Original Article

Relationship Between Salivary \( \alpha \)-Amylase Activity and Heart Rate for Evaluation of the Sympathetic Nervous System of Children With Autism

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The purpose of the present study was to examine the validity of salivary \( \alpha \)-Amylase Activity (sAA) as an evaluation index of the activity of the sympathetic nervous system (SNS) in children with autism. Participants in the study were 7 boys with autism (mean age, 107±8 months). The participants’ sAA, heart rate (HR), and exercise intensity were measured during learning that accompanied physical activity. The data were divided into 2 groups: a high-exercise intensity group and a low-exercise intensity group. The results indicated that both sAA and heart rate rose significantly in the post-learning period compared to the pre-learning period; a significant correlation was observed between the changes in heart rate value and exercise intensity just before measuring the post values. Conversely, a significant correlation was observed between the changes in sAA value and the total amount of exercise during learning, but only in the high exercise intensity group. Recently, sAA has been studied as an index of mental stress. However, the present study, under conditions of sufficient sympathetic nervous system activation, confirmed that sAA is a valid index for the evaluation of the sympathetic nervous system activity of children with autism, and revealed that although sAA and heart rate are both indices of sympathetic nervous system activity, they have different properties.

Key Words: salivary biomarker, salivary amylase, sympathetic nervous system, heart rate, children with autism

Introduction

Regulation of physiological arousal level is thought to be impaired in the autonomic nervous systems (ANS) of individuals with autism. In an electrophysiological study using heart rate (HR) and electrodermal activity, specificity of arousal modulation was reported (Rogers & Ozonoff, 2005), and in a biochemi-

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cal study, abnormal levels of catecholamines and other transmitters were reported (Lam, Aman, & Arnold, 2006). It has also been suggested that these abnormal arousal levels are associated with specific behaviors, such as stereotyped behavior (Hutt & Ounsted, 1966). However, much remains uncertain about the association between arousal levels in autism and specificity of behavior (Hayashi & Katada, 1998; Rogers & Ozonoff, 2005).

States of anxiety, agitated behavior, passivity, and lethargy have been indicated in some reports, which represent over- or under-arousal arising from dysfunction in the autonomic nervous system in individuals with autism. These states limit the ability of individuals with autism to attend to, process, and interact with their environment, and may restrict their learning of normative behaviors and skills (Goodwin, Groden, Velicer, Lipsitt, Baron, Hofmann, & Groden, 2006). In providing support for effective learning with the aim of improving the quality of life of people with autism, it is therefore thought to be necessary to have an accurate understanding of the activity status of their autonomic nervous systems, and take appropriate approaches as needed.

Electrophysiological methods, including measurement of heart rate, blood pressure, cardiac output and blood volume, are often used to evaluate autonomic nervous system activity. However, not all of these measurement methods are appropriate in the daily life settings of individuals with autism, and so not all of them are useful from the perspective of ecological validity. Therefore, in the present study, when selecting indicators to evaluate autonomic nervous system activity in children and adults with autism, we focused, from the perspective of ecological validity, on biological substances (biomarkers) in saliva. These have attracted attention in recent years because of their non-invasive collection and advances in measurement methods (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007). Specifically, there have been many reports on salivary α-amylase activity (sAA), a digestive enzyme in saliva, as a possible indicator reflecting activity of the sympathetic nervous system (SNS) in healthy adults (Yamaguchi, Hanawa, & Yoshida, 2007).

The usefulness of sAA as a physiological index reflecting autonomic nervous system activity as a result of stress in children and adults with severe motor and intellectual disabilities, who may have difficulty communicating, has also been reported (Takeda, Onishi, Yamaguchi, & Takeya, 2006; Takeda, Watanabe, Onishi, & Yamaguchi, 2008). A portable measurement device has been developed for sAA (Yamaguchi, 2007; Yamaguchi, Kanemori, Kanemaru, Takai, Mizuno, & Yoshida, 2004), with which measurement values can be obtained instantaneously and simply in daily life settings. Using this device, sympathetic nervous system activity in autistic patients can be evaluated quantitatively and objectively in daily living settings, and the ecological validity of the measurement environment can be assured. Moreover, objective and quantitative evaluation of sympathetic nervous system activity in special needs education, a daily life setting for children with autism, and evidence for the autonomic nervous system characteristics in
children with autism obtained from physiological indicators, may lead to effective support for children with autism and contribute to improving the quality of their education. However, no studies have evaluated sympathetic nervous system activity in individuals with autism in daily life settings with the use of sAA values, and thus the utility of sAA has not been demonstrated.

