Anthropological Review • Vol. 80(1), 115–125 (2017)

DE GRUYTER OPEN

ANTHROPOLOGICAL REVIEW

Available online at: https://doi.org/10.1515/anre-2017-0008

Body mass index, general fatness, lipid profile and bone mineral density in young women and men

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Abstract: The bone tissue is metabolically active. Throughout the entire life, it undergoes changes in the form of bone resorption processes which are successive, with the participation of the resorbing cells and bone formation processes. The aim of the study was to evaluate mineral density and bone mass tissue and the lipid profile, BMI, total body fat in young females and males. The study involved 100 people (50 females and 50 males) studying in Warsaw at the age of 23,2 ± 4,0 years. The densitometry method of the forearm was used for the assessment of bone mineral density (BMD) and bone mass (BMC). The method of bioelectrical impedance was used for the assessment of body components. Basic body dimensions and indicators were assessed using anthropometric measurements. Body height, body mass and the needs for the densitometry study of the forearm were measured. The total cholesterol concentration was determined in the blood serum using diagnostic kits, as well as high-density lipoprotein (HDL-C) and triglycerides. The concentration of the low-density lipoprotein (LDL-C) was calculated. While in men the occurrence of a significant, positive correlation was stated between the concentration of the HDL cholesterol fraction and the mineral density and T-score index in the ultra-distal point, the analysis of the compounds of mineral density (BMD), bone mass (BMC) of the forearm, T-score index with somatic features in women showed a significant, positive relation between the body weight and the bone mass mineral density and T-score indicator in the proximal point. Also, a significant weak, positive correlation was observed between the BMI, the mineral density and T-score indicator in the proximal point. In men, the occurrence of significant, positive correlations was stated between the body weight and BMC, BMD, T-score indicator in the proximal point of the forearm bone and ultra-distal point. Similar relations were observed between the BMI, mineral density, T-score and bone mass in the proximal point and in the ultra-distal point. Based on several noted weak, positive correlations between the lipid profile and BMD, the results of this study of women and men cannot unequivocally indicate the dependence of the bone tissue state on the lipid level in the blood serum of young women and men. Therefore, the issues raised require further investigation.

Original Article Received: February 1, 2017; Accepted for publication: February 25, 2017
DOI: 10.1515/anre-2017-0008

Key words: total cholesterol, low-density lipoprotein, high-density lipoprotein, triglyceride, bone mineral density (BMD), bone mineral content (BMC), body mass

Introduction

The bone tissue is metabolically active. Throughout the entire life it undergoes in the form of bone resorption processes, which are successive, with the participation of the resorbing cells (osteoclasts) and bone formation processes (bone reconstruction) with the participation of osteoblasts.

The state of the bone tissue and the accelerated loss of bone mass in young people, which is diagnosed more often, is an important aspect of the national and international research. Risk factors related to the occurrence of osteopenia, and, in consequence, to osteoporosis, result predominantly from the unbalanced diet and unhealthy lifestyle, and most of all, physical exercise (IOF 2008). The appropriate dose of physical activity, proper nutrition with special emphasis on calcium intake and an adequate exposure to the sun providing the endogenous synthesis of vitamin D has a huge impact on the proper course of bone formation (Charzewska et al. 2004; Andersen et al. 2005; Chwojnowska et al. 2008).

Processes related to bone tissue remodelling are subject to the endocrine control, primarily by parathyroid hormone, calcitonin, vitamin $1.25(OH)_2 D_3$, but also by estrogens, glycocorticoids and other hormones. Furthermore, what is also essential is the para- and autocrine control by cytokines, growth factors and via the nervous system (Togari et al. 2008)

The literature has well documented the relationships between bone mineral density (BMD) and bone mass (BMC), and vitamin D and calcium (Uusi- Rasi et al. 2013; Lee et al. 2014). Some studies point to another important relationship between the state of bone tissue (the occurrence of osteoporosis), and the lipid level in the blood serum (Brownbill et al. 2006; Ghadiri- Anari et al. 2016).

