

Does Physical Activity Lower the Risk for Metabolic Syndrome: A Longitudinal Study of Physically Active Elderly Women

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Abstract

Background: There are few studies assessing the health of older women with respect to their physical activity. This study sought to determine whether changes in the physical activity of 59 women aged 60+ measured seven years apart and the risk of the participants developing the metabolic syndrome (MetS) were related to each other.

Methods: The physical activity of the participants was measured using the accelerometers in 2009 and 2016. Their risk for the MetS was assessed as per the NCEP-ATP III criteria.

Results: The number of steps the participants took daily increased between 2009 and 2016 from $10.944 \pm 3,560$ to 11.652 ± 4865 . Women who maintained a high level of physical activity between the measurements, or increased it, had a significantly higher mean concentration of high-density cholesterol in 2016 (80.3 vs. 64.5 mg/dL and 79.2 vs. 66.9mg/dL, respectively). In the latter, a lower concentration of triglycerides (TG) (123.8 vs. 158.3mg/dL) was also observed. In 2016, only 7 women met 3 or more criteria for MetS compared with 24 in 2009; at the same time, the mean number of the MetS criteria met by a participant fell from 2.2 ± 1.4 to 1.4 ± 1.0 .

Conclusions: The number of MetS criteria that the participants met in 2016 was lower than in 2007, probably due to the high number of steps taken daily. Therefore, their risk of developing cardiovascular diseases was lower too.

Background

The concomitance of high blood pressure, hyperglycemia, central obesity, and elevated cholesterol or triglyceride levels known as the metabolic syndrome (MetS) is indicated as one of the major socioeconomic problems faced by the contemporary world [1]. Research shows that MetS increases the risk of type 2 diabetes mellitus and cardiovascular diseases, and its components are counted among the main causes of death worldwide [2]. An early and accurate diagnosis of MetS enabling the application of effective therapies can therefore be very instrumental in protecting the health and well-being of populations [1], particularly the elderly and women. The available reports show that the risk for MetS increases with age and that women are more likely than men to develop it [3].

There is a growing body of evidence that the risk of developing MetS can be reduced by physical activity [4]. While most authors point to moderate-to-vigorous exercise as being much more effective [5] than light-intensity exercise [4], there is general consent that all attempts to quit a sedentary lifestyle can help prevent the development of MetS [6].

Older people who are the most sedentary within the population [7] and develop MetS the most often [3, 8], are recommended to choose moderate-to-higher intensity exercise such as walking. As a low-impact and affordable form of exercise requiring neither special skills nor equipment (9), walking is very well suited to the needs and physical capabilities of older people. It is also has the advantage over other sports and

recreational activities that it can be easily included into one's daily activities and practiced into very old age [9]. It is also of importance that the increasing availability of step-counting technology makes it possible for people to monitor and regulate their daily physical activity [10].

The authors of a recent systematic review found that all reports they had analyzed pointed to an inverse relationship between the number of steps taken daily and the presence of MetS [4]. In the case of the middle-aged and older adults, it is recommended that they take 10.000 steps per day to prevent the development of MetS [11–14].

Strong associations between the daily number of steps and the risk of MetS development are mostly reported by the authors of cross-sectional studies [15]. Relatively few longitudinal studies have so far been undertaken to determine relationships between the physical activity the elderly and age and their risk of MetS [16].

Given the above, this study set out to assess association between physical activity and a risk of MetS in a group of women aged 60+ with elevated body mass index (BMI), a high percentage of body fat (PBF), and visceral fat accumulation (VFA).

Methods

Design and participants

One hundred and six physically active women aged 60+, the participants of a program run at the University of Third Age (U3A), volunteered to be screened for the study. Of those, 51 failed to meet the study inclusion criteria which required the participants to be able to walk without a prosthetic aid, to not use medications for metabolic disorders, to not smoke cigarettes, and to submitting a participation consent form. Therefore, the 2009 study group consisted of 89 women.

The analysis of participants' physical activity and biochemical parameters was conducted in 2009 and 2016. The 2016 study group was smaller (59 women) because 2 participants died, 7 could not be located, 5 could not be reached for other reasons, and 12 refused to participate in the study again.

The mean age of women assessed in 2016 was 62.9 ± 4.3 years. Twenty-one of them (35.6%) were university graduates, 29 (59.2%) had secondary education, and 9 (15.2%) had basic vocational education. The participant questionnaires completed in 2016 showed that the women did not had change their dietary habits, start smoking cigarettes, or receive treatment for metabolic disorders between the measurements.

