Applicability Verification of iWakka Game to Children with Developmental Coordination Disorder

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Abstract

In our previous study, we developed a testing and training device, "iWakka," of the adjustability for grasping force. Moreover, we developed "iWakka Game," for autistic patients. In this study, we investigated the applicability of the iWakka Game to children with developmental coordination disorder (DCD). We developed a small-sized grasping body and improved the evaluation method. We applied to four children with DCD. Consequently, they completed the evaluation task and the method enabled the extraction of the characteristics of hand dexterity.

Keywords: Rehabilitation, Hand dexterity, Evaluation, Children with developmental coordination disorder

1. Introduction

In daily life, hands and fingers play an important role such as grasping a cup, and handling a chopsticks and forks with appropriate force. The adjustability for grasping force (AGF), which is one of the motor functions of fingers, is the ability to grasp an object with an appropriate force. In our previous study, a training and testing device, "iWakka," for the AGF was developed.[1] iWakka consists of a grasping body, "Wakka," and a measurement device. The measurement device consists of a control box, an iPad, and "iWakka Viewer". When patients grasp Wakka, iWakka Viewer shows the grasping force. They adjust their grasping force to get closer to the target grasping force. The measurement sampling time is 0.1 s, the measurement range is 100–500 g, and the resolution is 1.6 g. Morita et al. observed[2] that adding iWakka to constraint-induced (CI) movement

therapy had therapeutic effects for patients after a stroke. To apply iWakka to autistic patients, we also developed "iWakka Game", which is one of iWakka Viewers, by improving the game quality of the original one with the Lodz University of Technology and the Center of Autism Diagnosis and Therapy, Lodz, Poland.[3]

Developmental coordination disorder (DCD) is a common neurodevelopmental disorder characterized by impairments in the development of both fine and gross motor skills.[4] Because grasping is the basic ability for various activities, there is a need for therapists to evaluate the characteristics of hand dexterity and plan more effective training for their hands. However, few studies have focused on the characteristics of hand dexterity. The purpose of this study was to investigate the applicability of the iWakka Game to children with DCD and evaluate their characteristics of hand dexterity.

2. iWakka Game

This game is developed for autistic patients to train their grasping force by improving the quality of the original game. The brown bird in the iWakka Game rises when Wakka is gripped and falls when it is released. When a task begins, the target waveform with red stars moves from right to left. The waveform pauses when the bird hits the cloud placed above and below the bird. Three setting parameters and a target waveform are determined. The three parameters consist of the distance between the bird and the cloud, the measurement range, and the speed at which the waveform flows from right to left. The iWakka Game has nine types of waveforms, such as staircase, slope, and sine wave.

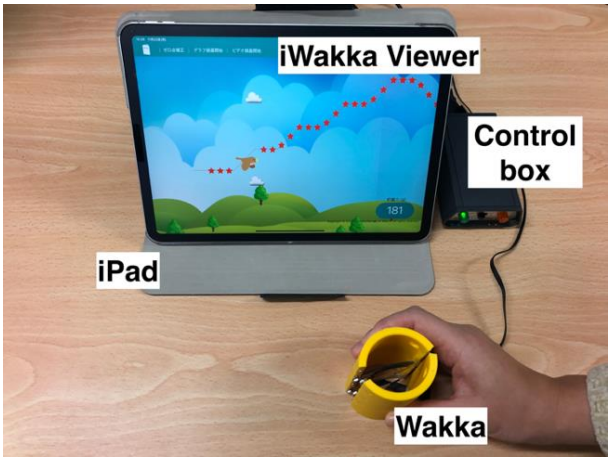

Fig. 1. iWakka.

The AGF is evaluated from the mean absolute error between the value of the target waveform and the bird's vertical position that indicates the grasping force by grasping Wakka. However, we could not evaluate the AGF for each isometric muscle activity (IC) to hold an object with a constant grasping force, concentric muscle activity (CC) to grip it while increasing grasping force, and eccentric muscle activity (EC) to release it while decreasing the grasping force.

