The Comparison of Pronation and Supination between Typically Developing Children and Children with ADHD

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Abstract—**Diagnostic methods of attention deficit hyperactivity disorder (ADHD) have soft neurological signs (SNS). Motion of pronation and supination is one of SNS tests. When diagnosing ADHD children, Medical doctors observe the regularity of children's pronation and supination. It is hoped that a quantitative and simple evaluation method is established. This study's aim is to compare differences of pronation and supination between typically developing children (TDC) and ADHD children in order to establish a more quantitative evaluation system. The subjects are 85 TDC and 29 ADHD (children aged 7-11). As results, we could obtain different motion between TDC and ADHD children by our system. These differences have the potential to become diagnostic criteria for ADHD.**

Index Terms—**Pronation and supination, acceleration and angular velocity sensor, attention deficit hyperactivity disorder**

I. Introduction

Attention deficit hyperactivity disorder (ADHD) is one of developmental disorders. ADHD's major symptoms are inattention, hyperactivity, and impulsivity. These symptoms prevent children from performing daily activities and learning. Therefore it is necessary to find these symptoms in the early stage, and to provide an appropriate diagnosis result about ADHD. Diagnostic methods of ADHD have soft neurological signs (SNS). SNS is minor dysfunction which shows the development delay and the maturity of the central nervous system [1, 2]. Therefore it is possible to obtain medical diagnosis. Pronation and supination of forearms is one of many diagnostic tests of SNS. This motion involves movements to bend the elbow to 90 degrees, and to rotate the palm and the back of the hand. Other examples are convergence, heel gait and finger to nose tests and so on. When ADHD children are pronating and supinating their arms, Medical doctors evaluate the regularity of children's pronation and supination. When this motion is monitored, it is possible to examine neuromotor development. However, this diagnosis method has a demerit in which diagnosis results between doctors are not consistent. Therefore it is hoped that a more quantitative and simple evaluation method of pronation and supination is established.

Various studies about the relationship between developmental disability and soft neurological signs have been reported so far [3-9]. In this study, we focused on pronation and supination of forearms and quantification of diagnosis.

Pronation and supination of forearms is simple motions in soft neurological signs. Three-dimensional wireless acceleration and angular velocity sensors are used to establish a simple and easy evaluation system for this motion. In a previous paper, we have created diagnostic criteria of pronation and supination of forearms by data of typically developing children (TDC aged 6-11). After that, we compared TDC with attention deficit hyperactivity disorder (ADHD) and could obtain significant differences between the two groups [10].

The aim of this paper is to obtain differences between TDC and ADHD children in order to establish quantitative evaluation system by full speed of pronation and supination. As a result, we could obtain differences between TDC and ADHD children in full speed. It is concluded that these differences have the potential to become diagnostic criteria for a developmental disability.

Manuscript received January 8, 2014; revised February 10, 2014. This work was supported in parts by Grant-in Aids for Scientific Research, Ministry of Education, Science, Sports, Culture and Technology, Japan (No. 25560287), Kakihara Science and Technology Foundation.

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II. Evaluation System of Pronation and Supination

A. System Configuration

The developed evaluation system of pronation and supination shows in Fig.1. This system consisted of four three-dimensional wireless acceleration and angular velocity sensors (WAA-006, WAA-010, ATR-Promotions), a guide monitor, a charge-coupled device camera (CCD camera) and a notebook computer. The four sensors were attached to the limbs of the subject, with one sensor on each respective hand and one sensor on each respective elbow. Before starting the measurement, the subject saw a guide monitor. The demonstration guide showed a motion that pronates and supinates both hands at the speed of 300 times a minute. Directions of three axis in acceleration and angular velocity

