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# Dose-response association between physical activity and metabolic syndrome

**Research Article**

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**Abstract:** Aim. Study was aimed to examine the association between the level of physical activity and metabolic syndrome and it's components in Lithuanian urban population. Methods. Data from the survey of the HAPIEE (Health, Alcohol, and Psychosocial factors In Eastern Europe) study were presented. A random sample of 7115 individuals aged 45-72 years was screened in 2006-2008. Physical activity was assessed in hours of physically demanding activities and sports in a typical week. The diagnostic criteria for the metabolic syndrome were determined by National Cholesterol Education Program Adult Treatment Panel report. Results. Prevalence of the metabolic syndrome was 27.2% in men and 34.2 in women. In the highest physical activity level prevalence of the metabolic syndrome decreased from 33.3% to 24.5% in men and from 38.6% to 32.9% in women as compared to the lowest physical activity level ($p<0.01$). The multivariable adjusted odds ratios for the metabolic syndrome in the 1st, 2nd, 3rd and 4th physical activity quartiles were 1.00, 0.68, 0.69, 0.51 in men ($p<0.0001$) and 1.00, 0.76, 0.78, 0.75 in women ($p=0.001$). Conclusions. Physical activity has a significant protective role on metabolic disorders. Adequate leisure-time physical activity is an important non-pharmacological and low-cost alternative in preventing the metabolic syndrome.

**Keywords:** *Physical activity • Lifestyle • Metabolic syndrome • Population*



## 1. Introduction

Modern humans live in an environment that provides much comfort but is designed to eliminate moving. Lack of exercise and sedentary work in industrialized countries has become more and more common. Over the past 5 decades, a substantial accumulation of epidemiological and experimental data has established a causal relationship between low levels of leisure-time physical activity (LTPA) and an increased risk of cardiovascular disease (CVD) [1]. The metabolic syndrome (MS) is a cluster of metabolic abnormalities including abdominal obesity, glucose intolerance, arterial hypertension, and dyslipidemia [2]. It has been demonstrated that individuals with MS are at increased risk of cardiovascular events, as well as diabetes [3,4]. The pathogenesis of the syndrome is complex and so far incompletely understood, but the interaction of obesity, sedentary lifestyle, dietary and genetic factors are known to contribute to

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its development [5,6]. It is well known that physical activity (PA) has a protective role in the morbidity and mortality from cardiovascular disease (CVD) mainly through its positive impact on the risk factors, such as increased body weight, high blood pressure, glucose intolerance, and abnormal blood lipids profile. Studies among different ethnic groups have shown an inverse dose – response relationship between LTPA and prevalence of the MS [7,8]. What is less clear is the shape of the dose-response relation between PA and metabolic disorders. Investigations with more than two levels of PA compared still receive high attention of epidemiologists. Prevalence of the MS in Lithuanian population is high and increases with age, especially in women [9,10]. In Lithuania the mortality from CVD remains one of the highest in Europe and is the first in deaths structure. According to 2010 data, only 28% of Lithuanian adult men and 29% of women achieved the WHO recommended PA level during leisure time [11]. Also there is a lack of population-based PA studies in Lithuania and insufficient attention is paid to PA promotion [12]. Thus the aim of this study was to examine the association between the level of LTPA and presence of the MS and it's components in a cross-sectional population-based study.

# 2. Methods

## 2.1. Study sample

Data from the survey performed in the framework of the international Health, Alcohol and Psychosocial factors In Eastern Europe (HAPIEE) study are presented. A random sample of 10940 Kaunas city men and women aged 45–72 years, stratified by gender and age was randomly selected from the Lithuanian population register; 7115 responders (3236 men and 3879 women) participated in this health survey and were screened from 2006 to 2008. The response rate was 64.8%. The study was approved by the ethics committee at the University College London, UK and by the regional ethics committee at Kaunas University of Medicine (Lithuania).

## 2.2. Lifestyle habits

Lifestyle habits were evaluated using frequency questionnaire. The standard questionnaire included questions regarding the respondent's age, perceived health, education, smoking and alcohol consumption habits, dietary patterns. Smoking habits were assessed according to a current smoking status. A subject who smoked at least one cigarette per day was classified as a current smoker. According to frequency of alcohol consumption, subjects were assigned to one of the three categories: 1 – less than once a month / never; 2 – several times a month; 3 – once a week and more often.

