33rd Annual International Conference of the IEEE EMBS
Boston, Massachusetts USA, August 30 - September 3, 2011

Evaluation System for Minor Nervous Dysfunction by Pronation and Supination of Forearm using Wireless Acceleration and Angular Velocity Sensors

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Abstract— **We developed a simple, portable and easy system to the motion of pronation and supination of the forearm. This motion was measured by wireless acceleration and angular velocity sensor. The aim of this system is evaluation of minor nervous dysfunction. It is for the screening of the developmental disorder child. In this study, in order to confirm the effectiveness of this system, the reference curve of the neuromotor development was experimentally obtained. We studied 212 participants (108 males, 104 females) aged 7 to 12 years attending the kindergarten school. We could obtain the reference curve of the neuromotor development using this system. We also investigated the difference of neuromotor function between normally developed children and a ADHD child. There is a possibility that abnormality of the minor nervous dysfunction can be detected by using this system.**

I. Introduction

AN of the child with developmental disorder like learning disorder(LD), attention deficit hyperactivity (ADHD), and pervasive developmental disorder (PDD), etc. has been a social problem. It is important to find the child with such a developmental disorder at the early stage, and to do an appropriate caring for his development. It is difficult to check the abnormalities of the child with the developmental disorder even if a doctor diagnoses by the neurological method for the paralysis and the sensory disorder. However, when the symptom that is called minor nervous dysfunction is checked, it is possible to obtain medical diagnosis from minor dysfunction which shows the development delay and the maturity of the central nervous system [1-4]. A number of standardized neurological test have been extensively used in research and clinical practice: e.g. Examination of the Child with Minor Neurological Dysfunction [5]; and Neurological Examinaotion for Subtle Signs [6]. However, as for these evaluation methods the one by doctor's personal subjectivity is large, and the evaluation between doctors is unequable. It is hoped that a more objective evaluation method is established. In this study, we developed the system that was able to evaluate the neuromotor development of the child by pronation and supination of the forearm. The motion of pronation and supination shows one of the minor nervous dysfunction symptoms. The pronation and supination is movement to fix the axis of the forearm, and to rotate the palm and the back of the hand. For the analysis of this motion, video recording with optical markers has been used. Average values of the digitized data of each marker were used for further calculations, after correction for outliers [7, 8]. The method of using the video recording with makers is not a simple system and such analysis was not easy and required long time.

We developed a simple and easy system to measure the motion of pronation and supination of the forearm using wireless acceleration and angular velocity sensors. The aim of this system is evaluation of minor nervous dysfunction. It is helpful for the screening of the developmental disorder child. In this paper, we describe our developed system and we obtained the reference curves of indexes of neuromotor development by this system.

Manuscript received April 17, 2011. This work was supported in parts by Grant-in Aids for Scientific Research, Ministry of Education, Science, Sports, Culture and Technology, Japan (No.21300168, No.23650267), Kakihra Science and Technology Foundation.

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II. Developed System

A. Measurement System

Figure 1 shows the measurement system of the motion of pronation and supination of the forearm. The system is consisted by four wireless three dimensional angular velocity and acceleration sensors (WAA-006, ATR-Promotions), a guide monitor, a CCD camera and a notebook PC.

The size of the wireless which can measure acceleration and angular acceleration sensor is 39 mm(W), 44 mm(H) and 12 mm(D). The weight of the sensor is 20 g. The notebook PC was used for the data acquisition and making the demonstration guide on the outside monitor. The CCD camera is used for the recording the motion of the subject.

The subjects attached four acceleration sensors on the back of right and left hands and on the both elbows as shown in Fig. 2.

