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# Low Levels of Physical Activity Are Associated with Increased Metabolic Syndrome Risk Factors in Korean Adults

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**Background:** Low levels of physical activity (PA) are strongly associated with the development of metabolic syndrome (MetS) and chronic diseases. However, few studies have examined this association in Koreans. The primary purpose of this study was to examine the associations between PA and MetS risks in Korean adults.
**Methods:** A total of 1,016 Korean adults (494 males and 522 females) participated in this study. PA levels were assessed using the International PA Questionnaire. MetS risk factors were determined using clinically established diagnostic criteria.
**Results:** Compared with the highest PA group, the group with the lowest level of PA was at greater risk of high triglyceride (TG) in males (odds ratio [OR], 1.87; 95% confidence interval [CI], 1.07 to 3.24) and of hemoglobin A1c ≥5.5% in females (OR, 1.75; 95% CI, 1.00 to 3.04) after adjusting for age and body mass index. Compared with subjects who met the PA guidelines, those who did not meet the guidelines were more likely to have low high density lipoprotein cholesterol in both males (OR, 1.69; 95% CI, 1.11 to 2.58), and females (OR, 1.82; 95% CI, 1.20 to 2.77). Furthermore, those who did not meet the PA guidelines were at increased risk of high TG levels in males (OR, 1.69; 95% CI, 1.23 to 2.86) and abnormal fasting glucose (OR, 1.93; 95% CI, 1.17 to 3.20) and MetS (OR, 2.10; 95% CI, 1.15 to 3.84) in females.
**Conclusion:** Increased levels of PA are significantly associated with a decreased risk of abnormal MetS components.

**Keywords:** Hemoglobin A, glycosylated; International physical activity guestionnaire; Metabolic syndrome; Physical activity

## INTRODUCTION

The prevalence of obesity has increased at an exponential rate in recent decades [1]. Obesity is strongly associated with metabolic syndrome (MetS) and comorbidities such as insulin resistance, type 2 diabetes mellitus (T2DM), cardiovascular disease, and cancer, as well as increased risks for all-cause mortality [2-4]. Consequently, prevention of obesity and MetS has become an important health issue worldwide.

A strong body of evidence suggests that independent of adiposity, low levels of physical activity (PA), or cardiorespiratory fitness are major contributors to the development of MetS and obesity-related abnormalities in adults [5-9]. Thus, participation in regular PA is strongly recommended to attenuate or prevent the risks of MetS or comorbid conditions [10,11]. The current PA guidelines from the American College of Sports

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Medicine (ACSM) recommend moderate-intensity (≥30 min/day, ≥5 days/wk) or vigorous-intensity PA (≥20 min/day, ≥3 days/wk) in combination with strength exercises 2 to 3 times/wk to promote health in adults [12]. The current PA guidelines for Korean adults are similar to ACSM's [13]. However, data from the 2009 Behavioral Risk Factor Surveillance System reported that only half of United States adults met the current PA recommendations [14]. Furthermore, only one quarter of Korean adults (25.9% of the total population; 27.7% of males and 24.1% of females) reported that they participated in moderate or vigorous PA in 2008 [13].

Some cross-sectional and longitudinal studies have suggested that increased levels of moderate to vigorous PA reduce the risk of MetS or cardiometabolic abnormalities in adults [7-9]. However, most studies addressing the relationship between PA levels and MetS risk factors or related comorbidities were performed in Western countries [7-9]. In addition, studies have reported that, given a similar body mass index (BMI) or waist circumference (WC), Caucasians have less total body fat [15] and visceral adipose tissue [16,17] and are at lower risk for T2DM [18] than Asians, thereby limiting extrapolation of those observations to Asian populations. Although a limited number of studies have shown that higher levels of leisure-time PA are associated with a reduced likelihood of MetS in Asian countries including Korea, few studies have adequately addressed the association between PA and MetS components. [19-22]. Furthermore, it is unclear if meeting the current PA recommendations is associated with MetS risk factors in Koreans. Therefore, the goal of this study was to evaluate the association between PA levels and MetS risk factors in Korean adults. This study also compared the risk of having MetS and its components in subjects who met the current PA recommendations and those who did not.