## 2.3. Dietary assessment

Nutrition habits were evaluated using semi-quantitative food frequency questionnaire. Twenty food groups were included into the food frequency questionnaire. Using the exploratory factor analysis method dietary patterns were described by the five factors (1 – fresh vegetables, fruit; 2 – sweets; 3 – cereals, curd cheese; 4 – potatoes, meat, boiled vegetables, eggs; 5 – chicken, fish). According to each of the five dietary habits all the responders were pooled into two groups of positive and negative factor scores. Positive value of each dietary pattern factor score indicated more frequent than average consumption of a particular food group [13].

## 2.4. Physical activity

LTPA was assessed by the interview method using short questionnaire, asking about physically demanding activities, such as housework, gardening, and maintenance of the house also engagement in sports, games or hiking in a typical week on summer and winter seasons. LTPA was measured by hours a week. Before the analysis, the averages of actively spent hours in summer and winter were calculated and all the responders according to LTPA were divided into four equal groups (quartiles), separately men and women: the 1$^{st}$ quartile (inactive and least active): ≤8.5 hours/week for men and ≤12.0 hours/week for women; the 2$^{nd}$ quartile 8.6-15.0 hours a week for men and 12.1-17.5 hours/week for women; 3$^{rd}$ quartile 15.1-23.0 hours/week for men and 17.6-25.5 hours/week for women; the 4$^{th}$ quartile (the most active) >23.0 hours/week for men and >25.5 hours/week for women.

# 3. Measurements

Blood pressure was measured three times with an osicillometric device (Omron M5-I), and the average values were used for the analysis. Specially trained nurses measured waist circumference by a standard meter (with an accuracy of 0.5 cm); height (with an accuracy of 0.5 cm) and weight (with an accuracy of 0.5 kg). The responders were classified in three body mass index (BMI) categories: 18.5 to 24.9 kg/m$^2$ (normal weight), 25.0 to 29.9 kg/m$^2$ (overweight), and ≥30 kg/m$^2$ (obese). 7 persons with the underweight (BMI <18.5 kg/m$^2$) were excluded from the further analysis. Biochemical analyses for glucose and lipids were done for responders (fasting for at least 12 h) on an empty stomach. Concentration of glucose in capillary blood was determined by an individual glucometer "Glucotrend". Lipid concentrations in serum were measured on a Roche COBAS MIRA autoanalyser, using a conventional enzymatic method with reagents from Boehringer Mannheim Diagnostics and Hoffman-La Roche.

## 4. Metabolic syndrome definition

The diagnostic criteria for the MS were determined by National Cholesterol Education Program Adult Treatment Panel 3rd report criteria: fasting plasma glucose ≥6.1 mmol/L, waist circumference ≥102 cm (men) and ≥88 cm (women), blood pressure ≥130/85 mm Hg, triglycerides ≥1.7 mmol/L, high-density lipoprotein cholesterol <1.0 mmol/L (men) and <1.3 mmol/L (women). The MS was defined as a combination of 3 and more metabolic abnormalities mentioned above [14]. Definition of the MS was chosen respectively to the results of our previous research: CVD risk was higher in subjects with the MS, defined by NCEP-ATP III definition [10].

## 5. Statistical analysis

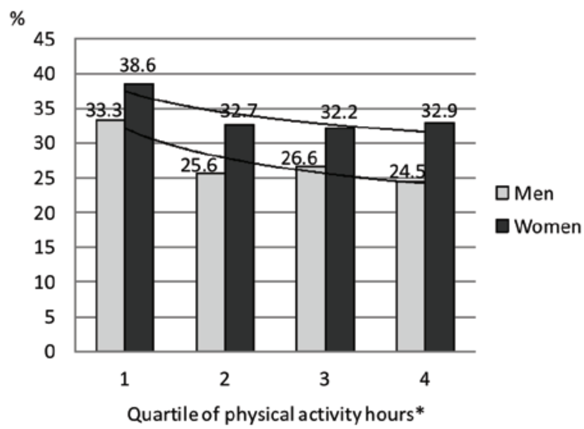
According to LTPA differences in men and women populations all the analyses were performed separately. The direct method was used for age standardization of prevalence of the MS among men and women using European population as a standard [15]. Firstly, *chi square* tests were used to compare the prevalence of categorical variables between subjects with different levels of LTPA. Secondly, the binary logistic regression models were employed to estimate the effect of different levels of LTPA on the odds of MS and its components. First the analyses were performed adjusting for age and education, and then further for age, education and perceived health status. The last model was adjusted for all the confounders adding lifestyle habits: diet, smoking and alcohol consumption. P value <0.05 was considered as statistically significant. SPSS for Windows 19.0 was used for statistical analysis.

