Relationship among Physical Activity, Smoking, Drinking and Clustering of the Metabolic Syndrome Diagnostic Components

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Aim: To examine the relation between lifestyle and the number of metabolic syndrome (MetS) diagnostic components in a general population, and to find a means of preventing the development of MetS components.

Methods: We examined baseline data from 3,365 participants (2,714 men and 651 women) aged 19 to 69 years who underwent a physical examination, lifestyle survey, and blood chemical examination. The physical activity of each participant was classified according to the International Physical Activity Questionnaire (IPAQ). We defined four components for MetS in this study as follows: 1) high BP: systolic BP ≥ 130 mmHg or diastolic BP ≥ 85 mmHg, or the use of antihypertensive drugs; 2) dyslipidemia: high-density lipoprotein-cholesterol concentration < 40 mg/dL, triglycerides concentration ≥ 150 mg/dL, or on medication for dyslipidemia; 3) Impaired glucose tolerance: fasting blood sugar level ≥ 110 mg/dL, or if less than 8 hours after meals ≥ 140 mg/dL), or on medication for diabetes mellitus; 4) obesity: body mass index ≥ 25 kg/m².

Results: Those who had 0 to 4 MetS diagnostic components accounted for 1,726, 949, 484, 190, and 16 participants, respectively, in the Poisson distribution. Poisson regression analysis revealed that independent factors contributing to the number of MetS diagnostic components were being male (regression coefficient b = 0.600, p < 0.01), age (b = 0.027, p < 0.01), IPAQ class (b = -0.272, p = 0.03), and alcohol consumption (b = 0.020, p = 0.01). The contribution of current smoking was not statistically significant (b = -0.067, p = 0.76).

Conclusion: Moderate physical activity was inversely associated with the number of MetS diagnostic components, whereas smoking was not associated.


Key words: Metabolic syndrome, Diagnostic components, International Physical Activity Questionnaire, Smoking, Alcohol

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Introduction

Cardiovascular risk factors, such as high blood pressure (BP), dyslipidemia, impaired glucose tolerance (IGT), and obesity are known to tend to cluster
together\textsuperscript{1–3}. This clustering is now widely known as metabolic syndrome (MetS) and is closely related to insulin resistance\textsuperscript{3, 4}. Several diagnostic criteria have been proposed for MetS from different institutions and for different ethnic groups\textsuperscript{1, 4–6}; however, numerous studies have shown that separate components of MetS are associated with a higher risk of coronary heart disease and stroke, and that a rise in the number of MetS components increases the incidence of cardiovascular disease (CVD) events following myocardial infarction\textsuperscript{7–9}. Thus, preventing the development of each component of MetS using diagnostic criteria is more important than dichotomizing people into two groups with and without MetS, and preventing the development of MetS.

**Aim**

The aim of the present study was to examine cross-sectionally the relation between lifestyle, including physical activity, smoking and alcohol drinking, and the number of MetS diagnostic components in a general population, and to find a means of preventing the development of MetS components. We evaluated physical activity using the classification of the International Physical Activity Questionnaire (IPAQ)\textsuperscript{10}. IPAQ was developed as an instrument for cross-national monitoring of physical activity and inactivity.

**Methods**

**Participants**

We analyzed baseline data from the high-risk and population strategy for occupational health promotion (HIPOP-OHP) study\textsuperscript{11–14}. In brief, HIPOP-OHP was an interventional survey to establish a methodology for reducing CVD risk factors at the workplace. This study population consisted of full-time workers at 12 large-scale companies throughout Japan. Each company had 500–1,000 employees. Researchers followed the data of CVD risk factors, lifestyle and consciousness about health based on nutrition, physical activity and smoking for four years\textsuperscript{11–14}. This study was performed as part of the management of health and safety with the approval of the Safety Hygiene Committee at each company. Accordingly, all employees were enrolled in this study; however, participation was voluntary, and we explained that there was no need for participants to answer the required questionnaire if they did not want to. Approval for the study was obtained from the Institutional Review Board of Shiga University of Medical Science for ethical issues (No. 10–16). During 1999–2000, baseline data were collected from 7,346 male and female workers aged from 19 to 69 years old.

The present study examined baseline data from 3,365 participants (2,714 men and 651 women) aged 19 to 69 years (mean ± SD: 42.9 ± 9.0 years) who underwent a physical examination, lifestyle survey, and blood chemical examination.

