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Metabolic disturbances in sedentary and active Polish male students with normal body mass index and waist circumference

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Abstract

Study aim: To evaluate circulating lipoproteins, glucose, insulin and the index of insulin resistance (HOMA-IR) in male Polish students with normal BMI and waist circumference (WC) in the context of their physical activity.

Material and methods: A total 170 male students with normal BMI and WC less than 102 cm were accepted for the study (56 sedentary and 114 physically active). Body weight and height were determined using standard medical equipment. Waist circumference was measured using non-stretchable tape. The percentage of body fat was determined from the sum of the thickness of four skinfolds. Circulating lipoproteins, glucose and insulin level was determined.

Results: Active participants had significantly lower plasma TC, LDL-C, TC/HDL ratio, LDL/HDL ratio, insulin and HOMA-IR compared to sedentary subjects ($P < 0.001$). However, even among active participants, as many as 58% were characterized by high TG, 17% high TC, 12% high LDL-C and 20% high TG/HDL ratio.

Conclusion: In male students with normal body composition according to BMI and WC distorted metabolic variables were observed. Additionally, physical activity markedly decreased but not eliminated these disturbances. Thus, using BMI and WC for body composition classification as healthy possibly provide a false results concerning metabolic status.

Keywords: Metabolic disturbances – Lipoproteins – Insulin – Glucose – Physical activity

Introduction

Obesity and overweight significantly increases the risk of non-communicable diseases including type 2 diabetes and cardiovascular disease [6, 29]. On the other hand, the reliability of methods used for body fatness determination is still under discussion [15, 30].

In population-based studies the body mass index (BMI, kg × m^{-2}) is the most widely used index of body shape and a good marker of all-causes morbidity and mortality [13]. On the other hand, it is well documented that the relationship between incidents of cardiovascular disease (CVD) and BMI is J-shaped or U-shaped since incidents of CVD are high in subjects with very low and very high BMI values [5]. In consequence of this discrepancy waist circumference (WC) was included into World Health Organization (WHO) classification of body composition [27]. Is needed other easily calculated indices of body shape (BRI, ABSI) were proposed as more precise markers of morbidity and mortality [32, 33].

Other doubts concerning BMI pertain to determination of body adiposity, well recognized risk factor of adverse health effects. Numerous studies have indicated that BMI provides misleading results concerning body adiposity and other indices have been proposed to be more reliable as for example waist circumference and/or waist-to-height ratio [1, 31]. Moreover, many authors have noted that BMI provide false results of body composition in physically active subjects and athletes who are characterized by low body fat and high fat free mass with the latter affecting body mass to much greater extent than the former [19, 39].

Additionally it should be stressed that visceral fat which proxy measure is waist circumference is not the only fat depot which adversely affects metabolic profile including insulin resistance and circulating lipoproteins. It is well documented that excess of subcutaneous fat but also ectopic fat adversely affect metabolic risk [14, 20].

In consequence, taking into account the above mentioned doubts concerning BMI reliability as an index of body composition and health risk, the questions arises concerning metabolic profile of individuals classified as

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normal according to BMI and WC WHO standards. This issue seems to be important in young population due to possible health consequence later in the life but especially in men with higher risk of CVD than women [19, 34, 38].

Thus, our study was undertaken. It evaluated circulating lipoproteins, glucose, insulin and the index of insulin resistance (HOMA-IR) in male students of Józef Piłsudski University of Physical Education with normal BMI and WC in the context of their physical activity. At the same time calculated TC/HDL, LDL/HDL and TG/HDL ratio which are used to predict development of diabetes, coronary heart disease and cardiovascular mortality [11, 21]. According to many researchers, they can become a valuable tool in the field of primary and secondary prevention strategies [23, 26].

Material and methods

Subjects

A total of 214 male students of Józef Piłsudski University of Physical Education in Warsaw volunteered to participate in the study. The students were approximately 21 years old. They were recruited on the basis of word of mouth and advertisements in students' dormitories at Józef Piłsudski University of Physical Education. All of them declared not taking any medications and supplements on the regular basis. Of them, 146 students reported participation in different sports for 1 to 2 h daily (swimming, games, martial arts) at least for five times a week, however none of them were high performance athletes. A further 68 students were not engaged in any structured, regular physical activity and were accepted as sedentary ones. During the study all participants were living in a big city (over 1 million inhabitants) and most of them consumed at least three meals daily. Participants' selection was performed after anthropometric procedures. All participants provided written informed consent and the study protocol was approved by Józef Piłsudski University of Physical Education Ethics Commission.