## 6. Results

General characteristics of the study population according to LTPA level are given in Tables 1 and 2. In the oldest age group (≥65) the highest proportion of the responders were the most physically active (51.4% of men and 37.9% of women). Education and LTPA level were not statistically significantly associated (p=0.05). Body mass index was related to LTPA level among men but not among women. Prevalence of current smoking was lower in the highest LTPA level as compared to the lowest (21.7 and 34.6% among men; 6.1 and 34.6% among women; p<0.0001). 35.5% of men and 23.8% of women in the highest LTPA level rated their health as very good and good and this proportion was higher as compared to the lowest LTPA quartile (27.0 and 19.1%, respectively, p<0.0001). More frequent alcohol consumption was observed in women in the highest LTPA level as compared to the lowest. Central obesity and elevated blood glucose level were less prevalent in higher LTPA quartiles (p<0.001). Men in the highest level of LTPA demonstrated less prevalent decreased HDL-cholesterol level (p<0.0001). Physically active people tend to choose a healthier diet: more frequent consumption of fresh fruit and vegetables, cereals and curd cheese (p<0.01). Men n the highest LTPA quartile were consuming more meet products, potatoes and eggs as compared to the men in the lowest LTPA (p=0.03). Summarizing study sample general characteristics we can assert that higher level of LTPA was related to healthier lifestyle habits and better perceived health (Table 1 and Table 2).

Prevalence of the MS in middle- and older-aged Lithuanian population was high, especially in women: 27.2% in men and 34.2% in women (*chi square* 76.5, df = 1, p<0.0001). With each increasing LTPA quartile prevalence of the MS decreased: from 33.3% to 24.5%

**Figure 1.** Prevalence of the metabolic syndrome according to the NCEP-ATP3 criteria in leisure-time physical activity quartiles among men and women[1]




** higher LTPA quartile indicates higher physical activity level;*
*[1]age standardized.*

*LTPA – leisure-time physical activity; NCEP-ATP3 – metabolic syndrome, diagnosed by National Cholesterol Education Program Adult Treatment Panel 3rd report criteria.*
*The relationship between LTPA level and presence of metabolic syndrome: men chi square 35.3, df = 3, p<0.0001; women chi square 16.1, df = 3, p = 0.001.*