**Data collection and standardization**

Physical and laboratory data were standardized according to the manual of the HIPOP-OHP research group\textsuperscript{13}. Briefly, after a 5-min rest, blood pressure was measured twice for each participant using the same automatic sphygmomanometer (BP-103iII; Nihon Colin) at each company, and the mean value was recorded. To measure lipid levels in each participant, the company established a contract with a clinical laboratory; blood testing was standardized through the US Cholesterol Reference Method Laboratory Network (CRMLN)\textsuperscript{15}. The body mass index (BMI) was calculated as weight (kg) divided by height squared (m\textsuperscript{2}). Drinking habits for each subject were assessed by a questionnaire common to all companies\textsuperscript{12}. The frequency of alcohol consumption during a typical week and the total alcohol intake on each occasion were determined and used to calculate the alcohol intake per week. This value was then divided by 7 to obtain the average alcohol intake per day. Subjects were asked to estimate their alcohol intake based on gou, a traditional Japanese drinking unit corresponding to 23 g ethanol. One gou is equivalent to 2 US and UK drink units, or 180 mL sake, and its ethanol content is roughly equivalent to that of a bottle of beer (663 mL), two single shots of whiskey (70 mL), a half glass of shochu (110 mL), or 240 mL wine. Drinkers were defined as those consuming more than 0.5 gou (0.6 drinks) per week (1 g ethanol a day).

Participants were asked about the type of, and time spent on, physical activities in their spare time for recreation, exercise or sport in the previous month. Physical activity of each participant was converted into MET-minutes per week (= MET level × minutes of activity/day × days per week) according to IPAQ\textsuperscript{10}, and participants were classified into four classes of physical activity as high (≥ 3,000 MET-minutes per week), moderate activity (< 3,000 but ≥ 1,500 MET-minutes per week), some activity (< 1,500 but ≥ 600 MET-minutes per week), or sedentary (< 600 MET-minutes per week).

We defined four components for MetS in this study according to previous studies\textsuperscript{4–6} as follows: 1) high BP: SBP ≥ 130 mmHg or DBP ≥ 85 mmHg or the use of an antihypertensive drug; 2) dyslipidemia:
either serum high-density lipoprotein-cholesterol (HDLc) concentration <40 mg/dL, serum triglycerides (TG) concentration ≥150 mg/dL, or on medication for dyslipidemia; 3) IGT: fasting blood sugar level ≥110 mg/dL, or if less than 8 hours after meals ≥140 mg/dL), or on medication for diabetes mellitus; 4) and obesity: BMI ≥ 25 kg/m².

Statistical analyses

The chi-square statistical test for nominal variables and one-way analysis of variance for continuous variables were performed to assess whether there were significant differences among groups stratified by the number of MetS diagnostic components. Associations between the number of MetS diagnostic components and lifestyle were analyzed by Poisson regression models, including sex, age, IPAQ classification, alcohol consumption (mL/day), smoking (non-, ex-, or current smoker; non-smoker serves as a reference), and interaction terms (IPAQ x sex, alcohol consumption x sex, current smoking x sex) as independent variables. Furthermore, participants were stratified as with or without obesity, and associations between the number of MetS diagnostic components, excluding the obesity component and lifestyle, were analyzed by Poisson regression models. All p values were two-sided, and p < 0.05 was considered significant. All analyses were performed using SPSS v15 (Chicago, IL, USA).

Results

Among the 3,365 participants, those who had 0 to 4 MetS diagnostic components accounted for 1,726, 949, 484, 190, and 16 persons, respectively, in the Poisson distribution. Characteristics of participants by group according to the number of MetS diagnostic components are shown in Table 1. The mean SBP, DBP, BMI, alcohol consumption, and percentage of high BP, dyslipidemia, IGT, obese, and ex-smokers were higher in groups with a higher number of MetS diagnostic components. The percentage of women was lower in groups with a higher number of MetS diagnostic components. Current smokers were most prevalent in the group with 2 MetS diagnostic components. The mean IPAQ class tended to be lower in the group with 4 MetS diagnostic components than the other groups; however, it did not reach statistical significance by univariate analysis (p = 0.08).

The results of Poisson regression analysis are shown in Table 2. Independent factors that contributed to the number of MetS diagnostic components were being male (regression coefficient b = 0.600, p < 0.01), age (b = 0.027, p < 0.01), IPAQ class (b = −0.272, p = 0.03), and alcohol consumption (b = 0.020, p = 0.01). The contribution of current smoking was not statistically significant (b = −0.067, p = 0.76).

The results of Poisson regression analysis on associations between the number of MetS diagnostic components, excluding the obesity component, and lifestyle stratified by the presence of obesity are shown in Table 3. Without obesity, the variables independently contributing to the number of MetS diagnostic components, excluding obesity, were being male (b = 0.781, p < 0.01) and age (b = 0.044, p < 0.01). With obesity, no variable independently contributed to the number of MetS diagnostic components.

