■ORIGINAL ARTICLE

Associated Movements of the Little Finger during the Precision Grip with the Thumb and Index Finger

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Abstract: We studied the relationship between the coordinated precision grip force of the thumb and index finger and the positions and associated movements of the little finger. Subjects (n = 10) pinched the pinch-meter and followed the target wave, which was made by a triangular wave and two horizontal waves. When following the target wave (TW) with precision grip, subjects preformed two tasks: changing the little finger positions to neutral, flexion and extension (Task-1) and performing flexed and extended movements (Task-2). The errors between TW and the following wave resulting from precision grip with the thumb and index finger were recorded. We found that the change of the little finger position and joint movements influenced the coordinated precision grip force. Furthermore, we found a relationship between the plus or minus directions of error, and the direction of the little finger's joint movements and little finger positions. This study indicates that the little finger position influences coordinated precision grip force, but showed no involvement between the thumb and the index finger.

Keywords: power coordination, little finger, precision grip

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Introduction

In our daily living, we can grasp and operate manifold objects appropriately. For this to be accomplished, we coordinate both a complex system of sensory-receptors and motor skills with the object's properties. Finding normal finger functions and coordinating fingers are necessary for occupational therapists when providing therapy for the loss of finger functions in orthopedic and cerebral vascular disease patients. There are two prehension synergies used when holding an object in static tasks by individual digits. The first is to change the hand shape and configuration according to the object's shape, weight, friction and center of gravity, and the second is to grasp and operate the objects. According to Napier (1956), even though we have grasped the same object, prehensile activities can be classified into the two categories of 'power grip' and 'precision grip'. Power grip is used to fix objects in the hand with the palm. Precision grip is used for the purpose of fine control of prehensile forces on a manipulated object, which is usually held by the tips of the fingers and opposing thumb. Kamakura (1978) found that the shape of the hand while grasping an object was decided by the purpose and operation of the grasp; furthermore, the contact positions between the object and hand when grasping a large number of objects were classified. This classification indicated that the contact positions varied by individual. However, Kamakura also revealed that the characteristic contact positions were derived from the physical properties of objects according to the intent of the grasp and operation. The second synergy is to coordinate the grip and pinch power to accomplish the smooth grasp and operation of the object. Previously, power coordination was measured using the precision grip between thumb and index fingers, which is the minimum unit of grasping. According to Johansson & Westling (1984), an appropriate amount of grip and pinch power was provided when people grasped objects depending on the object's material and weight, so that the object would not to slide out. They found that the precision grip power when holding an object in space consisted of two elements: minimum pinch power requirements, and redundant power (safety

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margin). Furthermore, Nakamura (1993) reported that subjects provided 5~7% of maximum precision grip force during perturbation when vertical load force was applied suddenly to the grip apparatus. Goto (2003) found that fixing the wrist joint influenced the finger joint's motion during precision grip between the thumb and index finger. In terms of operating environment, Nakajima (2012) indicated that an obstacle's position influenced the trajectory and velocity of precision grip. Yamashita (2005) found that the thumb and index finger each have a functional role during this precision grip. When EMG amplitude was measured using graded increases of precision grip force, the thumb took on a 'fixed' role (FR) and index finger had the 'role of gradual power coordination' (GPC) showing no change in the thumb's precision amplitude but a gradual change in the index finger. Coordinated precision grip force and the functional role between the thumb and index finger has been reported. However, many kinds of object-dependent tasks are carried out in daily life that require skilled manipulations with not only a thumb-index finger pinch but also whole-handed manipulations involving all five digits. Recent studies on whole-hand grasping have shown that the force of individual digits is related to the direction of rotational torque in the rotational equilibrium for hand-held objects (Zatsiorsky et al., 2003). According to Taguchi (2002), when rotating a circular cylinder, it was found that the little finger used a highly coordinated movement. The results of chaos analysis of the trajectory of the five fingers showed that the index and middle fingers were highly chaotic, while the thumb and little finger showed little chaos (8). Hence, each finger assumed a functional role during grasping and operation, the middle, ring and little fingers taking on a functional role during a precision grip between the thumb and index finger. This study investigated the little finger's functional role during a precision grip between the thumb and index finger. If the little finger is not directly engaged in prehension, but is involved in the coordinated precision grip force between the thumb and index finger, it may be necessary to consider that the functional unit is not each finger but the whole hand, with all fingers influencing one another.

Method

Participants

Ten right-handed male and female volunteers (average age 25.8 ± 4.80 years old) were selected as subjects for this study. None had previous histories of neuropathies or trauma in the upper limbs. All volunteers gave informed consent according to the procedures approved by the ethics committee of Sapporo Medical University.

Apparatus and experimental setup

A pinch meter (PM) was used (Fig. 1) which was horseshoe shaped and consisted of two parallel stainless bars and a strain gauge, and which was attached to a baseboard. Amplified electric signal waves measuring grip between the thumb and index finger were produced on the PM, and shown on the oscilloscope (DL1640, Yokogawa, Japan). The oscilloscope was set at the subjects' eye level, and its display preferences were fixed to a vertical axis of electric voltage 2.0 v/div, and horizontal axis of recording time 500 ms/div. Additionally, the target wave (TW) was projected onto the oscilloscope. The TW was made by a functional generator (FG-272, KENWOOD, Japan). The TW consisted of a triangular wave and two horizontal lines. The triangular wave was 0.2 Hz and the amplitude was set at 10% of maximum voluntary contraction (MVC). The two horizontal lines were drawn in both the upper and lower regions of the triangular wave in the oscilloscope. We temporarily recorded the TW and following wave, which were made from the PM in the oscilloscope by a data-recorder (RD-135T, TEAC, Japan). The recorded waves were analog-digital converted with a sampling rate of 1,000 Hz by an A/D converter (AND-1400, canopus, Japan). After A/D conversion, the digital wave data were recorded using a PC (PC9821Ne, NEC, Japan) and analyzed with Microsoft Excel 2000 software on a standard EPSON Type-VF computer.

Tasks

To determine whether the little finger is related to the coordinated precision grip force between the thumb and index finger, subjects were asked to match the target

Fig. 1. Pinch Meter (PM).

wave with the following wave made by precision grip force. In this study, two task variations were set (Task-1, Task-2) to investigate the power coordination between the motion position of the joints' of the little finger and precision grip force.

Task-1

In Task-1, subjects pinched the PM with the thumb and index finger (Fig. 2a). On the oscilloscope display, three lines emerged: a triangular wave and two fixed horizontal lines in the upper and lower axis. When the subjects held the PM with minimum pinch power, the following wave line descended to the lower line. When the triangular wave descended to match the lower horizontal line, subjects estimated the timing of when to start the task, and the subjects would start following the TW. Upon applying pressure to the PM, the following wave line ascended. Subjects would have to follow the ascending TW. After reaching the maximum amplitude of the TW, subjects would have to maintain the upper horizontal line position. After 1 up and down cycle of the triangular wave, subjects estimated the timing of when to start the descent when TW was at the upper horizontal line. Subjects then followed the TW from the upper horizontal line to the lower horizontal line. In Task-1, 3 positions of the little finger were purposely set (neutral, flexion and extension of MP, PIP and DIP joints). Trial 1 was completed after two cycles. Subjects did 3 trials with each of the little finger positions (2 × 3 × 3 = 18 trials).

Task-2

Task-2 investigated the influence of muscle contraction and movements of the joints of the little finger during the coordinated precision grip force between the thumb and index finger (Fig. 2b). The timing to start the following in Task 2 was identical to that of Task 1. At the start of following, the position of little finger remained in a neutral position. Upon applying pressure to the PM, the wave line to be followed was raised, and subjects had to follow it. After reaching the maximum TW amplitude, subjects maintained the position of the upper horizontal line and move the little finger joints while maintaining the position. Upon one ascending-descending cycle after the TW arrived at the upper horizontal line, the subjects flexed the little finger joints from the neutral position to an extended position. With flexion of the little finger, subjects coordinated the precision grip force for one period. Then the subjects flexed their little fingers, closing them back to the neutral position. After remaining in the neutral position for one period, subjects extended the little finger joints from the neutral position, and extended the precision grip for 1 period. In the next period, subjects changed their little fingers' position from extension to neutral, and followed the TW from the upper horizontal line to the bottom line. Subjects repeated the process in 3 trials.

Procedure

Subjects were given an orientation session before the experiment to become familiar with the experimental apparatus and to ensure that they were able to accomplish the tasks. Before the experiment, subjects washed their hands with soap to normalize their skin, and sat in a chair with the elbow joint rested on an armrest and flexed at 90°. The right forearm was placed in an intermediate position to facilitate a natural grasping position for the hand. The pinch meter was fixed in a horizontal position on vertical beams of the armrest and set in front of the subjects' forearm, and the distal side of the

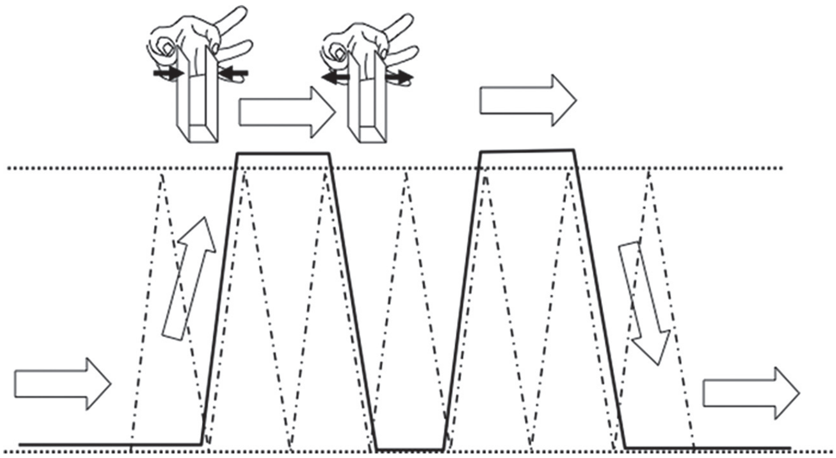

Fig. 2a. Experimental Task-1.
Task-1 was to find whether the change of little finger position (joint angle) influence the power coordination. Dotted line shows upper and lower parameters of waves made from functional generator. Dashed line shows triangular waves displaying period lengths and spacing. Solid line was the target wave (TW) which subjects had to follow.

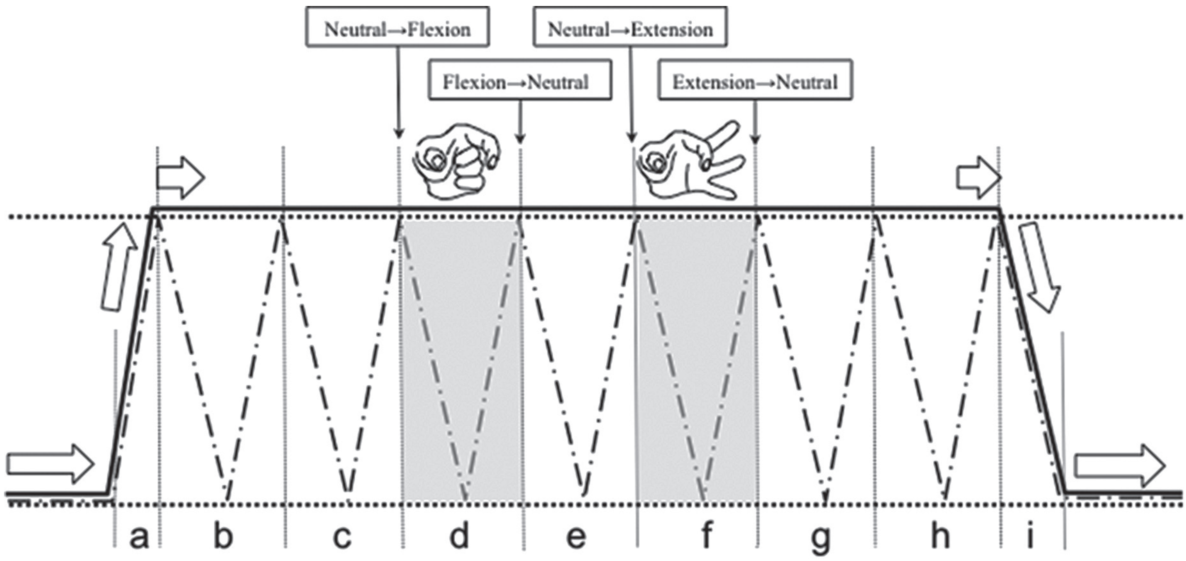

Fig. 2b. Experimental Task-2.
Task-2 was to find the influence for the power coordination of little finger joint movements with precision grip. Dotted line shows upper and lower parameters of waves made from functional generator. Dashed line shows triangular waves displaying period lengths and spacing. Solid line was the target wave (TW) which subjects had to follow. "b", "c" and "h" periods were neutral positions of little finger. "d" period was little finger flexed period and "f" period was little finger extended period. "e" and "g" periods were neutral positions including the rapid time of changing fingers position.

subjects' wrist joint was left unobstructed. The oscilloscope was set in front of the subjects, and the subjects monitored the electric wave on the oscilloscope monitor by holding the pinch meter. After the subjects practiced the tasks to ensure smooth performance, the experiment commenced and subjects performed Task-1. Following a short rest to prevent fatigue, subjects performed Task-2. During Task-1, the order of the positions of the little finger was arranged randomly in order to prevent a learning effect.

Data processing and statistics

Data processing was performed using a data-recorder, and statistics were calculated using SPSS10. All statistical analyses were performed at a significance level of $p < 0.05$. Data from two waves (TW and following wave) and data from the two horizontal lines (upper and lower) were collected by the data-recorder, then converted using an A/D converter from analog to digital (A/D) with a sampling rate of 1,000 Hz. After A/D conversion, the digital wave data were recorded in the PC and analyzed by Microsoft Excel 2000. 90 data entries from Task-1 and 30 data entries from Task-2 were analyzed. The error between TW and following wave were calculated as follows: Raw Error = following wave – TW.

Both plus and minus types of errors emerged, and were computed. Total errors was calculated as follows: Error = Σ | Raw Error (following wave – TW). If the error was minor, the level of ability of the coordinated precision grip force between the thumb and index finger was high. During data collection, the time the triangular wave took to travel from the bottom to the upper horizontal lines was 1.25 seconds and the time it took to maintain the force at the upper horizontal line was 2.5 seconds. Therefore, the measurement of data per unit of time was calculated. In Task-1, mean errors were calculated for the three periods of 'compression', 'holding' and 'decompression', and then compared using ANOVA for post hoc test. In Task-2, mean errors were calculated for each of the 'compression', 'neutral', 'flexion', 'extension' and 'decompression' periods, and then compared using ANOVA for post hoc test. Testing for significant difference between Task-1 and Task-2 was done using the Tukey-Kramer test performed at a significance level of $p < 0.05$.

Results

Relationship between little finger position and power coordination

Fig. 3 shows the errors between TW and following wave at each of the periods: compression, holding and decompression in each little finger position (neutral, flexion, and extension) in Task-1. The errors of the three periods proved to be similar in all little finger positions. The errors of the reduced zone were the largest and those of the holding zone were the lowest of the three periods.

The error of each period was significantly different by ANOVA ($p < 0.05$), so the Tukey-Kramer test was used. The error of the continuous holding period was significantly lower than both the compression period and the decompression period ($p < 0.05$). Compared to the little finger positions, the neutral position of the little finger had the lowest tendency of error of the three little finger positions. Fig. 4 shows the characteristic errors of the holding period in the three little finger positions. The two errors were separated from raw errors. The plus error of the following wave was greater than that of the TW, and the minus error of the following wave was lower than that of the TW. When comparing the plus and minus errors, the plus error was significantly larger than the minus error in the flexed position of the little finger ($p < 0.05$). When comparing the plus and minus rates of the little finger in the flexed position, the plus errors were significantly larger than the minus errors ($p < 0.05$). Furthermore, the minus rate errors of the little finger in the extended position were significantly larger than the errors of little finger in the flexed position ($p < 0.05$).

Relationship between voluntary movement of little finger and power coordination

Fig. 5 shows the difference in errors due to changing the little finger positions from neutral to flexion to extension in Task-2. We computed the mean data of each little finger position for the compression and decompression periods. ANOVA tests confirmed that the difference in errors of each little finger position and power coordination over the compression, neutral, flexion, extension, and decompression positions were

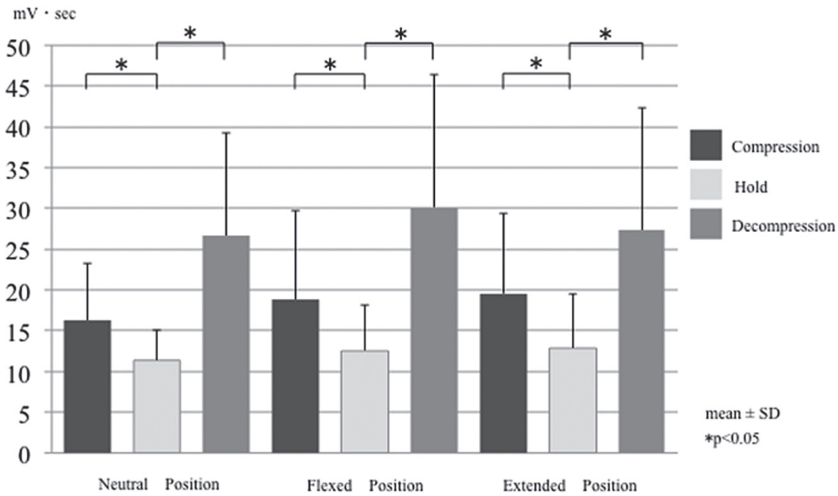

Fig. 3. Error Difference of the Three Little Finger Positions During the Three Conditions (Compression, Hold, and Decompression) in Task-1.