## METHODS

### Participants

The cross-sectional study was explained to Korean adults who visited the hospital in the city of Goyang for general health check-ups between November 2008 and February 2009, and those who agreed to participate and signed the consent forms were recruited for this study. Subjects were included if they were ≥18 years of age and nonmorbidly obese (BMI <40 kg/m2). However, subjects were excluded if they had psychiatric or personal disorders or chronic substance abuse. In addition, subjects who experienced excessive body weight gain or loss (±approximately 5 kg) or who required additional medical monitoring due to cardiac or cancer-associated surgery during the past three months were also excluded. A total of 1,016 (494 males, 522 females) subjects agreed to participate in the current study, and written informed consent was obtained from all subjects. The study was approved by the Ethics Review Committee of MizMedi Hospital in Seoul, Korea.

### Anthropometric measurements

Body weight (kg) and height (cm) were measured using the JENIX system (DS-102; Dong Sahn Jenix, Seoul, Korea) while subjects were wearing light-weight clothing or a hospital gown without shoes. BMI ($kg/m^2$) was calculated by dividing weight (kg) by height squared ($m^2$), and WC (cm) was measured at midway between the lowest rib and the iliac crest using a Gullick II tape with subjects in the standing position at the end of a normal expiration. Two measurements were taken from each subject and the mean value was used for the analysis. All anthropometric measurements were collected by the same individual.

### Physical activity assessment

PA levels were assessed by the International PA Questionnaire (IPAQ): short last 7 days self-administered format. The IPAQ has been used worldwide for PA surveillance and international validation has been previously reported elsewhere [23]. In addition, the reliability and validity of the IPAQ Korean version has been established [24]. The short IPAQ form is comprised of separate domain scores for walking, moderate-intensity activities, and vigorous-intensity activities, as well as sedentary behavior including work, transportation, domestic chores, gardening and leisure-time. Sedentary behavior (min/wk) was estimated as the time spent seated during an ordinary weekday and weekend. Based on self-reported frequency (day) and duration (hr) of physical activities, corresponding metabolic equivalent (MET-hr/wk) values were calculated using the following equations [23]: Walking (MET-hr/wk)=3.3×walking hours×walking days; Moderate PA (MET-hr/wk)=4.0×moderate PA hours×moderate PA days; Vigorous PA (MET-hr/wk)=8.0×vigorous PA hours×vigorous PA days; Total PA (MET-hr/wk)=sum of walking+moderate PA+vigorous PA

Then, the subjects were separated by gender and categorized into quartiles: lowest PA (<9.3/<5.5 MET-hr/wk), low PA (9.3 to 21.9/5.5 to 14.9 MET-hr/wk), moderate PA (21.9 to 43.7/

14.9 to 34.7 MET-hr/wk), or highest PA (>43.7/>34.7 MET-hr/wk). In addition, using the estimated total PA levels (expressed as min/wk) based on IPAQ measurement protocols, subjects were classified into two categories: those who met the current PA recommendations (≥150 min/wk of moderate-intensity PA or ≥60 min/wk of vigorous-intensity combined with ≥2 days/wk of strength exercises) and those who did not.

**MetS**

MetS was defined using the National Cholesterol Education Program Adult Treatment Panel III criteria [25], and criteria specific to Asian-Pacific populations were used to determine WC [26].

1) Abdominal obesity: WC ≥90 cm in male and ≥80 cm in female
2) Hypertriglyceridemia: triglyceride (TG) levels ≥150 mg/dL
3) Hyperglycemia: fasting plasma glucose levels ≥100 mg/dL
4) Low high density lipoprotein cholesterol (HDL-C): HDL-C levels <40 mg/dL in males and <50 mg/dL in females
5) Hypertension: systolic blood pressure (BP) ≥130 mm Hg or diastolic BP ≥85 mm Hg

Participants were diagnosed with MetS when at least three of the above criteria were satisfied.