3. iWakka for Children with DCD

3.1. *iWakka Game*

Figure 1 shows iWakka. Before testing using the iWakka Game, a preliminary experiment was conducted to verify its applicability to children with DCD. We decided the three parameters required to complete the tasks appropriately. The distance between the bird and cloud was 100 g. The measurement range was 100–400 g. The speed was 2.97 mm/s from the right to the left of the screen on an iPad. Notably, a grasping device with a smaller outer diameter and an evaluation method to extract the characteristics were required.

3.2. *Grasping device*

The small-sized grasping body Wakka was developed to reduce the outer diameter by 83%. This was decided based on the requirements of therapists and the ratio of the length from the wrist to the tip of the middle finger. The average ratio is 190–220 mm for adults and 150–190 mm for elementary school children. The relationship between the amount of deformation and the force of the device is linear. Table 1 shows a comparison of the small-sized and original Wakka. The spring constant of the small-sized Wakka was 5.96×10^2 N/m, implying that grasping it with a force of 60.8 g produced a deformation of 1 mm.

Table 1. Comparison of the small-sized and original Wakka.

	Small-sized Wakka	Original Wakka
Spring constant [N/m]	5.96×10^2	4.82×10^2
Outer diameter [mm]	54	65
Height [mm]	80	80
Weight [g]	81	112

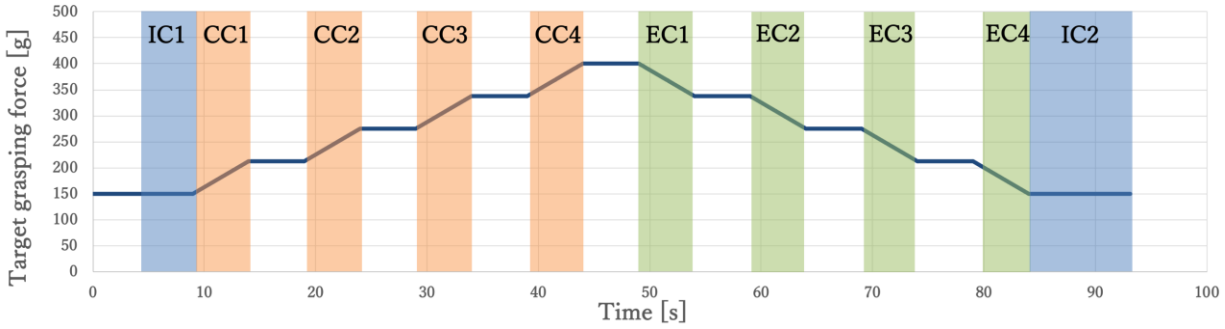

Fig. 2. Target waveform and sections to be evaluated.

3.3. *Evaluation method for hand dexterity*

The waveform shown in Fig. 2 was selected to evaluate the characteristics of hand dexterity. Total time was 93 s. The waveform was subdivided into IC, CC, and EC sections and the ranges of grasping forces. IC was evaluated twice at 150 g. The first evaluation began 3 s after the start. CC and EC were evaluated in four sections of the range of the grasping force. The average absolute error between the grasping force and the target grasping force in each section was calculated as the *AGF*, as shown in Eq. (1).

$$AGF_{(*)} = \frac{1}{T_{(*)}} \sum_{k=1}^{N_{(*)}} |f_d(k) - f(k)| \text{ [g]} \qquad (1)$$

$(*)$ denotes the section, $f(k)$ denotes the measured grasping force, and $f_d(k)$ denotes the target grasping force. $T_{(*)}$ denotes the time taken for the section, $N_{(*)}$ denotes the number of data for the section. T_{IC1} is 6s, T_{IC2} is 9 s, and T for each of the CC and EC sections is 5 s. Because the measurement sampling time is 0.1 s, N_{IC1} is 60, N_{IC2} is 90, and N for each of the CC and EC sections is 50. However, if the bird hits the cloud, $T_{(*)}$ and $N_{(*)}$ is extended for the section. This means that the time of collision with the cloud is included in the calculation. The target grasping force at the start of the collision continues until the end of the collision. The smaller the *AGF*, the higher is the AGF ability.

Table 2. Subject information.