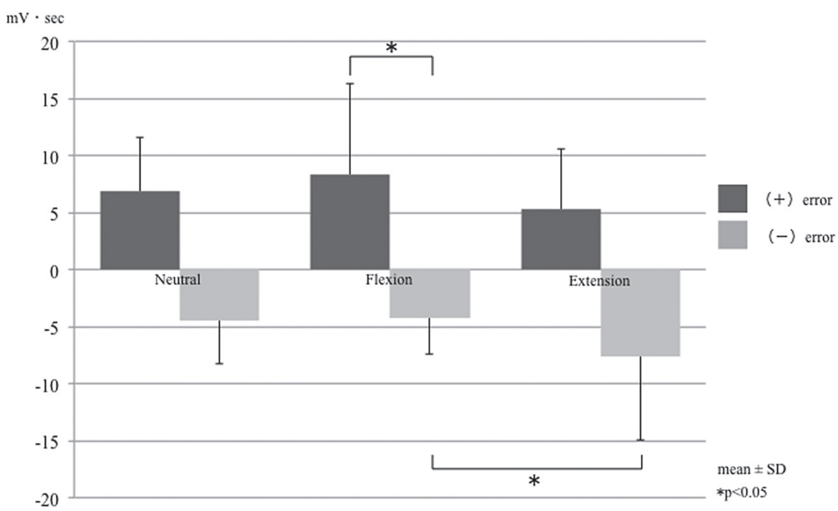

Fig. 4. Differences in Error of the Little Finger Positions During Holding Period (Task-1).

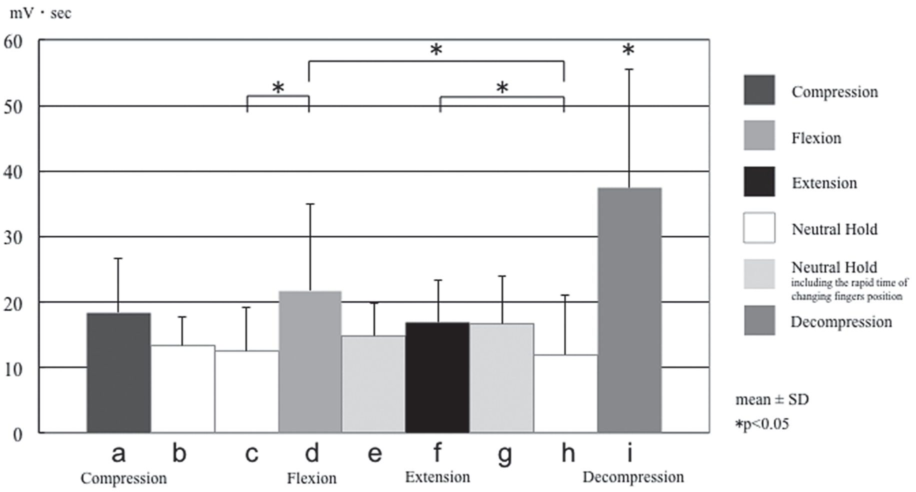

Fig. 5. Difference in Error by Changing Little Finger Positions (Neutral, Flexion, Extension) in the Task-2.

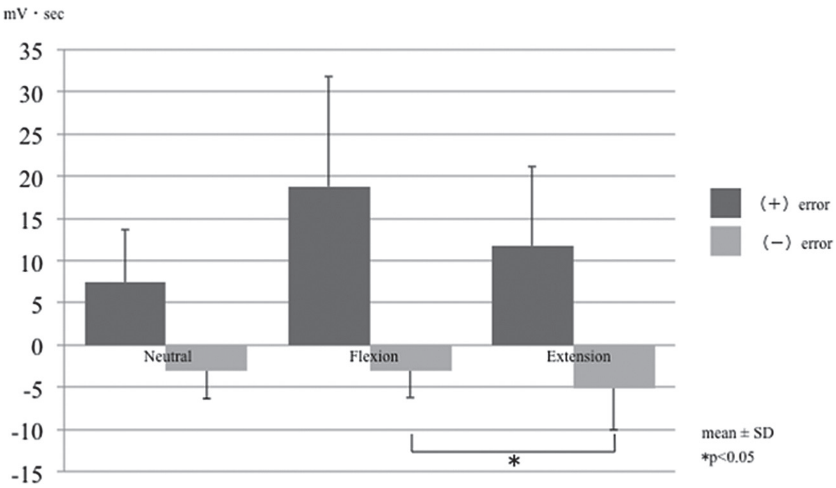

Fig. 6. Difference in Error Among the Three Little Finger Movements (Task-2).

statistically significant ($p < 0.05$). The results of the Tukey-Kramer test were significant between the periods of neutral position and flexion, and between the periods of the neutral position of the little finger and extension ($p < 0.05$). Furthermore, the differences in errors among all periods and the decompression period were statistically significant ($p < 0.05$). Raw errors were separated into plus and minus errors during flexion of the little finger (Fig. 5d), extension of the little finger (Fig. 5f), and neutral position of the little finger (Fig. 5b, c, h). The errors were then compared after separation. Regarding plus errors, the errors of the flexion of the little finger were the largest of the two periods. For minus errors, the errors of the extension of the little finger were the largest, and the difference of errors between the extension of the little finger and the errors of flexion of the little finger was statistically significant ($p < 0.05$) (Fig. 6).

Discussion

Task-1 and Task-2 experiments showed that keeping the little finger in a neutral and relaxed position produced the most coordinated force, and that a relationship existed between the plus or minus direction of error, and the direction of the little finger's joint movements and position. Regarding the characteristics of the little finger, the flexor muscles of the little finger were the flexor digitorum superficialis (FDS) and the flexor digitorum profundus (FDP), which were the same for the index finger. In this study, the coordinated precision grip force between the thumb and the index finger was performed by using the FDS and the FDP. Yamashita found that the thumb and index finger each have a functional role during precision grip (5). When the little finger was in the flexed position, a plus error occurred which was larger than the other positions of the little finger. This indicates that the flexed position was an easy position for the index finger muscles (FDS and FDP), which assumes that coordinated precision grip force between the thumb and the index finger provides the force, making it difficult for subjects to coordinate the fine adjustment of FDS and FDP. Also, when the little finger was in the extended position, a minus error occurred that was larger than the other positions of the little finger. It is believed that it was difficult for subjects to finely coordinate the adjustment of FDS and FDP force as the FDS and FDP were extended. Therefore, subjects couldn't raise the following wave to the TW. Furthermore, when the little finger was performing joint movements, the flexor muscle contracted during a flexed movement. The flexor muscle contraction of the index finger influenced the coordinated precision grip force between the thumb and the index finger. In the little finger extension, the digital extensor muscle and the extensor digiti minimi muscle contracted. Like the flexion muscles (FDS and FDP), the digital extensor muscle was the common muscle during index and little finger extension. Hence, when pinching using the precision grip between the thumb and the index finger, the concentric contraction of radial digits and the efferent contraction of ulnar digits occurred simultaneously in the FDS and FDP. Furthermore, the concentric contraction of the little finger and the efferent contraction of the index finger occurred simultaneously in the digital extensor muscle. This suggests that the position of the little finger and the contraction of flexor and extensor muscles in the little finger, which had no involvement in precision grip between the thumb and the index finger, influenced power coordination. It may be that the little finger has a functional role in coordinating the grip force, even if the little finger isn't directly engaged in the grasping action. When the little finger joints' position were in a relaxed position, the contraction of FDS and FDP was neutral in the little finger, thus suggesting that keeping the muscle contraction of the little finger neutral was important for the fine-tuning of the precision grip force between the thumb and the index finger. The results point to the little finger having a functional role when coordinating grip force even if the little finger isn't directly engaged in the grasping action. In previous studies, the functional roles of the thumb and fingers have been found to take a direct part in prehension and manipulation. Taguchi (2002) suggested that each finger had a functional role in the rolling manipulation of a circular cylinder. This study indicates that the little finger position influences the coordinated precision grip force, which was not directly involved with the thumb and the index finger. Thus, to engage in prehension and manipulation of the digits, the thumb and digits may be related in all prehension and manipulation actions. It is necessary to consider not only the movement of every individual finger, and the movements of the whole hand which operate as a functional unit, but also where and how each finger influences another. The results of this study were obtained under limited conditions and parameters of the experiment. Thus, broader generalizations regarding the strategies of coordinated precision grip force from our study were difficult to make. Further research will investigate the coordinated precision grip force under many varying conditions.

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Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

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■ORIGINAL RESEARCH

Effect of Education Programs for Caregivers with the Provision of the Elderly with Mental and Cognitive Impairments

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Abstract: Authors provided education programs for certified caregivers to cope with elderly care recipients' behaviors caused by mental and cognitive impairments. Thirty-three participants enrolled in all of the programs consisting of lectures and case studies about the features of mental and cognitive functions among elderly people. Authors administered self-rating questionnaires about "feeling care difficulties" three times as follows: before and after the basic training, and after the follow-up training. Authors used Friedman's Test and Bonferroni multiple comparison of analyses for levels of difficulties. The levels of items for 'understanding mental symptoms and anxiety', 'communication skills' and 'dealt with life disabilities' were reduced significantly. The participants could better deal with care recipients because they understood the factors causing their behaviors. However, authors should clearly teach how to deal with behaviors such as silence. Furthermore, medical staff with mental patients should actively collaborate with certified caregivers to deal with deviant behavior.

Keywords: Aged, Caregiver, Education, Mental disorders

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Introduction

Japan is a rapidly aging society. The morbidity rate of dementia in people over 65 years has reached over 14% (Shimokata, 2004), and the coping skills of certified caregivers who have provided the majority of care to those with behavioral and psychological symptoms of dementia (BPSD) are insufficient (The project team of dementia measures of the Mental Health of the Ministry of Health, Labour and Welfare 2012). Meanwhile, depression and anxiety patients consult psychiatric clinics frequently (Saito, 2009).The morbidity rate of mental and cognitive impairment in people over 65 years old who were provided with primary care was 48.1% (Watts, SC., Bhutani, GE., Stout, IH., Ducker, GM., Cleator, PJ., McGarry, J., & Day, M., 2002), and 10% of elderly people had anxiety, while the rate of anxiety coexisting with depression was high. Moreover, previous studies reported that the rates of depression, agitation and psychotic symptoms in Alzheimer's disease in home care patients were 80%, 80%, and 70%, respectively (Tractenberg, RE., Weiner, MF., Patterson, MB., Teri, L., & Thal, LJ., 2003). The number of elderly people with mental and cognitive impairments due to a decline in physical and mental functions with aging is increasing. Issues regarding general physicians' skills to diagnose depression and prescribe medication have been reported (Mellor, D., Davison, T., McCabe, M., & George, K., 2008a; Nakano et al., 2011) and it is necessary to construct a system of consultation by psychiatrists about residents' mental problems at institutions for the elderly (Loebel, JP., Borson, S., Hyde, T., Donaldson, D., Van Tuinen, C., Rabbitt, TM., & Boyko, EJ., 2008).

Long-term care insurance was introduced in 2000 in Japan to improve the care of elderly people with mental disorders, and care workers who are not mental health care specialists have provided the majority of care. In 2013, education for dementia care was included in the training programs of first grade caregivers, but a large number of certified caregivers providing care at present

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are second grade home helpers (HH). They received education in a short period to get the license and did not study dementia.

Authors investigated HH regarding the actual care of elderly people with mental disorders, and found that HH could not consult any medical professionals if they had trouble, and that they were experiencing problems (Harada & Yamane, 2013a). HH understood the need for collaboration with mental health care medical staff to cope with emergency correspondence regarding suicidal tendencies and sexual behaviors, but HH did not consult them about dealing with hallucinations, delusions and hypochondria that HH experience in daily care, even if they experienced difficulties because they thought that the difficulties in dealing with symptoms were caused by their lack of knowledge about the features of mental and cognitive functions among elderly people. Therefore, the education for certified caregivers is necessary (Harada, 2013).

Important research indicated that a comprehensive behavior-management-skills training program for certified nursing assistants who provide care for cognitively impaired nursing home residents reduced the residents' agitation levels (Burgio, LD., Stevens, A., Burgio, KL., Roth, DL., Paul, P., & Gerstle, J., 2002; McCallion, P., Toseland, RW., Lancey, D., & Banks, S., 1999,). As for depression, some previous research reported that skills for dealing with people with depression increased among care workers who attended depression training programs (Mellor, D., Davison, T., McCabe, M., & George, K.l., 2008a; Mellor, D., Russo, S., McCabe, MP., Davison, TE., & George, K., 2008b; Mellor, D., Kiehne, M., McCabe, MP., Davison, TE., Karantzas, G., & George, K., 2010).The fundamental position of Japan's Ministry of Health, Labour and Welfare initiated training systems and programs for dementia patients in 2012, and promoted care skills for dementia patients for certified caregivers; however, there is little research evidence about the programs.

Therefore, authors framed and implemented programs for certified caregivers that provide care services for elderly people with mental and cognitive impairments. The purpose of this study was to clarify the effects and durability of these effects, and examine issues involved when teaching care skills to certified caregivers.

Methods

Participants

The participants in this study were certified caregivers working in long-term care insurance community care offices in an area with a population of 320,000 and a 17.9% elderly population. Authors explained the purpose of this study to the managers of 12 home care offices introduced to the authors by community comprehensive service centers or home visit nursing stations. The authors recruited over 50 participants, but the home care offices were small, and there were a few offices that had meetings among certified caregivers. Finally, 2 offices consented to the proposal. There were 14 people working in the home visiting care offices linked to home visit nursing stations offices and 19 people working in home visit care and day service care offices linked to group homes for people with dementia. Both offices were managed by a social welfare corporation and the managers of the offices were professional care workers who provided care to elderly people with mental disorders and dementia.

Interventions

The program looked at the way in which participants grappled with studying actively and consisted of lectures about the features of mental and cognitive functions among elderly people and case studies for dealing with elderly people with mental and cognitive impairments (Amata, 2004; Hotta, 2012; Yamane, 1994; Takenaka, 2000; Japan Dementia Communication Conference, 2011). The basic program was done twice. The first time, authors provided a lecture about the behaviors of elderly people with mental and cognitive impairments, and the contents were based on previous research in which home care recipients were perceived by certified caregivers as creating difficulties in terms of care and coping. In the programs, participants studied a procedure for considering how care recipients behaved.

After 1−2 months, authors provided a second program with a review of the first lecture and case studies were provided by participants. The program lasted from one- to one-and-a-half hours, and the authors provided it three times; two groups consisted of 7 members and one group consisted of 19 members. After 6 months, the authors provided a follow-up program with a review of the basic program. In particular, communication skills and case studies were provided by participants. The program was carried out from August 2012 to March 2013 (Fig. 1).

Ethical concerns

Authors obtained approval from the participants after explaining that they would participate in this study of their own free will, that the records would be kept safely, and that they would not be used outside the auspices of this study in either oral or written form. The study protocol was approved by the Medical Ethics Committee at Kyoto University.

Session	The aim of the program	The study contents
The basic program the first time (Lecture)	Understanding the characteristics of elderly people with mental and cognitive impairments	• Confirmation of the program rules • Taking an active part in the programs, analyzing cases that the participants found difficult, and guaranteeing freedom of speech and ideas • Studying elderly people's environments by talking about their experiences of loss, isolation and solitude, and personality changes • Studying the peculiarities of mental symptoms in the elderly such as hallucinations, delusions and anxieties • Considering tactics to deal with care recipients • Considering the reasons for care recipients' silence and ignorance of social norms
1 to 2 months later the second time (Brief lecture and case study)	Focusing on communication skills and collaboration with medical staff on case studies	• Confirmation of the program rules • Considering why caregivers could not develop a good relationship with the care recipients • Considering the recipient's point of view • Understanding elderly people with schizophrenia • Considering the meaning of care recipients talking about suicide • Case studies about dealing with care recipients who could not limit their drinking or eating and those who are focused on social norms
6 months later the follow-up program (Lecture and case studies)	Focusing on communication skills and collaboration with medical staff on case studies	• Confirmation the rules of the programs • Considering why caregivers could not develop a good relationship with the care recipients • Considering the recipient's point of view • Understanding communication disorders in dementia • Case studies about dealing with care recipients' refusals, aggression and agitation

Fig. 1. Overview of the education program contents

Data collection

Authors administered self-rating questionnaires survey to participants three times as follows: before and after the basic training and after the follow-up training. Authors distributed and collected the self-rating questionnaires to participants directly at the time of training. Authors asked participants to write code numbers for personal identification so they could identify who wrote questionnaires and analyze the difference between before and after the basic training and after the follow-up training. The self-rating questionnaires asked about participants' attributes and "feeling care difficulties". The authors collected data of participant's attributes regarding age, sex, and number of experiences of care for recipients with mental and cognitive functional disorders: schizophrenia, depression, home care or day service in the first questionnaire before the basic training. The authors collected data regarding "feeling care difficulties" before and after the basic training and after the follow-up training, as well as data regarding impressions about the programs, and a free description after the programs regarding experiences of "feeling care difficulties" before the basic training and the follow-up training. There were 24 items about "feeling care difficulties" grouped as follows: dealing with psychiatric symptoms, depression, anxiety, refusal and aggression, communication skills, and dealing with cognitive impairments, which authors referred to in previous research (Harada, 2013). Feeling care difficulties were assigned levels from 1−4 on the Likert Scale.