**BP and blood assay**

BP was measured using standard auscultatory methods on the right upper arm while the subject was seated. All participants were asked to rest for 10 minutes in a seated position prior to the measurement. Blood samples were collected for biochemical tests after overnight fasting (>12 hours), and serum concentrations of fasting glucose, total cholesterol, TGs, HDL-C, and low density lipoprotein cholesterol were measured using an ADIVIA 1650 Chemistry system (Siemens, Tarrytown, NY, USA). Hemoglobin A1c (HbA1c) was evaluated using a HLC-723GHb (TOSOH, Siba, Japan).

**Statistical analysis**

Descriptive statistics (mean±standard deviation and percentages) for the entire sample and by gender were computed for each variables. An independent *t*-test was used to compare gender differences between subjects and PA characteristics, and the nonparametric Mann-Whitney test was performed for nonnormally distributed variables. A chi-square test was used for frequency, percentages, and moderate and vigorous PA categorical data. Logistic regression analyses were performed to assess the associations between PA levels and MetS and its components after adjusting for age and BMI. Quartiles were used for this analysis rather than the tertiles recommended by IPAQ categorical score in order to have sufficient classifications of PA levels and to balance the data distribution. A logistic regression model was also used to compare the risk of MetS and abnormal MetS components in subjects who met the current PA recommendations and those who did not, after adjusting for age and BMI. All statistical analyses were conducted using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA), and a *P* value of less than 0.05 was considered statistically significant.

## RESULTS

Metabolic and PA characteristics by gender are presented in Table 1. Males had significantly higher anthropometry and MetS components and lower HDL-C than females. In this study, males were more likely to participate in moderate or vigorous PA than females ($P<0.05$). More than 40% of males and 35% of females reported that they participate in moderate PA.

Results of the logistic regression analysis for MetS components on PA levels after adjusting for age and BMI are shown in Table 2. When examining the associations between MetS components and PA levels in males, the lowest PA group had 1.87 times greater risk of abnormally high TG levels than the highest PA group. In females, the least PA group had 1.75 times greater risk of HbA1c ≥5.5% compared to the highest PA group. Furthermore, the odds of having MetS more than doubled in the least PA group compared to the highest PA group.

Results of the logistic regression analysis for MetS components and the achievement of current PA recommendations after adjusting for age and BMI are shown in Fig. 1. Subjects who did not meet current PA recommendations were more likely to have low HDL-C for both males (odds ratio [OR], 1.69; 95% confidence interval [CI], 1.11 to 2.58) and females (OR, 1.82; 95% CI, 1.20 to 2.77) when compared with those who met the recommendations. Furthermore, males who did not meet the PA recommendations were 1.69 times more likely to have high TG levels than males who met the recommendations. Females who did not meet the PA recommendations were almost twice as likely to have abnormal fasting glucose levels (OR, 1.93; 95% CI, 1.17 to 3.20) and MetS (OR, 2.10; 95% CI, 1.15 to 3.84) compared to females who met the recommendations.

