccer players was slower than the control group. Kaga et al., (2002) reported that there was a period of relative bone fragility, and in which bone formation was delayed compared with the growth of tibia. The soccer players are in this stage, which may have caused lower values of t-SOS compared with the control group. However, no clear association between t-SOS and length of tibia, and ratio of tibial length to height was observed due to the small number of subjects. This issue requires further examination.

As explained above, when we teach soccer players, it is desirable for instructors to understand that there is a possibility of their being in the stage of growth in width or delay of bone growth if their length of tibia is long and

give appropriate instructions.

Nutrition factor affected the promotion of bone development (Wallace et al., 2002), and Matsueda et al, (2001) reported a positive correlation between calcium intake from milk and dairy products and the bone strength. The soccer players in this study showed a relatively strong positive correlation between bone strength and calcium intake from milk and dairy products. Puberty is the modeling stage in which the size of one increases, and in the spurt stage of the height, bone metabolic turnover is accelerated (van Coeverden et al., 2002). In addition, running activity increase bone turnover (Hetland et al., 1993). It is presumed that because soccer players are engaged in sports activities during the period in which bone metabolic turnover is accelerated, their calcium intake becomes greater than the control group for bone formation. These results suggest that the soccer players who require more calcium is greater the effect of calcium intake on bone formation. Therefore, it is important to secure the necessary amount of calcium in accordance with individual physical activity to acquire strength of tibia.

5. Conclusion

This sutdy aimed to clarify the relationship between physique and strength of tibia in junior high school soccer players using the speed of sound of tibia (t-SOS) as an index. The subjects of this study were 19 male junior high school soccer players, and a control group consisting of 45 male junior high school students who participated in no regular sports activities except for gymnastics classes required by the school curriculum. The results of the investigation are as follows.

- There were no significant differences between the soccer players and the control group in height and body weight. The length of tibia in soccer players (40.4±1.9 cm) was significantly longer than in the control group (38.4±2.2 cm) ($p < 0.05$). The ratio of tibial length to height in soccer players (24.8±0.9 %) was significantly higher than in the control group (23.9±1.1 %) ($p < 0.05$).
- t-SOS in the soccer players (3720±71 m/ sec) was significantly lower than in the control group (3778±113 m/ sec) ($p < 0.05$).
- There were no significant differences between the soccer players and the control group for calcium intake from milk and dairy products.
- The value of t-SOS demonstrated a relatively strong positive correlation with calcium intake from milk and dairy products in the soccer players ($r = 0.63$, $p < 0.05$).

These results suggest that the lower t-SOS values in junior high school soccer players were affected by the physical factor of longer length of tibia. Therefore, instruction for soccer players should reflect an understanding of these physical features. It is speculated that calcium intake has a significant effect on bone formation in junior high school soccer players; therefore, it is important for individuals to receive calcium in accordance with the amount of the individual physical activity.

References

Boot, A.M., de Ridder, M.A., Pols, H.A., Krenning, E.P., and de Muinck, Keizer-Schrama, S.M. (1997) Bone mineral density in children and adolescents: Relation to puberty, calcium intake, and physical activity. J Clin Endocrinol Metab 82(1), 57-62.

Foldes, A.J., Rimon, A., Keinan, D.D., and Popovtzer, M.M. (1995) Quantitative ultrasound of bone status. Bone 17: 363-367.

Fredericson, M., Chew, K., Ngo, J., Cleek, T., Kiratli, J., and Cobb, K. (2007) Regional bone mineral density in male athletes: a comparison of soccer players, runners and controls. Br J Sports Med 41(10), 664-668.

Garn, S.M. (1972) The course of bone gain and the phases of bone loss. Orthop Clin North Am 3(3):503-20.

Hetland, M.L., Haarbo, J., and Christiansen, C. (1993) Low bone mass and high bone turnover in male long distance runners. J Clin Endocrinol Metab 77(3), 770-775.

Kaga, M., Takahashi, K., and Seino, Y, (2004) Bipolarization of Frequency of Physical Activity in Childhood and Adolescence. Journal of the Japan Pediatric Society 108(4), 625-634.

Kaga, M., Takahashi, K., Suzuki, H., Matsueda, M.,

Moriwake, T., Miyatake, N., and Seino Y. (2002) Ultrasound assessment of tibial cortical bone acquisition in Japanese children and adolescents. J Bone Miner Metab 20, 111-115.