In the present study, with the aim of clarifying the validity of sAA as an index of sympathetic nervous system activity in children with autism, based on an investigation of its relationship with other physiological indicators, we measured sAA during morning exercise learning activities conducted in daily special needs educational settings.

Method

Participants

Participants were 7 autistic boys (mean age, 107±8 months) for whom consent was obtained for the study and whose saliva could be collected and heart rate measured. They were pupils in the elementary division of a special needs education school in which the same morning exercises were performed every morning. All of the participants had been diagnosed with autism by professionals at a medical institution. The range of the developmental age (DA) of the participants according to the Psychoeducational Profile-Revised (PEP-R) was 24–60 months; their mean DA was 45±11 months.

Target Learning Activities

The morning exercises were performed at the same time every morning (9:30–10:00 a.m.). They were the learning activities during which the target measurements were made. The morning exercises included exercising to music, in which the students circled the gymnasium running, walking, skipping, crawling, and rolling on their sides. The activity program is shown in Table 1. The duration of the actual learning time was about 14 minutes.

Measurement of Physiological Indices

sAA. Measurements were made using a salivary amylase activity monitor (CM-2.1; Nipro, Japan).

Heart rate. Measurements were made using a pulse oximeter (PULSOX-300i; Konica Minolta Sensing, Japan).

Amount of exercise. Exercise intensity was measured every 2 minutes during exercise using an activity monitor (Lifehorder Plus; Suzuken, Japan), and the sum of these measurements was the total amount of exercise. To correct for small variations in the duration of the learning time due to class or individual reasons, the total amount of exercise was divided by the time participating in the learning activities to obtain the mean amount of exercise, which was also used for data analysis. The amount of exercise before post-learning measurement was
measured by exercise intensity 2 minutes before the time of the post-learning measurement of sAA and heart rate.

**Measurement Protocol for Physiological Indicators**

Heart rate and sAA were measured simultaneously. The measurement points were divided into 2 phases: within 10 minutes prior to the morning exercises, and from the latter half of learning (13 and after in Table 1) to within 10 minutes after learning. The measured values selected and used as pre-learning and post-learning values were those obtained in a state with no unusual psychological condition, such as crying or panic, other than the physical arousal from the activity program. The amount of exercise was measured continuously during the morning exercise learning time.

**Statistical Analysis**

In the present study, measurements were made during the participants’ daily activities, but it was difficult to unify the number of measurement times of all participants after excluding experimental variables. Therefore, with reference to Sievers, Yee, Foley, Blanding and Berde (1991), the data obtained from a total of 26 measurements in the 7 participants (mean number of measurements: 4.1±2.1; minimum 1, maximum 7) were individually processed as a single datum and used in the analysis.

Statistical analysis was performed using JMP 8.0 (SAS Institute Japan). The following analyses were carried out, with \( p<.05 \) taken to indicate statistical significance in all analyses. When \( .05<p<.1 \), it was considered to be a significant trend.

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**TABLE 1** Morning Exercise Learning Program

<table>
<thead>
<tr>
<th>Order</th>
<th>Duration(s)</th>
<th>Type of Movement</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>2</td>
<td>50</td>
<td>crawling</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
<td>walking</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>5</td>
<td>75</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>7</td>
<td>50</td>
<td>rolling on their sides</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>8</td>
<td>70</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>9</td>
<td>45</td>
<td>crawling</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>10</td>
<td>60</td>
<td>skipping</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
<td>running</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>12</td>
<td>40</td>
<td>rolling on their sides</td>
<td>Counterclockwise</td>
</tr>
<tr>
<td>13</td>
<td>55</td>
<td>walking</td>
<td>Clockwise</td>
</tr>
<tr>
<td>14</td>
<td>70</td>
<td>running</td>
<td>Clockwise</td>
</tr>
<tr>
<td>15</td>
<td>80</td>
<td>lying on their back</td>
<td>Clockwise</td>
</tr>
</tbody>
</table>
Comparison of pre-learning and post-learning values. Paired $t$-tests were used for comparisons of pre-learning and post-learning values for sAA and heart rate.

