Biology of Sport, Vol.24 N°3, 2007

BONE MINERALISATION (BMC) AND DENSITY (BMD) IN EUMENORRHEIC EX-ATHLETES

B. Raczyńska[1], G. Raczyński[1], B. Długołęcka[1], H. Matusik[2], R.S. Lorenc[2]
Academy of Physical Education in Warsaw, II Faculty of Physical Education in Biała Podlaska, Poland

Abstract. The aim of the study was to assess bone mineral content (BMC;g) and bone mineral density (BMD; g/cm^2) of healthy, regularly menstruating women aged 18–40 years, who discontinued their sport career and to compare them with age–matched controls. The group included ex-swimmers (n=11), ex-rowers (n=8) and ex-judoists (n=7). They were compared with control women, never engaged in sports (n=23), matched by age. Questionnaires were used to collect data regarding sport activities in the past and physical activities at present, ovarian function as well as past and present nutrient intake. BMC and BMD were determined in the lumbar spine (L_2–L_4) by DXA. Bone stiffness was determined for the calcaneal bone by ultrasonography. All measurements were conducted twice, 12 months apart. Present physical activity was reportedly highest in ex-rowers, 4 of whom rated it as high, while none of the ex-swimmers declared that rating. Irregular menstrual cycles during the sport career were reported by 4 ex-swimmers, 2 ex-judoists and one ex-rower, the latter complained of secondary amenorrhoea lasting 9 months. Calcium intake in ex- swimmers, ex-judoists and ex-rowers amounted to 548±166, 735±286 and 823±269 mg/day i.e. 50, 92 and 103% of the RDA for Poland, respectively. Significance of high BMC without higher BMD was noted for ex-rowers, who differed significantly from both other ex-athletic groups and from the control subjects. Neither BMD nor bone stiffness differed significantly between any groups. All those observations were confirmed on second examination .It was concluded that a long-lasting sport career, and the associated high training loads, did not affect the present BMD in ex-athletes, in the absence of other osteoporosis risk factors (hormonal and/or dietary disorders) in the past.

(Biol.Sport 24:241-254, 2007)

Key words: Ex-athletes - Bone mineral content - Bone mineral density - Calcium intake - Physical activity

---

Reprint request to: Prof. B.Raczyńska, Academy of Physical Education in Warsaw, II Faculty of Physical Education, 21-500 Biała Podlaska, Akademicka 2, Poland
Tel.: (048–83) 342–88-27; E-mail: barbara.raczynska@awf-bp.edu.pl

Introduction

Physical activity is regarded as one of the most important external factors influencing bone mass throughout the life span. (19) Physical activity is essential for developing, in the adolescence period, of [peak bone mass] and for maintaining its optimum level in the adulthood. Physical exercise stimulates bone formation, the augmented bone mineral density (BMD) being likely to depend on the kind and magnitude of applied loads [1,4,7,31,36,41,45-48]. In contrast to an advantageous effect of moderate physical activity, its excessive volume and/or intensity, like in sport training, combined with a prolonged athletic career, may lead to decreases in bone mass [26,33,50]. The age at which one begins to practise sport training (pre- or post-adolescence) is another important factor [20,21,28].

Competitive female athletes working at high workloads are at risk for disorders of sex hormone secretion and inadequate nutrition. That statement was confirmed by many authors [2,8,10,23,24,33,35,43,49,50] in the nineties, who pointed to a relation between amenorrhoea or dysmenorrhoea and the risk of osteopoenia or of the peak bone mass. Such disorders were found to be more common in female athletes than in the general female population [33,50]. Hormonal disorders associated with physical exertion are rarely induced by the workload alone, the most common co-existing factor being nutritional mistakes [12,15,25,26,33,38, 40,43,50]. Particular attention is being paid to insufficient energy intake [12,16,24], but above all to insufficient calcium intake, which may disturb the homeostasis. The effect of calcium on bone status is unquestionable, especially in the period of attaining peak bone mass. The presented views suggest that the beneficial effect of physical exercise on bone metabolism may be seriously affected in women by many factors operating during the athletic career or later, after the career had been discontinued.