**Table 1.** Characteristics according to leisure-time physical activity level in middle- and older-aged men

| Characteristics: n (%) | | Quartile of leisure-time physical activity* 1st | 2nd | 3rd | 4th | χ2 (p) |
|---|---|---|---|---|---|---|
| **Age group:** | | | | | | |
| 45-54 | | 219 (26.8) | 232 (27.4) | 176 (23.3) | 149 (18.9) | 112.9 (<0.0001) |
| 55-64 | | 344 (42.1) | 373 (44.0) | 326 (43.1) | 234 (29.7) | |
| ≥65 | | 255 (31.1) | 242 (28.6) | 254 (33.6) | 404 (51.4) | |
| **Education**: | | | | | | |
| primary, secondary, vocationally | | 431 (52.7) | 397 (46.9) | 347 (45.9) | 373 (47.4) | 12.6 (0.05) |
| college | | 125 (15.3) | 152 (17.9) | 157 (20.8) | 146 (18.5) | |
| university | | 262 (32.0) | 298 (35.2) | 252 (33.3) | 268 (34.1) | |
| **Self-rated health** | | | | | | |
| Very poor and poor | | 132 (16.2) | 85 (10.0) | 80 (10.6) | 64 (8.1) | 36.6 (<0.0001) |
| Average | | 465 (56.8) | 476 (56.2) | 417 (55.1) | 444 (56.4) | |
| Good and very good | | 221 (27.0) | 286 (33.8) | 259 (34.3) | 279 (35.5) | |
| **Smoking:** no | | 535 (65.4) | 593 (70.0) | 550 (72.8) | 616 (78.3) | 34.1 (<0.0001) |
| yes | | 283 (34.6) | 254 (30.0) | 206 (27.2) | 171 (21.7) | |
| **Alcohol consumption:** | | | | | | |
| Less than once a month / never | | 235 (28.7) | 224 (26.4) | 190 (25.1) | 242 (30.7) | 11.4 (0.08) |
| Several times a month | | 264 (32.3) | 282 (33.3) | 266 (35.2) | 276 (35.1) | |
| Once a week and more often | | 319 (39.0) | 341 (40.3) | 300 (39.7) | 269 (34.2) | |
| **Body mass index:** | | | | | | |
| 18.5-24.9 kg/m² | | 162 (19.9) | 171 (20.2) | 164 (21.8) | 201 (25.6) | 18.7 (0.005) |
| 25.0-29.9 kg/m² | | 350 (43.0) | 380 (45.0) | 324 (43.0) | 361 (46.0) | |
| ≥30.0 kg/m² | | 302 (37.1) | 294 (34.8) | 265 (35.2) | 223 (28.4) | |
| **Dietary patterns:** | | | | | | |
| Fresh vegetables, fruit | negative value | 463 (56.9) | 405 (47.9) | 351 (46.6) | 371 (47.1) | 23.0 (<0.0001) |
| | positive value# | 351 (43.1) | 441 (52.1) | 403 (53.4) | 416 (52.9) | |
| Sweets | negative value | 435 (53.4) | 415 (49.1) | 394 (52.3) | 394 (50.1) | 3.9 (0.3) |
| | positive value | 379 (46.6) | 431 (50.9) | 360 (47.7) | 393 (49.9) | |
| Cereals, curd cheese | negative value | 548 (67.3) | 551 (65.1) | 489 (64.9) | 436 (55.4) | 28.8 (<0.0001) |
| | positive value | 266 (32.7) | 295 (34.9) | 265 (35.1) | 351 (44.6) | |
| Potatoes, meat, boiled vegetables, eggs | negative value | 324 (39.8) | 330 (39.0) | 298 (39.5) | 264 (33.5) | 8.9 (0.03) |
| | positive value | 490 (60.2) | 516 (61.0) | 456 (60.5) | 523 (66.5) | |
| Chicken, fish | negative value | 363 (44.6) | 370 (43.7) | 341 (45.2) | 359 (45.6) | 0.7 (0.9) |
| | positive value | 451 (55.4) | 476 (56.3) | 413 (54.8) | 428 (54.4) | |
| **Waist circumference:** | <102 cm | 529 (64.9) | 605 (71.4) | 543 (71.9) | 598 (76.0) | 24.6 (<0.0001) |
| | ≥102 cm | 286 (35.1) | 242 (28.6) | 212 (28.1) | 189 (24.0) | |
| **Blood pressure:** | <130/85 mm Hg | 103 (12.6) | 124 (14.7) | 120 (16.0) | 127 (16.2) | 5.0 (0.2) |
| | ≥130/85 mm Hg | 712 (87.4) | 720 (85.3) | 632 (84.0) | 657 (83.8) | |
| **Blood glucose level:** | <6.1 mmol/l | 499 (61.9) | 559 (67.5) | 504 (68.8) | 561 (74.1) | 27.0 (<0.0001) |
| | ≥6.1 mmol/l | 307 (38.1) | 269 (32.5) | 229 (31.2) | 196 (25.9) | |
| **Triglycerides:** | <1.7 mmol/l | 566 (69.6) | 622 (74.0) | 556 (74.0) | 578 (74.1) | 6.0 (0.1) |
| | ≥1.7 mmol/l | 247 (30.4) | 219 (26.0) | 195 (26.0) | 202 (25.9) | |
| **HDL cholesterol:** | ≥1.0 mmol/l | 662 (83.3) | 732 (88.9) | 656 (89.1) | 692 (90.5) | 22.6 (<0.0001) |
| | <1.0 mmol/l | 133 (16.7) | 91 (11.1) | 80 (10.9) | 73 (9.5) | |

** higher LTPA quartile indicates higher physical activity level; # positive value of each dietary pattern factor score indicates more frequent than average consumption of a particular food group; HDL – high density lipoprotein.*