Analysis

Authors analyzed the rates of the participants' characteristics, experiences and feeling of difficulty levels of the 24 items. Authors used Friedman's Test and Bonferroni multiple comparison of analyses to compare each pair with levels of difficulty as follows: before and after the basic training and after the follow-up training, and Mann-Whitney U test for the relations between experiences and feeling of difficulty levels.IBM SPSS Statistics (Statistical Package for Social Sciences v20 for Windows) was used for the statistical analyses, and the significance level was $p < 0.05$.Regarding feeling of difficulty, authors processed data excluding missing values for every feeling of difficulty level item.

Authors classified free descriptions into categories according to the contents of participants' comments on care and coping. In the following sections, double quotes and square brackets enclose categories and spoken contents, respectively.

Results

1. Characteristics and experiences of the participants' care

The participants were comprised of 2 male and 31 female individuals, and they were aged 46.8 ± 9.7; eight participants were regular workers employed full-time and twenty-five participants were part time workers. Their average number of years of experience as certified caregivers was 5.82 and the range was 1.2 to 13 years. Fourteen participants were professional care workers. The participation rates of whose who attended the training with dementia and mental disorders were 42.4% and 12.2%, respectively. The rates for giving care to patients with schizophrenia, depression, and others, were 15.5%, 33.3% and 21.1%, respectively (Table 1).

Table 1. Characteristics of the participants N = 33

			n (%)
Sex	Male		2(6.1)
	Female		31(94.9)
Employment	Regular worker		8(24.2)
	Part time worker		25(75.8)
License	Professional care worker		14(42.4)
	Home helper		19(57.6)
Attended the Training programs	Mental disorder	yes	4(12.1)
		no	29(87.9)
	Dementia	yes	14(42.4)
		no	19(57.6)
Care Experience	Schizophrenia	yes	5(15.2)
		no	28(84.8)
	Depression	yes	11(33.3)
		no	22(66.7)
	Other mental disease	yes	7(21.2)
		no	26(78.8)

2. Participants' experience for items of care difficulties

Regarding having had experience of the 24 items, over 50% of items both before the basic training and before the follow-up training had been experienced by 54.5% and 66.7%, 78.8% and 63.6%, 66.7% and 57.6%, 57.6% and 57.6%, 78.8% and 66.7%, 66.7% and 54.5% (1, 2, 7, 10, 12 and 22, respectively). Over 50% of items before the basic training or before the follow-up training were experienced at rates of 3, 15 and 17, respectively. Items at low rates were experienced at rates of 5, 8, 11, 19 and 24, respectively (Table 2).

3. The scores for feeling care difficulties (Table 3)

There were missing values before the basic training, so authors processed data excluding missing values every feeling of difficulty levels of items. Eighteen items' rates showed significant results between the score before after training.

The items' rates that showed significant results between the score before the training and after the basic training, and between the score before the training and after the follow-up training included 6 items as follows:

Table 2. Participants' experience of difficulty with each item N = 33

	before basic training		before follow-up training	
	yes n (%)	no n (%)	yes n (%)	no n (%)
1. Hallucinations and delusions	18(54.5)	15(44.5)	22(66.7)	11(33.3)
2. Fluctuations in care recipient's mood	26(78.8)	7(21.2)	21(63.6)	12(36.4)
3. Hallucinations in which someone steals	13(39.4)	20(60.6)	18(54.5)	15(45.5)
4. Sexual behaviors	7(21.2)	26(78.8)	8(24.2)	25(75.8)
5. Threatened by care recipients	4(12.1)	29(87.9)	0	33(100)
6. Causing care recipients anxiety about being dirty	11(33.3)	22(66.7)	10(30.3)	23(69.7)
7. Talking about suicide	22(66.7)	11(33.3)	19(57.6)	14(42.4)
8. Suicidal ideation	4(12.1)	29(87.9)	2(6.1)	31(93.9)
9. Care recipients not speaking and being silent	14(42.4)	19(57.6)	16(48.5)	17(51.5)
10. Mentioning anxiety about life	19(57.6)	14(42.4)	19(57.6)	14(42.4)
11. Many phone calls	2(6.1)	31(93.9)	2(6.1)	31(93.9)
12. Symptoms of hypochondria	26(78.8)	7(21.2)	22(66.7)	11(33.3)
13. Certified caregivers scolded by care recipients, but not understanding why	11(33.3)	22(66.7)	9(27.3)	24(72.7)
14. Care recipient's violence	15(45.5)	18(54.5)	10(30.3)	23(69.7)
15. Refusal of care that certified caregivers could not understand	20(60.6)	13(39.4)	14(42.4)	19(57.6)
16. Care recipients cannot dump trash	10(30.3)	23(69.7)	12(36.8)	21(63.2)
17. Ingnorance of social norms	16(48.5)	17(51.5)	17(51.5)	16(48.5)
18. Insufficienct care time	14(42.4)	19(57.6)	12(36.8)	21(63.2)
19. No sense of the value of money	3(9.1)	30(90.9)	5(15.2)	28(84.8)
20. Difficulties understanding life skills	16(48.5)	17(51.5)	6(18.2)	27(81.8)
21. How to maintain appropriate distance from care recipients	14(42.4)	19(57.6)	8(24.2)	25(75.8)
22. Hurting care recipient's pride	22(66.7)	11(33.3)	18(54.5)	15(45.5)
23. The appropriate way to speak to care recipients	14(42.4)	19(57.6)	7(21.2)	26(78.8)
24. Care recipients forget when certified caregivers will visit	8(24.2)	25(75.8)	5(15.2)	28(84.8)

2, 7, 12, 17, 18, 22 and 24. The items before the basic training, after the basic training and after the follow-up training of items were experienced by 3.06 ± .61 to 2.24 ± .61 to 2.15 ± .57 (χ^2 = 25.47, p < .000), 3.03 ± .77 to 2.13 ± .82 to 2.15 ± .57 (χ^2 = 16.69, p < .000), 2.83 ± .70 to 1.97 ± .62 to 1.70 ± .53 (χ^2 = 28.23, p < .000), 2.67 ± .82 to 1.87 ± .68 to 1.84 ± .63 (χ^2 = 15.39, p < .000), 2.96 ± .83 to 2.26 ± .83 to 2.18 ± .53 (χ^2 = 15.57, p < .000), 2.27 ± .59 to 1.93 ± .46 to 1.70 ± .64 (χ^2 = 26.44, p < .000) and 3.16 ± .83 to 2.21 ± .86 to 1.97 ± .65 (χ^2 = 15.96, p < .000), all of df = 2, with average scores of 2, 12, 17, 18, 22 and 24, respectively.

Items experienced with significant results only between the score before the training and after the follow-up training included 6 items as follows: 1, 10, 14, 15, 20, 21 and 23. The items' rates before the training and after the follow-up training were experienced by 2.54 ± .51 to 1.81 ± .58 (χ^2 = 14.83, p = .001), 2.64 ± .91 to 1.76 ± .50 (χ^2 = 15.64, p = .001), 3.12 ± .90 to 2.45 ± .67 (χ^2 = 7.80, p = .020), 3.31 ± .74 to 2.28 ± .63 (χ^2 = 12.43, p = .002), 2.77 ± .87 to 1.97 ± .53 (χ^2 = 13.35, p = .001), 2.57 ± .90 to 1.96 ± .71 to 1.76 ± .61 (χ^2 =

Table 3. The scores for items before and after the basic training and after the follow-up training

		Mean	SD	χ^2-Score	*P-value*	multiple comparison *P-value*
1. Hallucinations and delusions (n = 25)	before	2.54	.51	14.83	.001	
	basic	2.00	.67			**
	follow-up	1.81	.58			
2. Fluctuations in care recipient's mood (n = 27)	before	3.06	.61	25.47	.000	**
	basic	2.24	.61			**
	follow-up	2.15	.57			
3. Hallucinations in which someone steals (n = 18)	before	2.91	.85	8.97	.011	
	basic	2.17	.72			
	follow-up	2.00	.67			
4. Sexual behaviors (n = 12)	before	2.27	1.07	3.50	.174	
	basic	2.22	.88			
	follow-up	2.13	.66			
5. Threatened by care recipients (n = 9)	before	3.00	1.34	2.14	.343	
	basic	2.36	.92			
	follow-up	2.42	.61			
6. Causing care recipients anxiety about being dirty (n = 16)	before	2.75	.97	9.52	.009	
	basic	1.95	.76			
	follow-up	1.82	.68			
7. Talking about suicide (n = 26)	before	3.03	.77	16.69	.000	*
	basic	2.13	.82			**
	follow-up	2.15	.57			
8. Suicidal ideation (n = 14)	before	3.07	1.28	4.48	.107	
	basic	2.60	.28			
	follow-up	2.67	.65			
9. Care recipients not speaking and being silent (n = 17)	before	2.86	.79	13.56	.001	**
	basic	1.86	.66			
	follow-up	2.10	.72			
10. Mentioning anxiety about life (n = 21)	before	2.64	.91	15.64	.000	
	basic	1.88	.53			**
	follow-up	1.76	.50			
11. Many phone calls (n = 12)	before	2.67	1.18	1.27	.529	
	basic	2.20	.68			
	follow-up	2.06	.62			
12. Symptoms of hypochondria (n = 24)	before	2.83	.70	28.23	.000	**
	basic	1.97	.62			**
	follow-up	1.70	.53			

(continued)

12.16, p = .002) and 2.65 ± .88 to 1.76 ± .56 (χ^2 = 11.31, p = .004), all of df = 2, with average scores of 1, 10, 14, 15, 20 and 23, respectively. The scores of 3 and 6 items experienced with significant results between the scores before the training and after the basic training, but results of Bonferroni multiple comparison were not significantly, 3.03 ± .77 to 2.13 ± .82 to 2.15 ± .57 (χ^2 = 8.97, p = .011) and 2.75 ± .97 to 1.95 ± .76 to 1.82 ± .68 (χ^2 = 9.52, p = .009) all of df = 2, with average scores of 3 and 6, respectively. The score of 9and16 items experienced with significant results between the scores before the training and after the basic training, but the scores after the follow-up training deteriorated. Items were not significantly included 6 items as follows: 4, 5, 8, 11, 13 and 19.

The scores of 22 items after follow-up training showed significant differences between the participants who had experience before follow-up training and the participants who had no experience, 1.91 ± .725, 1.40 ± .27, z = −2.204 (p = .044, with average scores of 22.

		Mean	SD	χ^2-Score	*P-value*	multiple comparison *P-value*
13. Certified caregivers scolded by care recipients, but not understanding why (n = 16)	before	2.74	.93	1.27	.531	
	basic	2.26	.73			
	follow-up	2.33	.69			
14. Care recipient’s violence (n = 21)	before	3.12	.90	7.80	.020	
	basic	2.71	.87			**
	follow-up	2.45	.67			
15. Refusal of care that certified caregivers could not understand (n = 20)	before	3.31	.74	12.43	.002	
	basic	2.42	.81			**
	follow-up	2.28	.63			
16. Care recipients cannot dump trash (n = 17)	before	2.63	1.01	9.70	.008	*
	basic	1.68	.48			
	follow-up	1.81	.73			
17. Ignorance of social norms (n = 21)	before	2.67	.82	15.39	.000	**
	basic	1.87	.68			**
	follow-up	1.84	.63			
18. Insufficienct care time (n = 20)	before	2.96	.83	15.57	.000	**
	basic	2.26	.73			**
	follow-up	2.18	.53			
19. No sense of the value of money (n = 10)	before	2.54	1.13	.55	.761	
	basic	2.31	.63			
	follow-up	2.03	.54			
20. Difficulties understanding life skills (n = 19)	before	2.77	.87	13.35	.001	
	basic	2.23	.61			**
	follow-up	1.97	.53			
21. How to maintain appropriate distance from care recipients (n = 18)	before	2.57	.90	12.16	.002	
	basic	1.96	.71			**
	follow-up	1.76	.61			
22. Hurting the care recipient’s pride (n = 25)	before	2.72	.59	26.44	.000	**
	basic	1.93	.46			**
	follow-up	1.70	.64			
23. The appropriate way to speak to care recipients (n = 17)	before	2.65	.88	11.31	.004	
	basic	2.05	.61			**
	follow-up	1.76	.56			
24. Care recipients forget when certified caregivers will visit (n = 16)	before	3.16	.83	15.96	.000	*
	basic	2.21	.86			**
	follow-up	1.97	.65			

before: before the basic training; basic: after the basic training; follow-up: after the follow-up training
The Likert scale of feeling care difficulties (can handle with no feelings, can handle without feeling difficulties, can handle, but feel difficulties, and cannot handle and feel difficulties) were assigned from levels 1–4
Friedman’s test, df = 2, Bonferroni multiple comparison: significant at **p < .01, *p < .05

4. The contents of the free descriptions

There were 47 descriptions after the follow-up training. "How to deal with care recipients" was experienced by14: [We should provide care service to respect care recipients' feelings], "exchange information in the office" was experienced by 9: [It is important to behave jointly with other staff care recipient's behaviors which I felt difficulties to deal with], "multidisciplinary collaboration" was experienced by 10: [It is necessary to report and consult the mental medical staff the difficulties of dealing with care recipient's behaviors and request medical judgment], [It is necessary to exchange opinions with other professional staff], and "impressions of this program" was experienced by14: [I studied the case studies about cases with which the other staff deal with], [The way in which participants grappled with studying actively was good].

Discussion

In a comparison of "care difficulties" between before the training and after the basic and follow-up training, authors investigated the effects of this education program and other issues related to the education of certified caregivers.

1. Concerning the items for which the levels difficulty were reduced

Both after the basic and follow-up trainings, the average scores of the care items with respect to dealing with anxieties such as 'fluctuations in care recipient's mood' and 'symptoms of hypochondria', 'ignorance of social norms', 'insufficient care time' and 'hurting the care recipient's pride' decreased. The participants could understand that care recipients' anxieties were caused by the feeling of loss and loneliness elderly people experience; therefore, they could develop inner reserves and deal with care recipients with composure. Regarding 'hurting the care recipient's pride', the scores of the participants who had care experience were significantly higher than those who had no experience. The authors assume that the participants were confident having experienced mistakes; therefore, it is desirable that certified caregivers have training as soon as possible after they are employed.

Furthermore, the care difficulties of care recipient's regarding the rules of life caused differences in the values between certified caregivers and care recipients (Harada & Yamane, 2013b). Authors included the experience of the care recipients' feelings as if it had been the participants' own in the program, so the certified caregivers could understand care recipient's sense of values and thinking, and consider care recipients' feelings. It is easy for certified caregivers to understand care recipients' anxieties and the rules of life.

The average scores of the care items with respect to 'hallucinations and delusions', 'the appropriate way to speak to care recipients', 'refusal of care that certified caregivers could not understand' and 'care recipient's violence' decreased. The care items with respect to understanding psychiatric symptoms, the assessment of disabilities in life and communication skills were effects experienced after the follow-up training. If certified caregivers received acknowledgment and understand the recipients' mental disease, it is easy for them to deal with psychiatric symptoms and mental disabilities in practice. The participants should understand care recipients' communication disabilities and study them, then acquire communication skills to address this problem. In the implementation of case studies in this program, authors selected care recipients' behaviors which caused difficulties for participants in practice. Authors had shared differences with care recipients' responses, integrated our information and clarified how to deal with care recipients' behaviors which caused difficulties for participants. Consequently, the care difficulties for certified caregivers improved. The rate of experience of the items for which the levels of difficulty were reduced was high, meaning certified caregivers have a lot of experience of care; consequently, they can make the most of their opportunities.

2. Concerning the items for which the levels difficulty deteriorated after the follow-up training

The average scores of items 'care recipients not speaking and being silent' and 'care recipients cannot dump trash' deteriorated after the follow-up training. The certified caregivers have to finish care services after a limited length of time for care-plans under Long-term care insurance .Also, certified caregivers need to confirm care recipients' wishes in order to provide appropriate care services; they were sometimes hasty in reacting to care recipients' silence. The dissatisfaction with the behavior 'cannot dump trash' indicates the certified caregivers cannot clean rooms and provide the care services in the care-plan. Therefore, the authors assume that the participants thought they could deal with the care recipients' behaviors immediately after the basic program, but could not deal with them easily in practice. The follow-up programs supplemented the basic programs to clarify the factors that caused the behavior and why the care recipients behaved in that way. Consequently, 'feeling care difficulty' about these items could not be easily reduced. Previous research reported that skills to clearly deal with BPSD were taught in communication skills training for nursing assistants for the care for dementia patients (Spore, DL., Smyer, MA., & Cohn, MD., 1991; McCallion, P., Toseland, RW., Lancey, D., & Banks, S., 1999; Hukaya, Y., Suzuki, K., & Shitita, K., 2004; Cankurtaran, ES., Kutluer, I., Senturk, M., Erzin, GB., Gursoy, D., & Tombak, E., 2008; Levy-Storms, L., 2008; Roue, FP., Ortiz, KZ., Araújo, MSC., & Bertolucci, PHF., 2009; Burgio, LD., Stevens, A., Burgio, KL., Roth, DL., Paul, P., & Gerstle, J., 2002). Concerning care recipients 'not speaking and being silent' and 'care recipients cannot dump trash', it is necessary to teach both awareness of the background factors and how to practically deal with these issues in practice.