Discussion

Among the components of energy expenditure, the largest component (about 70%) is involved in basal metabolism. The second largest component is physical activity, which consumes about 15% total energy, so we only have conscious control over physical activity, which accounts for a relatively small part of total energy expenditure (16). There are few studies on the association between physical activity and metabolic syndrome. Dalacrote et al. studied 362 community-dwelling elderly in southern Brazil, and found no significant association between MetS and the IPAQ level of physical activity in men and women (17); however, in a study by Ekelund et al. in a population-based sample of 3,193 European youths, lower physical activity was independently associated with MetS after adjustment for sex, age, and other covariates (18). Hahn et al., in a population-based study of 1,653 elderly participants, also found that intense physical activities significantly reduced the odds of having MetS (19). In the present study, there were no statistical significant differences in the mean IPAQ class among groups by univariate analysis, and we found a significant inverse association between physical activities assessed by IPAQ and the number of MetS diagnostic components among mostly middle-aged participants by multivariate Poisson regression analysis.

We found a significant positive association between alcohol consumption and the number of MetS diagnostic components. Several cross-sectional studies have reported an association between alcohol drinking and metabolic syndrome prevalence; however, they showed inconsistent findings (20-24). Some reported that the relation is inversely linear (21), J-shaped (22), or positively linear (23), whereas another found no relation (24). A prospective study by Carnethon et al. found that no alcohol intake versus one to three drinks per day was associated with a significant 36% increase in the inci-
Table 1. Characteristics of Participants by Group According to the Number of Metabolic Syndrome Diagnostic Components

| MetS No | Person N | Age (years) | Female (%) | SBP (mmHg) | DBP (mmHg) | High BP (%) | Dyslipidemia (%) | Obese (%) | BMI (kg/m²) | IGT (%) | Dysglycemia (%) | Ex-smoking (%) | Current Smoking (%) | Alcohol (mL/day) |
|---------|----------|-------------|------------|------------|------------|-------------|------------------|-----------|-------------|---------|------------------|-----------------|-------------------|----------------|----------------|---|
| 0       | 1,726    | 41.2 ± 9.1  | 24.2       | 108.5 ± 10.2 | 66.6 ± 7.8 | 0            | 0                | 32.9      | 21.3 ± 2.0  | 0.62    | 34.1             | 15.1            | 41.9              | 18.5 ± 28.8       |
| 1       | 949      | 44.3 ± 8.7  | 15.8       | 121.8 ± 16.2 | 75.4 ± 11.2 | 3.7          | 39.5             | 23.8      | 23.3 ± 2.6  | 1.06    | 23.8 ± 32.9     | 47.7            | 50.6              | 238 ± 32.9        |
| 2       | 484      | 45.5 ± 8.2  | 13.0       | 132.0 ± 16.6 | 82.2 ± 11.0 | 6.3          | 63.4             | 22.6      | 25.9 ± 3.2  | 1.33    | 25.3 ± 34.1     | 7.1             | 50.0              | 226 ± 34.1        |
| 3       | 190      | 44.8 ± 9.1  | 10.5       | 140.9 ± 14.0 | 87.9 ± 9.5  | 0.6          | 94.2             | 27.5      | 27.5 ± 3.0  | 1.06    | 22.6 ± 29.0     | 46.3            | 46.3              | 226 ± 29.0        |
| 4       | 16       | 46.6 ± 7.7  | 6.3        | 139.5 ± 9.9  | 87.7 ± 7.2  | 0.01         | 100              | 27.9      | 27.9 ± 2.5  | 0.01    | 28.9 ± 44.2     | 43.8            | 43.8              | 289 ± 44.2        |
| p       |          | <0.01       | <0.01      | <0.01       | <0.01       | <0.01        | <0.01            | <0.01     | <0.01       | <0.01  | <0.01            | <0.01          | <0.01             | 0.21             |
| Total   |          | 3,365       | 19.0–69.0  | 19.4        | 75.5–197.5  | 3.5          | 26.1             | 14.5–47.6 | 0.379       | 0.078  | 0.067           | 0.019          | 0.01              | 0.01             |
| Range   |          |            |           |            |            |             |                  |           |            |        |                 |                |                  |                 |

The chi-square statistical test for nominal variables and one-way analysis of variance for continuous variables were performed to assess whether there were significant differences among groups stratified by the number of MetS diagnostic components. We defined four components for MetS in this study as follows: 1) High BP: SBP ≥ 130 mmHg, or DBP ≥ 85 mmHg, or the use of an antihypertensive drug; 2) dyslipidemia: HDLc < 40 mg/dL, TG ≥ 150 mg/dL, or on medication for dyslipidemia; 3) IGT: fasting blood sugar level ≥ 110 mg/dL, or on medicine for diabetes mellitus; 4) obesity: defined as BMI ≥ 25 kg/m². SBP = systolic blood pressure, DBP = diastolic blood pressure, BP = blood pressure, IGT = impaired glucose tolerance, BMI = body mass index, IPAQ = International Physical Activity Questionnaire classification.