**Table 2.** Characteristics according to leisure-time physical activity level in middle- and older-aged women

| Characteristics: n (%) | | Quartile of leisure-time physical activity* 1st | 2nd | 3rd | 4th | χ2 (p) |
|---|---|---|---|---|---|---|
| **Age group:** | | | | | | |
| 45-54 | | 262 (25.7) | 275 (29.5) | 250 (26.0) | 216 (22.8) | 14.8 (0.02) |
| 55-64 | | 407 (39.9) | 353 (37.9) | 397 (41.4) | 371 (39.3) | |
| ≥65 | | 352 (34.4) | 304 (32.6) | 313 (32.6) | 359 (37.9) | |
| **Education:** | | | | | | |
| primary, secondary, vocationally | | 438 (42.9) | 394 (42.2) | 374 (39.0) | 269 (39.0) | 12.6 (0.05) |
| college | | 247 (24.2) | 269 (28.9) | 277 (28.9) | 257 (27.2) | |
| university | | 336 (32.9) | 269 (28.9) | 309 (32.1) | 320 (33.8) | |
| **Self-rated health** | | | | | | |
| Very poor and poor | | 262 (25.7) | 156 (16.7) | 138 (14.4) | 129 (13.6) | 71.0 (<0.0001) |
| Average | | 564 (55.2) | 608 (65.3) | 608 (63.3) | 592 (62.6) | |
| Good and very good | | 195 (19.1) | 168 (18.0) | 214 (22.3) | 225 (23.8) | |
| **Smoking:** no | | 912 (65.4) | 872 (93.6) | 890 (92.8) | 888 (93.9) | 18.5 (0.0001) |
| yes | | 109 (34.6) | 60 (6.4) | 69 (7.2) | 58 (6.1) | |
| **Alcohol consumption:** | | | | | | |
| Less than once a month / never | | 650 (63.7) | 553 (59.3) | 519 (54.1) | 543 (57.4) | 22.4 (0.001) |
| Several times a month | | 266 (26.0) | 292 (31.3) | 325 (33.9) | 297 (31.4) | |
| Once a week and more often | | 105 (10.3) | 87 (9.4) | 116 (12.0) | 106 (11.2) | |
| **Body mass index:** | | | | | | |
| 18.5-24.9 kg/m$^2$ | | 194 (19.1) | 182 (19.5) | 173 (18.1) | 180 (19.1) | 8.6 (0.2) |
| 25.0-29.9 kg/m$^2$ | | 333 (32.8) | 321 (34.5) | 356 (37.2) | 359 (38.0) | |
| ≥30.0 kg/m$^2$ | | 489 (48.1) | 428 (46.0) | 427 (44.7) | 405 (42.9) | |
| **Dietary patterns:** | | | | | | |
| Fresh vegetables, fruit | negative value | 509 (50.1) | 400 (43.0) | 397 (41.4) | 363 (38.4) | 29.9 (<0.0001) |
| | positive value# | 507 (49.9) | 531 (57.0) | 562 (58.6) | 583 (61.6) | |
| Sweets | negative value | 561 (55.2) | 510 (54.8) | 507 (52.9) | 505 (53.4) | 1.5 (0.7) |
| | positive value | 455 (44.8) | 421 (45.2) | 452 (47.1) | 441 (46.6) | |
| Cereals, curd cheese | negative value | 433 (42.6) | 353 (37.9) | 347 (36.2) | 317 (33.5) | 18.5 (0.001) |
| | positive value | 583 (57.4) | 578 (62.1) | 612 (63.8) | 629 (66.5) | |
| Potatoes, meat, boiled vegetables, eggs | negative value | 598 (58.9) | 516 (55.4) | 558 (58.2) | 505 (53.4) | 7.6 (0.055) |
| | positive value | 418 (41.1) | 415 (44.6) | 401 (41.8) | 441 (46.6) | |
| Chicken, fish | negative value | 527 (51.9) | 430 (46.2) | 477 (49.7) | 486 (51.4) | 7.5 (0.057) |
| | positive value | 489 (48.1) | 501 (53.8) | 482 (50.3) | 460 (48.6) | |
| **Waist circumference:** | <88 cm | 427 (41.9) | 446 (47.9) | 459 (47.9) | 468 (49.5) | 13.4 (0.004) |
| | ≥88 cm | 592 (58.1) | 485 (52.1) | 500 (52.1) | 478 (50.5) | |
| **Blood pressure:** | <130/85 mm Hg | 261 (25.7) | 243 (26.2) | 256 (26.8) | 226 (23.9) | 2.2 (0.5) |
| | ≥130/85 mm Hg | 753 (74.3) | 686 (73.8) | 701 (73.2) | 719 (76.1) | |
| **Blood glucose level:** | <6.1 mmol/l | 636 (63.3) | 626 (68.5) | 629 (67.6) | 647 (70.5) | 12.2 (0.007) |
| | ≥6.1 mmol/l | 369 (36.7) | 288 (31.5) | 302 (32.4) | 271 (29.5) | |
| **Triglycerides:** | <1.7 mmol/l | 705 (69.9) | 674 (72.6) | 703 (73.7) | 710 (75.4) | 7.9 (0.047) |
| | ≥1.7 mmol/l | 304 (30.1) | 255 (27.4) | 251 (26.3) | 232 (24.6) | |
| **HDL cholesterol:** | ≥1.3 mmol/l | 716 (72.3) | 703 (76.3) | 699 (74.6) | 706 (75.7) | 4.9 (0.2) |
| | <1.3 mmol/l | 275 (27.7) | 218 (23.7) | 238 (25.4) | 227 (24.3) | |