However, the mechanism and the nature of this relationship (positive or negative) is vague and poorly understood. Lipid disorders and their relation to a low mineral density of the bones is defined as the multifactorial process difficult to be clearly explained. The operational mechanism of this action can be directly related to the biosynthetic pathway of cholesterol, which contributes to the activity of osteoclasts (Orozco 2004).

Some studies have noted a negative correlation between the atherogenic lipid profile and BMD (Orozco 2004; Cui et al. 2005) and other studies showed no relationship between them (Samelson et al. 2004; Solomon et al. 2005; Ghadiri-Anari et al. 2016), while still others even showed a positive correlation (Brownbill et al. 2006).

Orozco and colleagues (2004) stated that women after menopause, with the atherogenic lipid profile, defined reduction of the HDL cholesterol fraction, increase of concentration in the triglycerides serum (TG), prolonged post-prandial hyperlipidemia, the presence of small dense LDL and HDL particles easily undergoing oxidation and glycation, have lower BMD in the lumbar spine and in the femoral neck, and the increased risk of osteoporosis, compared to women of the same age with the normal lipid profile.

On the other hand, Brownbill and colleagues (2006) in the studies of 136 healthy Caucasian women after meno-

pause reported that the higher levels of triglycerides plasma and cholesterol significantly correlate with the higher BMD at various places of the skeleton.

Most national and foreign research concern attempts to assess the relation of the lipids with BMD and BMC; however, only in women at the menopause or post-menopause age, as well as correlations with the risk of osteoporotic fractures. The condition of the bone tissues depends largely on the factors acting on the bone system from the early age and on the peak bone mass. There are relatively few studies of the bone tissue in young women and men, in particular.

The aim of the study was to evaluate mineral density and bone mass tissue and the lipid profile in young women and men. The analysis of the study results has additionally included variables, such as: body mass, total body fat in the body, the Body Mass Index (BMI).

Material and methods

The study involved 100 people (50 women and 50 men) studying in Warsaw at the age of 23.2±4.0 years. The sample has been selected through the draw from the list of the University of Physical Education Academy students in Warsaw (random selection – systematic). The inclusion criterion for the study was the lack of medical contraindications for the collection of venous blood and for the densitometry test and body composition. All persons qualified for the study expressed their voluntary consent to participate in the project and were informed about the course of the study, as well as the possibility of withdrawal from participation in the project at any stage.

The project was approved for compliance with the rules of ethics by the Senate Ethics Committee for Scientific Research of the Józef Piłsudski University of Physical Education in Warsaw.

For the assessment of bone mineral density (BMD) and bone mass (BMC), the densitometry method of the forearm bone was used (in two measurement points: proximal and ultra-distal) DXA of the dual beam of the X-ray, with the NORLAND apparatus. The study was performed by a team with necessary qualifications and experience in the research using the above-mentioned method and apparatus on the entire study group.

The method of bioelectrical impedance was used with the JAWON analyser for the assessment of the body components. The basic body dimensions and indicators were assessed using the anthropometric measurements. The body height, body weight and the needs for the densitometry study of the forearm of the non-dominant limb were measured. BMI indices were calculated. All measurements were performed according to the applicable methodology and with the same measurement instruments (Weiner et al. 1969).

In order to determine the biochemical indicators, blood samples were taken from the elbow vein at rest in the morning on an empty stomach. The following day densitometry, anthropometric measurements and body composition testing were conducted. In the blood serum the total cholesterol concentration was determined (TC), as well as the HDL cholesterol fraction (HDL-C) and triglycerides (TG) using the diagnostic kits. The concentration of the LDL cholesterol fraction (LDL-C) was calculated from the Friedewald formula (Friedewald et al. 1972).

The following indicators were used to develop data in the form of numeri-

cal values: arithmetic means (X), standard deviations (SD) and the percentage shares in the set (%). All calculations and analyses were performed using the STATISTICA 11 (Stat. Soft. USA).