ISBN: 978-988-19252-5-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

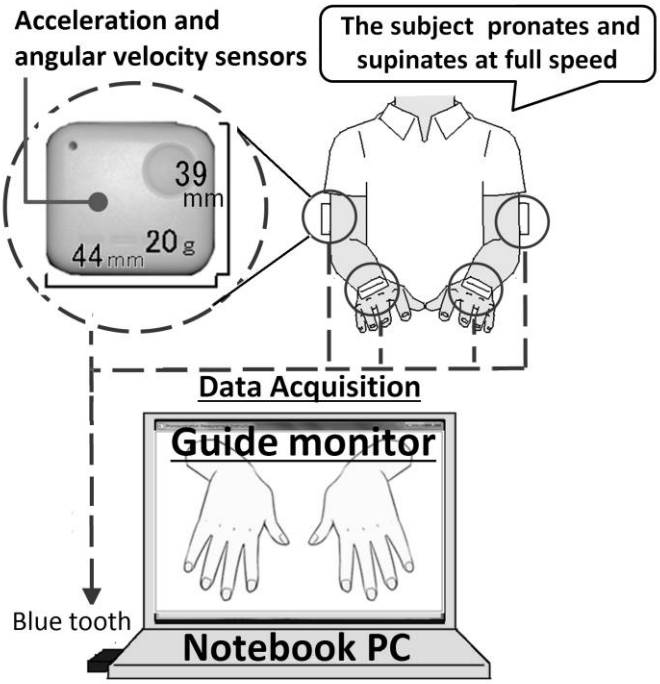

Fig. 1. Evaluation system for pronation and supination of forearms.

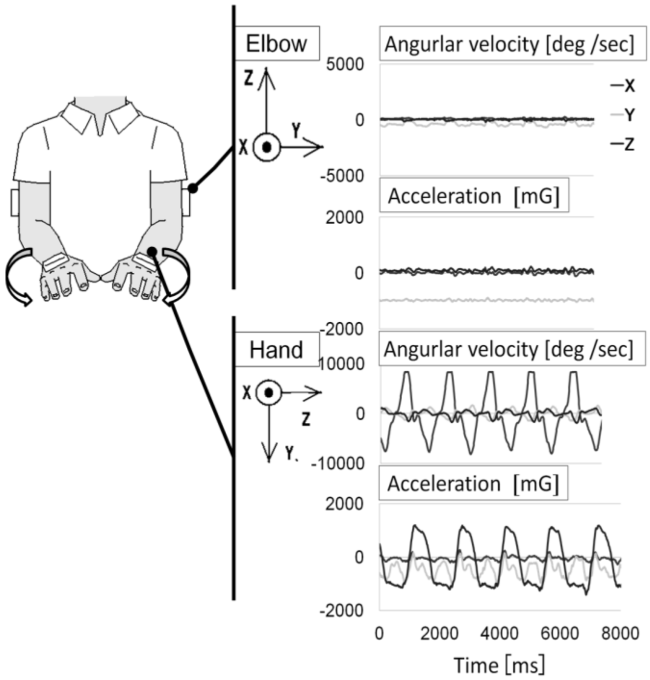

Fig. 2. Evaluation system for pronation and supination of forearms.

sensors show in Fig2. The size of sensors is 39 mm (W), 44 mm (H) and 12 mm (D). The weight of the sensor is 20 g.

Signals were transmitted by blue tooth to the notebook PC. The notebook PC was used for the data acquisition. The motion of the subject was recorded by the CCD camera.

III. Subjects and Method

A. Subjects

We measured the motion of pronation and supination at full speed to obtain diagnostic criteria. The subjects were 85 TDC aged 7–11 years from one elementary school and 29 children with ADHD aged 7–11 years.

Before starting the measurement, all subjects received an explanation of the purpose of study, procedures and hazards of measurement. All subjects agreed to participate.

B. Measurement Task

In the previous study, we compared pronation and supination between TDC and ADHD children in other tasks. We analyzed 2 tasks. First task is a motion that a subject pronates and supinates both hands at the speed of 80 times a minute (herein after referred to as "tempo 80"). Second task is a motion that a subject pronates and supinates both hands at the speed of 120 times a minute (herein after referred to as "tempo 120").