Association between sAA, heart rate, and amount of exercise. A logarithmic conversion was performed on the sAA and heart rate values in order to approach a normal distribution. The relationship between sAA and heart rate, and the relationship between the changes in sAA and heart rate and the amount of exercise were then evaluated using Pearson’s correlation coefficient.

Evaluation of total amount of exercise, mean amount of exercise, and amount of exercise before post-learning measurement of sAA and heart rate. Amount of exercise was analyzed using a Lifelyzer 02 Basic (Suzuken). The association between the total amount of exercise, the mean amount of exercise, and changes in sAA and heart rate was evaluated using Pearson’s correlation coefficient. In addition, as the amount of exercise before post-learning measurements was not normally distributed, the relationship with post-learning values for sAA and heart rate was evaluated using Spearman’s rank correlation coefficient.

Classification into low-exercise and high-exercise intensity groups, and analysis. Taking the mean amount of exercise at a level of Metabolic Equivalents (METs) $\leq 4$ (equivalent of fast walking) as a reference, the data points were divided into a low-exercise intensity group of METs $\leq 4$, and a high-exercise intensity group of METs $> 4$. The relationship between sAA and heart rate in each group was then analyzed. In addition, the relationships between the total amount of exercise and changes in sAA and heart rate were analyzed using Pearson’s correlation coefficient. The changes in sAA and heart rate were also compared between the groups with a $t$-test. Variance in the changes in heart rate was not equal, and so a Welch’s $t$-test was conducted for the changes in heart rate.

Ethical Considerations
The present study was approved by the Ethics Committee of the Graduate School of Comprehensive Human Sciences, University of Tsukuba. The purpose and methods of the study were explained orally and in writing to the participants and their guardians, and informed consent was obtained from the guardians. In addition, only those children who cooperated with the saliva collection and heart rate measurements were enrolled as participants.

Results

Comparison of Pre-learning and Post-learning Values
In the morning exercise learning sessions, the mean pre-learning value for sAA was $62.2 \pm 47.3$ KU/L, and the mean post-learning value was $93.4 \pm 48.9$ KU/L. The results of a $t$-test for paired data showed that sAA measured at the end of morning exercise learning was significantly higher than the pre-exercise value ($t(25) = 3.99, p < .01$, Fig. 1).

The mean pre-exercise heart rate was $84.9 \pm 19.9$ (bpm), and the mean post-
exercise value was 105.5 ± 25.4 bpm. Post-exercise heart rates were significantly higher ($t(25)=3.63$, $p<.01$, Fig. 1).

**Relationship Between sAA and Heart Rate**

*Relationship between all measured values for sAA and heart rate.* A significant correlation was found between all measured values for sAA (logarithmic conversion values) and all measured values for heart rate (logarithmic conversion values), with $r=−.30$ ($F(1, 50)=4.92$, $p<.05$, Fig. 2).

*Relationship between changes in sAA and heart rate.* No significant correlation was observed between changes in sAA and changes in heart rate.

*Comparison of the rate of change in sAA and heart rate.* The rate of change is obtained by dividing the absolute change by the pre-learning value and multiplying by 100. When these values were compared using Wilcoxon’s rank sum test, it was found that the rate of change in sAA was significantly higher than the rate of change in heart rate ($Z=−2.01$, $p<.05$).

**Relationship Between Amount of Exercise and sAA and Heart Rate Values**

*Relationship between total amount of exercise and amount of change in sAA and heart rate.* No significant correlation was obtained between the changes in sAA and the total amount of exercise, or between the changes in heart rate and the total amount of exercise.

*Relationship between mean amount of exercise and changes in sAA and heart rate.* No significant correlation was obtained between the changes in sAA and mean amount of exercise, or between the changes in heart rate and mean amount of exercise.

