Is Osteoporosis and Osteopenia a Health Risk in Professional Cyclists of Iran and Tour-de-France?

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Abstract

Introduction: The purpose of this study was to investigate the differences between femoral neck and lumbar vertebral bone mineral density (BMD) of Iranian and Tour-de-France professional cyclists with non-athletes.

Material and Methods: This investigation was in the form of a comparative and a cause-effect study, 17 professional cyclists having participated in Iran's first class cycling competitions [age (23.52±0.87 yr), height (174.94±2.81 cm), weight (73.12±3.17 kg), cycling participation background (5±2.2 yr)], 20 professional cyclists of Tour-de-France [with age (27.20±3.73 yr), height (180.05±7.45 cm), weight (71.50±5.21 kg), cycling participation background (9±3.2 yr)] and 17 healthy non-athletes participants [age (22.94±1.40 yr), height (172.65±2.40 cm) and weight (71.27±3.39 kg)] took part in this study. Data were collected using the mineral density assessing device Dual Energy X-Ray Absorptiometry (DXA). A medical history was also filled out by a specialist physician. In this research mineral density of femoral neck and second to fourth lumbar vertebral was evaluated. Data analysis included descriptive and inferential (One-way ANOVA) statistical methods ($p \leq 0/05$) using SPSS software (version 16).

Results: The obtained results in this study showed that there is significant difference between lumbar vertebral BMD of the participants ($F=17.89$, $P=0.001$). But there was no significant difference between the femoral neck BMD of the participants ($F=0.68$, $P=0.511$).

Discussion and Conclusions: The results indicated that there is no significant difference between femoral neck BMD of Iranian and France Tour cyclists comparing to non-athletes; while BMD of lumbar vertebral was significantly different among the participants. Based on the results, 50% of Tour-de-France cyclists and 17.6% of Iranian cyclists had Osteopenia. Non-athletes had normal BMD. Totally, none of the participants had Osteoporosis. In order to avoid Osteoporosis and Osteopenia during middle and old age, professional cyclists should practice other sport activities such as weight-bearing-exercise to improve their BMD.

Keywords: Bone mineral density, Femoral neck, Lumbar vertebral, Cycling.

Introduction

In addition to genetic (sex and ethnic group) and environmental (nutritional and hormonal status) factors [1, 2, 3], physical activity is an important determinant of bone density and microarchitecture [3, 4]. Skeletal tissue is highly adaptable and responds to meet mechanical demands. Mechanical strain can be generated by external stimuli (impact, weight bearing), which can be defined as "external loading", and by internal stimuli such as muscular forces [3]. Initiating sport activities in childhood and teens is an important basis of health and personal sanitary during middle and old age [5]. Sport training and physical activities are necessary for formation and maintenance of strong and powerful bones. Activities capable of stimulating Osteoblasts are those which influence all bones and accelerate calcium absorption. These activities are only achieved through weight-bearing-exercises [6]. A large number of authors have investigated the effect of sport training and physical activities on BMD. According to these investigation, Osteoblasts exhibit response to mechanical stimuli resulting from exercise and sport training and consequently increase bone formation significantly [7,8]. Borrer et al (2005) reported that physical activities and sport act as a conservating and stimulating factor of Osteoblasts that - through accumulating minerals - improves muscle power and the person', and reduces the risk of bone fractures. Moreover, initiating sport activities of different rates and intensities before maturation, accompanied with taking suitable amounts of calories and calcium, increase mineral content and lateral growth of the bones [9].

