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The correlation of bone density parameters with the body composition of students of the Police Academy – the perspective of preventing permanent damage to the body during physical training and interventions

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Helena Stokłosa[1ABCDE], **Władysław Mynarski**[2ABDE]

[1] Department of Anatomy, Academy of Physical Education, Katowice, Poland
[2] Department of Recreation, Academy of Physical Education, Katowice, Poland

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Abstract

Background & Study Aim: Above-average physical fitness required of candidates for police officers is determined by the level of somatic components belonging mainly to the musculoskeletal system. The aim of this study was a correlation between the parameters of bone density and selected somatic variables in the students of the Police Academy.

Material & Methods: The study involved 29 candidates for the police officers who were selected from a group of 91 individuals, after the initial selection that included the assessment of fitness and physical performance. The average age of subjects was 24.24±2.21 years. Body height and body mass was measured, and bioelectrical impedance method was used to evaluate body fat (FAT%, FAT mass), fat-free mass (FFM) and body mass index (BMI kg/m^2). Ultrasonography (Achilles, Lunar Corp.) was used to estimate the density of the calcaneus. Following variables were analyzed: BUA, SOS, SI, T-score and Z-score.

Results: The mean Stiffness index was high as in 20 subjects it was more than 100% (109-137%). Two students were diagnosed with osteopenia (T-score = –1.42, –1.56). BMI was within the normal range in 56% of the subjects, and the fat content was normal in 76% of the students. The relationship between somatic and ultrasound parameters of bones, assessed by the Pearson correlation coefficient, showed a statistically significant association of SOS and Stiffness index with body mass, BMI, body fat and fat free mass.

Conclusions: Candidates for the policemen were characterized by normal bone tissue structure, and the cases of osteopenia indicated the need for non-invasive assessment of bone density in preliminary medical examinations for early identification of persons with a risk factor for osteoporosis.

Key words: combat sports • health-related training • calcaneus ultrasonography • osteopenia • osteoporosis

Author's address: Helena Stokłosa, Department of Anatomy, The Jerzy Kukuczka Academy of Physical Education, ul. Raciborska 1, 40-074 Katowice, Poland; e-mail: h.stoklosa@awf.katowice.pl

INTRODUCTION

The candidates for the uniformed services, including the police, are required to have above-average and comprehensive physical fitness, special motor skills and relevant morphological and psychological predispositions. The evaluation of these individual characteristics is the basis for the selection of candidates, also in police academies. For this purpose, the motor performance tests and evaluation of physical traits are mainly used. The training program for police candidates comprises a comprehensive training approach of a general and special character. For this purpose, specific movement methods are utilized, including a variety of martial arts elements to optimally prepare them for difficult interventions. These activities increase the risk of injury due to hits, collisions with the ground during the fall, etc., which places high demands on the musculoskeletal system and body composition [1, 2]. It is therefore important to evaluate the fat mass (FM), fat-free mass (FFM), and bone mineral density (BMD). These somatic components, according to the concept of health-related fitness (H-RF), determine the so-called morphological fitness of the organism [3-6].

BMD forms the basis for the proper functioning of the musculoskeletal system, however, it is rarely considered in the evaluation of morphological fitness due to the use of X-ray measuring devices. The optimum level of BMD is acquired between 25 and 35 years of age, 75-80% of BMD is genetically determined, and the remaining 25% depends upon the rational physical activity and dietary factors [7, 8]. High level of physical activity and especially sports training in adolescence are factors determining the fitness and state of the musculoskeletal system in every period of man's life [9-11]. Therefore, physical activity is a means of preventing osteoporosis and reducing the risk of bone fractures [12-14].

In the diagnostics of metabolic bone diseases, most commonly applied is the test of bone mineral density with the use of dual energy X-ray absorptiometry (DEXA) and quantitative computed tomography (QCT). From the DEXA measurement a value is obtained (g/cm^3), which is referred to as the proper bone mineral density (BMD). In the literature, the results of the assessment of areal bone density are also presented, which determines the density of the bone region at a given width and length (g/cm^2) [15]. Based on the results of densitometry, the osteoporosis is recognized on the basis of diagnostic criteria developed by the World Health Organization – WHO [16].

Quantitative ultrasound (QUS) is a non-invasive and safe for health method, which provides information about the parameters of bone structure. The bone examined is usually the calcaneus, less frequently phalanges of fingers. The measurement results depend on the qualitative traits such as flexibility and microarchitecture of the bone. The speed of sound (SOS) in the calcaneus and broadband ultrasonic attenuation (BUA), allow to determine bone strength (Stiffness Index – SI) [7].