The aim of the study was to assess bone mineralization and density in ex-athletes who practised swimming (non weight-bearing activity), rowing (weight-bearing support activity bearing) or judo (weight-bearing activity), and to compare the results with those recorded in their mates of the same age, never engaged in sports. Another question was to find out whether very intense and long-lasting physical activity, together with other risk factors of osteoporosis either in the past or at present, could have influenced the present bone status.

Materials and Methods

Female ex-athletes (n=26) aged 18–40 years (11 swimmers, 8 rowers and 7 judoists) and 23 female non-athletes (controls) of the same age volunteered to participate in the study. Most ex-athletes used to be members of National representation teams. Control women were divided into 3 subgroups (A, B and C) so as to match the ex-athletic groups with respect to age. All subjects were examined medically and found healthy; all had normal ovarian function. The assessment of ovarian cycles was based on monitoring basal body temperature for 6 months. Ex-athletes were requested to fill questionnaires about their past career (age at beginning and discontinuing sport activities, duration of sport engagement, weekly training volume), ovarian cycles (age at menarche, ovarian cycles, secondary amenorrhoea, present use of contraceptives), present physical activity in leisure time (assessed by a 4-point scale: 0–sedentary, 1–low: 1–2 h weekly, 2–moderate: 3–4 h, 3–high: over 4 h weekly) as well as present and past calcium and phosphorus intake. Present calcium and phosphourus intake was assessed from three 24h recalls covering two working days and one weekend day. Mean daily intakes of these nutrients were determined by using a software based on Polish nutrition tables [32] and results were compared to Polish Recommended Dietary Allowances (RDA) [51]. Calcium intake in the childhood (up to 15 years of age), in the youth (15-25 years) and in the adulthood (over 25 years) was assessed retrospectively from responses to questions concerning frequency of milk and milk products consumption.

Body height and mass were measured by standard procedures. Body fat content was determined according to Durnin and Womersley [11] by measuring the skinfold thickness at four sites (biceps, triceps, subscapular and suprailiac. Bone mineral content (BMC; g) and bone mineral density (BMD; g/cm^2) were determined in the lumbar area (L_2–L_4) by dual X-ray absorptiometry (DXA) using Lunar DPX-L device. Bone Stiffness coefficient was determined in the calcaneal bone using a Lunar Achilles device. Two indicies were recorded: Broadband Ultrasound Attenuation (BUA, in dB/MHz) and Speed of Sound (SOS: ultrasound velocity, in m/s). The precision of measurements amounted to 0.1-2.5% (BUA), and 0.1-0.5% (SOS and Stiffness coefficient). Ale measurements were performed by the some technician and by using the some device. Examinations were performed twice, 12 months apart.

The results were processed by conventional statistical procedures including Student’s t-test for independent data (differences between ex-athletes and controls), and one-way ANOVA (differences between ex-athletes), the level of $p<0.05$ being considered significant.

Results

Basic somatic characteristics of studied groups are presented in Table 1. All groups were alike regarding body mass or height, BMI, and relative fat content.

Table 1
Anthropometric features (means ±SD) of ex-athletes and of control women

Group	Sport	Age (years)	Body mass (kg)	Body height (cm)	BMI (kg/m^2)	Fat content (%)
I	Ex-swimmers	21.70	64.4	170.1	22.22	23.4
	(n=11)	±2.94	±10.3	±5.9	±2.84	±5.1
II	A[&]	21.10	65.6	169.0	22.48	28.5
	(n=8)	±3.00	±16.6	±5.6	±5.00	±4.3
III	Ex-rowers	28.50	67.0	173.0	22.31	21.4
	(n=8)	±4.91	±9.0	±7.2	±1.32	±4.1
IV	B	28.50	60.8	167.2	21.72	25.6
	(n=8)	±5.67	±7.1	±4.3	±1.84	±3.8
V	Ex-judoists	34.50	61.4	163.5	22.94	25.8
	(n=7)	±4.69	±5.8	±7.9	±0.81	±6.5
VI	C	35.30	61.4	168.8	21.84	25.8
	(n=7)	±4.15	±5.6	±3.8	±2.29	±2.9

