Metabolic Risk Factors in Young Men With Healthy Body Fat But Different Level of Physical Activity

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Abstract

The study was performed to evaluate metabolic risk in young lean individuals characterized by different physical activity. A total of 194 students (93 active with 5–7 h weekly physical activity and 101 inactive) were accepted for the study. The following percentages of body fat were accepted as characteristic for lean men: 14% to 17% in active and 18% to 24% in inactive participants. Circulating glucose, insulin, triacylglycerols (TG), total cholesterol (TC), and high-dendity lipoprotein (HDL)-cholesterol (HDL-C) were assayed. Daily intake of energy and macronutrients was briefly assessed from 24 h food records collected over 4 days preceding blood collection. Insulin and TG differed with respect to physical activity and was lower by 37.5% and 12.5%, respectively, in active versus inactive participants. In active students with upper quartile of body fat percentage, the only significant difference was found between circulating insulin (by 28%, $p < .04$). In inactive participants with upper quartile of body fat, significant differences were found between levels of insulin and TG (by 25% and by 37.5%, respectively). Diet composition did not differ with respect to the percentage of energy derived from protein, fat, and carbohydrates. An inverse association between insulin level and the percentage of body fat seems to be physiological one because it has been noted in both active and inactive individuals. On the contrary, elevation in circulating TG found exclusively in inactive subjects seems to be secondary to the changes in adiposity and circulating insulin and is followed by tendency to higher levels of TC.

Keywords

metabolic risk, young males, body fat, physical activity

Background

Metabolic disturbances in chronic diseases, such as obesity, dyslipidemia, type-2 diabetes, and cardiovascular disease (CVD) are caused by both genetic and environmental factors (Ezzati & Riboli, 2013; Liao et al., 2015). It is generally accepted that irrespective of age, diet quality and regular physical activity play an important role in their prevention (Bruins et al., 2019; Shuval et al., 2014).

Numerous data have revealed that overweight and obesity occur when calories consumption exceeds their expenditure, that is, when there is a positive energy balance in the body. According to research, the risk of a positive energy balance is greater when the diet is abundant in ingredients with the highest energy density, that is, fats, especially saturated fatty acids (SFAs), which are found in

high amounts in animal food sources. These products, especially meat and its products, are rich in SFAs, which, when highly consumed, are deposited in the adipose tissue (Billingsley et al., 2018; Lambadiari et al., 2020). As the amount of fat in adipocytes increases, they enhance secretion of proinflammatory substances (i.e., tumor necrosis

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factor alpha [TNF-α], interleukin-6 [IL-6], and C-reactive protein [CRP]), and decrease anti-inflammatory responses (i.e., adiponectin). Moreover, according to the literature (Haus et al., 2010; Masquio et al., 2015), excessive consumption of fats, especially SFA, alters the cell's response to insulin. This causes disturbances in fats and carbohydrates metabolism, leading to the development of atherosclerosis and diabetes (Bays et al., 2013). Physical activity minimizes the risk of the aforementioned diseases mainly by reducing body mass and body fat stores (Jakcic et al., 2011; Reiner et al., 2013). In consequence, marked and favorable changes in adipokine and inflammatory marker synthesis and secretion have been reported improving metabolic processes such as insulin sensitivity and/or lipid and lipoprotein metabolism (Oikonomou & Antoniades, 2019).

It is worth noting that given the worldwide obesity epidemic and its negative health effects most studies concerning the relationship between body fat and morbidity have focused on overweight and/or obese individuals of different ages (Halle et al., 2021; Rauner et al., 2013). Effects of diet and physical activity on body composition and metabolic processes are observed also in young and nonobese subjects. Various data can be found on this issue in literature. Among them, there are works emphasizing the beneficial effect of proper nutrition and active lifestyle on the metabolic profile in people with normal body weight (Clark et al., 2014; Zubair et al., 2014). It was also proven that inappropriate eating behavior in adults, even if they are physically active, can lead to a number of metabolic disorders, which may or may not be accompanied by changes in body composition (De Souza et al., 2014). Most often reported wrong eating habits of young adults increasing the risk of metabolic disturbances are high consumption of sugar-sweetened beverages, breakfast skipping and eating at fast-food restaurants (Malik & Hu, 2019; Ogilvie et al., 2018).