Anthropometry

Body weight and height were measured using standard medical equipment (weight to nearest 0.1 g and height to nearest 0.1 cm). Body mass index (BMI) was calculated by division of body weight (in kg) by height in meters squared. Waist circumference (WC) was measured to nearest 0.1 cm between the lowest rib and iliac crest while the subjects were at minimal respiration using non-stretchable tape. All measurements were taken in subjects without shoes and in light sport clothing and were performed by well trained technicians or researchers and were taken two times but repeated for the third time in the case of discrepancy. The average values were calculated for the nearest measurements. For further procedures 56 sedentary and 114 active students with normal BMI (18.5–24.9) and WC less than 102 cm were accepted. In these groups the percentage of body fat was determined from the sum of the thickness of four skinfolds (biceps, triceps, suprailiac and subscapular) measured using a Harpenden Skinfold Caliper (British Indicators, Burgess Hill, UK) and calculated according to Durnin and Womersley [8].

Blood analyses

The participants were instructed to refrain from physical activity 48 hours before coming to the laboratory and to eat last meal at least 8 h before blood sampling. Blood was withdrawn between 7:30 and 9:00 a.m. from antecubital vein under aseptic conditions into plastic tubes with anticoagulant and centrifuged 15 min/4000 rpm at 4°C to obtained plasma. Plasma was stored at –70°C until analysis. Plasma glucose was determined using GOD-PAP method. Triacylglycerols (TG), total cholesterol (TC) and HDL-cholesterol (HDL-C) were assayed with colorimetric methods and commercial kits (Randox Laboratories, UK). Coefficients of variation for all variables did not exceeded 5%. The plasma concentration of LDL-cholesterol (LDL-C) was calculated according to the Friedewald formula [9]. Plasma insulin was measured using a standard radioimmunoassay (RIA) with human monoclonal antibodies against insulin and BioSource kits (Biosource, Belgium). Inter – and intra-assay coefficients of variation for insulin determination did not exceeded 7%. All measurements were done in duplicate. Insulin resistance index (HOMA-IR) was calculated according to Mathews et al. [24] formula:

$$\text{HOMA-IR} = [\text{glucose (mmol/L)} \times \text{insulin } (\mu\text{IU/ml})]/22.5.$$

Circulating glucose was classified according to the International Diabetes Federation with 5.5 mmol/l accepted as the upper level [17]. Concentrations of plasma lipoproteins were classified according to the recommendations of the a joint consensus statement from the European Atherosclerosis Society and European Federation of Clinical Chemistry and Laboratory Medicine (TG $\leq$ 1.7 mmol/L, TC $\leq$ 5.0 mmol/L, LDL-C $\leq$ 3.0 mmol/L and HDL-C $\geq$ 1.0 mmol/L) [28]. The desired values were respectively <4.5 for TC/HDL ratio, <3.0 for LDL/HDL ratio and <2.0 for TG/HDL ratio [16]. The cut-offs of normal insulin levels in Polish population are not established and in the current study plasma hormone concentrations were not evaluated. With respect to HOMA-IR we accepted that the upper limit is equal to the 75th percentile of HOMA-IR in sedentary students (2.254) [12].

Statistical analyses

All data were tested for normality using the Shapiro-Wilk test. The comparison of data was performed using the Mann-Whitney test. A Pearson's Chi-square test was used to analyze the differences between the incidence of normal and abnormal BMI and metabolic disorders. All calculations were done using a STATISTICA for Windows v.12 program (StatSoft, Tulsa, OK, USA). The value of $P < 0.05$ was accepted significant. All data are presented as mean ± SD (standard deviation).

Results

Sedentary and active did not differ with respect to age, weight, height and BMI. On the contrary, significant difference was noted in the waist WC, LBM, FAT % and FAT kg ($P < 0.001$).