[&]A,B,C – control groups

The present physical activity was reportedly highest in ex-rowers, 4 of whom rated it high, two as moderate and two as low or very low. In ex-judoists, one rated her activity as high, three as moderate, and three as low or very low. Seven swimmers rated their activity as moderate and 4 as low or very low. Only 6 subjects from the control group rated their activity as moderate and 17 as low or very low (Table 2).

Ovarian function throughout the sport career was reported to be normal in most subjects. Irregular menstrual cycles were reported by 1/3 ex-swimmers, 1/4 ex-judoists and by one ex-rower, who reported secondary amenorrhoea lasting 9 months. Seven ex-athletes and one control woman reported to have used contraception for the last two years (Table 3).

Biol.Sport 24(3), 2007

Tabele 2
Sport career of ex-athletes and the present physical activity of ex-athletes and of control women (means ±SD)

Group	Sport	Sport career: Age at starting trainings (years)	Sport career: Athletic experience (years)	Sport career: Weekly training volume (h)	Time period after termination of sport career (years)	Present physical activity: Very low	Present physical activity: Low	Present physical activity: Moderate	Present physical activity: High
I	Ex-swimmers (n=11)	8.90±0.83	7.86±2.24	23.9±3.7	4.95±1.74	3 (27%)	1 (9%)	7 (64%)	-
II	A[&] (n=8)	-	-	-	-	5 (63%)	2 (25%)	1 (12%)	-
III	Ex-rowers (n=8)	13.00±1.67	11.00±4.16	24.4±8.2	4.21±2.55	1 (12%)	1 (12%)	2 (25%)	4 (50%)
IV	B (n=8)	-	-	-	-	4 (50%)	2 (25%)	2 (25%)	-
V	Ex-judoists (n=7)	17.21±0.95	12.28±1.49	13.5±7.4	6.57±0.53	-	3 (43%)	3 (43%)	1 (14%)
VI	C (n=7)	-	-	-	-	-	4 (57%)	3 (43%)	–

[&] A,B,C – control groups

Table 3
Former menstrual cyclicity of ex-athletes and use of contraceptives by ex-athletes and by control women (means ±SD)

Group	Sport	Age at menarche (years)	Menstrual cycles during sport career (n)				Subjects using contraception (n)
			Regular (n)	Shortened (n)	Extended (n)	Secondary Amenorrhoea (n)	
I	Ex-swimmers (n=11)	13.18 ±0.25	7	1	3	-	4
II	A[&] (n=8)	13.20 ±0.27	8	-	-	-	1
III	Ex-rowers (n=8)	13.33 ±1.03	7	-	-	1 (9 months)	1
IV	B (n=8)	13.67 ±1.37	8	-	-	-	-
V	Ex-judoists (n=7)	12.85 ±1.57	5	-	2	-	2
VI	C (n=7)	13.57 ±1.13	7	-	-	-	-

[&] A,B,C - control groups

Mean daily calcium intake was lowest in ex-swimmers (548±166 mg/day) and covered only about 50% of the RDA. The respective values for ex-judoists were 735±286 mg/day (92%), and for ex-rowers – 823±269 mg/day (103%). Still lower values were found for control subgroups A, B and C, which ranged from 39 to 72% (Table 4). Regarding individual calcium uptake, the percentages of ex-swimmers and ex-judoists combined, and of all control women, who exhibited deficient calcium uptake (less than 600 mg/day) were alike (56 and 61%, respectively). Mean phosphorus intake exceeded the safe level of intake in all studied groups. All subjects reported consuming milk and milk products 3–4 times weekly in all periods in question.