In the case of physically active people, a common problem is the imbalance between energy consumption and energy expenditure, which often leads to the development of relative energy deficiency syndrome (REDS) (Mountjoy et al., 2014). This condition occurs when calorie intakes do not support exercise energy expenditure contributing to the impairment of many physiological processes. Energy deficiency in the body causes hormonal changes, above all, decrease in sex and thyroid hormones and increase in cortisol secretion (Elliott-Sale et al., 2018). This strategy may be beneficial for surviving the state of energy deficiency but is not optimal for the athlete's health and performance. In addition to disturbed gonadal function and bone metabolism, low energy availability through these hormonal changes causes an unfavorable lipid profile and endothelial function, thus increasing the cardiovascular risk. It also can

result in a reduction in glucose utilization, mobilization of fat stores, decreasing metabolic rate, changes that enhance the risk of obesity when physical activity declines. The authors of studies on this issue underline that mentioned metabolic disorders often precede changes in the body composition (Havel, 2001).

Another important point is that in the majority of existing studies concerning obesity, body fat has been evaluated according to the World Health Organization (WHO) standards using body mass index (BMI) (Okwuosa et al., 2013; Peltzer et al., 2014). However, BMI as the measure of body adiposity, especially in young individuals is criticized because it is related mostly to lean body mass (LBM) but not to fat mass (Cornier et al., 2011; Shah & Braverman, 2012). It is recommended that the percentage of body fat is the most reliable index of body composition in young adults (Carpenter et al., 2013). Unfortunately, at present, no officially accepted norms of the percentage of body fat are available. Abernathy and Black (1996) have postulated that in general population, healthy body fat for men varies from 12% to 20%; however, in this study subjects' physical activity was not taken into consideration.

This study was undertaken and aimed at the comparison of body composition, dietary intake, and metabolic profile in young lean males characterized by different physical activity. The aim was also to show the relationship between currently considered normal body fat content and the metabolic profile in young adults. We hypothesized that active lifestyle would positively influence circulating metabolic risk factors for diabetes and CVD in young men without overweight and/or obesity.

Methods

Subjects

The participants of the study were recruited among male students on the basis of word of mouth and advertisements in student dormitories. All who declared their participation in the study were living for at least 6 months in a big city with more than 2 million inhabitants. Before participation, all the students were asked about weekly hours of their physical activity and participation in high-performance sports. All the subjects were healthy nonsmokers, not taking any medication on a regular basis and gave their written consent prior the participation in the study. Approval to implement the study protocol was obtained from the Ethics Committee of the Józef Piłsudski University of Physical Education in Warsaw.

In total, 214 students volunteered to enroll the study. Of them, 108 were physical education students active due to the obligatory study program (swimming, running, games, martial arts) for at least 12 weeks before the study. Their weekly physical activity varied from 5 to 7 hours/

week. None of them were engaged in high-performance sport. A further 106 students of other specializations were not engaged in any structured activity and were accepted as inactive ones.

Anthropometry

Body weight and height were measured in all 214 participants to the nearest 0.1 kg and 0.1 cm, respectively, using standarized equipment and BMI was calculated. Body fat was determined from the sum of the thickness of four skinfolds (biceps, triceps, suprailiac, and subscapular) measured using Harpenden Skinfold Caliper (British Indicators, Burgess Hill, UK) and calculated according to Durnin and Womersley (1974). LBM also was calculated. Waist circumference was measured in the midway section between the lower edge of the ribs and the iliac crest with accuracy of 0.1 cm using nonstretchable tape. All measurements were performed in subjects without shoes and outer clothing and each was repeated twice and in the case of discrepancy was repeated for a third time. All measurements were performed by an experienced technician. The following values of body fat percentage were accepted as characteristic for lean men: 14% to 17% in active and 18% to 24% in inactive participants (American Council on Exercise, 2009). In consequence, a total of 194 students (93 active and 101 inactive) whose body fat was in agreement with the above standards were accepted for further procedure.