**Table 1.** Anthropometry, MetS components, and physical activity levels of the subjects

| | Total (*n*=1,016) | Males (*n*=494) | Females (*n*=522) | *P* value |
|---|---|---|---|---|
| Anthropometry | | | | |
| Age, yr | 50.3±13.8 | 51.2±13.9 | 49.4±13.6 | 0.040 |
| Height, cm | 164.0±8.3 | 170.0±5.7 | 158.2±5.9 | <0.001 |
| Weight, kg | 64.4±11.0 | 71.4±10.1 | 58.0±8.6 | <0.001 |
| BMI, kg/m$^2$ | 23.9±3.1 | 24.6±2.7 | 23.2±3.3 | <0.001 |
| SBP, mm Hg | 123.0±13.8 | 125.1±12.2 | 121.1±14.9 | <0.001 |
| DBP, mm Hg | 74.8±9.7 | 77.5±8.9 | 72.2±9.8 | <0.001 |
| WC, cm | 79.2±9.3 | 84.4±7.2 | 74.3±8.3 | <0.001 |
| HDL-C, mg/dL | 49.7±12.2 | 45.6±10.8 | 53.6±12.3 | <0.001 |
| TG, mg/dL | 130.5±85.1 | 153.6±95.7 | 109.1±67.2 | <0.001[a] |
| Glucose, mg/dL | 99.7±20.6 | 104.4±24.4 | 95.3±14.8 | <0.001 |
| HbA1c, % | 5.7±0.7 | 5.8±0.9 | 5.6±0.6 | <0.001[a] |
| MetS, *n* (%) | 248 (25.2) | 141 (29.7) | 107 (20.9) | 0.001[b] |
| Vigorous PA, min/wk | 49.2±168.4 | 59.2±189.5 | 39.6±145.2 | 0.064 |
| Participation rate, % | 19.6 | 24.3 | 15.1 | <0.001[b] |
| Moderate PA, min/wk | 117.4±305.7 | 143.5±319.4 | 92.7±290.2 | 0.008 |
| Participation rate, % | 39.8 | 44.3 | 35.4 | 0.002[b] |
| Walking, min/wk | 319.4±514.8 | 319.9±490.8 | 318.9±537.0 | 0.974 |
| Sedentary behavior, min/wk | 362.9±218.7 | 384.9±224.4 | 342.1±211.4 | 0.002 |
| Total PA, min/wk | 485.9±648.3 | 522.6±648.4 | 451.2±647.0 | 0.079 |
| Total energy expenditure, MET-hr/wk | 32.0±43.5 | 35.1±44.6 | 29.00±42.25 | 0.026 |

Values are presented as mean±standard deviation or percentages.
MetS, metabolic syndrome; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; WC, waist circumference; HDL-C, high density lipoprotein cholesterol; TG, triglyceride; HbA1c, hemoglobin A1c; PA, physical activity.
[a]*P* value according to the nonparametric Mann-Whitney test: median (interquartile range) for TG is 127.0 (94.0 to 191.8) and 93.0 (65.0 to 134.0) and for HbA1c is 5.6 (5.4 to 5.8) and 5.6 (5.3 to 5.8) in males and females, respectively, [b]*P* value according to the chi-square test (male vs. female).

## DISCUSSION

This study identified the association between PA levels and MetS components in Korean adults, and compared the risks of MetS and abnormal MetS components in subjects who met the current PA recommendation and those who did not. Consistent with previous studies [7,21,22,27,28], results of the present study suggest that subjects who participated in higher levels of PA and who met the current PA recommendations had significantly lower risks of MetS or abnormal MetS components compared to physically inactive individuals. These findings also extend the previous observation by Cho et al. [21], who demonstrated that higher leisure-time PA is significantly associated with lower prevalence of MetS after accounting for confounding factors such as age, smoking status, and alcohol consumption in Korean adults.

In the present study, the risk of abnormally high TG levels was approximately two times greater in the least PA group compared to the highest PA group in both males and females. The risk of abnormal fasting glucose and HbA1c ≥5.5% were significantly higher in the least PA group compared to the highest PA group in females, but not in males. Interestingly, these findings are contradictory to previous observations [29] demonstrating that the relative risk of abnormal postprandial glucose levels was approximately 12-fold higher in the less physically active group than the most physically active group in males, but not in females. Although further studies are required to explain these gender differences, the conflicting results may be partially explained by the difference in a heterogeneous condition (e.g., subjects without known diseases in the present study vs. subjects with T2DM) [29]. In addition, biological or pathophysiological gender differences [30] such as hormone levels or fat distribution may have also contributed to these conflicting results.

