JPFSM: Regular Article

Tracking of clustered metabolic syndrome risk factor in Japanese children: 3-year follow-up study

Kensaku Sasayama1* and Minoru Adachi2

1 Faculty of Education, Okayama University of Science, 1-1 Ridai-cho, Kita-ku, Okayama 700-0005, Japan
2 Graduate School of Education, Okayama University, 3-1-1 Tsushima-naka, Kita-ku, Okayama 700-8530, Japan

Received: March 7, 2017 / Accepted: June 12, 2017

Abstract The purpose of this study was to investigate the tracking of clustered metabolic syndrome (MetS) risk factor taking into account fatness and aerobic fitness from childhood to adolescence in Japanese children. This cohort study included 113 participants (47 boys and 66 girls) who were measured for MetS risk factors at 10 years and 13 years of age. Clustered MetS risk factors (MetS risk score) were calculated from the total gender-specific values (z-scores) of the following five parameters: waist to height ratio (W/H), predicted \( \dot{V}O_2 \)peak (p\( \dot{V}O_2 \)peak), triglycerides, high density lipoprotein cholesterol, and mean arterial pressure. The tracking coefficient of MetS risk score from childhood to adolescence was 0.647 (p < 0.001). Correlation coefficients of MetS risk scores (without W/H) between 10 and 13 years of age in the high W/H group (r = 0.713, p < 0.001) were higher than those in the low W/H group (r = 0.402, p < 0.01). In addition, correlation coefficients of MetS risk scores (without \( \dot{V}O_2 \)peak) between 10 and 13 years of age in the low \( \dot{V}O_2 \)peak (r = 0.630, p < 0.001) were higher than those in the high \( \dot{V}O_2 \)peak (r = 0.452, p < 0.01). In conclusion, we found that MetS risk was stable from childhood to adolescence in Japanese children. Furthermore, our results show that both fatness and fitness are crucial for tracking MetS risk.

Keywords: children, adolescents, tracking, metabolic syndrome

Introduction Metabolic syndrome (MetS) is a condition that has multiple risk factors including obesity, hyperglycemia, dyslipidemia, hypertension, and insulin resistance. These factors cause several diseases including arteriosclerosis and type 2 diabetes mellitus. Cardiovascular disease risk in adults increases with simultaneous multiple risk factors compared with a single risk factor. According to the Third National Health and Nutrition Examination (NHANES III) survey, the age-adjusted prevalence of MetS in adults from North America has increased from 29.2% (1988–1994) to 34.2% (1999–2006). In contrast, Ishizaka et al. reported a prevalence of MetS among Japanese males and females of 19% and 7%, respectively, for the same time period (1994–2003). Components of MetS have been confirmed in children and adults. Although MetS occurs less often in children, several studies have established a prevalence of MetS in approximately 3.0%–4.0% of children and adolescents. These phenomena have been reported in Japanese children. Furthermore, in previous cross-sectional studies, the risk for MetS has been reported to be associated with fatness and aerobic fitness in European, American, Canadian, Australian, and Asian children.

Recently, Camhi & Katzmarzyk reviewed clustering risk factors tracked from childhood to adulthood. The review, that cited seven papers, noticed that the range of tracked clustering risk factors from childhood to adulthood had a moderate to high correlation coefficient. In addition, the review stated that additional research was necessary to study short-term tracking because the follow-up ranged from 6 to 15.8 years in previous studies. Indeed, several previous studies reported that MetS risk in short-term tracking showed low stability in childhood. Furthermore, the review noticed that it was necessary to include the influence of fitness associated with MetS risk factor clustering and to examine different racial and ethnic groups. To our knowledge, longitudinal research has not been reported for Japanese children.

Little has been reported on short-term tracking and clustering risk factors, including fitness. After the Camhi & Katzmarzyk review, Bugge et al. reported on short-term tracking of clustering risk factors, including fitness. They reported that tracking was higher for lower fitness children, and there was a weak relationship with fatness. In addition, in longitudinal studies, the participants were European, American, and Canadian; there were no data for Asian children.

The purpose of this study was to track clustered MetS...
risk factors from childhood to adolescence in Japanese children. We also considered differences in tracking associated with levels of fatness and aerobic fitness. We hypothesized that the clustered MetS risk factors in the short-term were stable in Japanese children, and tracking is higher for high-fat or low-fit children.