3. Concerning items for which the difficulty level did not change before the training and after follow-up training

The difficulty level for deviant behaviors such as 'sexual behaviors' and 'suicidal tendencies' were not improved. Thesis items were characterized as to whether or not certified caregivers could resolve them. It is necessary that certified caregivers consult medical staff who deal with mental patients and help them cope in multidisciplinary collaboration. However, certified caregivers hesitate to consult medical staff who deal with mental patients and have issues about this (Harada & Yamane, 2013a). Certified caregivers were undecided whether they should consult medical staff who deal with mental patients and worried that medical staff who deal with mental patients would not respond to their consultations. The item "multidisciplinary collaboration" was experienced as [It is necessary to report and consult medical staff who deal with mental patients about the difficulties in dealing with care recipient's behaviors and request advice] in the free descriptions. The participants could understand that it is necessary to consult medical staff who deal with mental patients about the care recipients' behaviors with which they could not cope with through multidisciplinary collaboration and case studies. Medical staff who deal with mental patients should collaborate with certified caregivers actively and supply information about how to deal with care recipients' deviant behaviors.

4. Limitations

This study consisted of examinations conducted in one area with a small number of participants, so the effects of this program are inconclusive. Authors could not set up a control group because authors could only select a few offices as the subjects of the research. Six participants left during the research period, so the authors did not have many participants to confirm the durability of the effects of the education program. As a result, the authors could not clarify the difference in distribution of the levels of difficulty by the participants' characteristics such as age and number of experiences of care for recipients. Furthermore, the authors examined the care difficulties for certified caregivers, but they did not evaluate the index of outcome measures such as care recipient's QOL (Quality of Life); therefore, the effects of this program have limited explanatory power. However, the programs provided by this research are consistent in the number of times, as well as the time required to fit in the working shifts of staff in home care offices, so other offices could easily introduce a similar program. The staff in the offices to which the authors provided the programs exchanged information after the program. Thus, the effects of our programs are ongoing. Furthermore, it is necessary to do future studies with more participants and examine the results quantitatively, as well as construct systems to implement education programs.

Conclusion

The following 3 points were the effects and issues related to the programs:

1) The difficulty levels of the items 'understanding mental symptoms such as hallucinations, delusions, anxiety and hypochondria', 'understanding life skills such as ignorance of social norms' and 'communication skills such as the appropriate way to speak to care recipients' were reduced significantly.
2) Concerning the levels of items 'care recipients not speaking and being silent' and 'care recipients cannot dump trash', authors should teach caregivers how to deal with practically deal with them.
3) The levels of items for deviant behaviors were not effective. Medical staffs who deal with mental patients should collaborate with certified caregivers actively and deal with deviant behaviors through multidisciplinary collaboration.

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Facilitating Transfer of Skills and Strategies in Occupational Therapy Practice: Practical Application of Transfer Principles

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Abstract: In Occupational Therapy (OT) practice, practitioners assume that the skills and strategies taught to clients during rehabilitation will transfer to performance and participation in everyday life. Despite transfer serving as a practice foundation, outcome studies conclude that this assumption of transfer is not occurring and it often results in decreased efficacy of rehabilitation. This paper investigated key aspects of transfer and found concepts in the psychology literature that can support transfer of skills and strategies in OT. Six key principles proposed from educational psychology can serve as a guide for practitioners to better train for transfer. In this paper, we discuss the six principles and apply concepts from psychology. Each principle is supported with examples of how they may be incorporated into OT practice. If occupational therapists understand these principles and implement them in treatment, the efficacy of treatment may improve for many populations.

Keywords: Clinical reasoning, Occupational Therapy practice, Rehabilitation services

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Occupational therapy (OT) practice may be conceptualized as a learning process, where therapists serve as teachers, facilitating the learning process for clients working towards becoming more independent in everyday life activities. *Learning* is defined as a relatively permanent change in behavior as a result of experience or having the capacity for skill or knowledge acquisition (Berkeland & Flinn, 2005). As facilitators of learning, occupational therapists assist clients in a variety of learning processes including, helping clients learn or relearn skills, developing strategies to perform activities, and teaching caregivers skills that will help them care for or support clients with disabilities (Glogoski, Milligan & Wheatley, 2006). As a result, transfer seems to be a critical component in the domain of teaching and learning.

The purpose of teaching clients skills and strategies during occupational therapy is to support performance and participation in the broader contexts of everyday lives. It is not feasible to teach a client all the skills or strategies for every situation he or she might encounter when returning to home and community. Moreover, as many clients resume daily activities, is it unlikely that continuous support or a structured setting will be available to assist in using newly learned skills and strategies. Therefore, the skills and strategies must be acquired during therapy in a way that permits them to be independently applied by clients across a variety of situations that may differ from the initial learning event (Toglia & Kirk, 2000). This phenomenon, the use or application of prior learning in new contexts, is often termed "transfer" or "generalization" of learning (Flavel, 1979; Woodworth & Thorndike, 1901). For this paper, we treat transfer and generalization as overlapping constructs and use the following definition. Transfer is the degree that a skill learned in one context can be performed in another context, and *transfer of training* refers to the potential that learning one skill will influence the ability of the learning of another skill (Geusgens et al., 2007). Context refers to internal (emotion/mood state) or external (physical/social environment) circumstances associated with the learning or performance event (Roediger, Dudai & Fitzpatrick, 2007). These two defi-

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nitions are replete in the psychology literature (Guthrie, 1935; Hull, 1943; Perkins & Saloman, 1989; Thorndike, 1932). Transfer that is defined in this article is not to be confused with the term transfer used in OT to define how a person physically moves from one surface to another. Further, transfer can occur across environmental contexts, such as techniques to complete a modified cooking task learned in inpatient setting to use in the home. Transfer can also occur across tasks, for example when an individual who has learned to eliminate distraction (e.g., turn off the television) while paying bills, also does this while cooking a new recipe (Haskell, 2001; McKeough, Lupart & Marini, 1995).

According to Hammel and colleagues, social participation is increasingly becoming a core goal for rehabilitation as a whole (2008). Transfer of skills is one means to achieving this goal; however evidence is limited to support the occurrence of transfer in rehabilitation (Geusgens, Winkens, van Heugten, Jolles & van den Heuvel, 2007). In educational psychology, the concept of transfer has been rigorously studied. Transferring of learned skills is not expected to occur automatically, except in rare conditions when the transfer distance (the similarity between a learned skill and the new skill) is very near (or skills are very similar) (Perkins & Salomon, 1988). Transfer seems to be inconsistent in rehabilitation practice and research (Geusgens et al., 2007). One common assumption among researchers and practitioners is that skills and strategies taught to clients during therapy will be seamlessly and automatically implemented in various contexts of everyday lives (Geusgens et al., 2007). For example, in stroke populations, efforts primarily target remediation of functional impairment (e.g., upper extremity movement and strengthening/endurance) with the assumption that this will result in gains in everyday life activities (e.g., dressing, working) (Teasell, Foley, Salter & Jutai, 2008). Numerous follow-up studies with individuals with stroke demonstrate that this transfer is not occurring and functional outcomes remain poor, once individuals with stroke return to their premorbid activities (Murray & Lopez, 1997; Teasell et al., 2008). This limitation may stem from the failure to explicitly "teach for transfer" (Butterfield & Nelson, 1989; Perkins & Salomon, 1988) during the process of intervention.

Purpose

In a recent review of educational psychology literature, Geusgens and colleagues (2007) offered a list of "prerequisites for the occurrence of transfer" (p. 426). They argue that the adoption of these principles (see Table 1) during the therapeutic process may enhance the likelihood that skills learned would be retained and appropriately implemented by the clients across activities and environments upon discharge. However, discussion is lacking on how the principles may be understood and adopted by rehabilitation, specifically OT. The purpose of this paper is to provide a descriptive summary on the six principles proposed by psychology (Geusgens et al., 2007) and discuss their potential application to OT. We apply concepts from educational psychology to support each principle and provide examples of how each may be operationalized in the context of occupational therapy practice.

Transfer in OT Practice

The educational psychology literature has determined a number of specific, evidence-based principles related to teaching for transfer. As a caveat, these principles are discussed in general terms, as they would relate to clients who are capable of cognitive, goal-directed learning. For clients with neurological injury (i.e., TBI, CVA), practice guidelines for OT stress the importance of generalization and present it as a central tenet of cognitive rehabilitation (Cicerone et al., 2000). However, the research and outcomes on how transfer applies to clients with cognitive deficits (i.e. executive function) is limited but emerging (Geusgens et al., 2007). Therefore, we emphasize that application of these principles in populations with neurological injury may be different when compared to clients without cognitive deficits.

Six principles to support transfer of skills in occupational therapy

Principle I. A person should know what transfer is and how it works (Geusgens et al., 2007, p. 464).

While the definition of this concept is somewhat self-evident, it is often not addressed in OT. In essence, this principle states that therapists should explain to clients what transfer is and the process of how transfer works. For example, when working with a client on a light meal preparation, the occupational therapist should point out that the goal of the treatment is to transfer the strategies and processes they are learning in completing this exercise to meal preparation in their home. This should facilitate a discussion about the similarities and differences between the two contexts and a discussion about the application of the activity to their home. The underlying educational psychology principle associated with this principle is the concept of "teaching for transfer" (Butterfield & Nelson, 1989; McKeough, Lupart & Marini, 1995; Perkins & Salomon, 1988). Teaching for transfer is simply structuring the learning environment

Table 1. Prerequisite principles to promote occurrence of transfer

1	A person should know what transfer is and how it works
2	A person should be aware of one's own functioning before he or she will acknowledge that a strategy is needed to improve it
3	A person should be able to judge when and where transfer can be applied
4	General knowledge should be taught, as this type of knowledge is easier to transfer than specific knowledge
5	The connection between what is learned and the situation in which it is learned should be broken by practicing a strategy or skill while varying the practice situation as much as possible
6	Transfer should be addressed during learning, as it cannot be expected to occur automatically

and the activity to promote transfer. This concept of teaching for transfer is the foundation for the remaining principles.

Principle II. A person should be aware of one's own functioning before he or she will acknowledge that a strategy is needed to improve it (Geusgens et al., 2007, p. 464).

Clients must understand they have a problem before they may be willing and able to adapt existing or new behaviors to address it. Intuitively, this principle is also supported by studies that show that impaired self-awareness is associated with poor outcomes (Fleming, Strong & Ashton, 1998; Prigatano & Wong, 1999; Sherer et al., 1998). Cognitive psychology and therapeutic models (e.g., Barco et al., 1991; Toglia & Kirk, 2000) describe two main aspects of awareness: (1) pre-existing knowledge or beliefs regarding one's abilities, task demands and how to compensate for limitations (termed "metacognitive knowledge" [e.g., Toglia, 1991] or "intellectual awareness" [Barco et al., 1991]) and (2) knowledge of performance acquired during task execution via self-monitoring processes (termed "on-line awareness" [Toglia, 1991] or "emergent awareness" (Barco et al., 1991). In the context of learning and transfer, reduced self-awareness of deficits may result in decreased motivation to engage in the initial learning of skills or strategies; if the client does not understand that a problem exists, he or she might view strategies as unnecessary (Toglia, 1991). Reduced self-awareness may also result in the inability to appropriately recognize situations in which learned skills or strategies should be used (Toglia & Kirk, 2000).

The importance of awareness in the therapeutic process and to functional outcomes seems to be recognized by OT's, particularly in populations with brain injuries (Radomski & Latham, 2008). As such, there are a number of suggested ways to improve clients' self-awareness during the course of OT, and randomized controlled trials are emerging to support them (Goverover et al., 2007; Schmidt, Fleming, Ownsworth, Lannin & Khan, 2012). The general perspective is that awareness interventions, rather than focusing on improving awareness in isolation, should occur in the context of improving a functional ability and should use real-life and familiar activities and settings (Fleming & Ownsworth, 2006; Toglia & Kirk, 2000). This "occupation-based" awareness training is thought to best facilitate the emergence of awareness because it allows clients to compare their stored knowledge and expectations of performance with their current performance, thereby permitting error-recognition and the eventual restructuring of knowledge and beliefs about their abilities. This is accomplished via direct feedback regarding task performance and structured self-evaluation. For example, a therapist working with a client on community reintegration could set up a structured shopping experience that incorporates awareness-training techniques. In a practical approach, the therapist would provide an introduction to the task and its goals, after which the client would predict his or her task performance, estimate the level of difficulty or how much time or effort it will take, and pre-plan for any problems. Actual task performance should be videotaped so that the client can evaluate his or her performance and compare it with his or her initial predictions. Following this, the therapist and client would compare and discuss their observations and perceptions of task performance, including how consistent the client's performance was with his or her predictions and expectations. The video would be used to support this discussion as well as to review errors, positive aspects of task performance, and potential opportunities for compensatory strategy use. Such experiences would continue in the service of improving pre-task metacognitive knowledge, while techniques to improve online-awareness, such as periodic self-checking during task performance, would be introduced gradually. The therapist may begin by participating in or verbally guiding the client through the process, and would reduce the verbal guidance as it becomes habitual for the client.

Occupation-based approaches recognize the importance of providing opportunities for clients to implement the same learned awareness strategies in varied tasks and environments (Toglia & Kirk, 2000; Tsaousides & Gordon, 2009). For example, the client could start by applying the evaluation process in a simulated grocery store in the clinic, and then move to a small neighborhood grocery, to a larger grocery store or a clothing store in the mall and then to other non-shopping activities (e.g., meal preparation, laundry). Many features of occupation-based awareness interventions are consistent with the teaching strategies thought to enhance the likelihood of transfer including reducing the transfer distance by embedding learning in contexts in which it will later be required, teaching general skills and strategies which can applied in a range of contexts, and varying the practice/learning situation (Toglia & Kirk, 2000; Tsaousides & Gordon, 2009).

Principle III. A person should be able to judge when and where transfer can be applied (Geusgens et al., 2007, p. 464).

Once a client acknowledges performance deficits and learns skills or strategies to address them, he or she needs to be able to realize the occurrence of situations in which the skills or strategies should be used. Research in healthy adults show that individuals do not spontaneously recognize everyday situations to which learned material can be applied (Gick & Holyoak, 1983; Perkins & Salomon, 1988; Roediger, Dudai & Fitzpatrick, 2007), therefore it is unrealistic to expect that clients with disabilities can do this automatically. Instead, therapists should assume that spontaneous transfer is not the norm and incorporate methods into treatment that will facilitate a client's ability to recognize and anticipate situations which might prove difficult and thus require learned skill or strategy use. This is particularly relevant in situations that require "high-road transfer," which depends on deliberate mindful abstraction of skill or knowledge from one context for application in another context (Salomon & Perkins, 1989). When contexts (environments) are very different and fail to trigger automatic associations, then cognitive effort is required to discover or extract generic qualities that two contexts possess to make connections based upon common elements. For example, driving a car vs. driving farm tractor are different contexts but contain similar elements for abstraction (e.g. functional operation).

Salomon and Perkins (1989) describe two modes of high-road transfer, "forward reaching" and "backward reaching." Therapists can incorporate teaching methods into their interventions to facilitate both of these modes. Steps to promote forward reaching high-road transfer occur during the learning process and involve abstracting learned skills (acquired ability) or strategies (plans) in preparation for application elsewhere in the future. An example of forward reaching transfer is where the therapist simply tells the client how to apply cooking skills for meal preparation learned in the clinic to meal preparation in his or her home. Once the client understands the general idea of transfer, the therapist may ask, "How might you apply these skills in a friend's kitchen? Or camping?" This would exercise and strengthen the client's own forward reaching capability. In addition, after learning a particular skill or strategy, the client could be asked to brainstorm different daily life situations to which it could be applied.

In contrast, backward reaching high-road transfer is required when one experiences, or anticipates experiencing, a performance problem. He or she must identify the key problematic characteristics of the situation and draw upon ("reach backward into") past experience for knowledge, skills or strategies that could be applied to solve the problem. To strengthen this type of problem solving ability, therapists can place their clients in novel situations that require the application of previously learned strategies. If a client wants to be independent in shopping, the therapist could take the client to an unstructured context (e.g. mall) and, if the client becomes overwhelmed by distractions, the therapist would cue the client to think about what he or she has been practicing in therapy and implement some strategy to help him or her feel more in control of the situation. Therapy sessions could also involve homework assignments that guide clients to become more aware of everyday situations which may be problematic or to which strategies can be applied.

In essence, high-road transfer requires the client to develop the skills to perform basic "task analysis" to identify, summarize and organize common elements or demands of various situations and then map them onto their strengths, limitations, and the skills or strategies learned during OT. Clients will need a high level of support from their therapist to initially perform these abstractions, but the process may become habitual with repeated practice (Siegler, 2004).

Principle IV. General knowledge should be taught, as this type of knowledge is easier to transfer than specific knowledge (Geusgens et al., 2007, p. 464).