This study also showed that the risk of having MetS was greater in the least PA group and in those who did not meet the current PA recommendations, and that these relationships were somewhat stronger in females than in males. These results are consistent with previous observations by Vaughan et al. [8] who reported a stronger association between PA levels and the incidence of MetS in females than in males. Previous studies have shown that females are generally less active than males [13,14]. Thus, even a small increase in PA levels may result in a lower risk of MetS in females. Furthermore, compared to females, males are exposed to more habitual risk factors related to MetS (such as smoking or drinking) [31,32], which may also influence the study results.

Kesaniemi et al. [33] reported that engaging in the recommended levels of PA significantly decreases the risk of chronic health conditions. In agreement with this finding, the present study observed that Korean adults who met the current PA

**Table 2.** Odds ratios (ORs) for metabolic syndrome risk factors across physical activity levels

| PA levels (MET-hr/wk) | OR (95% CI) | | | | *P* value |
|---|---|---|---|---|---|
| | Least (<9.3) | Low (9.3-21.9) | Moderate (21.9-43.7) | Highest (>43.7) | |
| Male, *n* | 123 | 121 | 122 | 123 | |
| BP ≥130/85 mm Hg | 0.98 (0.57-1.69) | 1.04 (0.60-1.77) | 0.94 (0.55-1.61) | 1.00 | 0.701 |
| Glucose ≥100 mg/dL | 0.76 (0.44-1.32) | 0.81 (0.47-1.40) | 0.76 (0.44-1.31) | 1.00 | 0.132 |
| HDL-C <40 mg/dL | 1.49 (0.85-2.62) | 1.52 (0.87-2.65) | 1.12 (0.63-1.98) | 1.00 | 0.137 |
| WC ≥90 cm | 0.74 (0.33-1.70) | 0.89 (0.39-2.00) | 0.74 (0.32-1.70) | 1.00 | 0.790 |
| TG ≥150 mg/dL | 1.87 (1.07-3.24) | 1.54 (0.89-2.68) | 1.44 (0.83-2.51) | 1.00 | 0.030 |
| HbA1c ≥5.5% | 1.09 (0.60-1.96) | 0.73 (0.41-1.31) | 0.84 (0.46-1.51) | 1.00 | 0.567 |
| MetS | 1.52 (0.80-2.87) | 0.94 (0.49-1.80) | 1.14 (0.60-2.17) | 1.00 | 0.578 |
| PA levels (MET-hr/wk) | Least (<5.5) | Low (5.5-14.9) | Moderate (14.9-34.7) | Highest (>34.7) | *P* value |
| Female, *n* | 131 | 132 | 125 | 130 | |
| BP ≥130/85 mm Hg | 1.03 (0.57-1.88) | 0.74 (0.40-1.34) | 1.19 (0.66-2.15) | 1.00 | 0.366 |
| Glucose ≥100 mg/dL | 1.67 (0.93-3.00) | 0.69 (0.37-1.29) | 1.27 (0.70-2.31) | 1.00 | 0.501 |
| HDL-C <50 mg/dL | 1.20 (0.71-2.00) | 1.31 (0.79-2.18) | 1.10 (0.65-1.85) | 1.00 | 0.525 |
| WC ≥80 cm | 2.13 (0.78-5.87) | 0.54 (0.20-1.46) | 0.84 (0.30-2.41) | 1.00 | 0.997 |
| TG ≥150 mg/dL | 1.65 (0.89-3.07) | 0.88 (0.52-1.89) | 1.08 (1.01-1.16) | 1.00 | 0.191 |
| HbA1c ≥5.5% | 1.75 (1.00-3.04) | 0.77 (0.44-1.35) | 1.32 (0.75-2.32) | 1.00 | 0.816 |
| MetS | 2.08 (1.02-4.24) | 0.71 (0.34-1.49) | 0.95 (0.45-2.00) | 1.00 | 0.356 |

Adjusted for age and body mass index.
PA, physical activity; CI, confidence interval; BP, blood pressure; HDL-C, high density lipoprotein cholesterol; WC, waist circumference; TG, triglyceride; HbA1c, hemoglobin A1c; MetS, metabolic syndrome.