The research protocols of studies conducted in 2009 and 2016 were approved by the Ethics Commission at The Jerzy Kukuczka Academy of Physical Education (resolution no. 3/2009).

Biochemical and anthropometric measurements

Between 8:00 and 10:00 a.m., fasting blood samples were taken from participants and their systolic / diastolic blood pressure (SDP and DBP, respectively) was measured using a standard mercury *sphygmomanometer*. *The results of two measurements taken at an interval of 15 minutes were averaged for analysis.* The serum concentrations of glucose, high-density lipoprotein cholesterol (HDL-C), and serum triglycerides (TG) were determined using enzymatic assays and the commercially available diagnostic kits (Randox UK, cat. no. GL 2623, CH 200, CH 203, TR 1697). Serum was separated in the usual manner and analyzed immediately or kept frozen at -80°C until analyzed.

Waist circumference (WC) was determined to *the nearest* 0.5 cm using an anthropometric tape at midway between the lowest rib and the iliac crest in a standing position. PBF and VFA at the umbilical level were determined using an InBody 720 analyzer [L₄-L₅] [17, 18] as per the manufacturer's instructions (Biospace Co., Ltd., Seoul, Korea).

The presence of MetS was determined in line with the NCEP/ATP III revised guidelines [19]. According to the guidelines, MetS occurs when three or more of the following criteria are met: (1) WC ≥ 88 cm; (2) TG ≥ 150 mg/dl; 3) HDL-C < 50 mg/dL; 4) systolic blood pressure (SBP) ≥ 130 mm Hg and diastolic blood pressure (DBP) ≥ 85 mm Hg; 5) fasting glucose level ≥ 100 mg/dl.

Physical activity assessment

In both 2009 and 2016, participants' physical activity (PA) was measured using the accelerometers (ActiGraph GT1M, Manufacturing Technology Inc., FL, USA) after their PBF and VFA were determined. The accelerometers were worn by the participants in the small pockets of the elastic belts positioned near the right iliac crest at least 12h each day over a period of 8 days and were only removed for water exercises and before bedtime. The first day's readings were excluded from analysis to be sure that the potential reactivity of participants did not compromise the reliability of measurements [20]. All participants were instructed to record before going to bed the duration and type of each physical activity they performed during the day (e.g. sitting and watching TV, using the computer, sitting at school, commuting).

The time sampling interval of the accelerometers was set at 1 min, an epoch commonly used to measure free-living physical activity (PA) and in epidemiological research [20], and the step mode was activated. The accelerometers' readings were processed in ActiLife v6.13.1 (Pensacola, FL, USA).

Data and statistical analysis

The statistical analysis of the data was performed in STATISTICA 12.5 (StatSoft, USA). The descriptive statistics below represent means and their 95% confidence intervals.

The data subjected to statistical analysis were the numbers and percentages of women who met, or did not meet, the diagnostic criteria for each MetS component in 2009 and 2016, as well as their daily

numbers of steps as a measure of physical activity [21–24].

In order to divide women aged <65 and ≥65 years into physically high active and physically low active, the threshold values of 10.000 and 9.000 steps per day, respectively, were used. The first number was adopted from Bassett et al. [15], Freak-Poli et al. [25], Harris et al. [26], Tudor-Locke et al. [27] who recommend that adults take at least 10.000 steps per day to stay healthy. For women aged 65+, it was lowered to account for the likely effect of their age on their activity.

Using the number of steps the participants took each day, they were divided into four physical activity groups. Women in the LL group (low-low) were below the recommended activity thresholds in both 2009 and 2016. Women in the HL group (high-low) reached their activity thresholds in 2009 and those in the LH group (low-high) in 2016. The HH group (high-high) included women who reached or exceeded their activity thresholds in both 2009 and 2016.

Differences between participants' anthropometric parameters, MetS components, and physical activity levels measured in 2009 and 2016, as well as between-group differences in the number of steps, were assessed for statistical significance using a paired t-test. The longitudinal changes in MetS components (the effect of time, TE), the between-group differences in MetS components (the effect of physical activity, PAE), and the associations between the groups' physical activity and changes in MetS components (the interaction effect, INT) were assessed by a multivariate repeated-measures ANOVA (MANOVA). The effect size was determined by calculating eta squared (η^2) as per the following formula: $\eta^2 = \text{SS effect} / \text{SS total}$, where SS effect is the sum of squares for a given effect and SS total is the total of squares for all effects, interactions, and errors [28]. The 95% confidence intervals calculated for individual MetS components were also analyzed [29, 30].