Dietary Habits

Daily intake of energy and macronutrients was briefly assessed from 24 h food records collected over 4 days preceding blood collection and analyzed using Dieta 5 computerized program purchased from the Institute of Food and Nutrition in Warsaw. A set of pictures of foods and meals was shown to the participants by an experienced interviewer. The household measures of dietary intake were converted into gram weights. An interviewer assigned codes to the food reported by the subjects and performed computer analysis.

Blood Analysis

Subjects were asked to refrain from physical activity for 48 h before blood sampling. Blood was withdrawn in the morning between 8:00 and 8:30 after overnight fasting. Venous blood was collected under aseptic conditions into plastic tubes containing anticoagulant and centrifuged at 4°C. Plasma was stored at −70° until analysis. Glucose was determined using the GOD-PAP method. Triacylglycerols (TGs), total cholesterol (TC), and high-density lipoprotein (HDL)-cholesterol (HDL-C) were assayed colorimetrically using commercial kits (Randox Laboratories, Great

Britain). Coefficients of variation for these analyses did not exceed 5%. The plasma level of low-density lipoprotein (LDL)-cholesterol (LDL-C) was calculated according to the Friedewald equation (Friedewald et al., 1972). Circulating insulin was determined using standard radioimmunoassay with monoclonal antibodies against insulin and commercial kits (BioSource, Belgium). The sensitivity of the method was 1 μIU/mL, inter and intra-assay coefficients of variation were 9.3% and 6.8%, respectively. All analyses were run in duplicate.

Statistical Analysis

Data distribution was tested using the Shapiro–Wilk's test. Comparison of variables in active and inactive students was analyzed using nonparametric Mann–Whitney test because of skewness of anthropological and biochemical variables. Pearson correlation coefficients between the percentage of body fat and biochemical variables were calculated from logarithmically transformed data. Moreover, in both groups, metabolic variables were calculated with respect to the lower and upper quartile of the percentage of body fat. Data are presented as mean ± SD. Statistical significance was set at $p < .05$.

Results

Age, body mass, body height, and BMI did not significantly differ in active and inactive students (Table 1). However, active students were characterized by lower adiposity expressed as the percentage of body fat and fat mass ($Z = -3.457$, $p < .001$ and $Z = -2.974$, $p < .001$, respectively) and slightly but significantly higher LBM ($Z = 1.965$, $p < .05$) versus their inactive counterparts. Among metabolic variables, only circulating insulin and TG differed with respect to physical activity level and was lower by 37.5% and 12.5%, respectively, in active versus inactive participants.

Diet composition did not differ with respect of the percent of energy derived from protein, fat, and carbohydrates; however, inactive subjects were characterized by a tendency to lower daily energy intake ($Z = 1.769$, $p > .07$) (Table 2).

In active students, the percentage of body fat was not significantly correlated with metabolic variables. On the contrary, in inactive subjects, the percentage of body fat was significantly correlated with circulating insulin and TG ($r = 0.360$, $p < .04$ and $r = 0.340$, $p < .001$, respectively).

In active students, separated according to the quartiles of body fat percentage, the only significant difference was found between circulating insulin (by 28%, $Z = -2.455$, $p < .04$) (Table 3). In contrast, in inactive participants with upper quartile of body fat, significant differences were

Table 1. Anthropometric and Biochemical Variables in Active and Inactive Lean Students (Means ± SD).