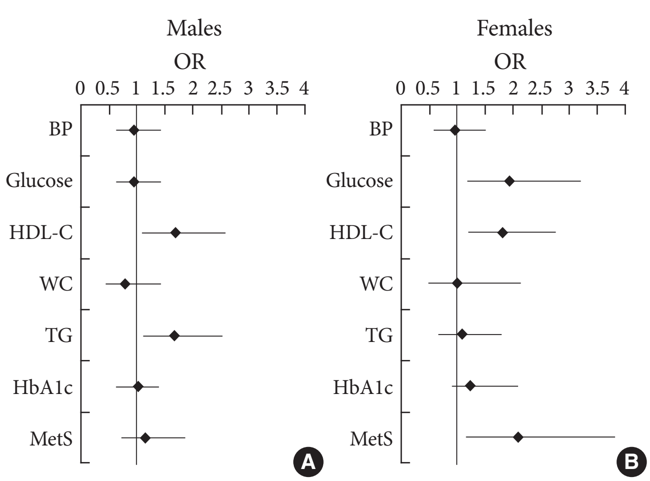


**Fig. 1.** Odd ratios (ORs) for metabolic syndrome (MetS) risk factors according to current physical activity (PA) recommendations. (A) Males. (B) Females. Adjusted for age and body mass index. Reference group: those who met the PA recommendations. BP, blood pressure; HDL-C, high density lipoprotein cholesterol; WC, waist circumference; TG, triglyceride; HbA1c, hemoglobin A1c.

recommendations were more likely to have a substantially reduced risk of developing MetS than those who did not meet the recommendations. In addition, there were higher levels of abnormal metabolic parameters and incidence of MetS in males who participated in less than 9.3 MET-hr/wk and in females who participated in less than 5.5 MET-hr/wk. This suggests that a cutoff point of at least 9.3 MET-hr/wk for males and 5.5 MET-hr/wk for females may be necessary to reduce the risk of developing MetS in Koreans. In Korea, the current PA recommendations are similar to those from U.S. health organizations (e.g., ACSM), but evidence to support these PA guidelines is lacking. Additional research is needed to examine the optimal amount of PA needed to enhance health benefits for Korean adults.

The prevalence of MetS in Korea is higher than in other Asian countries [34]. In addition, the prevalence of obesity has been increasing continuously over recent years [35]. These changes are concomitant with decreased levels of PA and increased consumption of westernized foods [36]. Although many Western countries have shown that increased PA reduces the risk factors associated with MetS or chronic diseases in adults [27,28], this hypothesis had not been tested extensively in Korean adults. Therefore, the findings presented in this study have significant public health implications for developing effective strategies to prevent MetS, as well as for developing evidence-based PA guidelines for Korean adults in the future.

This study has several limitations. First, the IPAQ was used to determine PA levels, and subjects were divided into two categories (those who met the current PA recommendations and those who did not) using IPAQ measurement protocols. However, self-reported estimates of PA levels are known to be more prone to bias and misclassification than an objective measure such as an accelerometer [37,38] Future studies should utilize more objective tools to accurately measure PA levels.

Secondly, convenience sampling was used for subject recruitment in this study, which may make the findings less applicable to the general population due to potential selection bias. In addition, given the lack of demographic data, it was not possible to control some potential confounding factors, which may have biased the study results. Further studies that control for possible confounding factors are necessary to confirm the findings of the present study. Finally, due to the cross-sectional study design, it was not possible to determine a causal relationship between PA levels and MetS or its components. Population-based longitudinal or intervention studies that include adjustments for confounding factors are necessary to explore this potentially causal relationship in Korea adults.

In conclusion, there was an inverse relationship between PA levels and MetS risk factors in Korean adults. Indeed, subjects who met the current PA guidelines had significantly lower risk of MetS than those who did not meet the recommendations. Further studies, in particular intervention studies, are needed to examine whether the current PA guidelines are sufficient for preventing MetS and enhancing the long-term health benefits for Korean adults.

## CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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