* higher LTPA quartile indicates higher physical activity level; # positive value of each dietary pattern factor score indicates more frequent than average consumption of a particular food group; HDL – high density lipoprotein.

in men and from 38.6% to 32.9% in women (p<0.01, Fig. 1).

Table 3 shows odds ratios of the MS for the different levels of LTPA. The age- and education-adjusted odds ratios for the MS in the 1st, 2nd, 3rd and 4th LTPA quartiles were 1.00, 0.67, 0.68 and 0.49 in men (p<0.0001 for trend), and 1.00, 0.76, 0.74 and 0.70 in women (p=0.001 for trend), respectively (Model 1). After further adjustments for self-rated health, smoking, alcohol intake and dietary patterns this inverse relation did not appreciably change (Models 2 and 3) (Table 3).

Multivariate-adjusted (age, education, self-rated health, smoking, alcohol intake, and dietary patterns) odds ratios for the MS components (increased waist circumference, elevated blood pressure, glucose intolerance and dyslipidemias) are shown in Table 4. Men in the highest LTPA quartile were less likely to suffer from almost all metabolic disorders as compared to men

**Table 3.** Adjusted odds ratios of the metabolic syndrome in different levels of leisure-time physical activity

| Quartile of LTPA* | Model 1 | | | Model 2 | | | Model 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | *p* value | OR | 95% CI | *p* value | OR | 95% CI | *p* value |
| **MEN** | | | | | | | | | |
| 1st | 1.00 | | | 1.00 | | | 1.00 | | |
| 2nd | 0.67 | 0.54-0.83 | <0.0001 | 0.69 | 0.56-0.86 | 0.001 | 0.68 | 0.55-0.85 | 0.001 |
| 3rd | 0.68 | 0.55-0.85 | 0.001 | 0.71 | 0.57-0.89 | 0.003 | 0.69 | 0.55-0.86 | 0.001 |
| 4th | 0.49 | 0.39-0.62 | <0.0001 | 0.53 | 0.42-0.66 | <0.0001 | 0.51 | 0.40-0.65 | <0.0001 |
| p for trend | | | <0.0001 | | | <0.0001 | | | <0.0001 |
| **WOMEN** | | | | | | | | | |
| 1st | 1.00 | | | 1.00 | | | 1.00 | | |
| 2nd | 0.76 | 0.63-0.92 | 0.005 | 0.78 | 0.64-0.94 | 0.009 | 0.76 | 0.63-0.93 | 0.007 |
| 3rd | 0.74 | 0.61-0.90 | 0.002 | 0.78 | 0.64-0.94 | 0.009 | 0.78 | 0.64-0.95 | 0.013 |
| 4th | 0.70 | 0.58-0.84 | <0.0001 | 0.74 | 0.61-0.90 | 0.002 | 0.75 | 0.61-0.91 | 0.004 |
| *p* for trend | | | 0.001 | | | 0.007 | | | 0.01 |

** higher LTPA quartile indicates higher physical activity level. LTPA – leisure-time physical activity; OR – odds ratio; CI – confidence interval. Model 1 – adjusted for age and education; model 2 – adjusted for age, education and self-rated health; model 3 – adjusted for age, education, self-rated health, dietary patterns, smoking and alcohol consumption habits.*