Table 1. Anthropometric characteristics of sedentary and active male (mean ± SD)

Variables	Sedentary (n = 68)	Active (n = 146)
Age [years]	21.7 ± 1.8	21.0 ± 2.0
Weight [kg]	76.3 ± 12.1	79.0 ± 10.6
Height [cm]	181.4 ± 6.3	181.7 ± 6.3
BMI	23.1 ± 3.2	23.9 ± 2.7
WC [cm]	86.5 ± 9.8	76.4 ± 3.9*
LBM [kg]	63.4 ± 8.6	69.1 ± 7.9*
FAT [%]	16.5 ± 5.2	12.3 ± 4.5*
FAT [kg]	12.9 ± 5.5	10.0 ± 4.8*

BMI, body mass index; WC, waist circumference; LBM, lean body mass; *$P < 0.001$ – significantly different vs. sedentary.

Table 2. Classification of sedentary and active male according to BMI and WC standards established by WHO

BMI	Sedentary (n = 68)	Active (n = 146)	χ^2 (*p*) 0,495 (0,7809)
Underweight <18.5	0.0 (0)*	1 (1)	
Normal weight 18.5–24.9	82 (56)	78 (114)	
Pre-obesity 25.0–29.0	15 (10)	18 (27)	
Obesity class I 30.0–34.9	3 (2)	3 (4)	
WC < 102	82 (56)	78.1 (114)	

BMI, body mass index; WC, waist circumference; *In brackets – number of subjects from each group.

Classification of body composition of sedentary and active participants according to BMI and WC standards revealed that the percentage of underweight, overweight and obese subjects did not differ (82% of sedentary students vs. 78% of active, for normal weight).

Analysis of Perason's Chi-square test of independence showed that the level of physical activity was not related to the incidence of normal and abnormal BMI values.

The circulating TC, LDL-C, TC/HDL ratio, LDL/HDL ratio, insulin and HOMA-IR were significantly lower in active vs. sedentary ($P<0.001$).

Table 3. Metabolic characteristics of sedentary and active male with normal BMI and WC (mean ± SD)

Variables	Sedentary (n = 56)	Active (n = 114)
TG [mmol/L]	1.6 ± 0.7	1.5 ± 0.7
TC [mmol/L]	3.8 ± 0.7	3.2 ± 0.7*
HDL-C [mmol/L]	1.1 ± 0.2	1.1 ± 0.3
LDL-C [mmol/L]	2.3 ± 0.7	1,8 ± 0.7*
TC/HDL ratio	2.8 ± 0.7	2.2 ± 0.9*
LDL/HDL ratio	1.7 ± 0.6	1.2 ± 0.8*
TG/HDL ratio	1.9 ± 0.5	1.0 ± 0.6
Glucose [mmol/L]	3.8 ± 0.4	3.6 ± 0.7
Insulin [µIU/ml]	9.9 ± 7.8	3.9 ± 1.7*
HOMA-IR	2.0 ± 1.6	0.8 ± 0.4*

TG – triacylglycerols; TC – total cholesterol; HDL-C – HDL-cholesterol; LDL-C – LDL-cholesterol; HOMA-IR – insulin resistance; *$P < 0.001$ – significantly different vs. sedentary.

However, circulating TG, HDL-C, TG/HDL ratio and glucose did not differ in both groups. The analysis of distorted metabolic variables indicated that in some individuals of both groups plasma TG, TC, LDL-C, glucose, and HOMA-IR were significantly higher than the accepted limits.

However, for sedentary individuals the frequency of disturbances was significantly higher than in active ones (30% vs. 17% for TC, 36% vs. 12% for LDL-C, 37% vs. 1% for HOMA-IR and 10% vs.2% for LDL/HDL ratio). On the contrary, the frequency of disturbed plasma TG, HDL-C and glucose, LDL/HDL ratio and TG/HDL ratio did not differ in both groups. Simultaneously in both groups, a large percentage of participants were characterized by a higher circulating TG and TG/HDL ratio in relation to the accepted limits. Analysis of Perason's Chi-square test of independence showed that the level of physical activity was related to the incidence of distorted metabolic variables.

