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## Original Research

# Physical activity, dietary vitamin C, and metabolic syndrome in the Korean adults: the Korea National Health and Nutrition Examination Survey 2008 to 2012

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## ABSTRACT

**Objectives:** Metabolic syndrome is a global public health problem, and regular physical activity is a well-known critical factor in its management. A recent study suggests that the effect of exercise on metabolic syndrome may be enhanced by sufficient plasma vitamin C concentrations. We therefore examined the combined effect of physical activity and dietary vitamin C on the risk of metabolic syndrome in the general Korean population.

**Study design:** Cross-sectional study.

**Methods:** We analyzed data from 22,671 adults aged 20 years or older from the Korea National Health and Nutrition Examination Survey 2008–2012. Physical activity was computed as the total metabolic equivalent (METs-hr/week) summed from MET scores of walking, moderate activity, and vigorous activity. Vitamin C intake was assessed using a 24-h dietary recall. Participants were classified into four combined groups based on median values of physical activity and vitamin C intake.

**Results:** After adjustment for potential confounders, the odds ratio (OR) for metabolic syndrome in individuals with both high physical activity and vitamin C intake (vs. both low physical activity and vitamin C intake) was 0.79 (95% confidence interval (CI), 0.71–0.87). The estimated combined effect was more than either high physical activity alone (OR, 0.81 (95% CI, 0.73–0.90)) or high vitamin C intake alone (OR, 0.89 (95% CI, 0.80–0.99)), although each of those was beneficial.

**Conclusions:** Physical activity and dietary intake of vitamin C are both associated with a lower risk of metabolic syndrome. Our findings suggest further that a combination of physical activity and a diet rich in vitamin C may help in preventing metabolic syndrome.

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## Introduction

Metabolic syndrome (MetS) is a cluster of risk factors for cardiovascular disease (CVD) and type 2 diabetes, constituting a major public health problem worldwide.<sup>1–4</sup> The increasing prevalence of MetS has reached epidemic proportions, affecting 20–30% of the adult population worldwide.<sup>1</sup> Because the prevalence of MetS increases dramatically in an aging population, managing MetS and identifying its contributing factors are important to lessening its burden in global health.<sup>1</sup>

Lifestyle is a key factor in the development and management of MetS; in particular, diet and physical activity (PA) are suggested to be their critical components.<sup>5,6</sup> The American Heart Association (AHA) recommends both components in a strategy to prevent MetS and CVD.<sup>7</sup> In fact, there is consistent epidemiological evidence showing that moderate-to-vigorous PA is associated with the reduced risk of developing MetS as well as each components.<sup>8–12</sup> One follow-up study reported that PA in middle age may prevent the onset of MetS in old age.<sup>10</sup> In addition, oxidative stress is known to have an important pathogenic role in the development of MetS and its subsequent complications.<sup>13,14</sup> In this context, several epidemiologic studies show that antioxidants (e.g., vitamin A, C, and E) are associated with reduced risk of MetS.<sup>15,16</sup> Moreover, one study reports that a deficiency in plasma vitamin C is associated with reduced fat oxidation during aerobic exercise, and suggests that a diet rich in vitamin C may be necessary for effective exercise-related weight management.<sup>17</sup>

Based on biologically plausible evidence from studies of PA and from studies of antioxidants, a conjoined study of the two components is needed to resolve their metabolic consequences, yet no investigation has examined the combination of those effects on the risk of MetS. This study therefore aimed to investigate combined effects of PA and dietary vitamin C intake on the risk of MetS in a well-defined general adult population.

## Methods

### Study participants

The Korea National Health and Nutrition Examination Survey (KNHANES) is an ongoing series of cross-sectional surveys designed to assess health and nutrition status from a nationally representative sample of the civilian non-institutionalized South Korean population.<sup>18</sup> We analyzed data from KNHANES 2008–2012 for adults aged 20 years or older. There were 28,670 adults available with data for health interview, health examination, and nutrition survey. We excluded 2270 subjects who had not fasted or had missing data of MetS components, 402 subjects who had missing data of PA or vitamin C intake, and 483 subjects lacking data on covariates. Additionally, we excluded subjects who had any limitation in daily life activities due to health impairment ( $n = 2725$ ) or psychiatric disorders ( $n = 119$ ). Finally, 22,671 participants were included in the analyses. The KNHANES study was approved by the Institutional Review Board of the

Korea Centers for Disease Control and Prevention, and all participants provided written informed consent.

### Physical activity assessment

PA was measured using a Korean version of the International Physical Activity Questionnaire (IPAQ) short form.<sup>19</sup> The IPAQ assesses three types of activity (walking, moderate PA, and vigorous PA) undertaken across a comprehensive set of four domains: leisure time, household/gardening, work-related, and transport-related PA. The IPAQ is the most commonly used tool to assess PA, and its short form has been validated against accelerometers/pedometers. Participants were asked to recall the type (intensity), frequency (day), and duration (hours) of PA in the previous seven days. Total hours per week were computed for each activity using metabolic equivalent (MET) values, and weekly MET values for each activity were multiplied by hours: walking = 3.3 METs  $\times$  day  $\times$  hr; moderate PA = 4.0 METs  $\times$  day  $\times$  hr; and vigorous PA = 8.0 METs  $\times$  day  $\times$  hr.<sup>20</sup> Total MET scores were created by summing the weekly MET values for the three activity types. Total PA levels were categorized into high and low based on the median:  $\geq 21$  and  $< 21$  METs-hr/week.

### Dietary intake

Data on dietary intake were collected in a single 24-h dietary recall (DR) by interview.<sup>18</sup> Vitamin C, energy, total fat, and dietary fiber intakes for each respondent were computed using the food composition table produced by the Korea National Rural Resources Development Institute.<sup>21,22</sup> Vitamin C intake levels were categorized into high vs. low based on the median:  $\geq 85$  mg/day and  $< 85$  mg/day, respectively.

### Anthropometric measurements and other variables

Body mass index (BMI) was calculated from body weight and height ( $\text{kg}/\text{m}^2$ ). Demographics (age, sex, education, household income) were obtained from interviewer-administered questionnaires, and behavioral characteristics (smoking status, alcohol consumption) were self-reported. Household income was available as quartiles in each survey year. Education was classified as less than high school, high school, or more than high school. Alcohol consumption was categorized as never,  $\leq$  once a week, 2–3 times/week, or  $\geq 4$  times/week, and smoking status was classified as nonsmoker, former smoker, or current smoker.

### Metabolic syndrome components

Blood pressure was taken with participants in a seated position, measured three times after rest periods of at least 5-min, and the lowest measure was used in the analysis. Waist circumference (WC) was measured three times, and the mean value was used in the analysis.

Blood samples were obtained after an overnight fast ( $> 8$  h). Triglyceride (TG) levels, fasting blood glucose (FBG), and high-density lipoprotein cholesterol (HDL-C) were analyzed by the enzyme method (Hitachi, Japan) in a certified central laboratory (NeoDin Medical Institute, Seoul, Korea).<sup>23</sup>

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