The Shapiro-Wilk test was used in order to investigate the nature of the distribution of data under study The analysis revealed that the distribution was not normal therefore nonparametric approach was used (Mann-Whitney U test). The significance of differences was adopted at the level of $p<0.05$.

The Spearman's rank correlation analysis was conducted in order to determine the relations between the mineral density, mineral content in the forearm bone and the T-score indicator, and the lipid profile, the height, body mass, BMI and content of the body fat. The significance of differences and correlations was adopted at the level of $p<0.05$.

Results

Table 1 presents the anthropometric characteristics for young males and females. The value analysis in the context of the differentiation degree of somatic features for females and males led to the conclusion that the group of young females had a statistically significantly ($p<0,001$) lower body height (by 7,7%), body weight (by 25%) and smaller value of the BMI (by 12,2%), and the higher fat content (by 7,6%) compared to males.

Considering the values related to the mineral density (BMD) in the proximal and ultra-distal point of the forearm bone, the statistically ($p<0,001$) lower values in both points were reported in females as compared to males (respectively, by 24.6% and 17.1%).

Similarly, in the case of the bone mass (BMC), lower ($p<0.001$) values were noted in comparison to males, both in the case of the proximal point (by 33.4%), and the ultra-distal point (by 29.3%), (Table 1).

When we move to the analysis of the results which describe the lipid profile of the studied group, the statistically higher ($p<0,001$) content of the HDL cholesterol fraction was observed by 24.5% and

Table 1. Descriptive characteristics (Mean ± SD) for anthropometrics, body composition and bone status

Variable	Females (n=50)	Males (n=50)
	(Mean ± SD)	
Age (years)	23.0 ± 3.64	23.4 ± 4.3
Weight (kg)	61.2 ± 8.35	81.6 ± 9.9 ***
Height (cm)	168.5 ± 6.69	182.5 ± 8.0 ***
BMI (kg/m2)	21.5 ± 2.22	24.5 ± 2.4 ***
FAT (%)	23.8 ± 4.53	16.2 ± 5.1 ***
BMD dis.(g/cm^2)	0.377 ± 0.067	0.5 ± 0.089 ***
BMD prox. (g/cm^2)	0.750 ± 0.073	0.905 ± 0.076 ***
BMC dis.(g)	1.395 ± 0.206	2.094 ± 0.290 ***
BMC prox. (g)	1.937 ± 0.263	2.739 ± 0.335 ***
T – score dis.	0.424 ± 1.029	0.708 ± 1.270
T – score prox.	–1.064 ± 1.153	–0.966 ± 0.854

Significantly different from females at *$p<0.05$, **$p<0.01$, ***$p<0.001$.

Table 2. Lipid profile marked in blood serum of men and women

Variable	Females (n=50)	Males (n=50)
	(Mean ± SD)	
TG (mmol/l)	0.9 ± 0.43	1.1 ± 0.5
TC (mmol/l)	4.97 ± 0.85	4.6 ± 0,8 *
LDL-C (mmol/l)	1.83 ± 0.78	1.9 ± 0.7
HDL-C (mmol/l)	2.74 ± 0.58	2.2 ± 0.5 ***

Significantly different from females at *$p<0.05$, **$p<0.01$, ***$p<0.001$.

the concentration of total cholesterol by 8%. No significant changes were stated in the concentration of triglycerides and LDL-C cholesterol fraction (Table 2).

Among the studied group of females and males, the vast majority was characterised by normal levels of cholesterol as well as its fractions and triglycerides. 4% of women and the same percentage of men were characterised by high values of the total cholesterol. However, larger percentages of abnormal values were noted in the case of TG concentration, where 14% of females and 10% of males revealed the borderline high level (Table 3).