Materials and methods

Participants. This study was performed in Ibara City, Okayama Prefecture, Japan. Our study covered all 13 public elementary schools in Ibara City. In the first study, 368 participants (aged 10 years) were investigated in September 2008, and follow-up included 142 participants (aged 13 years, dropout rate = 61.4%) in September 2011. After excluding participants with missing data (blood samples, n = 24; aerobic fitness, n = 5), a total of 113 participants (47 boys and 66 girls) were available for this study. The procedure conformed to the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of Okayama University (approval number: epi.37). All participating children and their parents provided written informed consent before participation.

Anthropometry. Height (precision of 0.1 cm) and body weight (precision of 0.1 kg) were measured in light clothing without shoes. Waist circumference (precision of 0.1 cm) was measured with a metal anthropometric tape midway between the lower rib margin and iliac crest. The waist-to-height ratio was calculated and reported as waist/height (W/H). Obesity index was calculated as follows: [Obesity index (%) = weight (kg) − standard weight for height (cm)] / standard weight (kg) × 100.

Aerobic fitness. Aerobic fitness was defined as the predicted peak oxygen consumption (pVO2peak) from a 20 m shuttle run test. The pVO2peak was calculated using the method reported previously. Results of the 20 m shuttle run test were provided from the schools.

Blood pressure. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured from the right arm using the automatic oscillometric method (UEDA USM-700G). SBP and DBP were taken from children in a seated, relaxed position after at least 10 min rest. Measurements were conducted between 9:30 and 12:00 h. Mean arterial pressure (MAP) was calculated as follows: MAP = DBP + [0.333 × (SBP − DBP)].

Blood samples. Plasma triglycerides (TG) and high-density lipoprotein cholesterol (HDL-c) levels were measured in a nonfasted state, between 9:30–12:00, when children were in school. TG and HDL-c were measured using the Wako L-Type method (Wako Chemical, Japan).

Statistical analysis. Participant characteristics and MetS risk variables are reported as the mean ± standard deviations. Characteristic differences in age were examined using a paired Student’s t-test. Although there is no international definition in youth, clustered metabolic syndrome risk factor is usually defined using three to six risk factors. In this study, clustered metabolic syndrome risk factor (MetS risk score) was calculated from the gender-specific values (z-scores) of the following five parameters: W/H, pVO2peak, TG, HDL-c, and MAP. In addition, MetS risk score was constructed by summing z-scores of five variables. Gender-adjusted partial correlation coefficients (r) were calculated to determine the tracking of the five MetS risk variables and MetS risk score from childhood to adolescence. Values ranging from 0.00 to 0.29 indicate a low correlation, from 0.30 to 0.59 a moderate correlation, and from 0.60 to 1.00 a high correlation. Furthermore, to examine the influence of W/H and pVO2peak, children were divided into Low/High W/H and Low/High pVO2peak groups, and the MetS risk score (without W/H or pVO2peak, respectively) tracking coefficients were calculated within each of the two age groups, using gender-adjusted partial correlation coefficients. Low/High W/H and Low/High pVO2peak groups were divided into two groups using a median split of W/H and pVO2peak at 10 and 13 years old. In other words, Low W/H and pVO2peak groups showed less than the median of W/H or pVO2peak at 10 and 13 years old. In contrast, the High W/H and pVO2peak groups showed above the median of W/H or pVO2peak at 10 and 13 years old. All analyses were performed using SPSS Statistics software version 20.0 (IBM, Armonk, NY). Results were considered to be statistically significant at p < 0.05.

Results

Participant characteristics. The descriptive characteristics of the participants within the two age groups are shown in Table 1. Height and weight of 13-year-olds were significantly higher than that of both 10-year-old boys and girls. W/H of 13-year-olds was significantly lower than that of 10-year-old boys and girls. pVO2peak of 13-year-olds was significantly higher than that of 10-year-old boys. HDL-c of 13-year-olds was significantly higher than that of 10-year-old girls. MAP of 13-year-olds was significantly lower than that of 10-year-old boys.

Gender-adjusted partial correlation in MetS risk factor from children aged 10–13 years. Gender-adjusted partial correlation coefficients among risk factors and MetS risk score from children aged 10 to 13 years are shown in Table 2. Correlation coefficients were higher for HDL-c (r = 0.804, p < 0.001), W/H (r = 0.753, p < 0.001), and pVO2peak (r = 0.715, p < 0.001).TG (r = 0.436, p < 0.001) and MAP (r = 0.397, p < 0.001) indicated a moderate relationship and the MetS risk score (r = 0.647, p < 0.001) indicated a high relationship.
**Table 1.** Participants characteristics by age