Table 2. Independent Factors that Contributed to the Number of Metabolic Syndrome Diagnostic Components—Results of Poisson Regression Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression coefficient</th>
<th>p value</th>
<th>Regression coefficient</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>0.600</td>
<td>&lt;0.01</td>
<td>0.781</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.027</td>
<td>&lt;0.01</td>
<td>0.044</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>IPAQ class</td>
<td>-0.272</td>
<td>0.03</td>
<td>-0.379</td>
<td>0.14</td>
</tr>
<tr>
<td>Alcohol (mL/day)</td>
<td>0.020</td>
<td>0.01</td>
<td>0.018</td>
<td>0.54</td>
</tr>
<tr>
<td>Current smoking</td>
<td>-0.067</td>
<td>0.76</td>
<td>0.166</td>
<td>0.91</td>
</tr>
<tr>
<td>Ex-smoking</td>
<td>0.078</td>
<td>0.21</td>
<td>0.063</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Results of analysis by Poisson regression models on associations between the number of MetS diagnostic components and lifestyle are shown. Covariates included sex, age, IPAQ classification, alcohol consumption (mL/day), current smoking (current smoker or non-smoker), and ex smoking (ex-smoker or non-smoker). IPAQ = International Physical Activity Questionnaire classification.

Table 3. Independent Factors that Contributed to the Number of Metabolic Syndrome Diagnostic Components Stratified by Obesity—Results of Poisson Regression Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regression coefficient</th>
<th>p value</th>
<th>Regression coefficient</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male gender</td>
<td>0.781</td>
<td>&lt;0.01</td>
<td>0.479</td>
<td>0.11</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.044</td>
<td>&lt;0.01</td>
<td>0.005</td>
<td>0.14</td>
</tr>
<tr>
<td>IPAQ class</td>
<td>-0.379</td>
<td>0.14</td>
<td>-0.174</td>
<td>0.47</td>
</tr>
<tr>
<td>Alcohol (mL/day)</td>
<td>0.018</td>
<td>0.014</td>
<td>0.014</td>
<td>0.54</td>
</tr>
<tr>
<td>Current smoking</td>
<td>0.166</td>
<td>0.048</td>
<td>0.054</td>
<td>0.65</td>
</tr>
</tbody>
</table>

Results of analysis stratified by the presence of obesity by Poisson regression models on associations between the number of MetS diagnostic components (excluding obesity) and lifestyle are shown. Covariates included sex, age, IPAQ classification, alcohol consumption (mL/day), and smoking (current smoker or not). IPAQ = International Physical Activity Questionnaire classification.
dence of MetS. Alcohol consumption is associated with changes in the consumption of several food groups and nutrients. Further study is therefore needed, incorporating nutritional analyses.

We found no association between smoking and the number of MetS diagnostic components. Previous cross-sectional studies indicated that BMI is lower in cigarette smokers than non-smokers. One reason that young adults start smoking is to lose weight. The association between smoking and MetS is controversial. A prospective study by Onat et al. found a protective effect against developing MetS of smoking 11 or more cigarettes a day in women. No association was found in a cross-sectional study and a prospective study. Other studies found a positive association of smoking with MetS. Smoking is known to adversely affect lipid metabolism and insulin resistance. More importantly, smoking is a potent risk factor for cardiovascular disease and cancer morbidity and mortality; therefore, we should strongly discourage smoking to lose weight and to prevent MetS development.

The analysis of non-obese participants in our present study revealed that only two variables, being male, and age contributed to the number of MetS diagnostic components. In the analysis of obese participants, no variable contributed to the number of MetS diagnostic components. This was probably due to a lack of statistical power with fewer participants.

The strengths of our study include being population-based, large-scale, and multi-site with highly standardized methods. Since the study included men and women of a broad range of ages, the findings are likely to be generalizable to middle-aged Japanese. The study was limited by its cross-sectional design and lack of analyses of other lifestyles, such as a nutritional survey. Second, we did not measure waist circumference (WC); however, we showed in a population-based study that BMI and WC correlated very well in men and women, and that BMI could be used instead of WC in a study when the latter was not available. Although the measurement of WC is widely advocated as a simple anthropometric marker of health risk, there remains no uniformly accepted protocol. Third, nutritional analyses are required.

In conclusion, moderate physical activity was inversely associated with the number of MetS diagnostic components, whereas smoking was not associated.

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Investigators and members of the research group are listed in the appendix of reference 12.

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