Table 4 illustrates the values of coefficients of the Spearman's rank correlation

Table 3. Classification of total cholesterol (TC), triglyceride (TG), high-density lipoprotein (HDL-C) and low-density lipoprotein (LDL-C) in plasma levels

Classification	Female (n=50) n (%)	Male (n=50) n (%)
TC (mmol/l)		
Desired (<5.2 mmol/l)	31 (62)	42 (84)
Border high (5.2–6.1 mmol/l)	17 (34)	6 (12)
High (≥6.2 mmol/l)	2 (4)	2 (4)
TG (mmol/l)		
Normal (< 1.7 mmol/l)	43 (86)	45 (90)
Border high (1.7–2.3 mmol/l)	7 (14)	5 (10)
HDL-C (mmol/l)		
Small (<1.0 mmol/l)	0	0
High (≥1.5 mmol/l)	50 (100)	50 (100)
LDL-C (mmol/l)		
Optimal (2.6 mmol/l)	46 (92)	45 (90)
Almost optimal (2.6–3.3 mmol/l)	1 (2)	2 (4)
Border high (3.4–4.1 mmol/l)	2 (4)	3 (6)
High (4.1–4.9 mmol/l)	1 (2)	0
Very high (> 4.9 mmol/l)	0	0

TC – total cholesterol, TG – triglyceride, LDL-C – low-density lipoprotein, HDL-C – high-density lipoprotein

Table 4. Character of correlation compounds between mineral density (BMD), mineral content (BMC) in the forearm bone, T-score indicator and lipid profile of females and males

Features of bone tissue		TC		TG		HDL-C (mmol/l)		LDL-C (mmol/l)	
		r	p	r	p	r	p	r	p
					Females				
Dis R+U	BMD [g/cm²]	0.016	0.914	0.168	0.244	0.024	0.867	0.145	0.315
	BMC [g]	0.097	0.502	0.052	0.718	0.119	0.411	–0.049	0.733
	T–score	0.013	0.928	0.164	0.255	0.029	0.842	0.144	0.319
Prox R+U	BMD [g/cm²]	0.187	0.193	0.235	0.100	–0.062	0.669	0.136	0.348
	BMC [g]	0,172	0.231	0.288*	0.043	–0.055	0.703	–0.037	0.798
	T–score	0.218	0.128	0.234	0.102	–0.049	0.734	0.122	0.399
					Males				
Dis R+U	BMD [g/cm²]	–0.023	0.875	0.079	0.586	0.336*	0.017	–0.041	0.779
	BMC [g]	0.022	0.880	0.242	0.091	0.151	0.295	–0.063	0.663
	T–score	–0.023	0.874	0.079	0.584	0.336*	0.017	–0.040	0.781
Prox R+U	BMD [g/cm²]	0.060	0.677	0.096	0.506	0.071	0.624	–0.018	0.903
	BMC [g]	–0.066	0.649	0.181	0.208	0.203	0.158	–0.126	0.382
	T–score	0.061	0.675	0.096	0.508	0.071	0.623	–0.017	0.905

TC – total cholesterol, TG – triglyceride, HDL–C – high–density lipoprotein, LDL–C – low–density lipoprotein. Significantly different from females at *$p<0.05$, **$p<0.01$, ***$p<0.001$.

in relation to the parameters of the bone tissue and females lipid profile. In women, a significant ($p<0.05$), weak, positive relation was stated between the concentration of triglycerides, and the content of minerals in the proximal point.

In men, the occurrence of a significant ($p<0,05$), positive correlation was reported between the concentration of the HDL cholesterol fraction, and the mineral density and T-score index in the ultra-distal point (Table 4).

The analysis of the compounds of mineral density (BMD), bone mass (BMC) of the forearm, T-score index with somatic features showed a significant, positive relation in women between the body weight and the bone mass ($p<0.01$), mineral density ($p<0.05$) and T-score indicator ($p<0,05$) in the proximal point. Also a significant ($p<0.05$), weak, positive correlation was observed between the BMI, and the mineral density and T-score indicator in the proximal point (Table 5).