Results

Participants' anthropometric parameters, risk of MetS, and PA changed statistically significantly between 2009 and 2016 (Table 1). Their BMI was higher after seven years, but the risk of MetS decreased from 39 to 12%, and the number of women meeting 3 or more criteria for MetS fell by 35.6%. Decreases were also noted in the concentrations of HDL-C and TG, which are MetS risk factors.

The means of the MetS components calculated for all participants were within the normal ranges in both 2009 and 2016, contrasting with the elevated mean values of their VFA and PBF (table 1).

Fig. 1 and Table 2 show that between 2009 and 2016, the number of women who met the criteria for MetS decreased from 24 to 7. The 2016 numbers of participants with elevated TG and BP concentrations and WC ≥ 88cm were lower by 50%, 32.5%, and 36.1%, respectively, but the number of women with raised fasting glucose (< 100 mg/dL) increased by 23%. The number of participants with normal HDL-C increased between measurements by as much as 58.6% (34 vs. 58).

The mean daily number of steps taken by participants in 2016 was higher than in 2009 by 6.5% (10.944 vs. 11.652 steps), because women aged < 65 increased their physical activity more than enough (from 11.596 to 12.847 steps; 10.8%) to compensate for reduced physical activity among women aged \geq 65 years (9.673 vs. 9.322 steps; 3.3%).

Table 3 shows changes in the physical activity of the study groups between 2009 and 2016. Groups LH and HH increased physical activity statistically significantly ($p=0.002$ and $p=0.04$, respectively) while the physical activity of the HL group decreased significantly ($p=0.012$). As for women in the LL group, the change in their physical activity proved negative and non-significant.

Changes in PA volumes and the risk for MetS

According to MANOVA (Fig. 2a-f), the effect of time (TE) was significant for the concentrations of HDL-C ($F=15.789$, $p<0.001$), TG ($F=17.182$, $p<0.0001$) and fasting glucose ($F=19.309$, $p<0.0001$), but not for SBP, DBP, and WC. In 2016, the HH group and the LH group had significantly higher concentrations of HDL-C than in 2009 (64.5 mg/dL [CI: 58.8, 70.2] vs. 80.3 [CI: 73.2, 87.3] and 66.9 [CI: 55.2., 78.6] vs. 79.2 [CI: 73.2, 87.3], respectively). Moreover, the LH group had a significantly lower concentration of TG (158.3 mg/dL [CI: 105.4, 211.2] vs. 123.8 mg/dL [CI: 82.3, 165.4]). TG decreases in the other three groups were not significant.

All groups had higher levels of fasting glucose in 2016, but significant changes were noted only in the HH group (87.6 mg/dL [CI: 81.9, 90.3] vs. 95.8 mg/dL [CI: 99.9, 100.8]) and the LL group (94.3 mg/dL [CI: 86.0, 102.7] vs. 107.3 mg/dL [CI: 94.3, 120.3]). The fasting glucose level in the HH group was <100 mg/dL in both 2009 and 2016.

WC was the only of the five MetS components that was associated with the levels of participants' physical activity ($F=5.392$, $p=0.003$). In 2009, the HH, LH, and HL groups had smaller mean WC than the LL group. After seven years, it was still smaller in the groups that had maintained or increased physical activity (HH and LL), but in the HL group it increased and was similar to the LL group's WC.

Discussion

Overweight and obesity may lead to metabolic syndrome that doubles the risk of developing cardiovascular disease (CVD) after menopause [31–33]. According to many studies, the risk can be reduced by physical activity and exercise as they improve atherogenic dyslipidemia, blood pressure, body composition, insulin sensitivity, and fat metabolism [34–35].

In our study, we recruited a group of elderly women and compared the numbers of steps they took daily in 2009 and 2016 to see whether changes in their physical activity and their risk of MetS were related to each other.

The average daily number of steps taken by the study participants increased between the measurements from 10.944 to 11.652 steps. The minimum number of steps recorded in 2016 was lower than in 2009 by 1.808 (4.905 vs. 3.097), but their maximum number rose by 2.580 (from 19.958 to 22.538), challenging the widespread opinion that ageing people tend to become physically less active, or choose a sedentary lifestyle.

The participants had higher mean PBF and BMI in 2016, but mean WC, one of MetS components, did not change significantly and still was in the normal range (<88cm²). VFA, which is an independent risk factor for many metabolic diseases [36–41], was 133.3 cm² in 2009, significantly exceeding the healthy limit of 100 cm². Its 2016 value of 131 cm² was an interesting finding, because WC, especially women's, tends to increase with age. A smaller number of women who met the MetS criteria in 2016 indicated a lower risk of developing MetS in the group.