In OT, there is a tendency to be task-oriented or focused on a specific activity—therapists work with clients to address a specific skill or provide them with specific strategies for improving their performance of a task (Toglia, 2005). According to this principle, however, a different approach may be required when trying to promote transfer (Geusgens et al., 2007). Task specific knowledge does not transfer as well as general knowledge. The educational psychology principle underpinning this principle is the concept of "transfer distance". Transfer distance refers to how similar the learning environment and activities are to the transfer environment and activities (Butterfield & Nelson, 1989. General knowledge has greater similarity to multiple activities and contexts than task specific knowledge and is therefore easier to transfer. For example, instead of discussing specific strategies to reduce fatigue while cooking a meal, the occupational therapist should focus on teaching the concepts that support conservation of energy and general strategies such as pacing and planning. Transfer distance also involves the concept of "high and low road transfer" (Salomon & Perkins, 1989). Low road transfer is transfer that occurs between two very similar activities (e.g., driving a car vs. driving a truck) whereas high road transfer is the general abstraction and application of a strategy between two different contexts (e.g., energy conservation techniques to dressing) (Salomon & Perkins, 1989). Low road transfer can occur fairly automatically and relies on long-term memory [Salomon & Perkins, 1989] whereas high road transfer involves multiple cognitive processes, but has a far broader range of applicability in the real world. Teaching general knowledge or strategies will promote high road transfer. In OT for example, teaching general metacognitive strategies to help clients identify goals, create a plan, implement a plan, and evaluate their work can have broad application across multiple performance areas (Toglia & Kirk, 2000). While high road transfer may ultimately be the goal, this principle is dependent on the ability of the client (e.g. clients with severe brain damage have more limitations).

Principle V. The connection between what is learned and the situation in which it is learned should be broken by practicing a strategy or skill while varying the practice situation as much as possible (Geusgens et al., 2007, p. 464).

As mentioned earlier, a *context* is defined as a situation where an event occurs; it can be an internal state (feeling a particular way, e.g. being happy when seeing friends) or an external state (physical environment where something occurs) (Roediger, Dudai & Fitzpatrick, 2007). This principle links a specific task or strategy and the context in which it is learned; this link is influenced by how much the task or strategy is practiced and the various situations in which it is practiced (Schneider & Shiffrin, 1977). Further, this link is supported by consistent mapping (initial practice in one context) and varied practice (practice in different contexts). *Consistent mapping* involves sustained task performance in a static context across time—there will be differences in performance in the beginning, but automaticity will develop across hundreds to thousands of trials (Schneider & Shiffrin, 1977). For example, reading is not an automatic skill but requires time and practice to recognize and comprehend letters, words and sentences, and to understand how the words may be rearranged to form sentences, paragraphs and stories. In time, recognition of words becomes automatic with constant exposure and practice; however, comprehension of the material read always requires effort to process each new piece of information (Logan, 1997). In OT, a therapist working with pediatric clients on reading may encounter fluctuations in their performance due to internal contexts (feeling sad), external contexts (noisy therapy gym) or both. Consistency in performance is required before practice may be varied.

Similarly, *varied practice* refers to allowing practice to occur in a variety of similar contexts. This permits retaining and adapting certain pieces of information from one context to the next, which is thought to increase the chances that the task or strategy will transfer from the initial context of practice into the application of novel contexts (Salomon & Perkins, 1989). An example of varied practice in OT might include assessing and 'fitting' a new vehicle for a client. In the new car, the controls for operation may be similar but may vary in location and shape. These slight variations in context require re-adaptation of prior knowledge and strategies to reorient in order to use skills to operate the new vehicle. Repeated exposure will eventually foster transfer of skill. By practicing in varying contexts, the client increases the likelihood of successful performance in future novel contexts.

This principle of transfer is critical for OT. The continuum of consistent mapping and varied practice presents how therapy should structure a context to facilitate transfer. A client should first gain mastery over a strategy or skill in one context and demonstrate consistent performance before moving to different contexts and transferring that strategy/skill over.

Principle VI. Transfer should be addressed during learning, as it cannot be expected to occur automatically (Geusgens et al., 2007, p. 464).

If the intention of teaching a skill/strategy is for use in daily performance, then this intention should be explicitly stated and concentrated on throughout the process. Assuming a skill or strategy taught to a client will automatically transfer and be used is a misconception. For example, in the context of education, the objectives of a teacher's lesson plan are typically stated before a lecture, instantiated through the lecture and revisited at the end to ensure the content was covered (Salomon & Perkins, 1989). While this example is pertinent to education, it would be efficacious to apply this basic approach to OT.

Transfer appropriate processing and bridging are two concepts that support transfer in learning. *Transfer appropriate processing* is categorized as a type of memory dependent learning where the memory of an event is typically best retrieved under similar or original circumstances in which it was encoded. Additionally, the amount of information recorded and the initial context of encoding directly impacts performance based on degree of similarity or dissimilarity of the context of retrieval (Morris, Bransford & Franks, 1977). Practitioners can utilize this concept to improve the performance of a client on a specific task. For example, therapists working on dressing with a client who has hemiplegia may want to evaluate how the client performs in their home since it is the most appropriate and relevant context for completing the activity. *Bridging* is another concept that highlights teaching a specific condition or resembling condition in order for specific transfer (high or low road) to occur in the context of OT. If a client with a knee replacement wants to dress and sequence through a morning routine, it would be recommended to use the client's own clothes and practice dressing where the clients typically completes activity (e.g. at bedside instead of bathroom). Both TAP and bridging are requisites for transfer in order to maximize the probability of the skills and strategies being used in various contexts.

The advantage of using transfer appropriate process, bridging and this final principle in OT may seem intuitive, and it is often glossed over. However, transfer has far reaching implications for therapists and clients. For example, a client with a right below knee amputation is being taught to use a new prosthesis for a meal-prepping task. The therapist should first work with the client to state goals and expectations for OT. The overall goals might include having the client don the prosthesis independently and ambulate with a cane in the kitchen without any loss of balance. Before, during and after a cooking task, there should be discussion of overall goals, specific strategies for movements, task priorities and safety. More importantly, there should be a discussion of the differences and similarities between the practice environment in therapy and home environment in relation to the cooking task. This might include an evaluation of the client's home environment, having the client complete the same cooking task, discussing the client's performance and what needs to be altered to improve transfer. It is important for therapists to limit our assumptions about transfer occurring automatically and instead, clearly address it in the context of OT.

Conclusion

One expected outcome of OT and rehabilitation is that skills or strategies acquired by clients will be readily accessible for use in their daily activities and environments. In other words, what is learned in a clinical setting will transfer or generalize to everyday life for each individual client. Evidence for the occurrence of transfer in practice is lacking as suggested by a recent review of transfer in cognitive rehabilitation (Geusgens et al., 2007). We propose that this may stem from a fundamental disconnect on how to promote transfer in OT. The six principles and their supporting concepts previously described are borne from educational psychology; yet, they bear significant implications for OT practice. These six principles apply to existing OT practice models and support the work of therapists as they teach skills and strategies to clients in order to support and maintain performance and participation. To our knowledge, these principles have not been formally tested in structured experimental research studies; however, the concepts supporting them have been extensively studied in psychology. We recommend practitioners and researchers to begin to use these principles and assess the impact on the functioning of their clients. Research on transfer is a new field of inquiry that may bear great significance on evaluating the efficacy of OT interventions. Once occupational therapy begins to view practice as a type of learning and the benefits of training for transfer, we may augment our interventions and practice frameworks to include principles of transfer.

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■ORIGINAL ARTICLE

Correlation of the Hand 20 with the International Classification of Functioning, Disability, and Health and comparison of the results with those of the Disability of the Arm, Shoulder and Hand

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Abstract: The present study aimed to determine the correlation of the Hand 20, a patient-based outcome evaluation widely used in Japan, with the International Classification of Functioning, Disability, and Health (ICF) and compare the results with those of previous studies on the Disability of the Arm, Shoulder and Hand (DASH) score. As a result of the study, it was found that the Hand 20 includes 5 items in the chapters of Body Functions, 23 items in the chapters of Activity/Participation, and 2 items in the chapters on Personal Factors in the ICF. The results show that the Hand 20 has a larger number of assessment items categorized into the muscle function (b740) and hand dexterity (d440) than that of DASH. The present study concludes that the Hand 20 is a measurement method suitable for assessing hand functions and performance. These findings provide insights to select appropriate outcome assessment methods and interpret outcomes between the two different methods.

Keywords: ICF, Hand20, DASH

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Introduction

In the recent approaches for outcomes evaluation of orthopedic rehabilitation, not only objective outcomes focusing on functional or biological aspects but also patient-based outcomes have come to play an important role in determining the impacts of disease or effects of intervention on psychosocial aspects (Dawson & Carr, 2001). Health-related quality of life (QOL) is the most common patient-based outcome of medical care. Its assessment system includes comprehensive, disease-specific, and body region-specific scales (Mcdowell, 2006).

The Disabilities of the Arm, Shoulder, and Hand (DASH) score has been widely used as a body region-specific scale for outcomes evaluation in the field of hand surgery. The DASH questionnaire consists of 30 questions pertaining to disability/symptoms and 4 pertaining to work and participation in sports/performing arts. Each item is scored by each patient using a Likert scale (Hudak, Amadio & Bonbardier, 1996). The questionnaire has been translated into each patient's native language, and its reliability, validity, and responsiveness have been verified (Christina, Isam & Charlotte, 2003; Imaeda, Toh, Nakao, Hirata & Ijichi, 2006; Offenbäacher, Ewert, Sangha & Stucki, 2003; Padula et al., 2003). However, the scope of the DASH questionnaire was reported to be limited to the 18- to 65-year-old age group ("The DASH outcome measure", n.d.) and some questions are difficult to respond to because of cultural background, except in the United States (Lee et al., 2004, 2005).

The Hand Frontier, a nonprofit organization, developed the Hand20 questionnaire, which takes into consideration the Japanese cultural background, and reported its reliability, validity, and responsiveness, as well as its concurrent validity with the DASH version by the Japanese Society for Surgery of the Hand [DASH-JSSH] (Suzuki et al., 2010). Considering that the DASH-JSSH consists of questions that elderly respondents tend not to respond to, such as those pertaining to the item "Having

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sexual life," the Hand20 was designed to exclude such items. Moreover, the Hand20 reinforces 19 of the 20 questions with illustrations for the convenience of elderly respondents to further avoid unanswered items, which if missing could affect the overall score (Fig. 1). Additionally, the Hand20 has some particular items which ask about activities using the affected hand, facilitating effective intervention. These advantages have led to the wide acceptance of the Hand20 in Japan (Yoshida et al., 2011; Iwatsuki et al., 2011).

Thus, in Japan, either the DASH or Hand20 is primarily used as a patient-based evaluation tool in the field of hand surgery. However, when comparing the usefulness of the 2 scoring systems in determining the effects of intervention, it is important to know the characteristics of each evaluation tool and judge them appropriately. Thus, adequate consideration of the subjective difficulties in measuring specific aspects of a patient's health condition by each evaluation system is important.

Cieza et al. (2002, 2005) proposed to consider the association of an assessment instrument with the International Classification of Functioning, Disability and Health (ICF) score because the ICF is necessary to achieve a consensus on the appropriate functional outcome parameters and is useful for comparing study results or choosing the appropriate assessment system. In addition, given that determining which outcome parameters should be evaluated and how they should be evaluated are important in outcomes assessment, the instrument's scope of scoring functional aspects should be based on the ICF score, thereby elucidating the relationship between intervention and its outcome.

The concurrent validity of the Hand20 with the DASH was previously reported. As suggested by Cieza et al. (2005), further determining the correlation of an assessment tool with the ICF may reveal the characteristics in each scope of scoring and may be useful in comparing outcomes. Furthermore, Drummond, Sampaio, Mancini, Kirkwood & Stamm (2007) reported on the DASH score and clarified its association with the ICF.

In conforming with the guidelines proposed by Cieza et al., the present study aimed to determine the correlation of Hand20 with the ICF and compare the results with those of previous studies on the DASH score.

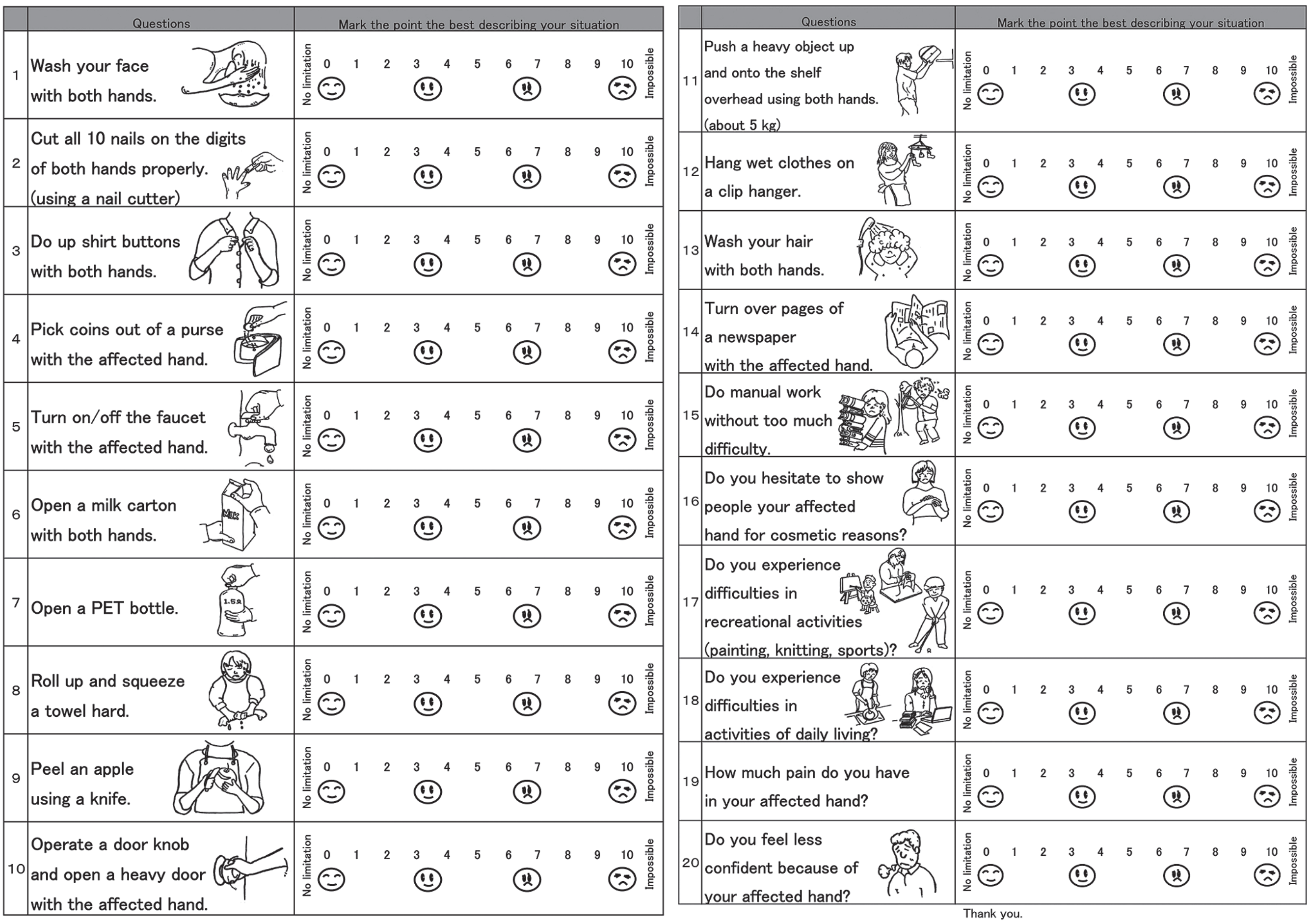

Fig. 1. Hand20

Methods

Determining correlation with the ICF

In the ICF (World Health Organization, 2008), information is classified into 2 parts: Functioning and Disability as Part 1 and Contextual Factors as Part 2. Along with these parts, the ICF code expresses regions with lower case letters as follows: in Part 1, "b," "s," and "d" represent body functions, body structures, and activities and participation, respectively; in Part 2, "e" represents environmental factors. Furthermore, 2 to 4 numbers are added for individual classification. The classification into the "activities and participation" category was common. Although they should have been fundamentally expressed as "a" (activities) and "p" (participation) (Ueda, 2010), it was decided to code them as "d" for comparison with previous studies.

The Japanese version of the Hand20 was used in this study. However, the codes written in English provided by previous studies (Suzuki et al., 2010) were used in this paper. We complied with the guidelines proposed by Cieza (2002, 2005). The correlation guidelines consist of 8 items to correlate with the appropriate ICF codes that correspond to all the concepts that might be considered as applicable to the second-level items in the evaluation table. The classification into either "other specified" or "unspecified" was not performed; instead, the coding for the relatively lower level was applied. Personal factors were coded as "pf." Factors that were not defined in the ICF code were coded as "nd."

Consequently, 2 researchers (T.I. and T.O.) acquired adequate prior knowledge of the ICF, correlation guidelines, and Hand20 and performed the correlation analysis independently. Subsequently, they compared each other's classifications. When a consensus on an assessment tool was reached between the 2 researchers, that instrument was adopted, as well as its corresponding classification codes. When no consensus was achieved, a third researcher (T.F.), who had been a lecturer on the ICF to the undergraduates in the university, made the decision.

Analysis

According to the above-mentioned correlation guidelines, the Hand20 was evaluated using the ICF codes. The rate of concordance of the final code after having reached an agreement (T.I and T.O) was expressed by the kappa coefficient. The coding of Hand20 was subsequently compared with that of the DASH. Although the DASH was classified into the second level including the "disability/symptom," "work," and "sports/performing arts" categories, the Hand20 could not be appropriately classified; therefore, we compared the scores from the "disability/symptom" category only. We also compared the differences in the number of codes and the rate of concordance of each ICF code between the DASH and the Hand20.