Table 4
Present daily intakes of calcium and phosphorus in ex- athletes and in control women (means ±SD)

Group	Sport	Calcium (mg)	Phosphorus (mg)	Ca : P
I	Ex-swimmers (n=11)	548±166 (49)[#]	883±219 (110)	1:1.6
II	A[&] (n=8)	430±125 (39)	727±82 (91)	1:1.7
III	Ex-rowers (n=8)	824±269 (103)	1269±520 (195)	1:1.5
IV	B (n=8)	548±114 (68)	841±117 (129)	1:1.5
V	Ex-judoists (n=7)	735±289 (92)	864±345 (132)	1:1.2
VI	C (n=7)	576±199 (72)	990±307 (152)	1:1.7

Mean values of bone parameters are presented in Table 5. Bone mineral content (BMC) in the lumbar spine (L_2-L_4) in ex-rowers was significantly ($p<0.01$) higher than in ex-swimmers, ex-judoists or in Subgroup B (12.8%, 11.7% and 15.2%, respectively). No significant between-group differences were found for either BMD or Stiffness Coefficient, but values tended to be highest in ex-rowers. Only in one ex-swimmer a lower BMD value was found (0.990 g/cm^2; z-score = –1.6). The 4 ex-swimmers who reported irregular menstrual cycles in the past had their BMD by 1.6% lower than in the remaining ones. The ex-rower, who had experienced secondary amenorrhoea, had her BMD by 19% lower than in her regularly menstruating mates. Ovarian cyclicity had no effect in ex-judoists. Analogous results were recorded at second examination, 12 months later, regarding all bone parameters and all groups of subjects (Table 5).

Table 5
Bone mineral content (BMC), bone mineral density(BMD) and bone Stiffness in ex-athletes and in control subjects matched for age of first examination (means ±SD)

Group	Sport	BMC (g)		BMD (g/cm^2)		Bone Stiffness (%)	
		Examination					
		I	II	I	II	I	II
I	Ex-swimmers (n=11)	54.6 ±11.4	54.1 ±10.6	1.24 ±0.15	1.23 ±0.15	103.4 ±9.0	103.0 ±8.8
II	A [&] (n=8)	55.9 ±8.1	56.6 ±9.5	1.24 ±0.11	1.26 ±0.13	107.0 ±11.8	107.3 ±12.3
III	Ex-rowers (n=8)	62.6 ±15.7[* a]	62.4 ±16.3	1.31 ±0.19	1.30 ±0.19	110.2 ±191	110.0 ±16.9
IV	B (n=8)	53.1 ±6.5	50.8 ±6.7	1.21 ±0.11	1.19 ±0.12	103.0 ±16.6	101.5 ±17.8
V	Ex-judoists (n=7)	55.3 ±8.7	57.0 ±9.4	1.28 ±0.11	1.27 ±0.11	108.2 ±21.6	106.5 ±19.8
VI	C (n=7)	58.2 ±7.5	58.0 ±8.0	1.27 ±0.11	1.29 ±0.12	100.5 ±17.9	98.2 ±19.4

[&]A,B,C – control groups
*Significantly different from the respective value in the control group; $p<0.01$ (Student's t-test)
[a]Significantly different from the respective values in group I and V; $p<0.01$ (one way ANOVA)

Discussion

Various effects of sport training on the bone status were reported [13,33,43,45,50]. Bones of young individuals are considered to exhibit a higher potential adaptivity do high work loads compared with adults [14] but, on the other hand, young, female, competitive athletes are more susceptible to female athlete triad and dependently to osteoporosis [33,43,50]. Female ex-athletes studied by us, with normal ovarian function, had stable bone mass as demonstrated by longitudinal examinations. With the exception of one ex-swimmer, their present bone density was within normal limits during the period of 12 months. Thus, prolonged sport training lasting, on the average, 10.38±2.93 years, started, in most cases (all ex-swimmers and 6 ex-rowers) before menarche, did not resulted in substandard BMD.