In this study, we analyzed task when the subject pronates and supinates at full speed.

Before starting the measurement, the subject saw a guide monitor. The demonstration guide showed a motion that pronates and supinates both hands at the speed of 300 times a minute. The subject bent the elbow to 90 degrees and pronated and supinated their arm as fast as possible. Measurement time is 10 seconds.

C. Data Analysis

Fig.2 shows the waveforms of the three-dimensional acceleration and angular velocity, when the subject pronates and supinates both hands at the speed of 80 times a minute. The above waveforms shows waveforms of hands, the below waveforms shows waveforms of elbows. The sampling frequency is 100Hz.

We have created three indices to evaluate the subject's motion from the acceleration and angular velocity sensors so far. These indices are accuracy (an index of correlation between the subject's motion and instructed motion), stability (index of motion of hands and arms) and cooperativeness (an index of precision of symmetrical movement between left hand and right hand).

In this study, we created three indices to evaluate pronation and supination at full speed. These indices are rotation speed, movement of hands and movements of elbows. Rotation speed shows a change of speed when the subject pronates and supinates at full speed. Movement of hands shows blurring of X axis of hands as in the Fig.3. Movement of elbows is an index for evaluating whether the subject's elbows pull away from their side. Moreover, these three indices have parameters to calculate index scores evaluating the subject's motion. Parameters of rotation speed include the following two kinds of parameters:

1) Average of continuous FFT peak frequency of acceleration on Z directions (both hands)

Fig.3 shows 4 kinds waveforms of acceleration on Z axis in hands. (A) is a waveform when the subject pronates and supinates slower than tempo 120. (B) is a waveform when the subject pronates and supinates faster than tempo 120. (C) is a waveform when the subject pronates and supinates a fixed speed. (D) is a waveform when the subject pronates and supinates an irregular speed. Rotation speed evaluates differences of these movement.

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ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

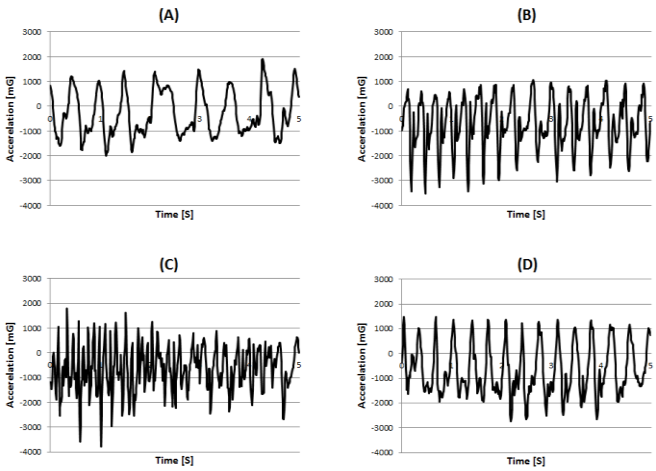

Fig. 3. Waveforms of accerelation on Z axis (hands)
(A) : a waveform when the subject moves slower than tempo 120
(B) : a waveform when the subject moves faster than tempo 120
(C) : a waveform when the subject move a fixed speed
(D) : a waveform when the subject move an irregular speed.

A parameter of movement of hands is as follows:

1) The average of absolute value total sum of acceleration on X direction (both hands)

2) The average of absolute value total sum of acceleration on Y direction (both hands)

Fig.4 shows 2 kinds waveforms of acceleration on X axis in hands. In fig.4, gray line shows waveform that the subject pronates and supinates while moving the subject's arms up-and-down. Black line shows waveform that the subject does not move X axis of hands when the subject pronates and supinates.

A parameter of movement of elbows is as follows:

1) The average of absolute value total sum of angular velocity on X direction (both elbows)

In Fig.5, gray line shows a waveform that the subject's elbows pull away from his side. Black line shows a waveform that the subject's elbows do not move.