In men, the occurrence of significant, positive correlations was stated between the body weight and BMC ($p<0.001$), as well as BMD ($p<0.01$) and T-score indicator ($p<0.01$) in the proximal point of the forearm bone (Table 5) and ultra-distal point (BMC $p<0.01$; BMD and T-score $p<0.05$). Similar relations were observed between the BMI, and mineral density ($p<0.01$), T-score ($p<0.01$) and bone mass ($p<0.05$) in the proximal point and in the ultra-distal point (BMD, BMC, T-score; $p<0.05$).

Table 5. Character of correlation compounds between the mineral density (BMD), mineral content (BMC) in the forearm bone, T-score indicator, and somatic parameters

Features of bone tissue		Body weight		Body height		BMI		Fat %	
		r	p	r	p	r	p	r	p
					Females				
Dis R+U	BMD [g/cm²]	0.019	0.898	-0.039	0.788	0.052	0.722	-0.134	0.352
	BMC [g]	0.277	0.51	0.222	0.122	0.203	0.157	-0.016	0.914
	t-score	0.019	0.895	-0.036	0.803	0.050	0.730	-0.135	0.351
Prox R+U	BMD [g/cm²]	0.336 *	0.017	0.211	0.140	0.285 *	0.045	0.085	0.555
	BMC [g]	0.376 **	0.007	0.274	0.055	0.279	0.051	0.021	0.887
	t-score	0.334 *	0.018	0.216	0.133	0.279 *	0.050	0.067	0.643
					Males				
Dis R+U	BMD [g/cm²]	0.313 *	0.027	0.054	0.710	0.333 *	0.018	0.049	0.737
	BMC [g]	0.366 **	0.009	0.130	0.368	0.346 *	0.014	-0.017	0.907
	t-score	0.313 *	0.027	0.054	0.710	0.333 *	0.018	0.049	0.737
Prox R+U	BMD [g/cm²]	0.392 **	0.005	0.090	0.536	0.425 **	0.002	0.021	0.885
	BMC [g]	0.455 ***	0.001	0.243	0.089	0.360 *	0.010	-0.095	0.512
	t-score	0.392 **	0.005	0.089	0.539	0.425 **	0.002	0.021	0.886

Significantly different from females at $*p<0.05$, $**p<0.01$, $***p<0.001$.

Discussion

The state of the bone tissue can be affected by many factors, which are often interrelated, as has been illustrated by numerous studies (Obermayer- Pietsch et al. 2000; Solomon et al. 2005; Havill et al. 2007; Rizzoli et al. 2010).

Most analyses relating to the condition of women's and men's bone tissue emphasised that a greater body weight and an even larger share of the muscle tissue is associated with the higher bone mass and often with a better mineralisation of bones in men compared to women (Havill et al. 2007). The mesomorphic type of body, which is characterised by a large share of active tissue, which is more frequent in men, provides an appropriate pressure on the bone essential for its proper development (Seeman 2009).

This relationship has been confirmed in the original research, where women were characterised by a significantly lower body weight and lower BMI values, and a higher content of the fat tissue in comparison to men. Somatic parameters, according to the previous research on dimorphic differentiation of the bone tissue, resulted in the lower BMD and BMC values at both measurement points.

In terms of the bone tissue, the analysis also included the BMD and BMC correlation with the lipid profile, both in women and men. Now, it is worth emphasising that gender is an important factor in the regulation of lipoprotein changes. As has been indicated in the earlier studies, the lipid profile of the serum in young women is characterised by a low-

er concentration of the LDL cholesterol fraction and triglycerides, and a higher concentration of the HDL cholesterol fraction (Freedman et al. 2004; Coehlo et al. 2005). A significantly higher content of the HDL cholesterol fraction and of total cholesterol was observed in women in relation to men, while no significant differences were reported in the concentration of triglycerides and the LDL cholesterol fraction.