Ex-rowers exhibited higher bone mineral content (BMC) than all other subjects (Table 5). Although training loads applied to swimmers or rowers are classified as non-bearing weight, the contribution of muscle force to overcome water resistance may have a greater impact on osteogenesis in the lumbar spine area in rowers than in swimmers. There are no conclusive data in the literature supporting the view that swimming negatively affects bone tissue [5], but a majority of authors emphasise a lack of positive effects. Lanyon *et al.* [22] point to a positive influence of mechanical stimuli from muscles on the bones, but this influence is best expressed in areas of highest tension, as e.g. in tennis player's hand [17]. Bass *et al.* [3] reported that BMD in those areas of the bone system of female gymnasts, which are exposed to smaller loads, was comparable to that in control subjects. We found the same in ex-swimmers, compared to their respective reference group, as well as in ex-judoists, although the latter were subjected to training classified as bearing weight and more diversified than in case of swimmers. An insufficient, present physical activity of ex-judoists, might explain the lack of advantageous changes in their bone tissue, since many factors related to the life style could shorten the period of bone stabilisation and sedentary life might be one of them. Adult women, who practised any kind of motor activity for one hour weekly had, according to Ethrington *et al.* [13], higher BMD than sedentary women. It thus seems that one of the risk factors towards osteoporosis are the training loads applied in the past, and the lack of physical activity after the sport career had been discontinued. Also, the time lag between the termination of sport career and menopause is of great importance, taking into account the maintenance of bone mass.

A direct threat for bone mineralisation in female athletes are menstrual disorders: oligomenorrhoea, amenorrhoea and anovulatory cycles. Drinkwater *et al.* [9,10] reported a much lower BMD in the lumbar spine of female athletes with menstrual disorders compared with those menstruating regularly. Also Keen *et al.* [18], in their longitudinal study, found BMD to be lower by 14–15% in the same spinal region of women who experienced menstrual disorders in their past. In this study, ex-athletes with prior menstrual disorders (1/3 swimmers, 1/4 judoists and 1/8 rowers) had lower BMD than their normally menstruating mates, although all BMD values were within normal limits (except one swimmer). It could be inferred that the possible negative effect of menstrual disorders could be compensated by a positive effect of physical training [14,37]. It was reported that extreme physical exertions applied prior to the adolescence period could bring about an insufficient peak bone mass; this might be associated with e.g. delayed menarche and retarded maturation due to low oestrogen levels [27]. The age at menarche recorded in our ex-athletes was, however, within normal values for Polish population [6], which would be indicative of a normal function of the hypothalamo-pituitary-ovarian axis in that period of life.

As follows from studies on female athletes, conducted in the nineties, decreases in bone mass were accompanied by dietary disorders, apart from the hormonal ones [39,40,42,43,50]. According to Sandler *et al.* [38], a decreased bone mineralisation may be associated with a low intake of calcium i.e. below 500 mg/day. Recker *et al.*, in their last report [34] shows, that bone mass accumulation in the lumbar spine, forearm and the whole skeleton of women aged 19–26 years, is positively correlated with the mode of nutrition, as an adequate calcium intake is indispensable for a full genome expression with respect to peak bone mass. Although no relationship between calcium and phosphorus intakes and bone parameters could be demonstrated in any group of subjects studied, it might seem that the present diet of ex-rowers, fully covering calcium demand, could positively affect their present bone mineralisation. It might be further presumed that calcium intake during their sport career was adequate, since rowers spent most of the time at training camps, where their diet was well controlled (44). The present calcium intake of swimmers corresponded to only 50% of the RDA. Swimmers and judoists usually stay at home while training, which creates more opportunities for dietary errors. On the other hand, the declared consumption of milk and milk products during most days of the week in the period of attaining the peak bone mass could have exerted an advantageous effect on the present bone mineralisation.

Establishing a reliable calcium demand has been a serious problem in recent years [15,29,30]. The need to adjust calcium supply to habitual consumption of other nutrients has been suggested. Special emphasis was put on an increased intake of phosphorus, used to supplement nutritional products in many developed countries.