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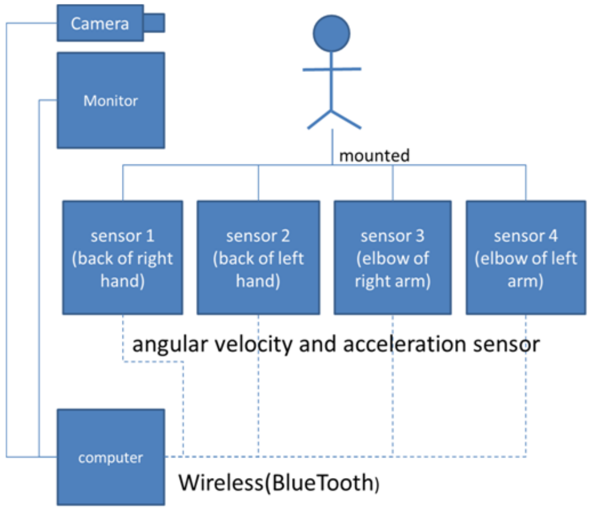

Fig. 1 The measurement system of motion of pronation and supination of the forearm.

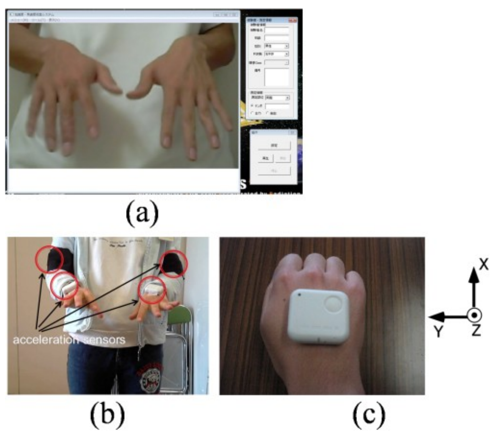

Fig. 2 (a) demonstration guide in the monitor, (b) subject put on four acceleration and angular velocity sensors, (c) coordinate of the acceleration and angular velocity.

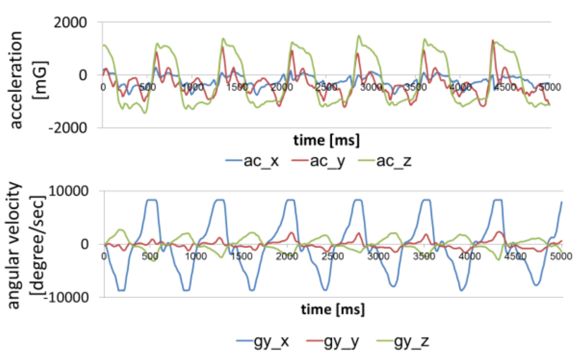

Fig. 3 Waveforms of acceleration in three directions (up) and waveforms of angular velocity in three directions (bottom).

B. *Data Analysis*

Three dimensional angular velocity and three dimensional acceleration signals are recorded with the sampling frequency of 1 kHz. These signals are transmitted by blue tooth to the acquisition PC. Measurement coordinate system of the acceleration and angular velocity is shown in Fig. 2 (c).

Fig. 3 shows the each of the waveforms of three dimensional acceleration and angular velocity when the subject pronates and supinates alternately during around 10 seconds. The low- pass filter of 4 Hz was put on these data.

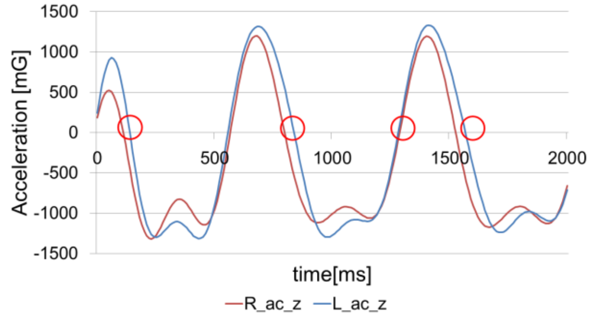

Fig. 4 Phase difference between the right hand and left hand waveforms of acceleration in X directions.

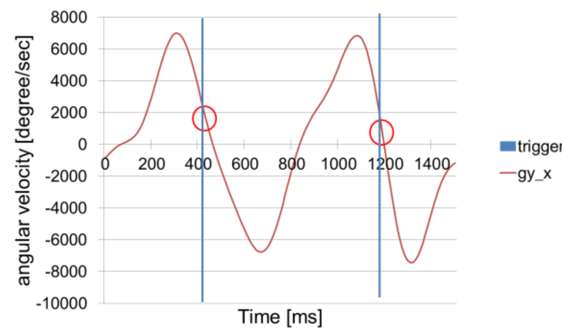

Fig. 5 Time difference between the trigger time and 0 crossing point time in angular velocity of the X direction.