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**FIG. 1** Comparison of Pre-Learning and Post-Learning Values

*Note.* The long horizontal lines represent the means; the short horizontal lines, the SDs. The left side of the Figure shows the changes in sAA seen in learning. The right side of the Figure shows the changes in heart rate seen in learning. For both sAA and heart rate, post-learning values were significantly higher than pre-learning values.
Relationship between amount of exercise before post-learning measurement and amount of change in sAA and heart rate. No significant correlation was obtained between the changes in sAA and the amount of exercise before post-learning value.

A significant trend ($r=.33$) was obtained between the changes in heart rate and the amount of exercise before post-learning measurement ($0.05 < p < .1$; Fig. 3).

Relationship between amount of exercise before post-learning measurement and post-learning values of sAA and heart rate. No significant correlation was found between post-learning sAA (logarithmic conversion value) and the amount of exercise before post-learning measurement, or between the post-learning heart rate (logarithmic conversion value) and amount of exercise before post-learning measurement.

**Relationship Between sAA, Heart Rate, and Amount of Exercise in the High-Exercise Intensity Group ($n=15$)**

Relationship between all measured values for sAA and heart rate. In the high-exercise intensity group (the mean value of the mean amount of exercise was $5.0 \pm 0.6$ Mets), the correlation coefficient for all measured values (logarithmic conversion values) for sAA and heart rate was 0.36, revealing a significant trend ($F(1, 28) = 4.08, 0.05 < p < .1$).

Relationship between changes in sAA and heart rate. No significant correlation was seen between changes in sAA and heart rate in the high-exercise intensity group.

Relationship between total amount of exercise and changes in sAA and heart rate. A
significant correlation was obtained between the changes in sAA and the total amount of exercise in the high-exercise intensity group: $r= .59 \ (F(1, 13) = 7.08, \ p < .05, \ \text{Fig. 4})$, however, no significant correlation was found between the change in heart rate and total amount of exercise.

**Relationship Between sAA, Heart Rate, and Amount of Exercise in the Low-Exercise Intensity Group ($n=11$)**

*Relationship between all measured values for sAA and heart rate.* In the low-exercise intensity group (the mean value of the mean amount of exercise was $3.2 \pm 0.4$ Mets), no significant correlation was obtained between any of the measured values (logarithmic conversion values) for sAA and heart rate.

*Relationship between changes in sAA and heart rate.* No significant correlation was found between the changes in sAA and heart rate.

*Relationship between total amount of exercise and changes in sAA and heart rate.* No significant correlation was obtained between the changes in sAA and total amount of exercise, or between the changes in heart rate and total amount of exercise.

**Between-Group Comparisons of Changes in sAA and Heart Rate**

*Between-group comparison of changes in sAA.* The mean change in sAA was $27.7 \pm 40.4$ KU/L in the high-exercise intensity group and $24.9 \pm 40.6$ KU/L in the low-exercise intensity group. No significant difference was found in the change in sAA ($t$-test).

\[
\rho = .33, \ .05 < \rho < .1 \\
N = 26
\]

**FIG. 3** Correlation of Changes in Heart Rate and Amount of Exercise before Post-Learning Measurement

*Note.* METs=Metabolic Equivalents.
Between-group comparison of changes in heart rate. The mean change in heart rate was 29.1 ± 33.1 bpm in the high-exercise intensity group, and 23.7 ± 23.7 bpm in the low-exercise intensity group. On t-test using Welch’s method, a significant trend was found between the mean amount of change in heart rate in both groups (t (24) = 1.44, p < .05). In other words, a large trend to significance was seen in the changes in heart rate in the high-exercise intensity group, as compared with the low-exercise intensity group.

Discussion

Changes in sAA and Heart Rate During Morning Exercise Learning

In the morning exercise learning, which was part of the daily routine for the children with autism who participated in this study, the post-learning values of sAA and heart rate were significantly higher than the pre-learning values. It is known that the sympathetic nervous system becomes hyperactive and heart rate increases as a result of physical activity or physical load. The increase in heart rate in this study was also thought to be a physiological phenomenon accompanying activation of the sympathetic nervous system from physical activity.

It has also been reported in research with healthy adults that sAA increases after physical activity (Chatterton, Vogelsong, Lu, Ellman, & Hudgens, 1996; Kivlighan & Granger, 2006; Walsh, Blannin, Clark, Cook, Robson, & Gleeson, 1999). The results of the present study were similar to those of previous studies.

