ABSTRACT

The present study assessed the peripheral circulatory function of women by measuring accelerated plethysmogram (APG) and then investigated its relationship to target maximum oxygen intake levels (established by the ministry of Health and Welfare of Japan). Based on the medical records of 511 women in whom APG was measured during a physical examination at some time between 1993 and 2001, the present study assessed female peripheral hemodynamics by measuring acceleration pulse wave, and after correcting for the effects of age and blood pressure, it investigated the relationship between APG index and target VO2max levels (established by the Ministry of Health and Welfare). VO2max was estimated by the indirect method. Peripheral hemodynamics was assessed by placing a Precaregraph (Misawa Homes Inc., APG-200) or a blood circulation checker (Future Wave Inc., BC-001). The results showed a significant positive correlation between APG index and the following parameters: age, weight, BMI, SBP and DBP. Although subsequent partial correlation analysis corrected for the effects of age, SBP and DBP, a significant positive correlation between APG index, which is used to assess peripheral hemodynamics, and VO2max was evident.

Key Words Accelerated Plethysmogram (APG); Maximum Oxygen Intake (VO2max)

1. INTRODUCTION

Accelerated plethysmogram (APG) is obtained by differentiating digital plethysmogram wave twice. Sano and colleagues attempted to evaluate peripheral hemodynamics by measuring the APG. They classified APG waveforms into seven types and calculated APG index based on the properties of inflexion point. They investigated its relationship to age, blood pressure, disease, and physical training. The results showed that APG could serve as an indicator to assess the effectiveness of medical check-ups and physical therapy. We also previously measured APG and confirmed improvements in peripheral hemodynamics after physical or alimentary therapy.

It is well known that a reduction in physical activity leads to a reduction in maximum oxygen intake (VO2max), and the prevalence of obesity, hypertension, hyperlipidemia and ischemic heart disease is low among individuals with a high level of VO2max. The report of the Ministry of Health and Welfare of Japan published “Recommended exercise allowance for maintaining health” in July 1989, which states that a certain level of VO2max is necessary for maintaining good health, and established a target VO2max level for different age groups.

To investigate age-induced changes in cardiorespiratory function, we investigated the relationship between APG and VO2max in female university students and middle-aged women. The results showed that APG index decreased markedly with age, and there was a significant correlation between APG index and VO2max. However, in order to use APG as a practical indicator, it is necessary to correct for the effects of aging and blood pressure, and this could lead to the establishment of quantitative assessment standards, as is the case with VO2max.

The present study assessed female peripheral hemodynamics by measuring acceleration pulse wave, and after correcting for the effects of age and blood pressure, it investigated the relationship between APG index and target VO2max levels (established by the Ministry of Health and Welfare).

2. METHODS

APG was measured in 511 women (age range, 18 to 71 years) who participated in a physical examination at some time between 1993 and 2001.

Based on medical records obtained at the time of APG measurements, height, weight, body mass index (BMI), percent body fat (% body fat), systolic blood pressure (SBP) and diastolic blood pressure (DBP) were extracted (Table 1). VO2max was estimated by the indirect method.

Peripheral hemodynamics was assessed by placing a Precaregraph (Misawa Homes Inc., APG-200) or a Blood Circulation Checker (Future Wave Inc., BC-001) at the tip of the right index finger more than two hours after a meal at room temperature (24–25°C). APG was measured after sufficient rest before the VO2max measurement. Each subject was instructed to sit in a chair and maintain the measurement site (finger tip) at the level of the heart. APG index were calculated using the following formula:

\[ X = b - (c + d) \]

The wave height of an inflexion point “a”, from the base line, was set at 100, and the relative wave height of the other inflexion

Table 1 Physical characteristics of subjects.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>47.4 ± 17.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>154.7 ± 6.3</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.2 ± 8.2</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22.8 ± 3.2</td>
</tr>
<tr>
<td>% body fat (%)</td>
<td>27.5 ± 5.8</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>129.2 ± 16.4</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>77.1 ± 10.7</td>
</tr>
<tr>
<td>APG index</td>
<td>20.4 ± 54.1</td>
</tr>
<tr>
<td>VO2max (ml/kg - min)</td>
<td>28.8 ± 7.5</td>
</tr>
</tbody>
</table>
As reported by Sano and colleagues and ourselves in a previous study, changes in peripheral blood vessels before organic changes in vascular tissue (e.g., proliferation of smooth muscle cells and fat deposition onto arterial walls) caused by such diseases as hypertension, hyperlipidemia, arteriosclerosis, hyperglycemia or obesity may reduce the supply of energy substrates and oxygen to the myocardium and the skeletal muscle. Decreased vascular function (e.g., increased intravascular pressure, constricted and occluded vessels, and reduced vascular elasticity) and organic changes in vascular tissue (e.g., proliferation of smooth muscle cells and fat deposition onto arterial walls) caused by such diseases as hypertension, hyperlipidemia, arteriosclerosis, hyperglycemia or obesity may reduce the supply of energy substrates and oxygen to the myocardium and the skeletal muscle. Normal blood pressure does not necessarily indicate normal hemodynamics, and some angina patients show no ECG changes at rest. Hence, from a preventive standpoint, it is important to assess functional changes rather than organic changes, enabling clinicians to predict peripheral circulatory function to some degree. Since APG captures functional changes rather than organic changes, further research is needed to clarify the effects of aging on the dynamic characteristics of circulatory control. Such research should involve the application of physical stimuli to the peripheral circulatory system, using such methods as lower body negative pressure loading or positional loading in which the height of the finger tip is altered.