The mean fasting glucose concentration increased in the group between 2009 and 2016 by 9.4%, but in both years it was in the reference range of 70-115 mg/dl (90 mg/dL and 98.8 mg/dL, respectively). This may have been due to participants' high physical activity improving their insulin sensitivity and glycemic control [42].

The results of cross-sectional studies conducted in the last several decades are similar in showing that physical activity and exercise have the potential to reduce lipid and lipoprotein concentrations [43]. Physically active individuals are reported to have lower concentrations of lipids and lipoproteins than sedentary people, which makes them less susceptible to cardiovascular diseases.

There is also solid evidence that as well as increasing the concentration of HDL-C exercising also reduces the concentration of triglycerides. According to the authors of cross-sectional and longitudinal studies, 15-20 miles of weekly jogging or brisk walking (involving energy expenditure of 1.200-2.200 kcals) can reduce the concentration of TG by 5 to 38 mg/dL while increasing HDL-C by 2 to 8 mg/dL [44]. In our study, the concentration of HDL-C increased between the measurements and the concentration of TG decreased. More pronounced changes were recorded in the groups that in 2016 were equally or more active physically than in 2009.

The observed stimulus-response relationship between physical activity and health indicates that 'more is healthier'. Therefore, elderly adults who already meet the physical activity guidelines may have additional health benefits from exercising more [45]. The findings of our study suggest that one of the benefits can be a lower risk of MetS at older age.

Limitations

The limitations of the study are twofold. Firstly, the relatively small number of participants impedes the generalization of its results and reduces the power of statistical testing. Secondly, the analysis omits the participants' dietary information, which was unavailable. Despite these limitations, the study provides an

interesting insight into associations between changes in physical activity and the risk of MetS of the same group of elderly women.

Conclusion

The paper presents the results of a longitudinal study that aimed to determine whether changes in the physical activity of elderly women and their risk of developing MetS are related to each other. Physical activity measurements were carried out seven years apart, in 2009 and 2016.

It has been found that in 2016 most women participating in the study took as many or more steps per day compared with 2009. As none of them was treated for metabolic disorders between the measurements, their lower risk of MetS seems to be best explained by their physical activity. This result needs to be interpreted with some caution because of the aforementioned limitations of the study. In order to validate it, a larger group of subjects and their dietary intake should be examined in future research.

Abbreviations

MetS – metabolic syndrome

HDL-C – high-density cholesterol

TG – triglycerides

VFA – visceral fat accumulation

BMI – body mass index

PBF – percent body fat

BP – blood pressure

DBP – diastolic blood pressure

SDP – systolic blood pressure

WC – waist circumference

PA – physical activity

95% CI – confidence interval

TE - the effect of time,

PAE - the effect of physical activity,

INT - the interaction effect,

TE – the effect of time

LL – low physical activity in 2009 and 2016

HL – high physical activity in 2009 and low in 2016

LH – low physical activity in 2009 and high in 2016

HH – high physical activity in 2009 and 2016

Declarations

Ethics approval:

The protocol was approved by the Ethics Committees at the Jerzy Kukuczka Academy of Physical Education, Poland, and the Palacký University in Olomouc, the Czech R.

Consent to participate:

All participants agreed in writing to participate in the study. The consent forms are in possession of the authors and can be made available upon request.

Consent to publish:

Not applicable

Availability of data and materials:

The study data are available from the corresponding author upon request

Competing interest:

The authors declare no competing interests.

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Authors' contributions:

Izabela Zając-Gawlak – study design and supervision, data collection and analysis, manuscript writing and proofreading; Jana Pelclová – study design and data analysis; Dorota Groffik – study design and proofreading of the manuscript; Miroslava Pridalová – data collection and manuscript proofreading; Agnieszka Nawrat-Szołtyśik – data collection and manuscript proofreading; Aleksandra Kroemeke – data analysis and manuscript proofreading; Aleš Gába – data collection and manuscript proofreading; Ewa Sadowska-Krępa – biochemical blood tests, analysis of their results, and manuscript proofreading.

The final version of the manuscript and its publication were unanimously approved.

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Figures

Image not available with this version

Figure 1

The numbers of MetS criteria met by participants in 2009 and 2016 (totals and %)

Image not available with this version

Figure 2

2 a-f Changes in PA volumes and MetS components between 2009 and 2016