Subject	Age	Sex	Disease	MABC-2 Manual Dexterity
1	6	Male	DCD, and at risk of Dysarthria	6
2	5	Male	DCD	6
3	7	Male	DCD, ASD, and ADHD	10
4	9	Male	At risk of DCD	5

4. Experiments and Results

4.1. *Subjects*

The four patients are listed in Table 2. All patients were diagnosed with DCD or at a risk of developing DCD. iWakka was used with the dominant hand.

4.2. *Characteristics of hand dexterity*

Figure 3 shows the AGF for each section. Comparing CC and EC, Subjects 1 and 4 had lower ability at EC than at CC. All AGF in the EC sections of Subject 1 were greater than all AGF in the CC sections. As for Subject 4, AGF_{EC2}, AGF_{EC3}, and AGF_{EC4} were greater than AGF_{CC3}, AGF_{CC2}, and AGF_{CC1} respectively, at the same grasping ranges. On the other hand, Subjects 2 and 3 had lower ability at CC than at EC. AGF_{CC2} and AGF_{CC3} of Subject 2 and AGF_{CC1}, AGF_{CC2}, and AGF_{CC3} of Subject 3 were relatively high. Furthermore, AGF_{IC2} of Subject 1 was greater than AGF_{IC1}, indicating that he had a low ability

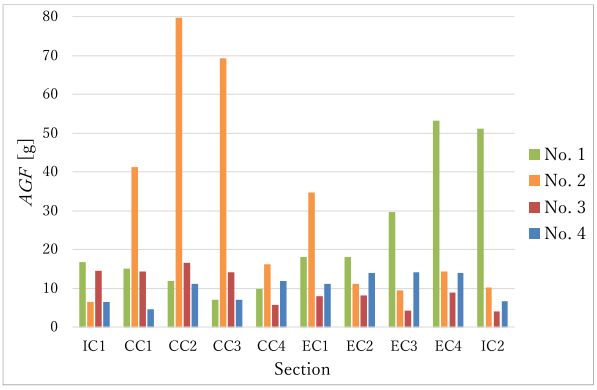

Fig. 3. *AGF* of each section.

to hold at 150 g after decreasing the grasping force. In addition, the AGF_{EC1} of Subject 2 was greater than AGF_{CC4} and AGF_{EC2}, indicating that the ability to switch from gripping to releasing force was low.

The comparison of CC and EC showed the difference in the ability of each muscle activity, and the comparison of neighboring sections showed the ability to switch between muscle activities.

5. Conclusion

We observed that the iWakka Game was applicable not only to autistic patients but also to children with DCD, aged 5–9 years, by using the small-sized grasping device, Wakka, and appropriate setting parameters. Moreover, the proposed evaluation method enabled the extraction of the characteristics of hand dexterity for each child. They had different characteristics of holding, gripping, and releasing in each range of grasping force that they were not good at. Improving each ability can enhance hand movements necessary for daily life. This result leads therapists to plan more effective training for hand dexterity.

References

1. Y. Morita, S. Nakajima, N. Sato, K. Yasaki, "Quantitative Evaluation System of Adjustability for Grasping Force", Journal of the Japan Society for Welfare Engineering, Vol. 18, Subject 2, pp. 5-10, 2016. (in Japanese)
2. Y. Morita, K. Ando, M. Nomura, K. Toshima, T. Tamaru, "Verification of Usefulness of Testing/Training Device of Adjustability for Grasping Force on Hemiplegic Patients after Stroke", Transactions of the Society of Instrument and Control Engineers, Vol. 55, Subject 1, pp. 78–84, 2018. (in Japanese)
3. M. Nomura, N. Kucharek, I. Zubrycki, G. Granosik, Y. Morita, "Adjustability for Grasping Force of Patients with Autism by iWakka: A Pilot Study", 2019 12th International Workshop on Robot Motion and Control (RoMoCo), pp. 50-55, 2019.
4. Dagmar F.A.A. Derikx, Marina M. Schoemaker, "The Nature of Coordination and Control Problems in Children with Developmental Coordination Disorder during Ball Catching: A Systematic Review", Human Movement Science, Vol. 74, p. 102688, 2020.

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