Table 4. The number of participants with disturbed metabolic profile in sedentary and active male students with normal BMI and WC

Variables	Sedentary (n= 56)	Active (n= 114)	χ^2 (p) 37,13 (<0,001)
TG (mmol/L)	55 (31)*	58 (67)	
TC (mmol/L)	30 (17)	17 (19)	
HDL-C (mmol/L)	3 (2)	2 (3)	
LDL-C (mmol/L)	36 (20)	12 (14)	
Glucose (mmol/L)	3 (2)	5 (6)	
HOMA-IR**	37 (21)	1 (1)	
TC/HDL ratio	5 (3)	2 (3)	
LDL/HDL ratio	10 (6)	2 (3)	
TG/HDL ratio	21 (12)	20 (23)	

TG – triacylglycerols; TC – total cholesterol; HDL-C – HDL-cholesterol; LDL-C – LDL-cholesterol; HOMA-IR – insulin resistance; *In brackets – number of subjects from each group; **75th percentile of HOMA-IR in sedentary established as cut–off in both groups.

Discussion

The most important finding of our study concern the frequency of distorted lipoproteins (TG, TC, LDL-C, HOMA-IR and TG/HDL ratio) in young with healthy BMI and WC. Thus, it could be postulated that both indices of body adiposity provide misleading results concerning their metabolic status. It is worth noting that despite the lack of overweight or obesity, 37% of young sedentary men are characterized by too high HOMA-IR index indicating the occurrence of insulin resistance. It is known that the most common cause of it is overweight or obesity. In addition, in both groups 20% are characterized by a TG/HDL ratio higher than the reference value. Vega et al. (2014) demonstrated that an elevated TG/HDL-C ratio to be just as effective as the Metabolic syndrome diagnosis in predicting the development of CVD and predicts of type 2 diabetes mellitus [37].

Moreover, in the case of classification of students for medical procedures some young individuals may be often misguided as healthy due to normal BMI and WC. According to literature data some participants of our study may be classified as metabolically unhealthy, normal weight/metabolically abnormal normal weight (MUNW/MANW) identified in other populations and recognized as those with high risk of health problems (CVD and type 2 diabetes-DM 2) later in life [4, 43]. This assumption seems to be of special importance in population characterized by very high risk of both CVD and type 2 diabetes mellitus which is confirmed by numerous studies. It is worth noting here that cardiovascular diseases are the main cause of death in men aged 45–54 and 70+ worldwide [41, 42].

Our data concerning lower frequency of metabolic disturbances in active in comparison with their sedentary counterparts are in agreement with many studies indicating positive health effects of an active lifestyle [35, 40]. On the other hand, our results concerning physically active participants suggest that active lifestyle does not eliminate adverse effects of other factors which contribute to metabolic disturbances such as heredity, prenatal and postnatal nutrition as well as air pollution [18, 22]. In the context of our study s special attention has to be paid to dietary habits of population and high consumption of fat and cholesterol but inadequate consumption of fish, carbohydrates, fruits, vegetables and fiber which has been shown in many studies [2, 25]. Moreover numerous studies have shown that young people consume a lot of sweetened beverages which bring about metabolic disturbances [10]. In addition, especially in active subjects of our study high consumption of over-the counter (OTC) medicines and dietary supplements have to be taken into consideration as a possible reason of metabolic disturbances despite their declarations provided before all procedures [3].

Interestingly in both groups the frequency of disturbances in circulating HDL-C was low and not significantly different with respect to physical activity level. However, this finding does not excluded potential health risk, since it is well documented that their adverse effects are also related to particle size and structure [7, 36].

We have to underline that our study has limitations concerning not precise registration of physical activity, lack of information about student dietary habits at the moment of the study and relatively low number of sedentary participants. Moreover, it is a cross-sectional study. However, our data indicate that metabolically unhealthy normal weight individuals are observed in Polish students despite their normality according to commonly accepted standards of body composition expressed as BMI and WC. As previously mentioned, it cannot be ruled out as probable the cause of this type of disorders is an unfavorable change in lifestyle and nutrition.

Conflict of interest: Authors state no conflict of interest.

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