**Table 4.** Adjusted odds ratios[1] of the metabolic syndrome components in different levels of leisure-time physical activity

| Quartile of LTPA* | WC | | GLU | | BP | | TRIGL | | HDL-C | |
|---|---|---|---|---|---|---|---|---|---|---|
| | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI | OR | 95% CI |
| **MEN** | | | | | | | | | | |
| 1st | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| 2nd | 0.76 | 0.62-0.95 | 0.79 | 0.64-0.98 | 0.84 | 0.63-1.12 | 0.82 | 0.66-1.01 | 0.64 | 0.48-0.85 |
| 3rd | 0.72 | 0.58-0.90 | 0.73 | 0.59-0.91 | 0.73 | 0.54-0.97 | 0.81 | 0.65-1.02 | 0.63 | 0.47-0.85 |
| 4th | 0.56 | 0.45-0.70 | 0.56 | 0.45-0.70 | 0.68 | 0.51-0.92 | 0.86 | 0.69-1.08 | 0.53 | 0.39-0.73 |
| p for trend | <0.0001 | | <0.0001 | | 0.054 | | 0.21 | | <0.0001 | |
| **WOMEN** | | | | | | | | | | |
| 1st | 1.00 | | 1.00 | | 1.00 | | 1.00 | | 1.00 | |
| 2nd | 0.77 | 0.64-0.93 | 0.81 | 0.66-0.98 | 1.01 | 0.82-1.26 | 0.91 | 0.74-1.12 | 0.83 | 0.68-1.04 |
| 3rd | 0.81 | 0.67-0.98 | 0.87 | 0.72-1.06 | 1.02 | 0.83-1.26 | 0.88 | 0.72-1.08 | 0.98 | 0.79-1.21 |
| 4th | 0.73 | 0.60-0.88 | 0.76 | 0.62-0.92 | 1.11 | 0.89-1.37 | 0.78 | 0.64-0.96 | 0.90 | 0.73-1.11 |
| *p* for trend | 0.006 | | 0.034 | | 0.81 | | 0.13 | | 0.34 | |

** higher LTPA quartile indicates higher physical activity level; [1] adjusted for age, education, self-rated health, dietary patterns, smoking and alcohol consumption habits. LTPA – leisure-time physical activity; OR – odds ratio; CI – confidence interval; WC – odds of waist circumference ≥102 cm for men and ≥88 cm for women; BP – odds of blood pressure ≥130/85 mmHg; GLU – odds of fasting blood glucose ≥6.1 mmol/l; TRIGL – odds of blood triglycerides ≥1.7 mmol/l; HDL-C – odds of high density lipoprotein cholesterol <1.0 mmol/l for men and <1.3 for women.*

living sedentary life: only odds of elevated blood triglycerides level did not reach the statistical significance. The effect of LTPA on women's metabolic disorders was weaker than in men but still remain significant for central obesity (OR = 0.73, 95% PI = 0.60-0.88, p = 0.001), glucose intolerance (OR = 0.76, 95% PI = 0.62-0.92, p = 0.006), and elevated blood triglycerides in the highest LTPA level as compared to sedentary responders (OR = 0.78, 95% PI = 0.64-0.96, p = 0.019).