Some investigators have claimed that athletes

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participating in sports called non-weight-bearing-exercise; such as cycling, swimming and rowing, possess lower BMD compared to those who participate in weight bearing exercises and sports like football, volleyball, gymnastic and ping-pong [10,11,12,13,14 ,15,16]. In general, performing sport training on a hard and stiff surface along with doing more jumping, shearing and impact activities, exerts more pressure on the bones and increases BMD [17,18]. Creighton et al (2001) showed that for sport training and physical activity to improve BMD, ground response force should be at least three times as much as body weight so that high pressure is exerted on the bones [19]. Ginty et al (2005) investigated the relationship between BMD of femur and lumbar vertebral with total body mass among thousand men aged between 26-28. Their findings showed that the more increase in training severity, the more increase in BMD of total body weight and hip bone, and vice versa [20]. Through two methods of gravitational force and muscle tension, physical activity and sport training lead to force transmitting toward the bones and as a consequent of the force exerted, BMD is improved [21]. Physical activities stimulate mechanical receptors and increase BMD in children and teenagers and, to a more restricted amount, in adults [22,23]. Rico et al (1993) studied the BMD of children and found that the BMD was lower in non-active children compared to their active counterparts. Moreover, they showed that BMD in people participating in weight-bearing-exercises was much higher than that of cyclists and swimmers [24]. Fiore et al (1996), comparing BMD of cyclists and non-athlete counterparts, reported no significant difference between the two groups [25]. Warner and Dalsky (1997) also found no significant difference between BMD of cyclists and that of non-athletic participants [26]. In contrast, Sabo et al (1996) reported that BMD of lumbar vertebral of Tour-de-France cyclists was 10% lower than BMD of non-athletes [27]. Warner et al (2002) compared BMD of road and mountain cyclists with BMD of non-athletes (control group) and observed no difference for absolute value of BMD among the three groups. But when the relationship between the participants' BMD and their weight was studied, the researchers found that mountain cyclists had higher values compared with road cyclists and non-athletes [28]. Nichols et al (2003) investigated BMD of young and old cyclists in comparison to control group and concluded that BMD of young cyclists was significantly different from that of non-athletes, while femur and lumbar vertebral BMD in elderly cyclists was 10% lower than that of non-athletes. Moreover, the researchers maintained that the difference of BMD between the two groups of cyclists is a consequence of desisting from weightlifting training after being 35 years old [29]. Maimoun et al (2004) compared the effect of physical activities on bone metabolism among eleven cyclists, thirteen swimmer, fourteen triathletes, and ten non-athlete men as the control group. They found that triathletes had higher BMD of femoral neck and lower limb compared to swimmers and control group; while no significant difference for BMD was observed among cyclists, swimmers and non-athletes [3]. Warning results were obtained in Medelli et al (2005) research, who studied professional cyclists. The authors evaluated lumbar vertebral BMD in 23 professional cyclists and found that 65% of these cyclists suffered from Osteoporosis [30]. Smathers et al (2009) compared lumbar vertebral BMD and femoral neck between 32 road cyclists and non-athlete counterparts. Road cyclists' BMD was significantly lower than that of control group and 25% of the professional cyclists and 10% of non-athletes had Osteopenia [31]. Johnov (1994) hypothesized that since a large portion of body weight is exerted on lumbar vertebral and femur on one hand, and on the other hand the highest probability of Osteoporosis-induce fracture is seen in these limbs, the limbs can be considered as an index for evaluating the BMD [32]. However, contradictory results are reported by investigators regarding the effect of non-weight-bearing-exercises on bone density. Moreover, identifying Osteoporosis risk factors in professional cyclists is of great importance. Therefore, the purpose of this study was to investigate femoral neck and lumbar vertebral BMD of Iranian and Tour-de-France professional cyclists in comparison to non-athletes.