The parameters analysed in the paper, which concern the lipid profile of the male and female students of the University of Physical Education in Warsaw differed from the previous studies performed on the students from this university by other authors. The original studies noted the abnormal values of total cholesterol (TC) in 38% women and 16% men, as well as triacylglycerols (TG), in 14% and 10%, respectively. The previous research on the male and female students from the same school, conducted by Malara and Lutosławska (2010), showed the borderline large TC in 31% women and 17.6% men, while the borderline high TG only in 1% of women and 2% of men. Given the HDL cholesterol fraction, among the UPE students from the previous 2010 study and original 2016 study, similar numbers of people were noted with a normal (high) concentration of HDL-C.

Compared to the research performed on students from another centre (Faculty of Physical Education and Sport, UPE in Biała Podlaska) original study illustrated a poorer distribution of the lipid profile among the students of UPE in Warsaw. In the study by Czeczelewski et al. (2014), the abnormal values of total cholesterol were reported only among women in 21.8%, while triglycerides in 11.5% women and 6.3% men.

The study analysed the relationship of the lipid profile with the condition of the bone tissue expressed through BMD and BMC parameters of the radius. A significant, although weak, positive relation was reported in women between the concentration of triglycerides, and the mineral content in the proximal point. While the occurrence of a significant positive correlation was observed in men between the concentration of the HDL cholesterol fraction and the mineral density and T-score indicator, however, only in one ultra-distal point, that is near the wrist.

The relationships between the lipid profile (in total, TC cholesterol, lipoproteins with small LDL-C density and lipoproteins with high HDL-C density of cholesterol and triglycerides TG) and BMD in different skeletal locations (lumbar spine, femoral neck and trochanter of the femur) were studied in 10,402 women, aged 20–91, of the Korean population. Based on the multivariate analysis, no significant correlations were reported in this study between the lipid profile and BMD, other than HDL-C fraction, which was positively correlated with BMD only in the lumbar spine of women after menopause. The authors emphasised that the results of that study did not confirm the hypothesis that the atherogenic lipid profile can be related to a higher risk of the occurrence of an underestimated mass and mineralisation of the bone tissue, although weak correlations between the lipid profile and BDM were noted (Jeong et al. 2010).

The study of 13,592 participants of the National Health and Nutritional Examination Survey (NHANES) III concerning the mineral density of the bones and lipids in raw analyses reported higher concentrations of total cholesterol and LDL, which were related to a smaller bone min-

eral density, while higher levels of HDL were related to a higher BMD. However, based on the fully adjusted model, no significant relation was founds between TC, LDL, HDL, BMD and BMC on the basis of a multivariate analysis. These results did not confirm the relationship between the level of lipids and the bone mineralisation (Solomon et al. 2005).

In most studies, weak positive correlations are indicated between HDL-C and BMD despite the absence of a generally strong correlation between the lipid profile and BMD, although mostly in women at the post-menopausal age (Yamaguchi et al. 2002; Jeong et al. 2010).

The study has some limitations. Certainly, the results relate to a small number of respondents and the test should be repeated in the future to try to extend for another group of young males and females. The project involved people living in a large urban area, so the results should be verified by research on males and females from smaller towns outside the central Poland.

Test results give a true measurement of the mass and minerals in the peripheral portion of the frame, so it can constitute a reference for BMD and BMC in the whole skeleton.

Conclusion

Based on several weak, positive correlations noted between the lipid profile (mainly HDL-C and triglyceride) and BMD, the results of this study of women and men cannot unequivocally point to the dependence of the condition of the bone tissue on the lipid level in the blood serum of young women and men. Therefore, the issues raised require further investigation.

The result of the study is worrying, as it points out the occurrence of abnormal values of total cholesterol and triglycerides, particularly among young women.

Lipid disorders, particularly occurring at an early age, cause a significant increase in the risk of cardiovascular disease in later years. The population of young people should be educated on the prevention of health disorders associated with abnormal lipid profile.

Acknowledgements

The study was conducted and financed within the DM-48 project included in the statutory activities of the Józef Piłsudski University of Physical Education in Warsaw.

Author contribution

AK-concept, study protocol, data collection, interpretation of results; KG-study protocol, data analysis, interpretation of results. All authors read and approved the final manuscript.

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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