## 7. Discussion

To our knowledge this is the first report to investigate the association between levels of LTPA and the presence of the MS in a large population of middle- and older-aged Lithuanian adults living in an urban area. Some published studies demonstrate a high prevalence (up to 39% in men and 22% in women) of the MS in adult populations in the USA, Mexico, Finland, Hungary and GB [16-20]. In Lithuanian adult population aged 45- 72 prevalence of the MS was also high: 27.2% in men and 34.2% in women. The results emphasize the newly established picture of a global epidemic. Our analysis addressed the association of LTPA with the MS. Higher levels of LTPA were associated with a significantly reduced odds of the MS in men and women, independent of age, education, self-rated health, smoking habits, alcohol intake, and eating habits. Our findings are in agreement with the other recent studies showing inverse relationships between a clustering of metabolic variables and reported LTPA. In our study the largest decrease in metabolic abnormalities was observed comparing the lowest LTPA level with the higher ones. However, each additional physical activity reduced the odds of metabolic disorders. In Sweden in a population-based sample of 64-year-old women with impaired glucose tolerance the prevalence of the MS with respect to LTPA was assessed [21]. The results showed an inverse linear association (p<0.05) between LTPA and MS in this group. Another population-based study in Sweden of clinical healthy 58-year-old men demonstrated that almost 23% had MS according to NCEP criteria: the MS was more common in the group that spent their leisure time with sedentary activities and was less common in the group that performed regular/competitive LTPA [22]. In Finland 4,500 randomly selected men and women aged 45–74 years were grouped into three LTPA categories: low, moderate and high [23]. The results of this study confirmed that the proportion of subjects with the MS, depressive symptoms (DS) and simultaneous presence of the MS and DS increased with decreasing LTPA (p<0.001). We have also found the protective LTPA effect on separate metabolic abnormalities such as elevated blood pressure, glucose intolerance, abdominal obesity and dyslipidemias. Exercise training has been shown to decrease visceral fat accumulation, improve insulin sensitivity, increase HDL-C, decrease triglycerides (TG) levels, and decrease blood pressure independent of weight loss, although the favorable effect of PA is stronger if associated with weight loss [24]. A cohort study with 1,621 adults conducted in an urban Portuguese population has found significant inverse associations between LTPA and obesity incidence: subjects classified into the last tertile of energy expenditure, had approximately a 40% lower risk of developing the disease [25]. Despite higher energy intakes, individuals with a high PA level were significantly protected against obesity incidence, relative risks (RR) = 0.25 (0.09-0.72) and RR = 0.47(0.27-0.94), for overall and central obesity, respectively. In Finish prospective cohort study of 8,302 men and 9,139 women aged 25-64 the protective effect of PA was observed in both sexes regardless of the level of obesity: multivariate-adjusted hazards ratios of hypertension associated with light, moderate, and high PA were 1.00, 0.63, and 0.59 in men (p trend<0.001), and 1.00, 0.82, and 0.71 in women (p trend=0.005), respectively [26]. This association persisted both in subjects who were overweight and in those who were not. PA is beneficially associated with blood lipids in different populations, especially HDL cholesterol and TG [27-29]. One mechanism by which exercise is responsible for lowered TG and increased HDL cholesterol is the increased use of TG as energy during exercise. A second one by which exercise increases HDL cholesterol is through another enzyme lecithin – it is known that exercise increases its activity [30]. Most of the studies of PA and lipoproteins done so far were clinical studies of exercise training. Those studies mainly involved white men and have limited application to the general population. Cross-sectional multi-ethnic study in Netherlands investigated the relationship between PA and blood lipids: HDL cholesterol and TG [31]. In the multivariate-adjusted models, the highest total PA tertile compared to the lowest tertile was beneficially associated with HDL and TG for the African-Surinamese. No statistically significant associations appeared for total PA among the European-Dutch and Hindustani-Surinamese. The adjusted models with the PA intensity score and HDL showed beneficial associations for the European-Dutch and African-Surinamese, for TG for the European-Dutch, Hindustani-Surinamese and African-Surinamese. Excepting HDL in African-Surinamese, the PA duration score was unrelated to HDL and TG in any group. As a major limitation of these findings authors indicated possible influence of diet on blood lipids that could play a role in the multi-ethnic study population and was not involved into the study. According to Finnish Diabetes Prevention Study results (a cohort of 486 middle-aged overweight men and women with impaired glucose tolerance were followed for an average of 4.1 years) the increase in total LTPA was associated with a decrease in the prevalence of hyperglycemia, low HDL cholesterol, and hypertriglyceridemia [18]. Increased moderate-to-vigorous LTPA decreased the prevalence of elevated fasting glucose, but no association with abdominal obesity, low HDL cholesterol, and high blood pressure was found.

Conclusion. The main results of this study showed that the prevalence of the MS was evidently higher in participants with lower LTPA compared with participants with higher LTPA. Furthermore, LTPA level was associated with life-style risk factors and perceived health status, outlining the importance of LTPA as part of the general health promotion. Future research should examine the prospective relationships between LTPA and the MS for better understanding the nature of the relationship found here.

## 8. Strengths and limitations of the study

It is the first study in Lithuania which aim was to compare performance of not only LTPA level on the MS defined by classical definition but also on its separate components and discuss plausible mechanisms between exercise and metabolism. In our study, analysis of the impact of LTPA on the MS was performed using binary logistic regression in separate multi-adjusted models. We had a considerable number of middle- and older-aged participants and a vast collection of potential confounders for adjustments. Also, according to the presence of interaction between gender and MS all the analyses were performed separately for men and women.

Our research has few limitations. First, the cross-sectional study design cannot assure time consequence between the risk factor (physical inactivity) and the disease. Definitely, long-term observational studies are needed to confirm the dose-response relationship between LTPA and metabolic disorders. Second, in our study LTPA was only self-reported and none specialized PA questionnaire was used. The intensity or type of LTPA was not taken into account and energy expenditures could not be calculated. And finally, we cannot assert that the study population of Kaunas city is perfectly representative of the general urban population of Lithuania.

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