The significant increase in sAA at the time of a physical activity that resulted in an elevated heart rate demonstrates the validity of sAA as an evaluation index of the sympathetic nervous system in children with autism.

![FIG. 4 Correlation of Changes in sAA and Total Amount of Exercise during Morning Exercise Learning in the High Exercise Intensity Group](image)

Note. METs=Metabolic Equivalents.
Relationship Between sAA and Heart Rate in Morning Exercise Learning

The significant positive correlation obtained between the measured values of sAA and heart rate suggests that sAA, like heart rate, can be used to assess sympathetic nervous system activity. However, no correlation was found between the changes in the two measures.

One way to explain this is in terms of differences in sensitivity of sAA and heart rate as indices for evaluating the activity of the autonomic nervous system in children with autism. In a study of children with autism and children with no disabilities, Goodwin et al. (2006) found that whereas 60% of the children with no disabilities showed a significant change in heart rate in stress conditions including physical exercise, such changes were seen in only 22% of the children with autism. Goodwin et al. (2006) suggest that a high baseline heart rate in children with autism may be the reason for this.

The present results suggest that among children with autism who have a chronically high heart rate; there may be some in whom changes in cardiovascular activity at a level that could be called significant are not seen in response to environmental stress. For this reason, heart rate is not necessarily an effective index for the evaluation of sympathetic nervous system activity in children with autism.

In the comparisons of rate of change in the present study, the rate of change in sAA was shown to be higher than that of heart rate. This suggests that sAA may be more sensitive than heart rate as an index of change in response to stimuli. Thus, using sAA to evaluate sympathetic nervous system activity among individuals with autism may be more useful than using heart rate, in terms of the ease of understanding the observed changes.

Another possible explanation of why no correlation was found in amount of change is that there may be differences in the parts of the sympathetic nervous system reflected by sAA and by heart rate. In recent years, sAA has attracted attention not only in relation to control of the sympathetic nervous-adrenal medullary (SAM) system, but also in relation to activation from direct nerve action on the salivary glands by the sympathetic nerves (Yamaguchi, 2007). In that case, the response time is thought to be faster than for responses of the sympathetic nervous-adrenal medullary system. Because sAA is controlled in these two ways, the difference in innervation compared to heart rate may be another reason why a correlation was not seen in the amount of change.

Relationship Between Amount of Exercise and sAA and Heart Rate Values

In the present study, the total amount of exercise was not correlated with changes in sAA or heart rate. Because the present results were from measurements in a normal daily life setting, there were slight individual differences among participants in the duration of their participation in the activities for various reasons arising from their school life. Thus, even if the total amount of exercise was about the same, there were mixed cases of long activity duration with
low-exercise intensity and short activity duration with high-exercise intensity. We therefore analyzed the relationship between the change in sAA and the mean amount of exercise, obtained by dividing the total amount of exercise by the duration of participation in learning. Although no significant correlation was found between mean amount of exercise and sAA, a positive correlation was obtained between amount of exercise before the post-learning measurement and amount of change in heart rate. Thus, it is possible that, in the change from pre-learning heart rate value, the results obtained depended more on the physical exercise intensity during the 2 minutes immediately before the post-learning measurement than on the change throughout the entire activity (about 10–15 minutes). Heart rate is therefore thought to be an index that changes greatly, depending on the immediate physical activity level, and is thought to be an appropriate index for evaluating activity status of the sympathetic nervous system immediately after stimulation or some other load is applied.

Metabolic Equivalents (METs), the unit for amount of exercise used in this study, is an index that expresses exercise intensity as a multiple of intensity at rest, with intensity at rest taken to be 1. Exercise at the intensity of walking is equivalent to an MET of 3. Normally, an exercise load of about METs 1–3 is insufficient to activate the sympathetic nervous system. To obtain physiological effects from exercise, a METs level of ≥3 is thought to be appropriate. In the Exercise and Physical Activity Guide for Health Promotion 2006 prepared by the Ministry of Health, Labor and Welfare of Japan (Office for Lifestyle-Related Diseases Control, General Affairs Division, Health Service Bureau, Ministry of Health, Labour and Welfare of Japan, 2007), exercise of METs ≥3 has been established as a target physical exercise level to promote health.