Parameters	Active students (n = 93)	Inactive students (n = 101)
Age (years)	19.7 ± 0.8	21.1 ± 0.8
Height (cm)	180.6 ± 6.3	180.6 ± 7.1
Weight (kg)	76.7 ± 8.6	77.2 ± 12.6
BMI	23.5 ± 2.6	23.7 ± 3.3
Fat (%)	11.9 ± 3.2*	15.1 ± 4.4
Fat (kg)	9.1 ± 3.2*	11.6 ± 3.6
LBM (kg)	67.6 ± 6.6**	65.6 ± 9.1
Waist (cm)	79.8 ± 6.0	80.7 ± 8.0
Glucose (mmol/L)	4.8 ± 0.6	4.8 ± 0.5
Insulin (µIU/mL)	7.2 ± 2.6*	9.9 ± 6.0
TG (mmol/L)	0.8 ± 0.4**	0.9 ± 0.4
TC (mmol/L)	4.4 ± 0.6	4.5 ± 0.7
HDL-C (mmol/L)	1.4 ± 0.3	1.4 ± 0.4
LDL-C (mmol/L)	2.5 ± 0.6	2.7 ± 0.5

Note. BMI = body mass index; LBM = lean body mass; TG = triacylglycerols; TC = cholesterol; HDL-C = high-density cholesterol; LDL = low-density cholesterol.
*$p < .001$. **$p < .05$—significantly different versus inactive subjects.

found between plasma levels of insulin and TG (by 25% and by 37.5%, respectively) in comparison with their counterparts with lower quartile of fatness.

Discussion

This study has indicated that lean active and inactive students markedly differ with respect to circulating insulin and TG. Taking into account that lower circulating insulin is a good measure of improved insulin sensitivity, it is clear that in active students, insulin sensitivity was better that in inactive ones (Abbasi et al., 2014). This assumption supports other data concerning the relationship between physical activity and insulin action (Malin et al., 2013; Newson et al., 2013). Plasma TG under fasting conditions of our study reflects its liver synthesis and

Table 2. Daily Energy and Macronutrient Intake in Lean Active and Inactive Male Students (Means ± SD).

Parameters	Active students (n = 93)	Inactive students (n = 101)
Energy (kcal/day)	2,860 ± 689	2,714 ± 670
(MJ/day)	11.4 ± 2.8	11.3 ± 2.8
Protein (g)	101.7 ± 26.5	98.5 ± 24.0
Protein (%)	14 ± 3	14 ± 4
Fat (g)	119.0 ± 39.4	114.5 ± 38.2
Fat (%)	37 ± 6.0	38 ± 7.0
SFA (g)	44.4 ± 7.8	45.0 ± 8.0
SFA (%)	14 ± 3	15 ± 3
Carbohydrates (g)	350.3 ± 98.6	325.0 ± 87.4
Carbohydrates (%)	49 ± 6	48 ± 7

Note. SFA = saturated fatty acids.

secretion into the blood (Nielsen & Karpe, 2012). However, it has been suggested that insulin sensitivity plays an important role in the regulation of liver lipogenesis which is stimulated with decreasing insulin sensitivity (Czech et al., 2013). Thus, it seems feasible that also in lean individuals physical activity positively affects insulin sensitivity and has a beneficial effect on TG liver synthesis.

In addition, it could be tentatively speculated that at least in healthy individuals both insulin and TG are the first targets of activity-induced metabolic changes which are accompanied by minor difference in body fat (by 3.2%). Interestingly, it has been demonstrated that beneficial metabolic effects of physical activity are also noted without changes in body weight but with decrease in liver and visceral fat depots, which are known to have stronger adverse health effects than subcutaneous fat (Dutheil et al., 2013; Vissers et al., 2013). In addition, there are data suggesting that visceral fat is more sensitive to physical activity that other fat depots (Whitaker et al., 2017). Thus, it could not be excluded that lower circulating insulin and TG in active students of our study was also due to changes

Table 3. Metabolic Variables in Active and Inactive Students With Respect to Lower and Upper Quartile of the Percentage of Body Fat (Means ± SD).