Results

1. Linking to the ICF in Hand20 (Table 1, 2)

As a result of having classified the items according to the ICF codes, 20 questions in the Hand20 were correlated with 30 ICF codes, covering 6 chapters: Sensory Functions and Pain, Neuromusculoskeletal and Movement-related Functions, General Tasks and Demands, Mobility, Self-care, and Community, Social, and Civic Life. These correlation codes included 5, 23, and 2 items pertaining to body functions, activities and participation, and personal factors, respectively. None of the items was classified as a body function/structure or an environmental factor.

For the body functions, 2 items were classified as sensation of pain (b280), 2 items were classified as muscle function (b730), and 1 was classified as muscle endurance function, respectively (b740).

For the "activities and participation" category, 2 items were classified as "carrying out daily routine" (d230) in Chapter 2 (General Tasks and Demands); 1, 4, and 7 items were classified as "lifting and carrying objects" (d470), "fine hand use" (d440), and "hand and arm use" (d445), respectively, in Chapter 4; 3 and 1 items were classified as "washing oneself" (d510) and "caring for body parts" (d520) in Chapter 5; 1 item was classified as "preparing meals" (d630) in Chapter 6; and 1 item was classified as "caring for household objects" (d650) in Chapter 7.

Question no. 17 "Do you experience difficulties in recreational activities? (e.g., painting, knitting, and sports)" was most frequently linked to the classification items, including "recreation and leisure" (d920), "sports" (d9201), "art and culture" (d9202), and "handicrafts" (d9203).

The kappa coefficient indicating the rate of concordance of the final code after a consensus was reached was substantial (Kappa index = 0.69, P = 0.02) (Landis & Koch, 1977). Items 11 ("Push a heavy object up and onto the shelf overhead using both hands; approximately 5 kg"), 14 ("Turn over pages of a newspaper with the affected hand"), and 15 ("Do manual work without too much difficulty?") in the Hand20 questionnaire required discussion with the third person to obtain an agreement.

Table 1. Linking between the Hand20 and the ICF

No.	Item Hand20	Meaningful Concept	ICF code/ICF category	Additional Information
1	wash your face with both hands	washing oneself	d5100 washing body parts	face
2	cut all 10 nails on the digits of both hands properly. (using a nail cutter)	caring for body parts	d5203 caring for finger nails	using a nail cutter
3	Do up shirts buttons with both hands.	fine hand use	d440 fine hand use	do up shirts buttons with the affected hand
4	pick up coins out of a purse with the affected hand.	picking up	d4400 picking up	coins out of a purse
5	turn on/off the faucet with the affected hand.	turning/twisting	d4453 turning or twisting the hands or arms	the faucet with the affected hand
6	open a milk curton with both hands.	fine hand use	d440 fine hand use	a milk curton
7	open a PET bottle.	open	d4453 turning or twisting the hands or arms	a PET bottle
8	roll up and squeeze a towel hard.	turning/twisting	d4453 turning or twisting the hands or arms	a towel
9	peel an apple using a knife.	cooking	d6300 preparing simple meals	
10	operate a door knob and open a heavy door with the affected hand.	turning/twisting opening/pushing	d4453 turning or twisting the hands or arms d4451 pushing	door knob a heavy door
11	push a heavy object up and onto the shelf overhead using both hands. (about 5kg)	putting down reaching muscle power function	d4305 putting down objects d4452 reaching d730 muscle power functions	overhead about 5kg
12	hang wet clothes on a clip hanger.	housework	d6400 washing and drying clothes and garments	wet clothes a clip hanger
13	wash your hair with both hands.	washing oneself	d5100 washing body parts	hair
14	turn over pages of a newspaper with the affected hand.	fine hand use hand and arm use	d440 fine hand use d445 hand and arm use	a newspaper
15	do manual work without too much difficulty.	muscle power functions muscle endurance functions	d230 caring out daily routines b730 muscle power functions b740 muscle endurance functions	manual work with the affected hand
16	do you hesitate to show people your affected hand for cosmetic reasons?		pf	
17	do you experience difficulties in recreational activities (eg., painting, knitting, sports, etc.)?	recreation painting knitting sports	d920 recreation and leisure (d9201 sports) (d9202 arts and culture) (d9203 crafts)	sports painting knitting
18	do you experience difficulties in activities of daily living?	carrying out daily routine	d230 carrying out daily routine	
19	how much pain do you have in your affected hand?	pain	b28014 pain in upper limb b28016 pain in joints	affected hand
20	do you feel less confident because of your affected hand?		pf	

2. The difference of item numbers between Hand20 and DASH (Table2)

For the DASH and Hand20 questionnaires, the concordance rate was calculated by dividing the number of items in the ICF first and then the second-level classifications by the total number of items: 2−13% for the DASH and 3−23% for the Hand20. The ICF code was concentrated on the “sensation of pain” (b280) and “hand and arm use” (d445) for the DASH and on “hand and arm use” (d445) alone for the Hand20. In addition, no item corresponded to “sleep functions” (b134) in the DASH and to “touch function” (b265), “mobility of bone functions” (b720), and “sensations related to muscles and movement functions” (b780) in the Hand20. For activities and participation, no item corresponded to “writing” (d170), “using transportation” (d470), “dressing” (d540), “eating” (d550), “doing housework” (d640), “informal social relationships” (d750), “family relationships” (d760), “intimate relationships” (d770), and “remunerative employment” (d850) in the Hand20. For body functions, no item corresponded to “muscle endurance functions” (b740) in the Hand20. For activities and participation, no item corresponded to “fine hand use” (d440) in the DASH.

Table 2. Comparison of the Hand20 with the DASH

ICF categories			Number of items (ratio; %)	
One-level classification	Two-level classifiacation		DASH	Hand20
body function				
Chapter 1 MENTAL FUNCTIONS	global mental functions	sleep functions (b134)	1 (2.2)	
Chapter 2 SENSORY FUNCTIONS AND PAIN	additional sensory functions	touch sensation (b265)	1 (2.2)	
	pain	sensation of pain (b280)	6 (13.0)	2 (6.7)
Chapter NEUROMUSCULOSKELTAL AND MOVEMENT-RELATED FUNCTIONS	functions of the joints and bones	mobility of bone functions (b720)	1 (2.2)	
	muscle functions	muscle power functions (b730)	2 (4.3)	2 (6.7)
		muscle endurance functions (b740)		1 (3.3)
	movement functions	sensations related to muscles and movement functions (b780)	1 (2.2)	
activities and participation				
Chapter LEARNING AND APPLYING KNOWLEDGE	applying knowledge	writing (d170)	1 (2.2)	
Chapter 2 GENERAL TASKS AND DEMANDS		carrying out daily routine (d230)	1 (2.2)	2 (6.7)
Chapter 4 MOBILITY	carrying, moving and handling objects	lofting and carrying objects (d430)	2 (4.3)	1 (3.3)
		fine hand use (d440)		4 (13.3)
		hand and arm use (d445)	6 (13.0)	7 (23.3)
	moving around using transportation	using transportation (d470)	1 (2.2)	
Chapter 5 SELF-CARE		washing oneself (d510)	1 (2.2)	2 (6.7)
		caring for body parts (d520)	1 (2.2)	1 (3.3)
		dressing (d540)	1 (2.2)	
		eating (d550)	1 (2.2)	
Chapter 6 DOMESTIC LIFE	household tasks	preparing meals (d630)	1 (2.2)	1 (3.3)
		doing housework (d640)	4 (8.7)	
	caring for household objects and assisting others	caring for household objects (d650)	1 (2.2)	1 (3.3)
Chapter 7 INTERPERSONAL INTERACTIONS AND RELATIONSHIPS			1 (2.2)	
	particular interpersonal relationships	informal social relationships (d750)	3 (6.5)	
		family relationships (d760)	1 (2.2)	
		intimate relationships (d770)	1 (2.2)	
Chapter 8 MAJOR LIFE AREAS	work and employment	remunerative employment (d850)	1 (2.2)	
Chapter 9 COMMUNITY, SOCIAL AND CIVIC LIFE		recreation and leisure (d920)	3 (6.5)	4 (13.3)
		pf	1 (2.2)	2 (6.7)

Discussion

In this study, the difference in the number of questions influenced the correlation with the ICF (10 chapters and 44 items for the DASH vs. 6 chapters and 30 items for the Hand20). In addition, the ICF code was concentrated on “sensation of pain” (b280) and “hand and arm use” (d445) for the DASH and on “hand and arm use” (d445) alone for the Hand20, which were considered characteristic of each scoring system. Regarding the correlation with the ICF, the rate of interrater agreement was significant.

The reliability and validity of the Hand20 were previously verified, and its concurrent validity with the DASH score was 0.91, indicating high correlation (Suzuki, 2010). However, the health-related QOL should not be interpreted using only the scores, and each scope of scoring should be prescribed with a common framework. It is important that the scores be considered as one of the indexes for comparing or choosing an assessment tool. In this study, the ICF proposed by the WHO (World Health Organization) was considered as the unifying framework. The Hand20 was compared with the DASH in conformity with the correlation guidelines proposed by Cieza et al. (2002, 2005). Regarding the results on the characteristics of the aspects of body functions in the Hand20, no item corresponded to the sleep functions under the mental functions in the first level in Chapter 1. In the DASH, sleep disorder is considered to be caused by arm pain and supplemented by the question “How painful is the affected hand?” in the Hand20. However, items related to touch function are not covered in the

Hand20 despite the fact that sensitivity to decreased touch function is a concern in peripheral neuropathy. To overcome this limitation, the use of disease-specific evaluation is recommended. For neuromusculoskeletal and movement-related functions, some differences were observed but were not relevant items in the DASH and the Hand20. It is a common point that items in the ICF are more focused on aspects of body functions.

For activities and participation, no item corresponded to "writing" in Learning and Applying Knowledge (Chapter 1). Conversely, "fine hand use" was as frequent as 23.3% in the Hand20. These results might be because the DASH focuses on disorders in the entire arms, whereas the Hand20 focuses on hand-specific, health-related QOL. Furthermore, the DASH included many questions on interpersonal interactions and relationships (informal social relationships, family relationships, intimate relationships, and remunerative employment). This difference in the conceptual framework led to the difference between the 2 instruments. Therefore, the fundamental principles of the Hand20 may be considered as based on the conceptual framework that disorders of the hand have a minimum influence on the aspects of participation.

In the Hand20, only few items are associated with self-care and instrumental activities of daily living such as dressing, eating, doing housework, and using transportation. These reflect the differences in the conceptual framework between the 2 assessment tools. The Hand20 is more focused on the hand and skill activities than the DASH. In contrast, for the personal factors, the DASH included only 1 item, whereas the Hand20 included 2 items, suggesting that the impact of hand disorder on personal factors is of particular concern.

Thus, the characteristics of the DASH include many social aspects such as health-related QOL, on which whole-arm disorders have an impact, whereas the Hand20 includes many performance aspects pertaining to health-related QOL, on which mainly hand disorders have an impact. Therefore, although the Hand20 is considered sensitive for evaluating performance aspects in disorders confined to the hand, it was suggested that it lacks sensitivity to measuring its impact on social aspects.

To utilize evidence derived from the study results, it is important to further consider whether an instrument should be used to guide the decision of appropriate treatment after having carefully examined the evaluation index used to measure the effect of intervention. In this study, the characteristics of the DASH and Hand20 were examined thoroughly. The results of this study will be useful in deciding which evaluation index should be used in clinical practice.

Conclusion

In conformity with the ICF correlation guidelines, as a result of having classified each item of the Hand20 and DASH, we found that the Hand20 is intended for diseases confined to the hand and that the DASH consisted of a comprehensive conceptual framework that includes social aspects on which whole-arm disorders have an impact. In addition, the sensitivity of the Hand20 for evaluating impaired touch function is unclear. Thus, identifying the differences in the conceptual frameworks between the 2 instruments is important for instrument selection and interpretation of results using the DASH and Hand20, which have been widely used in the field of hand surgery in Japan.

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■ORIGINAL ARTICLE

Effects of tendon and nerve gliding exercises and instructions in activities of daily living following endoscopic carpal tunnel release

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Abstract: The effects of postoperative therapy on psychological function following endoscopic carpal tunnel release (ECTR) have not been sufficiently investigated. This study investigated the effectiveness of instruction in tendon and nerve gliding exercises and activities of daily living (ADL) as postoperative treatment for 49 patients with carpal tunnel syndrome. Patients were randomized into 2 groups (intervention and control). After surgery, tendon and nerve gliding exercises and instruction in ADL were performed only on the experimental group on the day of the surgery. All patients were examined preoperatively and again 5−13 days postoperatively. Outcomes of pain, numbness, sensation, range of motion (ROM), anxiety, ADL and quality of life (QOL) were compared between groups. Differences were seen in pain, static 2-point discrimination, ROM, anxiety, and QOL. Tendon and nerve gliding exercises and instruction in ADL after ECTR appear likely to accelerate recovery.

Keywords: carpal tunnel syndrome, endoscopic carpal tunnel release, tendon and nerve gliding exercises, ADL-instruction

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Introduction

Carpal tunnel syndrome (CTS) develops when the median nerve is compressed at the wrist. Symptoms such as numbness and sensory impairment of the fingers in the area of the median nerve, failure of thumb opposition, finger movement disorders, and pain are characteristic of CTS (Phalen, 1966). Cutting the transverse carpal ligament is the most effective treatment for CTS (Uchiyama et al., 2009). Open carpal tunnel release (OCTR) (Phalen, 1966) was the choice of surgery until 1987, when endoscopic carpal tunnel release (ECTR) (Okutsu et al., 1987) was introduced as a minimally invasive alternative to OCTR using a smaller skin incision. ECTR avoids painful scarring, reduces the duration of hospitalization, and allows earlier recovery of movement. In addition, because postoperative external fixation is unnecessary, rehabilitation of patients can be accelerated (Okutsu, Ninomiya, Takatori & Ugawa, 1989).

Studies comparing the postoperative the results of ECTR and OCTR (Trumble, Diao, Abrams & Gilbert-Anderson, 2002; Tian, Zhao & Wang, 2007; Atroshi et al., 2009) showed that ECTR was associated with better improvements in muscle strength directly after surgery, but no differences in treatment results for subjective symptoms and activities of daily living (ADL) were reported. Agee et al. (1992) reported that post-ECTR tenderness caused a decrease in muscle strength, delaying ADL improvement. Atroshi, Johnsson, and Ornstein (1998) reported a strong correlation between ADL and postoperative patient satisfaction. There is therefore a need to improve early function and ADL

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after appropriate therapy.

Patient-perceived disability correlates as much or more with psychological distress as with objective impairment (Schiphorst Preuper et al., 2008). Correlations with psychological function are reported using Disability of the Arm, Shoulder, and Hand (DASH) scores (Niekel, Lindenhovius, Watson, Vranceanu & Ring, 2009), and Vranceanu, Jupiter, Mudgal & Ring (2010) stated that intervention for psychological function is important after surgery for CTS. In terms of psychological interventions, Inoue (2002) stated that a provision of objective and concrete information is effective. For physical intervention, finger exercises to prevent flexor tendon and neural adhesions must be prescribed (Yoshida, Okutsu & Hamanaka, 2008; Narazaki & Hashizume, 2008). Intervention effects on physical function have been examined, but intervention effects on psychological function have not been sufficiently investigated. The present study, therefore, sought to clarify the effects of interventions for physical and psychological functions on improvement of function, ADL, and quality of life (QOL) in patients treated using ECTR for CTS.

Methods

Subjects

From August 2010 until March 2011, a total of 86 patients (106 hands) diagnosed with CTS underwent ECTR at our institution. The content and purpose of the study were explained in advance to these patients, and consent to participate in this study was obtained from prospective subjects. Patients who had previously undergone carpal tunnel release (CTR) surgery, who had a combination of different upper limb disorders, or who had a medical or surgical history were excluded. In addition, patients with secondary CTS (caused by hemodialysis, wrist osteoarthritis, rheumatoid arthritis, or diabetes), upper limb numbness, pain, or sensory impairment (spine and spinal cord disorders, cerebrovascular disease) were excluded along with those who could not complete the questionnaire because of dementia, based on the judgment of the examiner. Subjects were randomly allocated to an intervention group or control group after preoperative evaluation according to sex, age, disease duration, severity (Hamada, Ide & Yamaguchi, 1985), and type of disorder, starting with patients with the earliest date of preoperative evaluation. Staff members not involved in the evaluation or treatment of these patients rolled a dice. When an odd number was rolled, the patient was assigned to the control group, and when an even number was rolled, the patient was assigned to the intervention group. During the intervention period, patients who refused to participate in the study, those with missing data, and those who were absent on the date of evaluation were excluded. Consequently, 25 patients were included in the intervention group (34 hands) and 24 were included in the control group (30 hands). Mean ages in the intervention and control groups were 59.8 ± 14.2 and 63.2 ± 11 years, respectively. This study was conducted after approval had been obtained from the hospital ethics committee (approval number: 54).