Studies on osteoporosis are carried out not only by using the densitometric methods, but also genetic approaches [17]. Polymorphism of MT1-MMP, MMP14 gene, according to Chinese scientists is associated with osteoporosis, assessed by the value of the ultrasound parameter BUA and BMD index.

Most studied factors are those that positively affect bone density and reduce the risk of osteoporosis. In general, low weight and low BMI are risk factors for osteoporosis, as well as stimulants such as alcohol, caffeine or nicotine. The effects of nicotine on bone condition were assessed by DEXA and QUS in individuals aged 36±0.7, who smoked cigarettes. Evaluation of BMD at the lumbar spine segment, hips and whole skeleton showed less sensitivity to nicotine than ultrasound parameters. There was a statistically significant negative effect of nicotine on the change of SOS parameter [18]. The adverse effects of cigarette smoking varied depending on the gender of respondents, and were observed in the SOS parameter in women, and in the BUA and SI parameters in men. By contrast, the BMI, body mass and FFM variables positively affect the BUA and SI in men, and additionally SOS parameter in women [19].

In the studies on the relationship between the body composition and density of the bones, the authors have been obtaining ambiguous results. In young recruits aged 19.8±1.0, the measurement of BMD, FAT mass and FFM were analyzed as factors determining physical fitness. The relationship between muscle strength and BMD was confirmed [20]. In young men serving in the army that were exercising for 6 months, the greatest impact of physical activity was found on the increase of the SOS parameter [21]. A significant relationship of muscle mass with BUA was also detected in young men. Participation in sports and gain in muscle mass increased SI as much as 10.22 ± 3.93% [22]. Studies on males in particular age ranges, revealed different effects of the body size on QUS parameters. The body height, weight, BMI, waist and hips circumferences, positively correlated

Parameters – bones properties possible to identification i.e. by the following indicators: speed of sound (SOS) in the calcaneus and broadband ultrasonic attenuation (BUA), allow to determine bone strength (SI).

FFM – active tissue mass, the mass of the skeleton, muscles and the remaining tissues, with the exclusion of the fat tissue.

BMI – weight-growth index determining slenderness – body corpulence.

Densitometry – tests evaluating bone mass.

Gene polymorphism – continuous and simultaneous presence of two or more forms of a gene in a population.

with BUA parameter, although no correlation was found for SOS parameter [23]. BUA parameter significantly correlated with the BMD results obtained from the measurements of the femoral neck and lumbar segment of the spine. This information is very important for screening, especially in people over 50 years of age, as a non-invasive ultrasound method allowing to assess condition of the bone tissue, for which the annual reduction in BUA parameter in men is 0.27% and 0.83% in women [24]. Early identification of osteopenia – precursor of osteoporosis, allows to take preventive measures and treatments.

In the police, as in the military, in addition to physical fitness, the morphological structure of the body is also important, including adequate bone density for strength training and typical martial arts exercises (pads, kicking, holding, punches, blocks, etc.). It is also important that the somatic characteristics, including the size and proportions of the body, the tissue and bone structure, correlates with motor abilities, which enables identification of appropriate selection criteria for the profession [25].

The aim of this study was a correlation between the parameters of bone density and selected somatic variables in the students of the Police Academy, and to answer the following questions:

– how does the somatic structure and bone density of tested candidates for police officers differ in comparison to theirpeer groups?
– to what extent the parameters of bone density are correlated with selected somatic variables of the subjects?

MATERIAL AND METHODS

Material

The study involved 29 candidates for the police officers, students of the Police Academy in Katowice (Poland), directed to the basic course. The average age of subjects was 24.24±2.21 years. Candidates were selected from a group of 91 individuals, after the initial selection, including the assessment of fitness and physical performance. The course apart from theoretical classes, also included physical education classes, self-defense and intervention techniques. The results of performance tests of maximum and explosive strength, as well as abdominal muscle strength endurance, and agility, obtained by successful candidates, exceeded the typical range for the population of 20- to 30-year-old men from Upper Silesia (region of Poland). The results were within the desired interval in terms of health benefits. Similar trends were observed in the case of maximal aerobic capacity (VO_2 max). In light of these results, the level of fitness and physical performance of men examined were considered above average. Comparison of the results obtained, to the statistical standards and physical parameters desirable for health of the population of Upper Silesia were presented in another article [6].

Osteopenia – reduced bone mass.

Anthropometry

Body height was measured with anthropometer with accuracy to 0.5 cm, in accordance with Martin-Saller technique [26].

Body composition

For the evaluation of weight and body composition, Tanita device (TBF-300, Japan) was applied. Bioelectrical impedance method was used to evaluate body fat (FAT%, FAT mass), fat-free mass (FFM) and body mass index (BMI (kg/m^2).