To evaluate motion of pronation and supination of both forearms, three kinds of indices are proposed. First index is a cooperativeness between motion of right and the left hand. The second index is an accuracy of comparison with the speed of the guide. Third index is a stability of the posture.

The index of the cooperativeness shows the difference of a slight balance of the movement of right and left hand. This index is obtained by using three parameters in acceleration and angular velocity. First parameter is the correlation coefficient of right and left acceleration waveform of the X direction. Second parameter is the phase difference of angular velocity of the X direction between the right hand and the left hand as shown in Fig. 4. Third parameter is the correlation coefficient of right and left angular velocity of the X direction.

The index of the accuracy is obtained by two parameters. One is the time difference between the trigger time and 0 crossing point time in angular velocity of the X direction as shown in Fig. 5. Another parameter is obtained by the variability of the peak frequency in the continuous Fourier transform of angular velocity of the X direction.

The index of stability of the posture is obtained by the variability of the maximum and minimum value of the acceleration in X axis. Variability of acceleration in all axis obtained by the sensors which are attached to both elbows are also used for this index.

To decide the standard value of each index value, ten healthy male adults, 28-year-old from 23-year-old were measured and calculated each indices. Ten healthy adult males' mean values are provided 90 points, and the value of each index value are decided based on these value.

III. Assesment of Neuromotor Development

In order to confirm the effectiveness of this system, the reference curve of neuromotor development of school age children was experimentally obtained. We measured 212 participants (108 males, 104 females) aged 7 to 12 years in the kindergarten school.

Before starting this experiment, all participants were introduced to the aim of this study, the procedures, and hazards of measurement. All children and their parents agreed to participate.

The subject put four acceleration and angular velocity sensors on the back of right hand, on the back of left hand, on the elbow of the right arm and on the elbow of the left arm.

The subject was asked to pronate and supinate both forearms alternately according to the guide video standing in front of the guide monitor. Duration of the movement of hands was around 10 seconds. There were five different tasks as follows.

1. The speed of both hands of pronation and supination is 80 times a minute.
2. The speed of both hands of pronation and supination is 120 times a minute.
3. Only the left hand is pronated and supinated as fast as possible with the right hand fixed.
4. Only the right hand is pronated and supinated as fast as possible with the right hand fixed.
5. Both hands are pronated and supinated as fast as possible.

IV. Results and Discussion

Fig. 6 and Fig. 7 show the relationship between each index values and the age of the children when the rotation speed of supination and pronation is 80 times a minute or 120 times a minute respectively. These results show that the three kinds of index value which are the cooperativeness, the accuracy and the stability improve as the age of children goes up. These curves mean the reference curve of development of neuromotor system for child. As for the result of the rotation speed of 120 times, the difference of the age is more remarkable than the result of the rotation speed is 120 times.

In order to evaluate the balance of neuromotor function, three kinds of index are displayed on a radar chart. Fig. 8 shows the radar charts of the mean value of adult, mean value

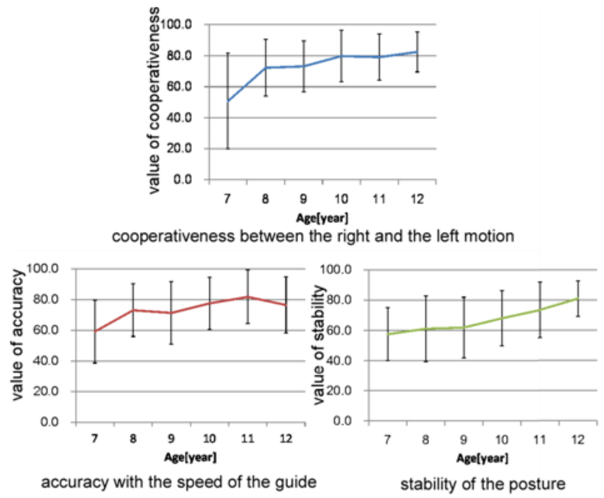

Fig. 6 The reference curves of the cooperativeness between the right motion and the left motion, the accuracy of comparison with the speed of the guide, and the stability of the postural when the speed of rotation was 80 times a minute .