Methods

During preoperative examination, the intervention and control groups received explanations and precautions regarding the surgery. Patients underwent surgery on an outpatient or overnight inpatient basis. All surgeries were performed using the Okutsu method (Okutsu et al., 1987) by a surgeon specializing in hand surgery. During medical examination on postoperative day 1, the bulky dressing was removed to facilitate free movement of the wrist and fingers. After surgery, intervention was limited to patients in the intervention group only on the day of the surgery, as described below. Nothing was performed besides a medical examination in the control group. All patients were examined preoperatively and again at 5−13 days postoperatively (mean, 8.1 ± 1.9 days).

Intervention

An occupational therapist provided instruction on finger exercises and ADL. Instructions on finger and tendon gliding (Wehbé & Hunter, 1985) and nerve gliding (Totten & Hunter, 1991) exercises were given to patients in the intervention group. Tendon-gliding exercises consisted of 5 types: finger stretches; hook fist; full fist; table top; and straight fist. Nerve gliding exercises included 6 types: 1) finger and thumb flexion with the wrist in a neutral position; 2) finger and thumb stretches with the wrist in a neutral position; 3) wrist and finger stretches with the thumb in a neutral position; 4) wrist, finger, and thumb stretches; 5) forearm supination while performing wrist, finger, and thumb stretches; and 6) thumb stretches with forearm supination. These exercises were performed with the head in the median line, the shoulder girdle in a neutral position, and the forearm placed on the table with the elbow flexed at a 90° angle. Each position was maintained for 5 s. Three sets of exercises were performed 10 times/day and continued until the first follow-up at 1 week after surgery. To avoid exacerbation of inflammation, patients were instructed to stop the exercises immediately if pain was experienced in the wound or the palm during exercise.

Taking into account the methods of Okutsu, Hamanaka, and Yoshida (2008) and Montgomery (1994), consultations were held between occupational therapists and doctors regarding the content of ADL instruction to be provided as part of the postoperative intervention in this study. The occupational therapist taught the following contents about ADL instruction. Patients were instructed to start with a light load in the pain-free range and to gradually increase load. To prevent numbness and pain, patients were instructed to minimize flexion and extension of the wrist. To prevent palmar dislocation in the flexor tendon and nerves and pain, patients were asked to avoid applying pressure or gripping of heavy loads involving holding a stretch for 1 month after surgery. Patients received an explanation that there may not be early improvement of ADL, and the disappearance of numbness and pain could take a relatively long time. Furthermore, brochures containing instruction on ADL and exercise were distributed after these consultations.

Evaluation

Occupational therapists not involved in the treatment intervention and blinded to the group allocation process performed the evaluations before and after surgery. Mean day of postoperative evaluation was 8 ± 1.8 days postoperatively (range, 5−13 days) for the intervention group, and 8.3 ± 2 days (range, 5−13 days) for the control group. The same occupational therapists performed all evaluations for each subject. Upper limb function (pain, numbness, perception, and range of motion (ROM)), anxiety, ADL, and QOL were evaluated.

An 11-point numerical rating scale (Jensen, Turner & Romano, 1994) was used for the evaluation of pain and numbness. This evaluation method included quantification of the current stimulation level, with the maximum stimulation level ever experienced set as 10. Perception was evaluated using the Semmes-Weinstein monofilament test (SWMT) (Aulicino, 2002) and static 2-point discrimination test (s2PD) (Aulicino, 2002) for the ventral part of the numbest finger. ROM was evaluated using the total active motion (TAM) assessment scale for the index finger. The Japanese version of the State Trait Anxiety Inventory (STAI) (Nakazato & Mizuguchi, 1982) was used to evaluate anxiety. With an anxiety scale created from self-evaluation questionnaires, both the temporary emotional state due to current living conditions and trait anxiety showing individual character tendencies can be measured. The present study only measured state anxiety.

The evaluation of ADL utilized the DASH symptom scale (Imaeda et al., 2005), published by the Japanese Society for Surgery of the Hand. The reliability, validity, and efficacy of the DASH scale have been confirmed (Imaeda et al., 2005). In this study, only items regarding disability/symptom were considered. The DASH is a 30-item disability/symptom scale concerning disability of the upper extremity. Scores for all items are then used to calculate a scaled score ranging from 0 (no disability) to 100 (most severe disability).

The Japanese version of the Euro QOL 5-Dimension scale (EQ-5D) (The Japanese EuroQol Translation Team, 1998) was used to evaluate QOL. The EQ-5D visual analog scale (VAS) evaluates health state on a scale from 0 to 100. Respondents indicate how they feel that day (with 0 as the worst and 100 as the best state). The EQ-5D describes health status according to 5 dimensions: mobility, self-care, usual activity, pain/discomfort, and anxiety/ depression. Each dimension has 3 levels, namely, “no problems”, “some problems” and “sever problems”. Responses to the 5 dimensions are collectively expressed in the standard way as an EQ-5D score using the value set, which ranges from a for perfect health (no problems in any dimensions) to −0.111 for worst health (severe problems in all dimensions).

Statistical processing

SPSS for Windows version 16 (SPSS, Chicago, IL, USA) was used for statistical analyses. The χ^2 test and Mann-Whitney U test were used to compare data in the intervention and control groups. Wilcoxon’s signed-rank test was used to compare data within groups before and after surgery. The significance level was established at 5% for all measures.

Results

Patient characteristics are shown in Table 1. No significant differences were observed between the control and intervention groups in terms of these characteristics. Tables 2 and 3 display the results of clinical parameters for both groups. No significant differences were evident in the preoperative comparison of all evaluation items between groups. Postoperative pain was significantly lower in the intervention group than in the control group, whereas TAM and EQ-5D (VAS) scores were significantly higher in the intervention group than in the control group ($p = .01$, $p = .02$, and $p = .01$, respectively).

In pre- and postoperative comparisons within each group, a significant increase in pain was only observed in the control group ($p = .001$). Both s2PD and STAI scores declined significantly in the intervention group after the intervention ($p = .002$, $p = .01$). The control group showed no significant change. Likewise, no significant change in EQ-5D (5 dimensions) was seen for either group, whereas the EQ-5D (VAS) score was significantly higher only in the intervention group ($p = .03$).

Table 1. Baseline characteristics of study patients

		Intervention (n = 25)	Control (n = 24)
Age (years)		59.8 ± 14.2	63.2 ± 11.0
Height (cm)		155.0 ± 7.1	157.4 ± 6.4
Weight (kg)		56.9 ± 10.4	59.9 ± 8.3
Women, n (%)		19 (76)	18 (75)
Bilateral symptoms, n (%)		9 (36)	6 (25)
Affected side (dominant), n (%)		18 (72)	17 (71)
Disease duration (days)		31.2 ± 40.7	36.3 ± 52.3
Baseline-ope (days)		17.3 ± 11.0	18.2 ± 16.5
Severity	I	26	20
	II	3	3
	III	5	7

Values are given as mean ± standard deviation.
*: Significant difference between groups.

Table 2. Comparison of functional status before and after surgery

		Intervention (n = 34)		Control (n = 30)	
NRS (pain)	Pre	2.3 ± 3.1		1.7 ± 2.8	†
	Post	2.5 ± 3.0*		3.7 ± 2.2*	
NRS (numbness)	Pre	6.7 ± 2.6	†	6.4 ± 3.0	†
	Post	3.0 ± 3.0		2.3 ± 2.5	
SWMT	Pre	3.7 ± 0.6	†	3.6 ± 0.8	†
	Post	3.2 ± 0.7		3.4 ± 0.5	
s2PD	Pre	5.8 ± 2.8	†	5.6 ± 3.1	
	Post	4.4 ± 2.9		4.6 ± 2.7	
TAM (°)	Pre	220 ± 20.7		213.8 ± 23.5	
	Post	218.8 ± 17.2*		204.7 ± 22.4*	

Values are given as mean ± standard deviation.
*: significant difference between groups; †: significant difference within group.
NRS, numerical rating scale; SWMT, Semmes-Weinstein monofilament test; s2PD, static 2-point discrimination test; TAM, total active motion.

Table 3. Comparison of STAI, DASH and EQ-5D scores before and after surgery

		Intervention (n = 25)		Control (n = 24)	
STAI	Pre	40.2 ± 8.9	†	38.1 ± 7.4	
	Post	34.7 ± 12.2		36.6 ± 9.9	
DASH	Pre	24.2 ± 18.1	†	24.3 ± 19.4	†
	Post	41.7 ± 20.9		47.2 ± 22.5	
EQ-5D (5 dimensions)	Pre	0.750 ± 0.1		0.77 ± 0.1	
	Post	0.75 ± 0.2		0.74 ± 0.1	
EQ-5D (VAS)	Pre	66.6 ± 19.8	†	68.5 ± 15.6	
	Post	77.2 ± 16.9*		67.7 ± 16.3*	

Values are given as mean ± standard deviation.
*: significant difference between groups; †: significant difference within group.
STAI, State Trait Anxiety Inventory; DASH, Disability of the Arm, Shoulder and Hand; EQ-5D, Euro QOL 5-Dimension; VAS, visual analog scale.

Discussion

This study examined the effects of finger exercises and instruction in ADL on postoperative improvements in hand function, ADL, and QOL in patients with CTS treated using ECTR. Tendon and nerve gliding exercises are reportedly effective in the prevention and improvement of adhesions affecting the gliding of nerves and tendons in the hand (Cook, Szabo, Birkholz & King, 1995; Burke, Ellis, Mckenna, Bradley & Dubin, 2003; Butler, 2000). These exercises are recommended as exercise therapy as part of conservative or invasive therapy in patients with CTS (Nathan, Meadows & Keniston, 1993; Cook et al., 1995). Gliding of the median nerve in such patients is decreased because of adhesions to surrounding tissue (Butler, 2000). Neurolysis is not performed because of technical difficulties and the narrow surgical field involved in the ECTR procedure (Hashizume, Nagoshi & Inoue, 1998). As a result, performing these exercises after ECTR may be necessary not only to prevent postoperative nerve adhesion, but also to encourage nerve gliding.

Perception tests convey information about nerve function. In this study, differences between the intervention and control groups were only seen in the results of the s2PD among the perception tests. Simsir, Sarsan, Akkaya, and Yildiz (2011) examined correlations between electrophysiological testing and perception tests and reported high correlations with s2PD scores, but not with SWMT scores. Katz, Gelberman, Wright, and Abrahamsson (1994) reported that because the s2PD reflects dysfunction of the median nerve, it is useful as a postoperative evaluation method. The results of the s2PD accurately reflect changes in the median nerve and this intervention may accelerate nerve recovery. Training in nerve-gliding exercises may therefore have positive effects on the recovery of nerves and surrounding tissue after ECTR.

When tissue is damaged as a result of injury or surgery, swelling and pain can occur. Mechanical stimulation during acute inflammation can lead to chronic inflammation and prevent normal healing (Gary, 2005). ECTR does not require extensive recovery time after surgery, so use of the hand may begin at an early stage. However, excessive activity may exacerbate hand dysfunction and delay recovery. Patients require a thorough explanation of how to resume postoperative ADL. In this study, occupational therapists provided individual intervention regarding postoperative ADL to patients in the intervention group. By instructing patients to increase the use of their hand in a step-by-step manner while performing ADL, excessive loads can be decreased and exacerbation of inflammation prevented.

Postoperative pain was significantly higher in the control group, whereas no significant changes were seen in the intervention group, suggesting that the postoperative restrictions on hand usage imposed for the ADL instruction in this study facilitated pain prevention in ECTR patients. Postoperative limits to ROM were also better in the intervention group than in the control group, but this result can be attributed to lower pain levels in the intervention group. Pain relief at an early stage is crucial to the retention of good postoperative hand function.

Anxiety may also exacerbate pain. Vranceanu et al. (2010) reported a correlation between acute postoperative pain and preoperative anxiety after minimally invasive surgery for CTS. In medical and physiological stress models, anxiety represents a psychological reaction caused by stress and perceiving a stressor as a threat causes anxiety (Spielberger, 1983). Preoperative anxiety is caused by daily stimuli such as thinking about or experiencing surgery. These feelings then become a stressor and may have large implications on recovery. In this study, anxiety showed no postoperative improvement in the control group. On the other hand, anxiety did show postoperative improvement in the intervention group. Inoue (2002) stated that objective and concrete information must be communicated in order to enhance feelings of control and alleviate anxiety and tension. Sustaining an uncomfortable psychological and physical state after surgery can be stressful. Objective information about the causes of pain and numbness and receiving instructions in coping methods can affect perception and may explain the differences in anxiety between the two groups in this study. When such information was clearly communicated to patients in previous studies (Hall & Stride, 1954; Langer, Janis & Worfer, 1975), pain and anxiety were alleviated. Instruction on ADL as utilized in this study should thus combine subjective and objective information to effectively alleviate anxiety and avoid the stress that delays complete postoperative recovery.

In this study, a brochure was distributed to patients in the intervention group to encourage the completion of postoperative exercises and communicate instructions for resuming ADL. In a study using a questionnaire on post-ECTR surgery, Yoshida et al. (2008) stated that patients reporting anxiety had received insufficient explanation from the medical staff and had demonstrated a lack of understanding of their condition. Visualization through a brochure makes the content of the instructions easier to understand and facilitates confirmation and repetition. Patients using the brochure can perform postoperative exercises and follow instructions on ADL more effectively. In this study, the intervention had a positive effect on the early improvement of postoperative physical and psychological function.

Objective evaluation indices such as the SWMT and tests of nerve conduction velocity have long been used to determine the therapeutic effects of interventions for CTS. In recent years, however, the importance of subjective evaluation indices has also come to be recognized (Itsubo et al., 2009). The present study used the DASH scale and EQ-5D as subjective measures to evaluate ADL and QOL.

The DASH scale is a questionnaire that allows self-evaluation of the symptoms and abilities of the hand, and has been reported as a useful index for evaluating improvement in disorders resulting from CTS (Kameda et al., 2007). A significant decrease in ADL for both groups was observed both pre- and post-operatively. Mackenzie, Hainer, and Wheatley (2000) reported that after ECTR, 2 weeks were required for grip and pinch strength to improve to preoperative levels. Muscular strength was not measured, but muscular strength may not have been sufficiently improved when patients completed the DASH scale. The presence of pillar pain may be another factor influencing postoperative recovery in CTS patients (Feinstein, 1993). Pillar pain has not been clearly defined, but pain in the thenar and hypothenar areas of the palm that appeared for 3 months after surgery is presumably caused by postoperative tendon synovitis and palmar cutaneous nerve injury (Ludlow, Merla, Cox & Hurst, 1997). Hunt and Osterman (1994) reported that pillar pain occurring in the early postoperative period delays the time until reinstatement or reuse of the hand and may result in decreased postoperative ADL. No differences in ADL were observed between groups after surgery. Responses to the DASH are supposed to be based on the state in the preceding week, not on the day of measurement. Good results were seen in the intervention group for physical and psychological function, but there is a possibility that these were not reflected by the DASH. Further investigation in consideration of the measurement time might therefore be warranted.

The EQ-5D is a comprehensive scale commonly used for the evaluation of changes health status. Differences in VAS scores were seen between the two groups in our study. The VAS score was increased only in the intervention group. Kuroda and Kanda (2007) reported a high correlation between the 5 dimensions evaluated on the EQ-5D and VAS scores, but suggested that subjective symptoms and mental state had a considerable effect on the latter. In this study, pain and anxiety were improved in the intervention group. These differences in postoperative pain and anxiety may have influenced the VAS scores.

This study had several limitations that need to be considered when interpreting the results. First, no detailed study was performed to determine the compliance of the intervention group with regard to performing the exercises and following the rehabilitation instructions at home after discharge. Differences in the degree of implementation of these exercises and instructions thus remain unclear. Second, the sample size was small. Third, only anxiety was evaluated among many possible contributory psychological factors. The connection between psychological perception and pain must be evaluated in greater detail and should include factors such as depression and self-efficacy. Future studies will focus on these issues.

Conclusion

This study examined whether prescribed tendon and nerve gliding exercises and instruction in ADL accelerated improvements in hand function, ADL, and QOL after ECTR for CTS. Our results suggest that successful encouragement and description of the expected course of improvements in physical and mental function through tendon and nerve gliding exercises and instruction in ADL can enhance QOL at an earlier stage after ECTR.

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■ORIGINAL ARTICLE

Visual Axis Analysis during Unassisted Eating and Robot-assisted Eating

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Abstract: This study examined differences of the visual axis and pupil diameter between unassisted eating and robot-assisted eating in 12 healthy subjects. A digital video camera and an eye tracker were used for synchronous measurements. Subjects carried cereal with a spoon or a meal support robot. The upper extremity position at which the visual axis was removed from food was designated as the critical visual point (CVP). Pupil diameter and CVP were used as an index. The results showed a CVP in unassisted eating; the visual axis was centered on the food from the start of the motion while eating to the CVP. However, the results for assisted eating showed no CVP, and the visual axis was located on the food during eating. These findings suggest that a subject with no somatosensory information depends solely on visual information, and identifies distance from the spoon to the mouth by visual information in robot-assisted eating.

Keywords: unassisted eating, robot-assisted eating, visual axis, eating

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Introduction

A registered occupational therapist (OTR) uses assistive technology (AT) to improve a person's activities of daily living (ADL) and instrumental activities of daily living. In AT, the input system of humans is used for visual, auditory, and somatosensory disorders. The output system of humans is used for upper extremity motion, finger motion, lower extremity motion, and trunk motion disorders (Demain et al., 2013; McIntyre & Atwal, 2005). Moreover, AT is used for mental disorders, higher brain dysfunction, and developmental disorders. However, the AT framework is provided according to its intended purpose. For example, AT support has a communication board and a speech generating device for people with speech, language, and hearing disorders (McIntyre & Atwal, 2005; Pedretti & Early, 2001; Willard et al., 2009).