If the subject's elbows pull away from their side, the maximum of angular velocity on the X direction increases

IV. Result and Discussion

We measured the motion of pronation and supination of the forearm of 85 typically developing children (TDC) and 29 attention deficit hyperactivity disorder (ADHD) children (subjects aged 7-11). From the measurement, we could obtain differences neuromotor function between TDC and ADHD children. Fig.6~8 shows the comparison between TDC and ADHD. Fig.6 shows the result of rotation speed, which is a change of speed when the subject pronates and supinates at full speed. Fig.7 shows the result of movement of hands, which is blurring of X axis of hands. Fig.8 shows the result of movement of elbows, which is an index for evaluating whether the subject's elbows pull away from their side. The horizontal axis represents 2 gropes, TDC and ADHD. White graph shows an average of TDC's values. Gray graph shows an average of ADHD's values.

From the results of rotation speed, average of rotation peaky

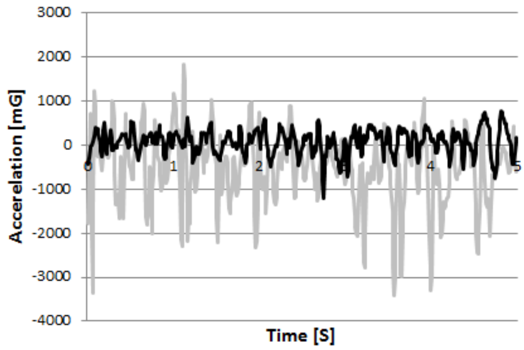

Fig. 4. Waveforms of accerelation on X axis (hands)
Black line : waveform when the subject does not move X axis of hands
Gray line : waveform while moving the subject's arms up-and-down.

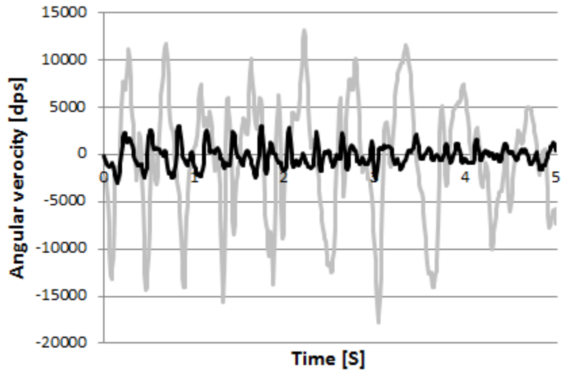

Fig. 5. Waveforms of accerelation on X axis (hands)
Black line : waveform when the subject's elbows do not move.
Gray line : waveform when the subject's elbows pull away from his side.

frequency has a tendency that ADHD's value is more than TDC's value. There is not the difference of 2 groups in dispersion of rotation peaky frequency. The result indicates that ADHD children pronate and supinate faster than TD children. And both groups move a fixed speed.

From the (A) result of movement of arms, average of absolute value total sum of acceleration on X axis has a tendency that ADHD's values are more than TDC's values. There is not the difference of 2 groups in left-and right sequence of arm motion. The result indicates that ADHD children move up-and down.

From the movement of elbows, average of absolute value total sum of angular velocity on X axis has a tendency that ADHD's value is more than TDC's value. The result indicates that ADHD children's elbows pull away from their sides.

From the results of three indices, it is indicated that ADHD children move restlessly. These differences have the potential to become diagnostic criteria of pronation and supination at full speed for a developmental disability.