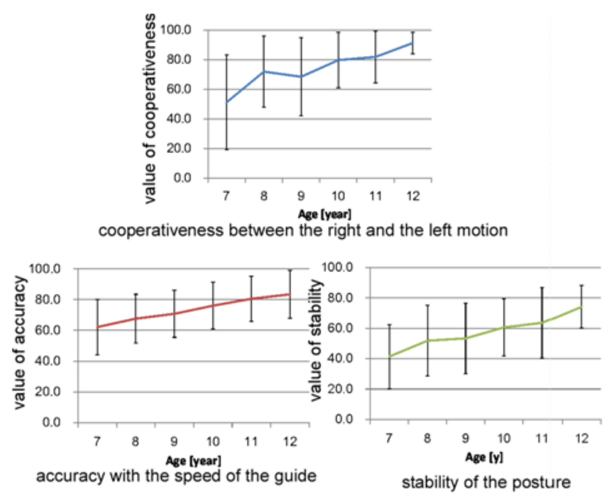

Fig. 7 The reference curves of the cooperativeness between the right motion and the left motion, the accuracy of comparison with the speed of the guide, and the stability of the postural when the speed of rotation was 120 times a minute.

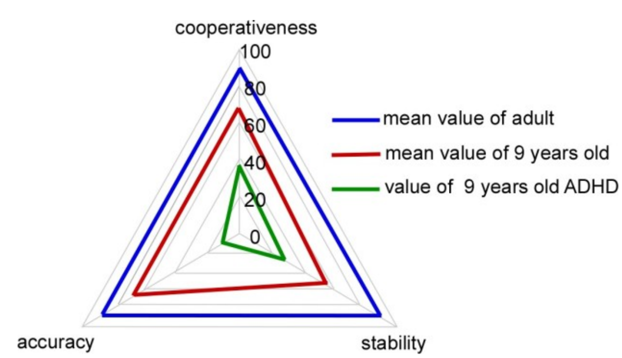

Fig. 8 Radar chart of the adult, average of 9 years old, and 9 years old ADHD patient.

of 9 years old children and the value of one 9 years old ADHD patient respectively when the rotation speed is 120 times a minutes. These graphs represent the relationship between the developmental balance of the neuromotor function and the age of children. The stability of posture of 9 years old children shows low performance compared with other two indices. In the 9 years old ADHD child, three kinds of neuromotor function are ill-balanced and he has bad performance overall compared with same year's old children.

In this study, we developed the portable and easy system which can measure the motion of pronation and supination of the forearms. The motion of pronation and supination represent the minor nervous dysfunction. It is possible to estimate the development of neuromotor function by evaluating the abnormality of the motion of pronation and supination. Typical method of evaluating the motion is using video recording of the subject with markers which are attached to the measurement point. Movements of markers are analyzed by the image processing. Such conventional system required large time for measurement and analysis. However, this system is very simple, portable and easy to measure the movement. Required measurement time for one subject's including the even putting and detaching the sensors is about three minutes.

We were able to obtain the reference curve of the neuromotor development by using this system. Although only one example, the difference between ADHD patient and normally developed children could be obtained. In this study, we analyzed two kinds of data which are the rotation speed is 80 times a minute and 120 times a minute. We have not used the data of full speed movement of single hand and both hands yet. We think that the cerebral development can be evaluated more in detail by analyzing these data.

V. Conclusion

In this study, we developed the evaluation system for the minor nervous dysfunction by measurement of the pronation and supination of the forearms. This system can use for screening the child with the developmental disorder etc., and has a big possibility of the application to the various filed. This system has a big possibility of the application to the various fields.

Acknowledgment

We appreciate Dr. Yushiro Yamashita and Dr. Takashi Ohya in Kurume University School of Medicine for the measurement of ADHD patient. We also appreciate Dr. Sachio Takashima in Yanagawa Institute of Developmental Disability for the discussion of usefulness of pronation of supination.

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