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th></th>
<th>Girls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10 years</td>
<td>13 years</td>
<td>p value</td>
<td>10 years</td>
</tr>
<tr>
<td>Age (years)</td>
<td>9.6 ± 0.5</td>
<td>12.6 ± 0.5</td>
<td>1.000</td>
<td>9.5 ± 0.5</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>133.9 ± 5.8</td>
<td>153.2 ± 8.4</td>
<td>&lt; 0.001</td>
<td>135.3 ± 5.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>30.3 ± 6.6</td>
<td>44.5 ± 10.5</td>
<td>&lt; 0.001</td>
<td>29.9 ± 4.6</td>
</tr>
<tr>
<td>Obesity Index (%)</td>
<td>-0.5 ± 14.3</td>
<td>0.8 ± 13.7</td>
<td>0.035</td>
<td>0.635</td>
</tr>
<tr>
<td>W/H</td>
<td>0.44 ± 0.05</td>
<td>0.42 ± 0.05</td>
<td>0.002</td>
<td>0.42 ± 0.04</td>
</tr>
<tr>
<td>$rV_{O2peak}$ (mL/kg/min)</td>
<td>51.2 ± 4.4</td>
<td>52.4 ± 4.9</td>
<td>0.015</td>
<td>46.3 ± 3.2</td>
</tr>
<tr>
<td>TG (mg/dl)</td>
<td>73.8 ± 46.4</td>
<td>75.4 ± 43.7</td>
<td>0.796</td>
<td>85.6 ± 43.1</td>
</tr>
<tr>
<td>HDL-c (mg/dl)</td>
<td>68.9 ± 13.7</td>
<td>69.4 ± 13.6</td>
<td>0.692</td>
<td>65.2 ± 14.0</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>78.8 ± 7.1</td>
<td>76.2 ± 6.5</td>
<td>0.023</td>
<td>76.8 ± 6.6</td>
</tr>
<tr>
<td>MetS risk score</td>
<td>0.0 ± 2.8</td>
<td>0.0 ± 2.8</td>
<td>1.000</td>
<td>0.0 ± 2.8</td>
</tr>
</tbody>
</table>

Values are means ± standard deviations.

W/H: Waist to height ratio. $rV_{O2peak}$: predicted $V_{O2peak}$. TG: Triglycerides. HDL-c; High density lipoprotein cholesterol. MAP; Mean arterial pressure. MetS risk score; clustered metabolic syndrome risk factor.

$p < 0.05$ for differences in age.

**Table 2.** The correlation coefficient in each MetS risk factor for children aged 10 to 13 years

<table>
<thead>
<tr>
<th>MetS risk score</th>
<th>n</th>
<th>r</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MetS risk score</td>
<td>113</td>
<td>0.647</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>W/H</td>
<td>113</td>
<td>0.753</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>$rV_{O2peak}$ (mL/kg/min)</td>
<td>113</td>
<td>0.715</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>TG</td>
<td>113</td>
<td>0.436</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>HDL-c</td>
<td>113</td>
<td>0.804</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>MAP</td>
<td>113</td>
<td>0.397</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

MetS risk score; clustered metabolic syndrome risk factor.

W/H: Waist to height ratio. $rV_{O2peak}$: predicted $V_{O2peak}$. TG: Triglycerides. HDL-c; High density lipoprotein cholesterol. MAP; Mean arterial pressure.

Correlation coefficients were adjusted by sex.

**Gender correlation of MetS risk score (without W/H) in Low and High W/H groups.** In boys, MetS risk scores (without W/H) in Low W/H at 10 and 13 years were $-0.30 \pm 1.74$ and $-0.63 \pm 1.92$, respectively, and those in girls were $-1.28 \pm 1.97$ and $-0.76 \pm 1.83$, respectively. In boys, MetS risk scores (without W/H) in High W/H at 10 and 13 years were $0.87 \pm 2.62$ and $0.87 \pm 2.57$, respectively, and those in girls were $1.05 \pm 1.85$ and $0.76 \pm 1.95$, respectively. Correlation coefficients of MetS risk scores (without W/H) between 10 and 13 years of age in the High W/H group ($r = 0.713$, $p < 0.001$) were higher than those in the Low W/H group ($r = 0.402$, $p < 0.01$) (Table 3).