Moreover we analyzed average of rotational peaky frequency in detail. (A) of fig.9 shows differences of average of rotational peaky frequency between right hand and left hand. All of subjects dominate hand are right hands. (B) of fig.9 shows differences of average of rotational peaky frequency between the first part and the latter part. From the results, it is indicated that the difference of rotation speed between right hand and left hand in ADHD children is smaller than that in TDC and the difference of rotation speed between

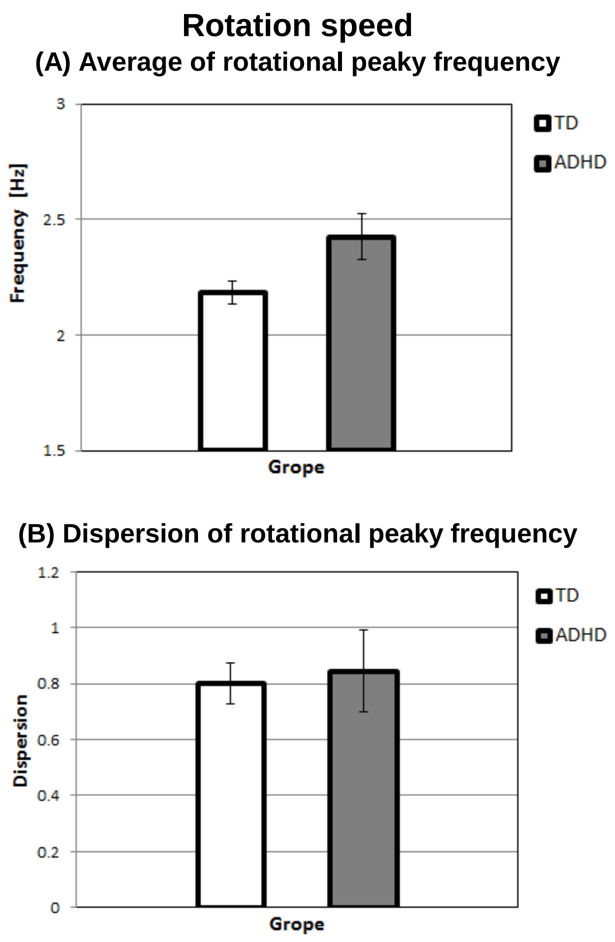

Fig. 6. Rotation speed.
(A) Average of peaky frequency's parameter is average of continuous FFT peak frequency of angular velocity on X directions (both hands)
(B) Dispersion of peaky frequency's parameter is dispersion of continuous FFT peak frequency of angular velocity on X directions (both hands)
White graph : TDC Gray graph : ADHD children

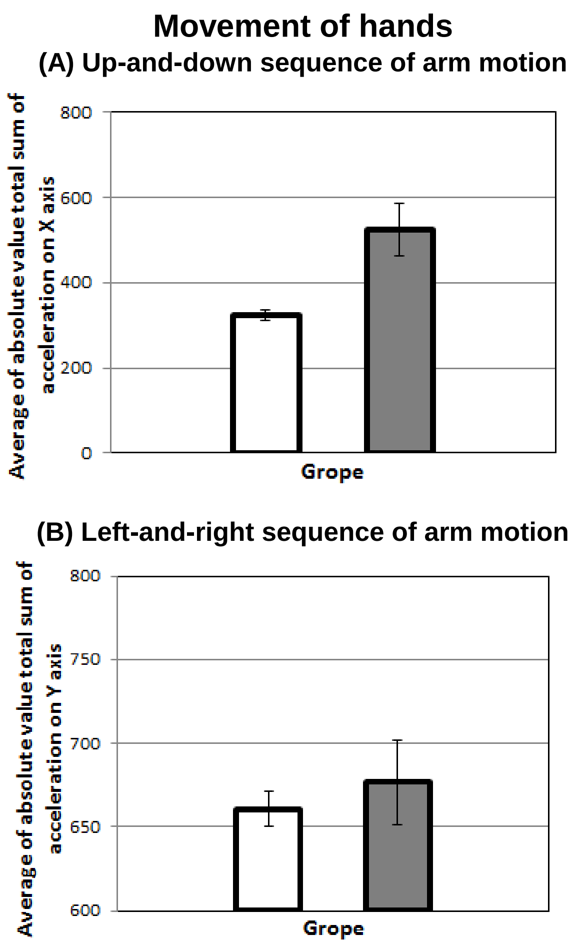

Fig. 7. Movement of hands.
(A) Up-and-down sequence's parameter is average absolute value total sum of acceleration on X directions (both hands)
(B) Right-and-left sequence's parameter is average absolute value total sum of acceleration on Y directions (both hands)
White graph : TDC Gray graph : ADHD children

the first part and the latter part in ADHD children is more than that in TDC.