Material and Methods

This investigation was in the form of a comparative and cause-effect study, 17 professional cyclists having participated in Iran's first class cycling competitions [age (23.52±0.87 yr), height (174.94±2.81 cm), weight (73.12±3.17 kg), cycling participation background (5±2.2 yr), 20 professional cyclists of Tour-de-France [with age (27.20±3.73 yr), height (180.05±7.45 cm), weight (71.50±5.21 kg), cycling participation background (9±3.2 yr)] and 17 healthy non-athletes participants [age (22.94±1.40 yr), height (172.65±2.40 cm) and weight (71.27±3.39 kg)] took part in this study. took part in our study after filling out a written consent letter voluntarily. First, the participants were familiarized with the study conditions and the various targets needed for data collection. Participants were chosen based on lacking factors effecting BMD: (1) not having experienced bone fracture; and (2) not having heritable Osteoporosis or former Diabetes, Thyroid or Parathyroid hyperactivity, neurological diseases and surgery, heart and respiratory diseases. Also people with a background of smoking or taking drugs affecting BMD such as Corten or anticonvulsant medicines [33] were not chosen to take part in the study. This screening was based on the questionnaires answered by the participants and confirmed by a specialist physician. Iranian cyclists had been practicing professional cycling at least for five years, four sessions weekly and 1.5 to 2 hours per session. Tour-de-France cyclists had a seven-year background, practicing 6 sessions per week and 3.5 to 4 hours per session. The data were recorded by a specialist using Dual Energy X–ray Absorptiometry (DXA), scales, a height meter and a medical questionnaire. Participants' weight was measured using digital scales of Beurer Company, German having an accuracy of 100 grams and their height was measured using a wall height meter of Beurer Company with an accuracy of 1 mm. To evaluate the BMD of the participants using DXA method, the BMD values were measured in Densitometry center by a specialist. In this study, two-body parts of Iranian and France Tour cyclists, namely lumbar vertebral (lumbar 2nd, 3rd and 4th vertebral) and hip bone femoral neck; each having its own clinical value of BMD, were investigated [34]. The results of each part were recorded in the computer individually, and the final data and colourful photograph were printed and analysed by a lab specialist. The total values for each person is calculated by the authors'.

Statistical methods

Data analysis included descriptive and inferential statistical methods ($p \leq 0.05$) using SPSS software (version 16). Criteria such as mean, standard deviation (S.D) and frequency distribution table of age, height and weight of the testees were used. In the inferential statistics, Kolmogorov–Smirnov test and Levene's test were used to normalize and homogenize the data respectively. One-way ANOVA was used to compare the BMD values of lumbar vertebral and femoral neck of Iranian cyclists, Tour-de-France cyclists and non-athletes, and if the differences turned out to be significant, Tukey test (tukey post hoc) was also used. Independent t–test was used to compare BMD values of femoral neck and lumbar vertebral of each group.

Results

The data presented in Table 2 and Figure 1, indicate that participants were significantly different in lumbar vertebral BMD ($P<0.05$) but not femoral neck BMD ($P>0.05$). BMD of femoral neck and also lumbar vertebral in Iranian cyclists and non-athletes were not significantly different, as shown in Table 3 and Figure 2 ($P>0.05$). But a significant difference was observed in BMD of lumbar vertebral and femoral neck BMD of Tour-de-France cyclists ($P<0.05$).

Table 1: Characteristics of participants.

Participants / Variables	Iranian Cyclists n=17 M±SD	France Tour Cyclists N=20 M±SD	Non-athletes n=17 M±SD
Age (years)	23.52±0.87	27.20±3.73	22.94±1.40
Height (cm)	174.94±2.81	180.05±7.45	172.65±2.40
Weight (kg)	73.12±3.17	71.50±5.21	71.27±3.39
BMI (kg/m^2)	23.89±0.74	22.07±1.27	23.90±0.96

Table 2: The participants' bone mineral density (BMD) of the femoral neck and lumbar vertebral.

Participants / Variables	Iranian Cyclists n=17 M±SD	France Tour Cyclists n=20 M±SD	Non-athletes n=17 M±SD	F	p
Femoral neck (gr/cm^2)	1.01±0.02	0.981±0.08	0.991±0.07	0.68	0.511
Lumbar vertebral (gr/cm^2)	1.00±0.03	1.114±0.01	0.992±0.06	17.89	*0.001

* $P < 0.05$, significantly different from baseline values.