Parameters	Insulin (µIU/mL)	Glucose (mmol/L)	TG[a] (mmol/L)	TC (mmol/L)	HDL-C (mmol/L)	LDL-C (mmol/L)
Active students						
Q1 (7.7 ± 1.7)	6.4 ± 1.4	4.7 ± 0.5	0.8 ± 0.4	4.4 ± 0.5	1.4 ± 0.4	2.5 ± 0.5
Q4 (15.5 ± 0.9)	8.2 ± 3.3**	4.9 ± 0.6	0.8 ± 0.4	4.3 ± 0.4	1.5 ± 0.3	2.4 ± 0.4
Inactive students						
Q1 (9.4 ± 2.6)	8.9 ± 6.3	4.8 ± 0.5	0.8 ± 0.3	4.4 ± 0.8	1.4 ± 0.3	2.6 ± 0.8
Q4 (20.5 ± 1.8)	11.1 ± 6.3**	5.0 ± 3.0	1.1 ± 0.5*	4.8 ± 0.8	1.4 ± 0.4	2.8 ± 0.8

Note. TG = triacylglycerols; TC = cholesterol; HDL-C = high-density cholesterol; LDL = low-density cholesterol.
[a]For abbreviations see Table 1.
*$p < .003$. **$p < .04$.

in visceral fat accompanied by small changes in subcutaneous fat depots. In consequence, even minor changes in total body fat do not exclude a positive health effect of physical activity. On the contrary, it has been postulated that increased visceral fat depots and its adverse metabolic effects are due to physical inactivity, and it might be a case in our inactive subjects (Belavý et al., 2014).

The analysis of metabolic variables in both groups with respect to quartiles of percentage of body fat strengthens our hypothesis concerning the sequence of metabolic events in response to physical activity. In active students with body fat at upper quartile substantial difference was observed exclusively in plasma insulin levels, higher by 28% than in active students with body fat at lower quartile. On the contrary, in inactive students, body fat at upper quartile markedly affected circulating insulin and TG (by 25% and by 37.5%, respectively) with slight tendency to higher circulating TC.

Thus, it seems that an inverse relationship between insulin and body composition is a physiological phenomenon possibly due to physiological secretory activity of adipose tissue. It is well documented that adipokines (e.g., adiponectin and leptin) and adipocytokines (e.g., TNF-α and IL-6) have the potential to affect insulin sensitivity (Ghadge & Khaire, 2019). In contrast, elevation in circulating TG seems to be secondary to the changes in adiposity and circulating insulin. The elevation in plasma cholesterol follows changes in adiposity, circulating insulin, and TG. This suggestion is in agreement with other findings concerning pronounced role of TG and insulin in the risk of CVD (Yao et al., 2020).

Summing up, it could be postulated that not only in obese people but also in individuals qualified as lean physical activity exerts a positive effect on metabolic risk factors. It seems feasible that the associations between body fat and plasma levels of insulin are simply a natural consequence of adipose tissue secretary activity. In contrast, changes in plasma levels of TG are induced by much higher body fat content and insulin levels and are observed before any disturbances in TC and its fractions are noted.

Another interesting observation from this study was that active people had a lower body fat content, although they did not differ in energy intake from their inactive counterparts. It can be assumed that the explanation for this difference was the higher energy expenditure in the group of physically active men. But, it cannot be ruled out that some of our participants underreported daily food intakes. Other authors, who observed underreporting in young people, explain it with a disturbed body image in young adults striving to achieve a currently fashionable, very thin body (Rennie et al., 2005). It has also been shown that underreporting is more common in subjects with higher body fat (Klingberg et al., 2008). This could

explain the tendency for lower energy intake among inactive participants of our study. Therefore, when considering the relationship between lifestyle and metabolic profile, we focused on the results of measuring body composition, treating it as a better indicator of nutritional status than self-reported dietary intake.

It should be pointed out that our study has several limitations. First of all, it was a cross-sectional study which does not provide information concerning case-effect relationship. Furthermore, it focused exclusively on male subjects. Our subjects consumed a specific diet with an excess of protein and saturated fat and with inadequate intake of carbohydrates which is known to adversely affect both insulin sensitivity and lipid and lipoprotein metabolism. On the contrary, we suppose that studies with healthy, young individuals provide more information about physiological processes than that with obese ones with metabolism markedly and adversely affected by excessive adiposity.

Declaration of Conflicting Interests

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