Due to the steadily increasing training loads, and to starting the sport career by steadily younger women, many years before having attained the peak bone mass, disorders of bone mineralisation may become a serious threat. This trend adds to a growing frequency of ovarian dysfunctions and dietary imbalance, which are the principal factors of risk of osteoporosis. Therefore, monitoring the bone status in athletes after they have discontinued their sport career seems of prime importance.

In conclusion. The results of our study were inconclusive as to the effect of swimming training on bone mass. No significant differences in BMD values recorded for lumbar spine (L_2-L_4) were found between all group studied, including the control one. Long-lasting sport career, and the associated high training loads, did not affect the present mineral density in ex-athletes (rowers, swimmers and judoists), in the absence of other osteoporosis risk factors (hormonal and/or dietary disorders) in the past.

References

1. Andreoli A., M.Monteleone, M.Van Laan, L.Promenzo, L.Tarantino, U.Tarantino, A. De Lorenzo (2001) Effects of different sports on bone density and muscle mass in highly trained athletes. *Med.Sci.Sports Exerc*. 33:507-511

2. Bachrach L.K., D.K.Katzman, J.F.Litt, D.Guido, R.Marcus (1991) Recovery from osteopenia in adolescent girls with anorexia nerrosa. *J.Clin.Endocrin.Metab*. 72:602-606

3. Bass S., G.Pearce, M.Bradney, E.Hendrick, P.Delmas, A.Harding, E.Seeman (1998) Exercise before puberty may confer residual benefits in bone density in adulthood: studies in active prepubertal and retired female gymnasts. *J.Bone Miner.Res.* 13:500-507

..4. Bennell K.L., S.A.Malcolm, K.M.Khan, A.Thomas, S.J.Reid, P.D.Bruckner, P.R.Ebelin, D.L.Wark (1997) Bone mass and bone turnover in power athletes, endurance athletes and controls: A 12 month longitudinal study. *Bone* 20:477-484

5. Beshgetoor D., J.F.Nicols, J.Rego (2000) Effect of training mode and calcium intake on bone mineral density in female master cyclists runners and non athletes. *Int.J.Sport Nutr.Exerc.Metab.* 10:290-301

6. Charzewski J., J.Lewandowska., T.Łaska-Mierzejewska, H.Piechaczek, J.Charzewska, A. Skibińska (1999) Antropology (in Polish). Academy of Physical Education, Warsaw

7. Chilbeck P.D., D.G.Sale, E.C.Webber (1995) Exercise and bone mineral density. *Sports Med.* 19:103-122

8. De Souza M.J., B.E.Miller, L.C.Sequenzia, A.A.Luciano, S.Ulreich, S.Stier, K.Prestwood, B.L.Lasley (1997) Bone health is not affected by luteal phase abnormalities and decreased avarian progesterone production in female runners. *J.Clin.Endocrinol. Metab*. 82:2867-2876

..9. Drinkwater B.L., B.Bruemer, C.H.Chesmut (1990) Menstrual history as a determinant of current bone density in young athletes. *J.Am.Med.Assoc*. 263:545-548

10. Drinkwater B.L., K.Nilskon, S.Olt, C.H.Chesmut III (1986) Bone mineral density after resumption of menses amenorrheic athletes. *J.Am.Med.Assoc*. 265:380-382

11. Durnin J.U., J.Womersley (1974) Body fat assessed from total body density and its estimation from skinfolds thickness measurements on 481 men and women aged from 16 to 72 years. *Br.J.Nutr.* 32:77-97

12. Edwards J.E., A.K.Lindeman, A.E.Mikesky, J.M.Stager (1993) Energy balance in highly trained female endurance runners. *Med.Sci.Sports Exerc*. 25:1398-1404

13. Etherington J., P.A.Harris, D.Nandra, D.J.Hant, R.L.Walman, D.V.Doyle, T.D.Spector (1996) The effect of weight – bearing exercise on bone mineral density: a study of female ex-elite athletes and the general population. *J.Bone Miner.Res.* 11:1333-1338