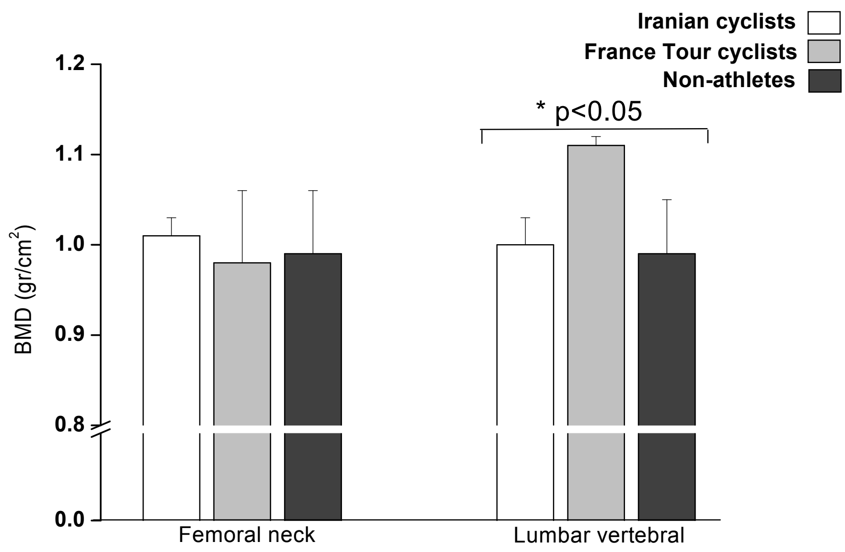

Figure 1: Group data showing the participants' mean bone mineral density (BMD) in the femoral neck and lumbar vertebral.

Table 3: Participants' femoral neck and lumbar vertebral bone mineral density (BMD).

BMD (gr/cm^2) / Participants	Femoral neck M±SD	Lumbar vertebral M±SD	T	P
Iranian Cyclists n=17	1.00±0.03	1.01±0.02	0.024	0.981
France Tour Cyclists n=20	0.981±0.08	1.114±0.01	4.185	*0.001
Non-athletes n=17	0.991±0.07	0.992±0.06	0.406	0.687

* $P < 0.05$, significantly different from baseline values.

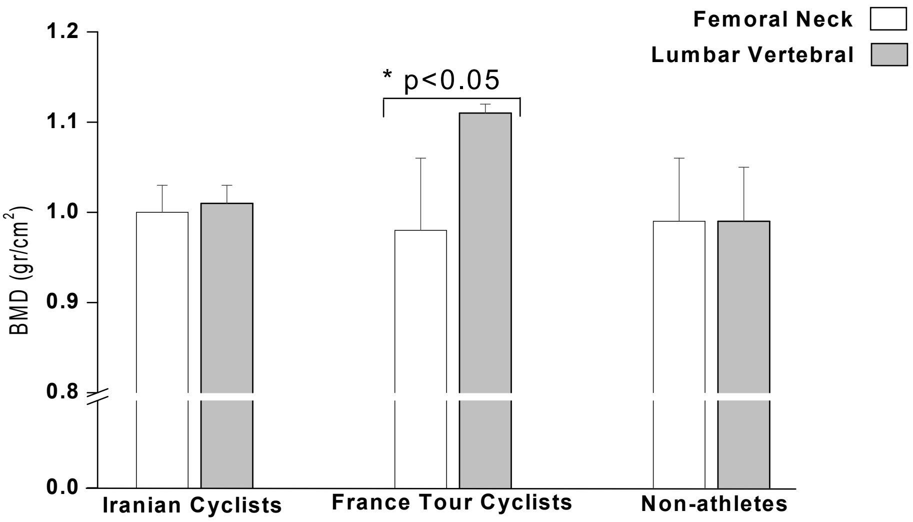

Figure 2. Group data showing the participants' mean bone mineral density (BMD) of the femoral neck and lumbar vertebral.

Discussion and Conclusion

Based on results obtained in this study, 50% of Tour-de-France professional cyclists had Osteopenia and the other 50% were healthy. BMD values of femoral neck of Tour-de-France cyclists were lower than that of the Iranian cyclists and non-athletes, however no significant difference was observed ($P>0.05$). BMD values of lumbar vertebral of Tour-de-France cyclists were significantly higher than that of the Iranian cyclists and non-athletes