Kaga, M., Takahashi, K., Suzuki, H., Matsueda, M., Moriwake, T., Makino, H., Yamamoto, K. and Seino Y. (1999) Standard values for ultrasonic measurement of the tibia in childhood and adolescence. J Jpn Soc Bone Morphom 9, 23-27.

Kalaï, E., Bahlous, A., Nbigh, A., Sahli, H., Sellami, S., and Abdelmoula, J. (2007) Effect of physical activity on bone turnover in young boys. Ann Biol Clin (Paris) 65(5): 519-524.

Kardinaal, A.F., Hoorneman, G., Väänänen, K., Charles, P., Ando, S., Maggiolini, M., Charzewska, J., Rotily, M., Deloraine, A., Heikkinen, J., Juvin, R., and Schaafsma, G. (2000) Determinants of bone mass and bone geometry in adolescent and young adult women. Calcif Tissue Int 66(2), 81-9.

Madić, D., Obradović, B., Smajić, M., Obradović, J., Marić, D., and Bosković, K. (2010) Status of bone mineral content and body composition in boys engaged in intensive physical activity. Vojnosanit Pregl 67(5):386-90.

Matsueda, M., Takahashi, K., Kaga, M., Moriwake, T., and Seino, Y,. (2001) Effects of Growth Rate and Life-Style on Bone Strength. Jpn J School Health 42(6), 486-495.

Merrilees, M.J., Smart, E.J., Gilchrist, N.L., Frampton, C., Turner, J.G., Hooke, E., March, R.L., and Maguire, P. (2000) Effects of diary food supplements on bone mineral density in teenage girls. Eur J Nutr 39(6), 256-62.

Ministry of Education, Culture, Sports, Science and Technology (2010) Annual Report of School Health Statistics 2009 [in Japanese].

Ministry of Education, Culture, Sports, Science and Technology (2005) Standard Tables of Food Composition in Japan, Fifth Revised and Enlarged Edition [in Japanese].

Nichols, D.L., Sanborn, C.F., Bonnick, S.L., Gench, B., and DiMarco, N. (1995) Relationship of regional body composition to bone mineral density in college females. Med Sci. Sports Exerc 27:178-182.

Okano, R., Naka, S., Katsuki, K. and Katsuki, M. (2003) The characteristics of the calcaneal bone stiffness and its relationships with the shapes and the fundamental physical fitness in the male athletes. J Clin Sports Med 20: 591-597.

Plochocki, J.H., Rivera, J.P., Zhang, C., and Ebba, S.A. (2008) Bone modeling response to voluntary exercise in the hindlimb of mice. J Morphol 269(3), 313-318.

Risser, W., Lee, E., Leblanc, A., Poindexter, H.B., and Risser, J.M. (1990) Bone density in eumenorrheic female college athletes. Med Sci Sports Exerc 22:570-574.

Roche, A.F. (1974) Differential timing of maximum length increments among bones within individuals. Human Biology 46, 145-157.

Roth, J., Glick, S.M., Yalow, R.S., and Berson, S.A. (1963) Secretion of human growth hormone: physiologic and experimental modification. Metabolism 12, 577-579.

Ruiz, J.C., Mandel, C., and Garabedian, M. (1995) Influence of spontaneous calcium intake and physical exercise on the vertebral and femoral bone mineral density of children and adolescents. J Bone Miner Res 10(5), 675-82.

Sasakawa Sports Foundation (2010) The 2010 SSF National Sports- Life Survey of young People.

Slemenda, C.W., Reister, T.K., Hui, S.L., Miller, J.Z., Christian, J.C., and Johnston, C.C., Jr. (1994) Influences on skeletal mineralization in children and adolescents: evidence for varying effects of sexual maturation and physical activity. J Pediatr 125(2), 201-207.

Soya, H. (1997) Exercise-Induced Growth Promotion and Growth Hormone: A Study on the Hypothalamo-Pituitary Axis. Japan Journal of Physical Education, Health and Sport Sciences 42(4), 283-291.

van Coeverden, S.C., Netelenbos, J.C., de Ridder, C.M., Roos, J.C., Popp-Snijders, C., and Delemarre-van, de Waal, H.A. (2002) Bone metabolism markers and bone mass in healthy pubertal boys and girls. Clin Endocrinol 57(1), 107-116.

Wallace, L.S. and Ballard, J.E. (2002) Lifetime physical activity and calcium intake related to bone density in young women. J Womens Health Gend Based Med 11(4), 389-398.