The next step, we compared between TDC and ADHD by ages in order to evaluate detail both groups. Fig.10~12 shows the comparison between TDC and ADHD by ages. Fig.10 shows the rotation speed's result of average of rotational peaky frequency. Fig.11 shows the result of movement of hands. Fig.12 shows the result of movement of elbows. In order to observe neuromotor function in relation to rapid growths, we evaluated value of TDC between the ages of 7 and 11. The horizontal axis represents age. Dotted line shows TDC's values. Solid line shows ADHD children's values. The vertical axis indicates the average of index value for TDC and ADHD. As shown in Fig.10, aging curves of neuromotor development have a tendency to increase between 7 and 11 years old as they grow older. Conversely, as shown in Fig.11 and Fig.12, aging curves of neuromotor development have a tendency to decrease between 7 and 11 years old as they grow older. These results indicate that TD children's pronation and supination movement is fast and calm as they grew older. It is inferred that these aging curves show growth of neuromotor

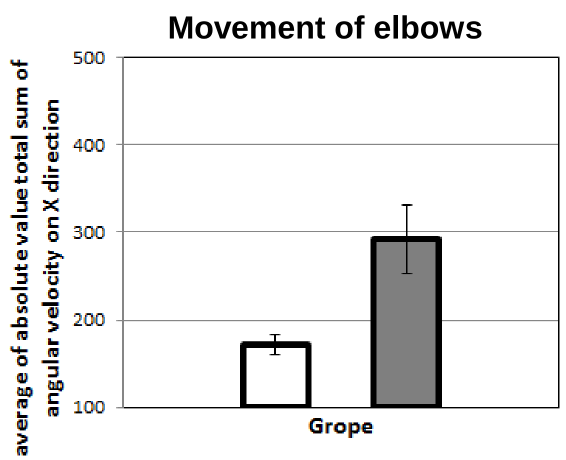

Fig. 8. Movement of hands.
This index's parameter is average absolute value total sum of angular velocity on X directions (both elbows)
White graph : TDC Gray graph : ADHD children

function for TDC.

We could obtain more accurate aging curves and differences between TDC and ADHD children by averaging these indices. We believe that these result obtained by our

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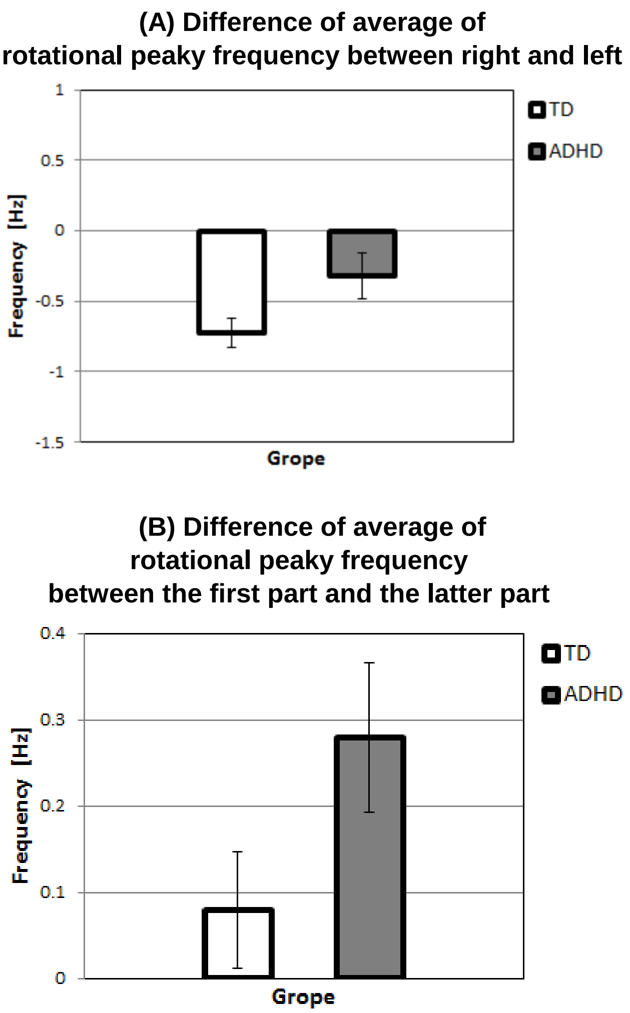