**Gender correlation of MetS risk score (without $rV_{O2peak}$) in Low and High $rV_{O2peak}$ groups.** In boys, MetS risk scores (without $rV_{O2peak}$) in Low $rV_{O2peak}$ at 10 and 13 years were $0.85 \pm 2.63$ and $0.90 \pm 2.46$, respectively, and those in girls were $1.04 \pm 1.89$ and $0.55 \pm 2.18$, respectively. In boys, MetS risk scores (without $rV_{O2peak}$) in High $rV_{O2peak}$ at 10 and 13 years were $-0.75 \pm 1.94$ and $-0.83 \pm 1.66$, respectively, and those in girls were $-0.95 \pm 2.10$ and $-0.99 \pm 2.15$, respectively. Correlation coefficients of MetS risk scores (without $rV_{O2peak}$) between 10 and 13 years of age in the Low $rV_{O2peak}$ ($r = 0.630$, $p < 0.001$) were higher than those in the High $rV_{O2peak}$ ($r = 0.452$, $p < 0.01$) (Table 4).
In previous studies, clustered risk factors have been reported by longitudinal studies in children and adolescents (r = 0.647, p < 0.001, Table 2). Furthermore, high-fat and low-fit children demonstrated a higher tracking risk factors in Japanese children. The present study is the first to investigate short-term tracking (<6 years) and the clustering risk factor included fitness. Bugge et al.23) reported a moderate correlation coefficient (baseline at age 6 years, follow-up 3–7 years later; 6–9 years of age, r = 0.514; 9–13 years old, r = 0.559; 6–13 years old, r = 0.381; all p values < 0.0001). Our study is the first to investigate short-term tracking of clustering risk factors in Japanese children. The present study confirmed that the clustering risk factor was high when tracking from childhood to adolescence (baseline at age 10 years, follow-up within 3 years, r = 0.647, p < 0.001, Table 2). Therefore, our results revealed that clustered MetS risk in the short-term was significantly stable from childhood to adolescence in Japanese children.

In the present study, tracking a single risk factor was also significant (Table 2). Correlation coefficients indicated a moderate (TG, MAP) to high (HDL-c, W/H, VO_2peak) relationship. The results demonstrated that fatness determined by waist circumference and aerobic fitness were higher than other variables, similar to previous studies23,36). Also, moderate tracking of TG and blood pressure was consistent with previous studies23,24,26,36). Although it is difficult to explain these phenomena in detail, we suggest that single risk factors in the short-term were moderate to high stable from childhood to adolescence in Japanese children.

We confirmed that relatively high-fatness, low-fit children had a higher tracking for MetS risk score when the children were classified according to their W/H and aerobic fitness levels. Cross-sectional studies have reported on clustered risk factors associated with body mass14,19,37), but longitudinal studies have not been reported, especially for Asian children. In short-term tracking for aerobic fitness, Bugge et al.23) observed results similar to ours (r values between the ages of 6–9, 6–13, and 9–13 years, first tertile (least fit) r = 0.50–0.67, second and third tertile r = 0.25–0.39). However, they showed a weak relationship with higher fatness and these results differ from ours (r values from 10 to 13 years, Low W/H, r = 0.40; High W/H, r = 0.71). Possible reasons for the discrepancy could be due to ethnicity and the different measurements taken. Indeed, in Japanese children, overweight and obesity prevalence is lower than that of other countries38). Based on our findings, it was suggested that Low W/H and better aerobic fitness is important to prevent future MetS risks in children.

This study has several limitations. First, TG and HDL-c were measured in a nonfasting state. There is a possibility that this may influence the MetS risk score. Second, the
MetS risk score in this study was calculated by summing z-scores of five variables. Therefore, a relatively high MetS risk score doesn’t predict future MetS risk. Third, the sample was relatively small, limiting the examination of gender differences on body mass and fitness relative to MetS risk. Although we did not report these data, the tracking coefficient of several parameters in girls was insignificant (at 10 and 13 years of age: Low W/H, r = 0.263, p = 0.215; High W/H, r = 0.396, p = 0.056; High VO2peak, r = 0.395, p = 0.062). Recent studies have reported on the differences between boys and girls in terms of body mass and fitness. Further investigations are required to clarify gender differences. Fourth, although the validity of this test was confirmed, this study reported on the VO2peak that was predicted from a 20 m shuttle run test. Fifth, this study did not examine body composition and physical activity. Since cross-sectional studies report that physical activity is associated with MetS risk, further study is required to examine these parameters.

Conclusion

This study confirmed that clustered MetS risk in the short-term was strongly stable from childhood to adolescence in Japanese children. In addition, we showed that relatively high fatness and low-fit children had a higher tracking for clustered MetS risk. The implications of our findings are that improvements in both fatness and fitness in Japanese children are important for tracking MetS risk similar to foreign countries.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

References