Studies investigating the relationship between APG index and age, SBP and DBP have shown a strong negative correlation. As reported by Sano and colleagues and ourselves in a previous study, APG index decreases with age, and thus there is a strong negative correlation between these factors ($r = -0.806, p < 0.001$). Furthermore, we found that the annual reduction rate in APG index was 5.4%, while that in VO$_2$max was much lower at 0.6%, thus clarifying that the degree of age-induced changes in peripheral circulatory function is much greater than that in cardiorespiratory function. Moreover, there was a significant positive correlation between VO$_2$max and APG index ($r = 0.440, p < 0.001$), suggesting a close relationship between VO$_2$max and peripheral circulatory function.

In the present study, while acknowledging that age, SBP and DBP have a strong effect on peripheral circulatory function, we corrected for their effects. The results still showed a significant correlation between APG index and VO$_2$max. Therefore, as reported in previous studies, there appears to be a close relationship between APG and VO$_2$max. The Ministry of Health and Welfare has established a target VO$_2$max level for women in their 20’s, 30’s, 40’s, 50’s and 60’s at 35, 34, 33, 32 and 31 ml/kg min, respectively. When VO$_2$max is lower than the age-adjusted target level, the incidence of having the risk factors associated with coronary arteriosclerosis or abnormal effort ischemic ECG findings is higher. As a result, establishing target levels of APG index could enable clinicians to predict peripheral circulatory function to some degree.

3. RESULTS

As shown in Table 2, there was a significant positive correlation between APG index and the following parameters: height ($r = 0.218, p = 0.000$), % body fat ($r = 0.153, p = 0.005$) and VO$_2$max ($r = 0.745, p = 0.000$). Conversely, there was a significant negative correlation between APG index and the following parameters: age ($r = -0.835, p = 0.000$), weight ($r = -0.113, p = 0.017$), BMI ($r = -0.248, p = 0.000$), SBP ($r = -0.305, p = 0.000$) and DBP ($r = -0.208, p = 0.000$). In addition, there was a significant negative correlation between age and VO$_2$max ($r = -0.779, p = 0.000$).

Even after correcting for the effects of aging, SBP and DBP, a significant positive correlation was seen between APG index and VO$_2$max ($r = 0.4050, p = 0.000$).

4. DISCUSSION

Decreased vascular function (e.g., increased intravascular pressure, constricted and occluded vessels, and reduced vascular elasticity) and organic changes in vascular tissue (e.g., proliferation of smooth muscle cells and fat deposition onto arterial walls) caused by such diseases as hypertension, hyperlipidemia, arteriosclerosis, hyperglycemia or obesity may reduce the supply of energy substrates and oxygen to the myocardium and the skeletal muscle. Normal blood pressure does not necessarily indicate normal hemodynamics, and some angina patients show no ECG changes at rest. In addition, ischemic changes are sometimes not evident on ECG, and some angina patients show no ECG changes at rest. Hence, from a preventive standpoint, it is important to assess functional changes in peripheral blood vessels before organic changes take place in arterial walls.

Studies investigating the relationship between APG index and age, SBP and DBP have shown a strong negative correlation. As reported by Sano and colleagues and ourselves in a previous study, APG index decreases with age, and thus there is a strong negative correlation between these factors ($r = -0.806, p < 0.001$). Furthermore, we found that the annual reduction rate in APG index was 5.4%, while that in VO$_2$max was much lower at 0.6%, thus clarifying that the degree of age-induced changes in peripheral circulatory function is much greater than that in cardiorespiratory function. Moreover, there was a significant positive correlation between VO$_2$max and APG index ($r = 0.440, p < 0.001$), suggesting a close relationship between VO$_2$max and peripheral circulatory function.

In the present study, while acknowledging that age, SBP and DBP have a strong effect on peripheral circulatory function, we corrected for their effects. The results still showed a significant correlation between APG index and VO$_2$max. Therefore, as reported in previous studies, there appears to be a close relationship between APG and VO$_2$max. The Ministry of Health and Welfare has established a target VO$_2$max level for women in their 20’s, 30’s, 40’s, 50’s and 60’s at 35, 34, 33, 32 and 31 ml/kg min, respectively. When VO$_2$max is lower than the age-adjusted target level, the incidence of having the risk factors associated with coronary arteriosclerosis or abnormal effort ischemic ECG findings is higher. As a result, establishing target levels of APG index could enable clinicians to predict peripheral circulatory function to some degree. Since APG captures functional changes rather than organic changes, further research is needed to clarify the effects of aging on the dynamic characteristics of circulatory control. Such research should involve the application of physical stimuli to the peripheral circulatory system, using such methods as lower body negative pressure loading or positional loading in which the height of the finger tip is altered.

The present study found that the annual reduction rate in APG index was 5.8%, whereas that in VO$_2$max was 1.4%. When compared to the results of our previous study, the annual reduction rate in APG index and VO$_2$max was similar. This could be explained by the fact that the number of subjects was increased from 55 to 511 women, and more women younger than 30 years of age served as subjects in the present study. Therefore, the data obtained in the present study is presumably more valid. The present study reconfirmed that aging affects APG more strongly than VO$_2$max does.

5. CONCLUSIONS

Even after correcting for the effects of aging and blood pressure, we identified a significant positive correlation between VO$_2$max and APG index, which is used to assess peripheral circulatory function. Therefore, the combination of VO$_2$max and APG could usefully assess not only cardiorespiratory function and peripheral circulatory function but also general health.
REFERENCES