($P<0.05$). Among 20 Tour-de-France cyclists, four cyclists had Osteopenia in hip bone and ten in lumbar vertebral. In other words, 20% and 50% of Tour-de-France cyclists had Osteopenia of hip bone and lumbar vertebral, respectively. Among Iranian cyclists, 2 (11%) and 1 (5.8%) had Osteopenia in hip bone and lumbar vertebral respectively. that is to say in general, 17.6% of Iranian cyclists suffered from Osteopenia, which is in agreement with the results reported by Medelli et al (2005) and Smathers et al (2009) [35,31]. Factors such as intensity of exercise (low or high intensity exercises) and cycling types (including road and mountain cycling) can be considered as probable reasons for this agreement [36,17,15,14,13,18,12,11,10]. According to Volf law, mechanical pressure or stress on the bones, through tendons and muscle influences bone formation and transformation [37]. In addition, the bone is considered as a piezoelectric crystal in which, mechanical pressure is converted to electrical energy and electrical changes along with the time when bone is under mechanical pressure, stimulates Osteoblasts and finally results in calcium formation [37]. Osteoblasts of femoral neck and lumbar vertebral in Tour-de-France cyclists were probably less stimulated and this caused BMD reduction. In men and women, 95% – 99% of BMD and bone mineral content (BMC) is gained at the end of the second decade of life, so that type, intensity and duration of physical activity is influenced [39].

Since in Tour-de-France cyclists, the number and duration of each training session was twice as much as those of Iranian cyclists, this higher intensity and longer exercising time has had negative effect on calcium absorption and Osteoblasts stimulation as a result of higher energy consumption [40], and consequently had resulted in BMD reduction. High level of BMD is a critical factor preventing Osteoporosis and a prediction index for bone fracture. Positive effects of physical activities on BMD value have been demonstrated by a large number of investigations [41]. In fact, physical activities affect bone tissue infrastructures. Bone structure is effectively under the influence of mechanical pressures exerted on the skeletal system. Regular and light activities like cycling and swimming produce fewer Osteogenic stimulations on bone tissue compared to irregular and high pressure activities such as football, volleyball and gymnastics [12,13,14,15,36 ,11,10]. For the sport training to improve BMD, ground reaction force should be at least three times as much as body weight [19] and since joint reaction force is involved in cyclists, sport activities not really in contact with the earth don't exert real Osteogenic stimulations on body skeleton [16,42]. Therefore, as Osteoblasts of Iranian and Tour-de-France cyclists are less stimulated, less calcium is absorbed and as a consequence of lower BMD level, higher rate of Osteopenia is observed in professional cyclists compared to the norm of World Health Organization (WHO): Normal > -1 SD; -2.5 SD < Osteopenia ≤ -1 SD; and Osteoporosis ≤ -2.5 SD.

It has been proved that weight–bearing–exercises are more Osteogenic than non–weight–bearing ones [12,13,14,15,36,11,10] and cause more increase in BMD. Since cycling is a non–weight–bearing–exercise, it probably does not influence BMD. In this study, no difference was observed in the BMD of femoral neck and lumbar vertebral of Iranian cyclists and non-athletes. Probably factors such as velocity, direction and magnitude of the forced exerted on the bones are effective on BMD increase and among these, magnitude of the pressure is the chief factors [10]. In general, one probable reason for the abnormality of femoral neck and lumbar vertebral BMD in Tour-de-France and Iranian cyclists compared to that of the non-athletes (control group) is that the cyclists had less contact with the ground 2–4 hours per day and this can be the main reason of BMD reduction in cyclists [35]. Moreover, because during cycling less reduction force is exerted on the hip bone and lumbar vertebral, the Osteoblast in these two limbs is less stimulated and does not influence BMD of professional cyclists. Considering that nutrition is one of the limiting factors in our study, this can also be one of probable factors resulting in the reduction of cyclists BMD. In other words, over consumption of protein and shortage of calcium lead to Osteoporosis [43]. Over consumption of protein has a higher effect on Osteoporosis compared to calcium shortage. Since professional athletes have a balanced diet, over consumption of proteins in professional cyclists make their bodies unable to store or immediately metabolize the extra protein. Consequently, liver converts amino acids to organic acids and these organic acids can be used for energy production, or be converted to lipids and acidify bloodstream. To compensate this acidification, kidney absorbs a large amount of calcium from the bones and dissipated it through urine, the result of which is BMD reduction [43,44]. Mayoux et al (1999) reported that short term and strength sports are more Osteogenic than endurance sports such as swimming and cycling [40] and more effectively increase BMD.

Conclusion

Based on our results, it is recommended that Iranian and Tour-de-France professional cyclists willing to improve their BMD, perform other sports such as cross-training (as strength sports and weight-bearing-exercises) beside cycling, in order to avoid Osteoporosis and Osteopenia during old age.