Evaluation of bone tissue

Achilles apparatus (Lunar Corp.) was used to ultrasonographically estimate the density of the calcaneus. Following variables were obtained:

– BUA (Broadband Ultrasound Attenuation) – absorption of ultrasounds by bone, depending on its structure;
– SOS (Speed of Sound) – the speed of the ultrasonic wave passing through the calcaneus;
– Stiffness index (SI) is the ratio of the stiffness of bone, expressed as a percentage calculated from the SOS and BUA;
– Z-score indicates how many standard deviations a given test result differ from the average of their age group;
– T-score determines the number of standard deviations of a particular result compared to the highest bone mass of young adults.

The value of T-score is the basis for the diagnosis of osteoporosis according to WHO [16]. Following diagnostic criteria are accepted:

norm – the value (+) (-) 1 T-score;
osteopenia – bone density value less than (-) 1, but greater than (-) 2.5 T-score;
osteoporosis – the value of T-score less than (-) 2.5.

Statistical analysis

Descriptive statistics were calculated for each variable, i.e. the arithmetic mean and standard deviation. Relationships between bone mineral density and somatic variables were evaluated with the Pearson correlation coefficient (r), assuming statistical significance at $p<0.05$.

RESULTS

The value of the weight-growth BMI index, according to WHO, indicated an overweight in 12 cases (25 <BMI> 29.9), obesity in two (BMI> 30), and the remaining 56% of subjects presented the normal range of the index (Table 1). Qualitative assessment of body fat as a percentage of the total body weight showed that the majority of students tested (76%) had values within the normal range (12-21%), while in one case a lower value occurred, and in six a moderate overweight was reported.

The mean value of SI was high as more than 20 subjects exceeded 100% (Table 2).

T-score of negative values of –1.42 and –1.56 indicated the presence of osteopenia in two subjects.

The relationship between somatic and ultrasound parameters of bones was measured with the use of Pearson correlation coefficient. This coefficient is influenced by extreme values, therefore this correlation was calculated in the group showing normal bone density (Table 3) and a test group in which the SI value was greater than 100% (Table 4). A statistically significant correlation was found between body weight, BMI, body fat content and the value of Z-score. SOS and SI parameters, showed a statistically significant correlation between body weight, BMI, body fat and FFM. BUA parameter reflecting the structure of trabecular bone was not associated.

DISCUSSION

According to the World Health Organization, osteoporosis, as well as atherosclerosis and cancer, are diseases of civilization. Most recent definition describes osteoporosis as a skeletal disorder characterized by decreased mechanical bone strength, which predisposes to an increased risk of fractures, and the bone strength is based on its two integral characteristics, i.e. density and quality [27]. Since osteoporosis is a major and growing threat to the health of

Table1. Statistical characteristics of somatic traits and body composition of the candidates for the police officers (n =29)

Variables	x ± SD	min. – max.
Body weight (kg)	82.06 ± 9.1	67.0 – 100.0
Body height (cm)	179.9 ± 6.1	160.0 – 192.0
BMI (/m^2)	25.45 ± 2.6	21.6 – 31.6
FAT (%)	17.6 ± 4.0	9.9 – 25.5
FAT (kg)	14.6 ± 4.7	7.2 – 25.4
FFM (kg)	66.8 ± 5.4	57.5 – 77.8

Table 2. Ultrasound parameters characterizing the calcaneus of examined candidates for the police officers (n=29)

Parameters	x ± SD	min. – max.
Stiffness (%)	109.5 ± 14.5	83.0 – 137.0
SOS (m/s)	1585.5 ± 35.9	1520.0 – 1668.0
BUA (dB/MHz)	128.9 ± 9.0	112.0 – 146.0
T – score	0.87 ± 1.3	–1.56 – 3.4
Z – score	1.09 ± 1.3	–1.36 – 3.6

Table 3. Correlation between somatic and ultrasound parameters of candidates tested to the police officers with the value of T-score ± 1SD (n=13)

Variables	SI	SOS	BUA	T-score	Z-score
Body weight (kg)	.48	.41	.38	.51	.58*
BMI (kg/m^2)	.45	.31	.44	.45	.56*
FAT (kg)	.43	.28	.45	.47	.56*

*p<0.05

Table 4. Significant correlations (p <0.05) between the somatic and ultrasound parameters in candidates tested for police officers with SI>100% (n=20)

Variables	SI	SOS
Body weight (kg)	–.58	–.64
BMI (kg/m^2)	–.56	–.69
FAT (%)	–	–.48
FAT (kg)	–.46	–.56
FFM (kg)	–.48	–.52

the population, not just women, but also men, studies assessing the condition of the bone tissue include also non-genetic factors [28, 29].