Fig. 9. Rotation speed in detail.
(A) Differences of average of rotational peaky frequency between right hand and left hand
(B) Differences of average of rotational peaky frequency between the first part and the latter part
White graph : TDC Gray graph : ADHD children

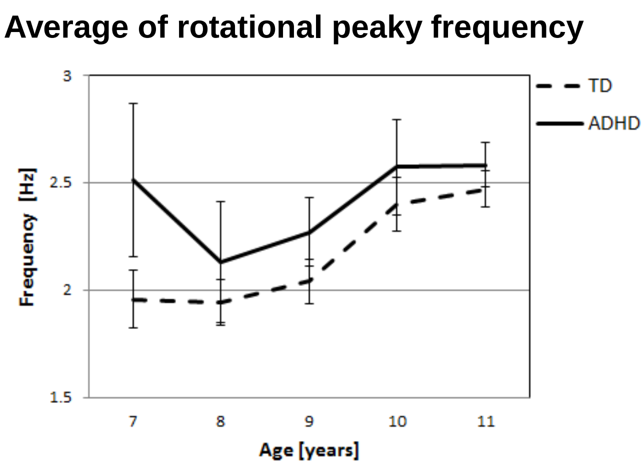

Fig. 10. Rotation speed by age.
Dotted line : TDC Solid line : ADHD children
Aging curves of neuromotor development have a tendency to increase between 7 and 11 years old as they grow older

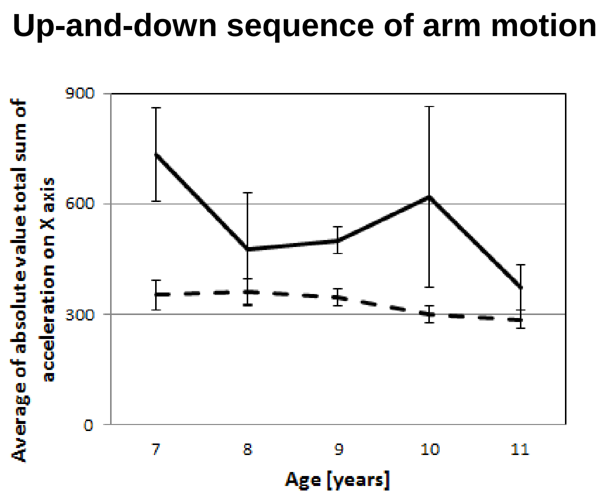

Fig.11. Movement of hands by age.
Dotted line : TDC Solid line : ADHD children
Aging curves of neuromotor development have a tendency to decrease between 7 and 11 years old as they grow older

Fig. 12. Movement of elbowsl.
Dotted line : TDC Solid line : ADHD children
Aging curves of neuromotor development have a tendency to decrease between 7 and 11 years old as they grow older

developed system have the potential to become diagnostic criteria for evaluation of a developmental disability. However, we could not obtain more accurate difference between TDC and ADHD children in the comparisons by age. This may be reason that ADHD' values are not only depend on ages but also their disorder levels. In order to obtain a satisfactory result statistically, we have to collect more subjects and compare ADHD children by their disorder levels.

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