References

1-Stager JM, Hatler LK (1988). Menarche in athletes: the influence of genetics and prepubertal training. Medicine and Science in Sports and Exercise 20:369-373.

2- Jouanny P, Guillemin F, Kuntz C, Jeandel C, Pourel J (1995). Environmental and genetic factors affecting bone mass. Arthritis and Rheumatism 18:61–67.

3- Maimoun L, Mariano-Goulart D, Couret I, Manetta J, Peruchon E, Micallef JP, Verdier R, Rossi M, Leroux JL (2004). Effects of physical activities that induce moderate external loading on bone metabolism in male athletes. Journal of Sports Sciences 22:875–883.

4- Nilsson BE, Wetlin NE (1971). Bone density in athletes. Clinical Orthopedics 77:177–182.

5- Gaeini AA, Rajabi H (2002). Fitness. Publishers: Organization Ministry of Culture and Islamic Publications (Tehran), pp: 10-26.

6- Gharib-Doust F (2003). Osteoporosis. Rheumatology Research Center of Iran Medical Sciences (Tehran) 412-421.

7- Karlsson MK, Magnusson H, Karlsson C, Seeman E (2001). The duration of exercise as a regulator of bone mass. Bone 28(1):128-32.

8- Vicente-Rodriguez G, Ara I, Perez-Gomez J, Serrano-Sanchez JA, Dorado C, Calbet JA (2004). High femoral bone mineral density accretion in prepubertal soccer players. Med Sci Sports Exerc 36(10):1789-95.

9- Borrer KT (2005). Physical activity in the prevention and amenorration of osteoporosis in women. Sports Med 35:779-830.

10- Uzunca K, Birtane M, Durmus-Altun G, Ustun F (2005). High bone mineral density in loaded skeletal regions of former professional football (soccer) players: what is the effect of time after active career? Br J Sports Med 39(3):154-57.

11- Nordstrom A, Olsson T, Nordstrone P (2005). Bone gained from physical activity and lost through detraining: A longitudinal study in young males. Osteo Int 16:835-841.

12- Markou KB, Mylonas P, Theodoropoulou A, Kontogiannis A, Leglise M, Vagenakis AG, Georgopoulos NA (2004). The influence of intensive physical exercise on bone acquisition in adolescent elite female and male artistic gymanasts. Journal of Clinical Endocrinal Metabolism 89:4383-4387.

13- David A, Greene A, Geraldine A Naughton D (2006). Adaptive skeletal responses to mechanical loading during adolescence. Sports Medicine 36:723-732.

14- Calbet JA, Moysi JS, Dorado C, Rodriguez LP (2004). Bone mineral content and density in professional tennis players. Calcified tissue Inter 62:491-466.

15- Calbet JA, Diaz-Herrera P, Rodriguez LP (1999). High bone mineral density in male elite professional volleyball players. Osteo Int 10:468-474.

16- Beshgetoor D, Jeanne F. Nichols, Rego I (2000). Effect of Training Mode and Calcium Intake on Bone Mineral Desity in Femal Master Cyclists, Runners and Non-Athletes. Int Journal Sport Nutritition and Exercise Metabolism10:290-301.

17- Bellew JW, Gehrig L (2006). A comparison of bone mineral density in adolescent female swimmers, soccer players, and weight lifters. Pediatr Phys Ther 18(1):19-22.

18- Egan E, Reilly T, Giacomoni M, Redmond L, Turner C (2006). Bone mineral density among female sports participants. Bone 38(2):227-33.

19- Creighton DL, Morgan AL, Boardley D, Brolinson PG (2001). Weight-bearing exercise and markers of bone turnover in female athletes. J Appl Physiol 90(2):565-70.

20- Ginty F, Rennie KL (2005). Positive, site specific association between bone mineral statue fitness, and time spent at high- impact activities in 16-to-18-yr old boys. Bone Miner 36:101-70.

21- Rahimian-Mashhadi M (2003). The comparison BMD of dominant and non-dominant hand in female-athletes. Olympics Journal of Iran 12(25):107-116.