Peripheral bone density tests of distal segment of radius of the non-dominant hand revealed in men aged 20-29 significant differences between socio-occupational groups [30]. Men with higher education were characterized by the highest density of trabecular and cortical layers of the radius bone. Higher education and the accompanying elements of a lifestyle, such as a balanced diet, understanding the importance of active recreation for health and actual activity in this field, less susceptibility to destructive habits such as alcoholism and nicotinism, are the reasons for the high bone density parameters of this group. Students of the Police Academy from the current study can be similarly classified in terms of these factors, and particularly physical activity, as they also presented high values of ultrasound parameters. This fact demonstrates the proper structure of the cancellous (BUA) and cortical (SOS) layers of bones.

The students of the Police Academy are young people who have a continuing increase in bone mass, up to about 35 years of age when it reaches the maximum value. High ultrasound parameters identified in subjects are consistent with the results of numerous studies [22, 31, 32] confirming that physical activity has positive influence on the values of the bone density. In all subjects with bone density in the normal range (T-score ± 1SD), there was no correlation between ultrasound parameters and body weight, body fat or BMI. These relationships were not reported either in the studies comparing the structure of the calcaneus in relation to recreational physical activity in Swedish population. As in our study, there was no correlation found between the bone density and age in the 22-33-year-old interval, or in the group of 45-59-year-olds [9]. In addition, studies of older men, aged 60-79 years showed independence of QUS parameters of age, while comparably to our study, body weight has been associated with SI, and BMI with SOS parameter [33]. Bone density tests, carried out on football players, revealed high SI values (130±15%) and T-score of 0.94 (-1.00, 3.35), although there was no association of SI, BUA and SOS parameters with age, and no correlation of height, weight and BMI with SOS index [31]. These different results obtained in cross-sectional studies, pertaining to interrelationship of bone mineral density and bone tissue structure are evidence of the need for longitudinal research.

Among the students of the Police Academy, osteopenia was found in two cases, though the physical fitness of these men was above average. The bone tissue is a morphological structure, which may be positively or negatively affected by exercise, depending on the type and intensity of training loads [12-14]. According to the theory of mechanotransduction, physiological processes occurring in the bones cause bone formation, when physical forces are properly converted into biochemical signals, which, in turn, activate effector cells and subsequently change the structure of the bone tissue. Exercise overload and intense effort, can cause metabolic acidosis, which negatively affects bone tissue [34]. Although bone tissue in osteoporosis may be the source of primary pain syndromes, most people do not experience any ailments. It was found that only 5% of patients with osteoporosis report pain [13]. Policemen examinations showed that musculoskeletal pain is most common in people with high BMI and lower level of physical activity [14].

Somatic structure and body composition variables are most frequently tested in various populations. We have carried out a comparison of body composition of students from the Police Academy and recruits entering military service. The subjects of both groups presented similar BMI, whereas recruits were characterized by 5% greater adiposity and lower by 9.2 kg fat-free mass [20]. A comparison of somatic parameters of students of the Academy of Physical Education, as a population with above-average physical activity resulting from the curriculum at the physical education specialization, showed that police candidates are characterized by a more massive body composition (body weight increased by 7.68 kg, BMI> 2.11) and higher adiposity of 2.83% [6].

Candidates for police officers, as a selected group of high physical activity, possessed the somatic structure traits that corresponded to athletes of diverse disciplines. When compared with the professional athletes, candidates for the police officers in terms of body height corresponded to runners (180.3±8.2 cm), their weight was similar to team sport athletes (81.7±7.3 kg), while BMI was close to combat sport athletes – wrestlers, judoists (25.4±3.6 kg/m^2) [35]. The results of this comparison indicated properly conducted selection of men for work in the police force, and the basic training that includes 37 weeks of courses shaping general and specialized physical fitness, is likely to positively affect not only the changes in body composition, but also bone density. Evaluation of the truthfulness of this assumption is a separate research problem.

CONCLUSIONS

Candidates for police officers presented high values of the ultrasound parameters used for bone testing, which indicates normal bone tissue structure.

Cases of osteopenia in the students of the Police Academy suggest the need to include non-invasive bone tissue evaluation to preliminary medical examination. It would allow early diagnosis of candidates affected by a risk factor for osteoporosis.

Candidates to the police forces in terms of somatic indexes and characteristics resemble professional athletes, which is probably caused by their high physical fitness and points to a well-conducted process of selection of candidates for the police officers.

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