Thus, even if activity of METs 1–3 is continued for a long time and the total amount of exercise is high, it is possible that accelerated activity in the sympathetic nervous system will not be measured. In fact, the 7 children in the present study had different exercise intensity loads resulting from participation in the exercise learning. This may have affected the correlation between the amount of exercise and changes in physiological indices in the group with a low mean amount of exercise.

That is why, with the mean amount of exercise set at METs 4 (equivalent to fast walking or riding a bicycle) as a reference, we divided the data into high- and low-exercise intensity groups for analysis.

Relationship between sAA, Heart Rate, and Amount of Exercise in High- and Low-Exercise Intensity Groups

A positive correlation was obtained between the change in sAA and the total amount of exercise in the high-exercise intensity group. Thus, in the case of exercise with a high intensity level, the amount of exercise obtained throughout the entire activity is proportional to the amount of change in sAA. No correlation was found between the change in sAA and the total amount of exercise in the
low-exercise intensity group. The reason that no correlation was found between the change in sAA and the total amount of exercise in all the data is thought to be the effect that occurred in the low-exercise intensity group.

Thus, in activities or conditions that are sufficient to accelerate sympathetic nervous system activity, sAA is an index that faithfully reflects changes in the sympathetic nervous system throughout the entire activity. In contrast, no correlations were found between the change in heart rate and total amount of exercise. This is thought to be due to the dependence on exercise intensity immediately before measurement, as described above. Thus, sAA and heart rate appear to have different characteristics as indices for the evaluation of sympathetic nervous system activity. sAA is predicted to be an index that faithfully reflects the activity of the sympathetic nervous system obtained throughout an entire activity for a given time, in cases when the activity being measured is sufficient to accelerate the activity of the sympathetic nervous system, whereas heart rate is predicted to reflect the state of activity of the sympathetic nervous system immediately following an exercise load.

In the low-exercise intensity group, no correlation was obtained between any of the variables. This may have been the result of factors other than the amount of exercise affecting heart rate and sAA values. Although this point needs to be investigated further, a low mean amount of exercise may indicate a low mean level of participation in learning. Psychological factors such as resistance to the activity may also be behind this, and it is possible that such factors also affect the sympathetic nervous system. Physical loads other than amount of exercise may also affect measurements. Examples are heat and cold, but sAA has also been reported to be related to physical loads such as temperature and pain (Chatterton et al, 1996). The data in the present study were collected during the summer, and thus it is possible that the level of participation in the activities was low because of the heat. Thus, even if activity level was low, sAA may have shown a high level as a result of heat and other physical loads and psychological factors such as resistance to the activities.

In the between-group comparisons of the high and low groups of exercise intensity, the amount of change in heart rate was larger in the high-exercise intensity group than in the low-exercise intensity group, whereas no differences were observed in sAA between the groups. This also suggests that sAA reflects the sympathetic nervous system activity status from factors other than amount of exercise in the low-exercise intensity group. In many previous studies, sAA has been reported to be associated with psychological and psychosocial factors (e.g., Nater, Rohleder, Gaab, Berger, Jud, Kirschbaum, & Ehler, 2005; Skosnik, Chatterton, Swisher, & Park, 2000), and associations with these factors are also conjectured in the present study.
Conclusion

In the present study, under conditions of sufficient sympathetic nervous system activation, it was confirmed that sAA is a valid index for the evaluation of sympathetic nervous system activity in children with autism, and that, unlike heart rate, which reflects the state of sympathetic nervous system activity over a short time, sAA is an indicator that reflects changes in the sympathetic nervous system over a more extended period when sympathetic nerve activity has been sufficiently activated.

In the future investigations should be conducted that include psychological and psychosocial factors. Also, the utility of sAA in evaluating sympathetic nervous system activity in children with autism should be evaluated with comparison to a control group in order to confirm the characteristics of sAA in children with autism.

Acknowledgments

We are sincerely grateful to the children, their guardians, and the school teachers and officials who cooperated with the present study. The present study was supported by a 2009 General Grant from the Gushinkai Foundation (2009.4 to 2010.3). The study was also funded in part by a Grant-in-Aid for JSPS Fellows (2010.4—).

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— Received June 6, 2011; Accepted December 10, 2011 —