22- Boot AM, Engels MA, Boerma GJ, Krenning EP, Sabine MPE, Keizer-Schrama M (1997). Changes in bone mineral density, body composition, and lipid metabolism during growth hormone (GH) treatment in children with GH deficiency. Journal of Clinical Endocrinol Metabolism 82:2423-2428.

23- Slemenda CW, Miller JJ, Hui SL, Reister TK, Johnston CC (1991). Role of physical activity in the skeletal mass in children. Journal of Bone Mineral Research 6:1227-1333.

24- Rico H, Revilla M, Hernandez F, Gomez – Castresana F, Villa L (1993). Bone mineral content and body composition in postpubertal cyclist boys. Bone 14:93–95.

25- Fiore CE, Dieli M, Vintaloro G, Gibilaro M, Giacone G, Cottini E (1996). Body composition and bone mineral density in competitive athletes in different sports. Int J Tissue React 18:121–124.

26- Warner SE, Dalsky GP (1997). Bone mineral density of elite male cyclists (Abstract). Med Sci Sports Exer 29:S5.

27- Sabo D, Bernd L, Pfeil J, Reiter A (1996). Bone quality in the lumbar spine in high -performance athletes. Eur Spine J 5(4):258-263.

28- Warner SE, Shaw JM, Dalsky GP (2002). Bone mineral density of competitive male mountain and road cyclists. Bone 30:281–286.

29- Nichols JF, Palmer JE, Levy SS (2003). Low bone mineral density in highly trained male master cyclists. Osteo Int 14:644–649.

30- Medelli J, Lounana J, Menuet JJ, Shabani M, Fardellone P (2005). Etude du métabolisme osseux et de la densité minérale chez le cycliste de haut niveau, In: Os, activité physique et ostéoporose. Sous la direction de Hérisson C, Fardellone P. MASSON 54:113-123.

31- Smathers AM, Bemben MG, Bemben DA (2009). Bone density comparisons in male competitive road cyclists and untrained controls. Med Sci Sports Exerc 41(2):290-6.

32- Janov A (1994). Osteoporosis, prevention and treatment: Interpreter (Farajzadeh S). publishers:

Movement Science, Tehran, Iran.
33- Gharib-Doust F (2001). Osteoporosis. Rheumatology Research Center of Iran Medical Sciences (Tehran) 62(64):153-158.
34- DXA scanning [Online] (2007). Available from URL: http://lasann.tripod.com/ dexa20scans.htm.
35- Medelli J, Shabani M, Lounana J, Fardellone P, Campion F (2008). Lowe bone mineral density and calcium intake in elite cyclists. J Sports Med Phys Fitness 48:00-00.
36- Alfredson H, Nordstrom P, Pietial T, pietila T Lorentzon R (1998). Long-term loading and regional bone mass of the arm in female volleyball players. Calcified Tissue Int 62:303-308.
37- Binbridge KE, Sowers M (2004). Risk factors for low bone mineral density and the 6-year rate bore loss among premenopausal woman. Osteo Int [Epub ahead of print].
38- Mc Ardala, William D (2003). Exercise Physiology: Interpreter (Khaledan A). Publishers: State Printing Center.
39- Rieth N, Courteix D (2005). Nutrition, exercice physique et masse osseuse : une équation à trois inconnues, In: Os, activité physique et ostéoporose. Sous la direction de Hérisson C, Fardellone P. MASSON 54: 69-74.
40- Mayoux-Benhamou MA, Leyge JF, Roux C, Revel M (1999). Cross-sectional study of weight-bearing activity on proximal femur bone mineral density. Calcif Tissue Int 64:179-183.
41- Kemmler W, Engelke K, Baumann H (2006). Bone status in elite mal runners. Eur J Appl Physiol 96(1):78-85.
42- Heinonen A, Oja P, Kannus P, Sievänen H, Mäntäri A, Vuori I (1993). Bone mineral density of female athletes in different sports. Bone Miner 23:1-14.
43- Daly R, Petit M (2007). Optimizing Bone Mass and Strength: The Role of Physical Activity and Nutrition during Growth. Publishers: Med Sport Sci, Basel, Karger: vol 51.
44- Specker B, Vukovich M (2007). Evidence for an interaction between exercise and nutrition for improved bone health during growth. Med Sport Sci 51:50–63.