14. Frost H.M. (1992) The role of changes in mechanical usage set points in the pathogenesis of osteoporosis. *J.Bone Miner.Res.* 7:253-261

15. Heaney R.P. (2000) The should be a dietary guideline for calcium. *Am.J.Clin.Nutr*. 72:658-664

16. Kaiserauer S., A.C.Snyder, M.Sleeper, J.Zierath (1989) Nutritional, physiological, and menstrual status of distance runners. *Med.Sci.Sports Exerc*. 21:120-125

17. Kannus P., H.Haapasalo, M.Sankelo, H.Sievänen, M.Pasanen, A.Heinonen, P.Oja, J.Vuori (1995) Effect of starting age of physical activity on bone mass in the dominant arm of tennis and squash players. *Ann.Int.Med*. 123:27-31

18. Keen A.D., B.L.Drinkwater (1997) Irreversible bone loss in former amenorrheic athletes. *Osteopor.Int.* 7:311 -315

19. Khan K., H.McKay, P.Kannus, D.Bailey, J.Wark, K.Bennel (2001) Physical Activity and Bone Health. Human Kinetics, Champaign, IL. p. 275

20. Khan K.M., K.L.Bennel, J.L.Hopper, L.Flicker, C.A.Nowson, A.J.Sherwin, K.J.Crichton, P.R.Harcourt, J.D.Wark (1998) Self-reported ballet classes undertaken at age 10-12 years and hip bone mineral density in later life. *Osteopor.Int.* 8:165-173

21. Kontulainen S., P.Kannus, H.Haapasolo, H.Sievänen, M.Pasanen, A.Heinonen, P.Oja, J.Vouri (2001) Good maintenance of exercise – induced bone gain with decreased training of female tennis and squash players: A prospective 5-year follow-up study of young and old starters and controls. *J.Bone Miner.Res.* 16:195-201

22. Lanyon L.E. (1984) Functional strain as a determinant for bone remodeling. *Calcif. Tissue Int.* 36:S56-S61

23. Lloyd T., C.Myers, J.R.Buchanan, L.M.Demers (1988) Collegiate women athletes with irregular menses during adolescence have decreased bone density. *Obstet.Gynecol.* 72:639-42

24. Loucks A.B., E.M.Health (1994) Induction of low T3 syndrome in exercising women occurs at a threshold of energy availability. *Am.J.Physiol*. 266:R817-R823

25. Loucks A.B., S.Horvath (1985) Athletic amenorrhea: a review. *Med.Sci.Sports Exerc.* 7:42-52

26. Loucks A.B., M.Verdun, M.Heath (1998) Low energy availability, not stress of exercise alters LH pulsatility in exercising women. *J.Appl.Physiol*. 84:37-46

27. Malina R.M. (1994) Physical growth and biological maturation of young athletes. *Exer.Sports Sci.Rev.* 22:389-433

28. Malina R.M. (1997) Menarche in athletes: delayed or simply late. *Med.Sportiva* 1:153-165

29. Nordin B.E.C. (2000) Calcium reguirement is a sliding scale. *Am.J.Clin.Nutr*. 71:1381-1387

30. Nordin B.E.C. (1997) The calcium controversy. *Osteopor.Int.*7 (Suppl. 3):17-21

31. Petterson U., P.Nordtstrom, R.Lorenzon (1999) A comparison of bone mineral density and muscle strength in young male adults with different exercise level. *Calcif. Tissue Int.* 64:490-498

32. Piekarska J., M.Łoś-Kuczera (1983) Dishes Composition and Nutritive Value (in Polish). PZWL, Warsaw

33. Putukian M. (1994) The female triad. Eating disorders, amenorrhea, and osteoporosis. *Med.Clin.North Am.* 78:345-356

34. Recker R.R., K.M.Davies, S.M.Hinders, R.P.Heaney, M.R.Stegman, D.B.Kimmel (1992) Bone gains in young adult women. *J.Am.Med.Assoc*. 268:2403-2408

35. Rencken M.L., C.H.Chesmut III, B.L.Drinkwater (1996) Bone density a multiple skeletal sites in amenorrheic athletes. *J.Am.Med.Assoc*. 276:238-240

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

37. Robinson T.L., C.Snow-Harter, D.R.Taaffe, D.Gillis, J.Shaw, R.Marcus (1995) Gymnasts exhibit higher bone mass then ranners despite similar prevalence of amenorrhea and oligomenorrhea. *J.Bone Miner.Res.* 10:26-35

38. Sandler R.B., C.W.Slemenda, R.E.La Porte, J.A.Canley, M.M.Schramm, M.L.Barresi, A.M. Kriska (1985) Post menopausal bone density and milk consumption in childhood and adolescente. *Am.J.Clin.Nutr*. 42:270-274

39. Seeman E. (1994) Reduced bone density in women with fractures: contribution of low peak bone density and rapid bone loss. *Osteopor.Int.* (Suppl. 1): S15-S25

40. Snead D.B., C.C.Stubbs, J.Y.Weltman, W.S.Evans, J.D.Veldhuis, A.D.Rogol, C.D.Teates, A. Weltman (1992) Dietary patterns, eating behaviors, and bone mineral density in women runners. *Am.J.Clin.Nutr*. 56:705-711

41. Snow-Harter C., M.L.Bouxsein, B.T.Lewis (1992) Effects of resistance and endurance exercise on bone mineral status of young women: A randomized exercise intervention trial. *J.Bone Miner.Res*. 7:761-769

42. Sundgot-Borgen J. (1998) Die Triade von Eβstörungen, Amenorrhoe und Osteoporose. Isostar Sport Nutrition Fundation 7:1-8

43. Sundgot-Borgen J. (1994) Risk and trigge factors for the development of eating disorders in female elite athletes. *Med.Sci.Sports Exerc*. 26:414-419

44. Szczepańska B., J.Malczewska (2003) Energy and some minerals content in daily food rations of Polish athletes during training camps. *Żyw.Człow.Metabolizm* 30:538-543 (in Polish)

45. Taaffe D.R., Ch.Snow-Harter, D.A.Connolly, T.L.Robinson, M.D.Brown, R.Marcus (1995) Differential of swimming versus weight – bearing activity on bone mineral status of eumenorrheic athletes. *J.Bone Miner.Res.* 10:586-593

46. Taaffe D.R., T.L.Robinson, C.M.Snow, R.Marcus (1997) High – impact exercise promotes bone gain in well – trained female athletes. *J.Bone Miner.Res.* 12:255-260

47. Vuori J. (1996) Peak bone mass and physical activity: a short review. *Nutr.Rev.* 54:S11-S14

48. Warren M.P., J.Brooks-Counn, R.P.Fox, C.Lancelot, D.Newman, W.G.Hamilton (1999) Lack bone accretion and amenorrhea: Evidence for a relative osteopenia in weigh bearing bone. *J.Clin.Endocrinol.Metab*. 72:847-853

49. Wolman R.L., P.Clark, E.Mc Nally, M.Harries, J.Reere (1990) Menstrual state and exercise as determinants of spinal trabecular bone density in female athletes. *Br.Med.J.* 301:516-518

50. Yeager K.K., R.Agostini, A.Naltiv, B.L.Drinkwater (1993) The female athlete triad: disordered aeting, amenorrhea, osteoporosis. *Med.Sci.Sports Exerc*. 25:775-777

51. Ziemlański Ś., B.Bułhak-Jachymczyk, J.Budzyńska-Topolewska, B.Panczenko-Kresowska, M.Wartanowicz (1998) Recomended dietary allowances for the Polish population (energy, protein, fat, vitamins and minerals). *New Med.* 1:1-27

Accepted for publication 27.06.2005

Acknowledgment

The study was supported by grant No 4P05DO6515 of the State Committee for Scientific Research in Poland