Eating and toilet hygiene are initial ADL acquisition targets of subjects with disabilities resulting from injuries such as head or spinal cord injuries. Eating and toilet hygiene are the goals of early ADL acquisition. Especially, acquisition of eating is important not only because of life support, but also for individual and social pleasure. A meal support robot (My Spoon, MA-R0010; SECOM, Inc., Tokyo) is an electrical eating device for people who have limited functionality of their arms or hands, and serves as one AT device (Soyama, Ishii & Fukase, 2003). A user with rheumatoid arthritis, cervical cord injury, or muscular dysplasia can operate My Spoon using a joystick or a button switch. Using My Spoon, one can choose food in a voluntary order with voluntary timing. Reportedly, the use of My Spoon improves the quality of life (QOL) and independent ADL.

Because of head and spinal cord injuries, simple motions such as carrying food from a plate to the mouth cannot be done smoothly. An OTR must teach proper eating motions. However, subjects desiring smooth eating motion cannot use My Spoon alone. For such

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cases, an OTR must offer support when introducing My Spoon. An OTR must understand the characteristics of AT when instructing subjects (Goto, Hatakeyama & Katayama, 2008). It is therefore important that the OTR know the physiological and psychological effects of AT on the subjects.

This study examines differences of the visual axis and pupil diameter between unassisted eating and robot-assisted eating in healthy subjects, in addition to their respective physiological responses.

Methods

Subjects

Subjects were 12 healthy volunteers (5 males, 7 females) from 20−26 years old (mean 22; standard deviation 2). All subjects had visual acuity necessary to obtain a driver's license, color sense, right-handedness, and affiliated psychic function. None had any disease or injury that would impair ADL. All subjects gave their informed consent to the experimental procedures, which were approved by the Ethics Committee of Yamagata Prefectural University of Health Sciences, Yamagata, Japan.

Instrumentation and Data Acquisition

Exploratory eye movements were recorded using an eye tracker (EMR-8B; nac Image Technology Inc., Tokyo) with a sampling frequency of 30 Hz, which detects infrared reflections from the cornea. EMR-8B consisted of an eye camera head unit attachment and a controller. The eye camera head unit includes a pupil camera and a field camera. A visual axis position was attached to a picture from the field camera with the controller. The field camera of the head unit did not have a skewness of lens and used lens of diameter 62 degrees (deg) that a wide image was obtained. The detection precision of upper extremity motion on the desk of the subjects was 0.2 deg of 40 deg inside the circle of the cycloduction axis. A digital video camera (30 frames per second, NV-GS320; Panasonic Inc., Osaka) was set outside the subjects. Data were recorded using a digital motion picture waveform real-time synchronous recording system (The Teraview; Gigatex Co. Ltd., Osaki). Meal tools were a spoon (stainless steel, 180 mm full length) and a My Spoon.

My Spoon has the following characteristics; a base, an arm and a hand part (with the spoon and fork). My Spoon dimensions are 370 mm deep, 280 mm wide, and 250 mm high, with a weight of 6.0 kg. My Spoon has a plate (245 mm deep, 245 mm wide, 58 mm high) divided into four sections. A user can easily operate My Spoon with the joystick. There are three types of operation modes; automatic, semi-automatic, and manual. This experiment used the manual mode of My Spoon with the joystick.

Procedures

Illumination in the test room was 652 lux, and the air temperature was about 24°C. The subjects sat on a chair (400−450 mm height) and put the forearm on a table (800 mm deep, 1,200 mm wide, 700 mm high) with the shoulders flexed to 0−20 deg of flexion and the elbow flexed to 70−90 deg of flexion. The subjects held the spoon or the joystick for the eating task prior to task commencement (Fig. 1). The respective distances between the mouth and the plate during unassisted eating and robot-assisted eating were 338−471 mm and 321−577 mm. The food used in the experiment was a doughnut-type cereal (Kokokun-no-chocowa; Kelloggs Co., Tokyo) 15 mm in diameter. The eyes of the subjects were masked to prevent the intervention of prior visual information. Visual masking was removed at the start of the eating task. When food was in the mouth of the subjects, the task was finished. Subjects were allowed to spit out the food from their mouths if they did not want to swallow it. A bowl for this was prepared beside the subjects. The eating tasks were unassisted eating and robot-assisted eating.

Unassisted eating procedure

For unassisted eating, subjects were instructed to eat food in the same way as in daily life. Types of motion, speed, and accuracy were not instructed to any subject.

Robot-assisted eating procedure

My Spoon was set at about 300 mm in front of the subjects. The center of the My Spoon plate was aligned with the midline of the subjects. The spoon tip of My Spoon was set to stop at about 50 mm to 100 mm from the mouth of each subject. When the spoon of My Spoon neared the subjects' mouths, the subjects showed some anxiety. Each subject set a distance of 50−100 mm for which it was easy to eat without anxiety. Next, the subjects performed three to five practice exercises to test the joystick operation of My Spoon. The subjects chose the food from any of four sections using the joystick, and the robot arm moved the section chosen by the subject. The subjects then maneuvered the hand part of My Spoon to the food. The robot caught the food in the spoon which was attached to the hand part, and moved it toward the mouth. Finally, the subject ate the food from the spoon. The subject operated the joystick during the start of task, while controlling the spoon position on the

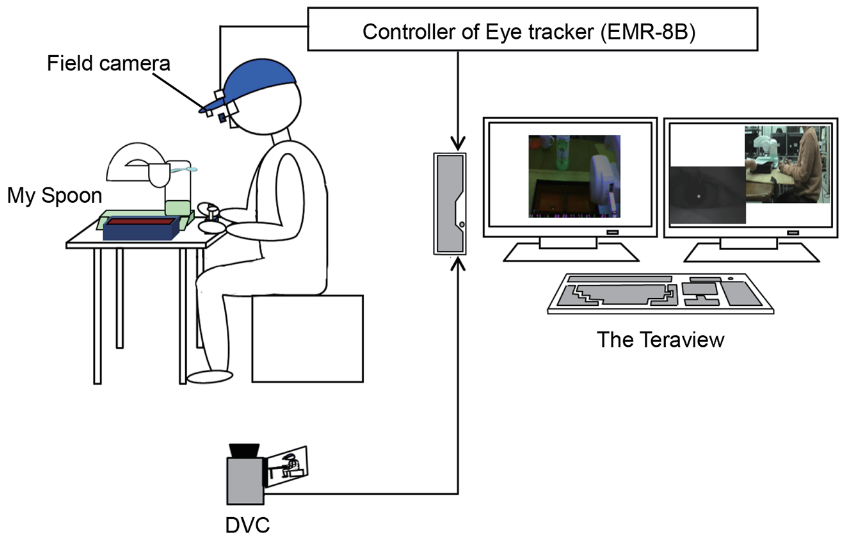

Fig. 1. Experimental setup
EMR-8B denotes the eye tracker. DVC denotes a digital video camera. The Teraview denotes digital motion picture waveforms real-time synchronous recording system.

plate, and while picking up the food.

Data Analysis

1. Motion Phases

Unassisted eating

Phases of each eating task were divided into three phases using video data. During phase 1 (P1), the spoon began moving and reached the food. During phase 2 (P2), the spoon picked up the food. During phase 3 (P3), the spoon moved from the plate to the mouth of the subjects (eating motion).

Robot-assisted eating

During P1, the spoon attachment of My Spoon moved and arrived on the plate. During P2, the spoon attachment controlled the spoon position and picked up the food. The phase ended before My Spoon began to move the spoon to the mouth of the subjects. During P3, the spoon attachment moved the spoon to within 50−100 mm of the front of the mouth, arrived at the mouth, and the subjects put the food into the mouth.

2. Classification of eye movement

The position of the visual axis was fed to a picture from a field camera, and pursued during the eating task. Furthermore, the eye movements were classified into three types; saccadic eye movements (SEM), smooth pursuit eye movements (SPEM), and fixation. SEM were determined to be eye movement of an angle speed greater than 50 deg/s. SPEM were determined to be eye movements which follow the food at an angle speed of less than 50 deg/s (Fukushima & Fukushima, 2004; Tazaki & Saito, 2013). Fixation was defined as inactive eye movements which continued longer than 0.10s (Manor & Gordon, 2003). Therefore, the eye mark was paused at the same position for more than three field camera images under these conditions.

3. Visual axis position and upper extremity motion

The visual axis position was divided into three categories; showing a plate and section with food; showing the spoon on the spoon bowl without the food, and showing the food. Other positions showed blinking and/or no placement of the plate, the spoon, the food. The Critical Visual Point (CVP) was defined as the upper extremity position at which the visual axis was removed from the food in P3.

4. Pupil diameter

The pupil diameter was measured at 30 Hz using Eye mark data analysis software (EMR-dFactory; nac Image Technology Inc. Tokyo). The pupil diameter of each subject was measured before and after the near reflex test. The reference of pupil diameter used the difference of the before and after the near reflex test (Tazaki & Saito, 2013). Judgment of three types of change in P3 was made; increase, decrease, or no change. The pupil diameter change in all trials included each type. The quantity of change of the pupil diameter was calculated the difference between the maximum and the minimum (min-to-max or max-to-min) of P3.

Results

Fig. 2 shows the respective transitions of the visual axis and the pupil diameter during unassisted eating for subject A. The spoon arrived at the food within 0.9 s from the task start (end of P1). The visual axis of the subject was on the food. Furthermore, the subject picked up the food with the spoon in 3.0 s (end of P2). During P2, the visual axis changed in order of the food, the spoon, and back to the food. Next, the spoon began to move toward the mouth and arrived at the mouth within 4.8 s from the task start (end of P3). In P3, CVP occurred at 3.9 s from the task start. CVP was 0.9 s from start of P3. The spoon at this time was located 221 mm from the left eye of the subject.

The order of the visual axis position with other trial was different. However, the eye movement patterns were similar to those shown by this subject. Furthermore, all subjects showed the same visual axis positions and eye movement patterns.

The visual axis of P1 was fixed on the food from task start to 0.3 s later. The visual axis was fixated on the food thereafter for 0.6 s. At that moment, the pupil diameter increased 0.5 mm; from 2.8 mm to 3.3 mm. During P2, the eye movement pattern changed in order of fixation (0.2 s duration), SPEM (0.6 s), fixation (1.0 s), and SPEM (0.3 s). In addition, SEM occurred between fixation and SPEM. The pupil diameter increased 0.7 mm; from 3.3 mm to 4.0 mm. During P3, the eye movement pattern changed in order of SPEM (0.6 s), SPEM (0.4 s), fixation (0.5 s), others (0.2 s), and fixation (0.1 s). The pupil diameter did not change. In the subject, the pupil diameter showed changes similar to other trials in P1-P2. However, this subject showed an increase in pupil diameter among five trials, a decrease in two trials and no change in three trials in P3 (Table 3).

Fig. 3 shows the respective transitions of the visual axis and the pupil diameter during robot-assisted eating for subject A. The spoon of the hand attachment arrived at the plate at 7.9 s from the task start (end of P1).

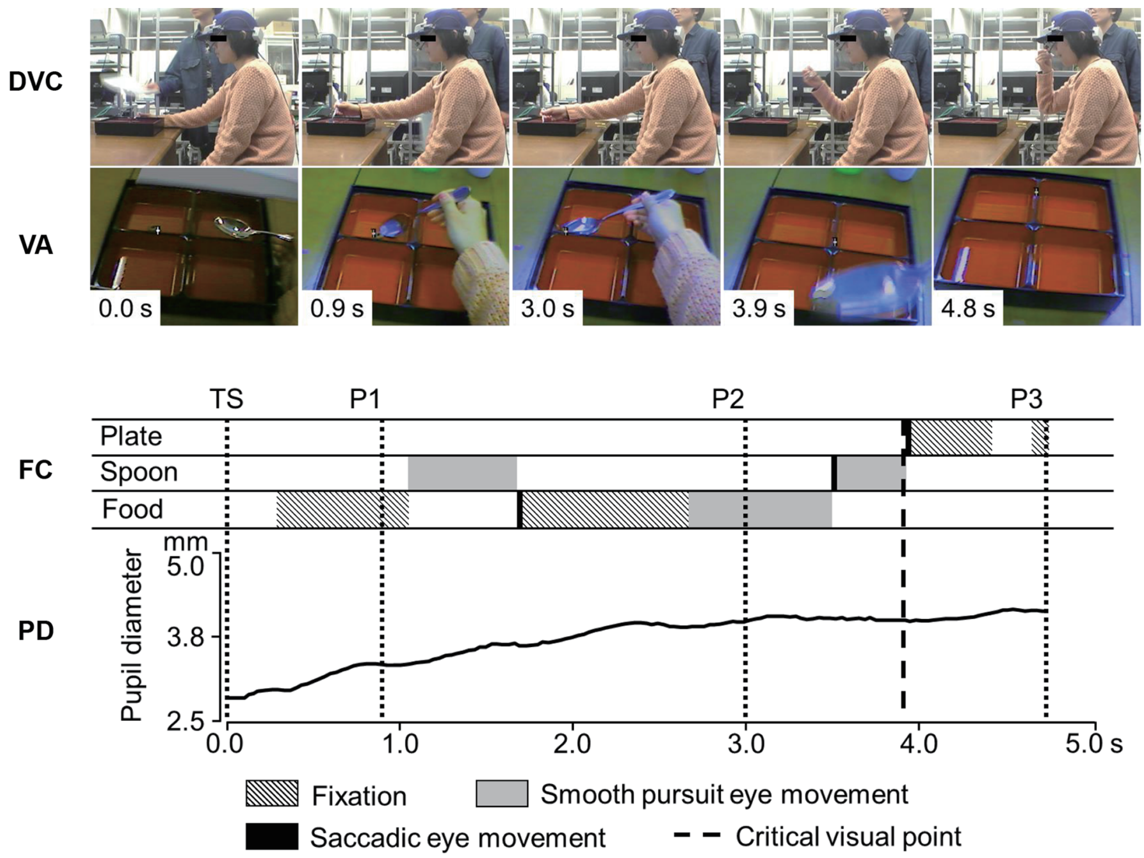

Fig. 2. Transition of visual axis and the pupil diameter during unassisted eating in the subject A

The figure shows digital video camera images (DVC), field camera images (FC), the position of visual axis (VA) and pupil diameter (PD). Slash line boxes of FC show fixation of eyes. Dotted boxes of FC show smooth pursuit eye movement. Black color boxes show saccadic eye movement. When the visual axis was located in the blank part in all phases, it was others. DVC and FC show the start of task, end of Phase 1, end of Phase 2, critical visual point (CVP), and end of task sequentially from the left. Left dotted line shows the task start. Dotted lines of P1, P2, and P3 show the end of each phase. The broken line shows CVP. Abbreviations are the same as those shown in Fig. 3.

During P1, the visual axis position shuttled back and forth among the plate, the spoon, the food, and other objects. Furthermore, the subject controlled the spoon to accommodate the food, and picked up the food with the spoon in 14.7 s (end of P2). During P2, the visual axis position changed in the following order; the spoon, the food, the plate, the spoon, the food, other objects, the food, the spoon, and the food. Next, the spoon began to move toward the mouth and arrived 97 mm from the mouth front within 23.4 s from the task start. The subject put the food in the mouth within 25.9 s from the task start (end of P3). The visual axis position was fixed only on the spoon during P3. The spoon at this time was located 152 mm from the left eye of the subject.

The order of the visual axis position differed from those of other trials. However, the visual axis positions and the eye movement patterns were similar to those shown by this subject. During P3, the visual axis position was on the spoon and the plate in some of the trials of the 10 subjects. Furthermore, all subjects showed the same visual axis position from P1 to P3 as that of this subject.

The visual axis of P1 was fixed on the food from the task start to about 0.3 s later. During P1, the eye movement fixation times were 0.1−0.3 s on the plate and 0.3−1.8 s on the food. Moreover, the eyes were fixated on the spoon at 0.5−0.6 s, and 0.9 s of SPEM. During this time, the visual axis position shuttled back and forth among the plate, the spoon and the food. At that moment, the pupil diameter increased 0.9 mm; from 3.0 mm to 3.9 mm. During P2, the eye movement pattern showed only fixation, which occurred eight times. Each fixation time was 1.1 s on the plate, 0.3−1.6 s on the spoon, and 0.2−0.7 s on the food. The pupil diameter increased 0.8 mm; from 3.7 mm to 4.5 mm. During P3, the visual axis position was only on the spoon. The eye movement patterns were fixation, SPEM, and SEM. The fixation time showed 0.2−0.8 s. Furthermore, the SPEM time showed 0.3−1.2 s only on the spoon. The pupil diameter decreased 1.7 mm; from 4.5 mm to 2.8 mm, which was similar to that of other trials for this subject. In all trials, this subject showed a decreased pupil diameter in P3 (Table 4).

Table 1 shows the elapsed times in respective phases and CVP times for unassisted eating in all subjects. The range of total elapsed time was 2.2−4.0 s in all subjects. The elapsed times of each phase were 0.8−1.3 s, 0.5−1.1 s, and 0.9−1.8 s. All trials of all subjects had a CVP in P3. The range of CVP times from the start of P3 was 0.5−1.1 s.

Table 2 shows the elapsed times in respective phases for robot-assisted eating in all subjects. The range

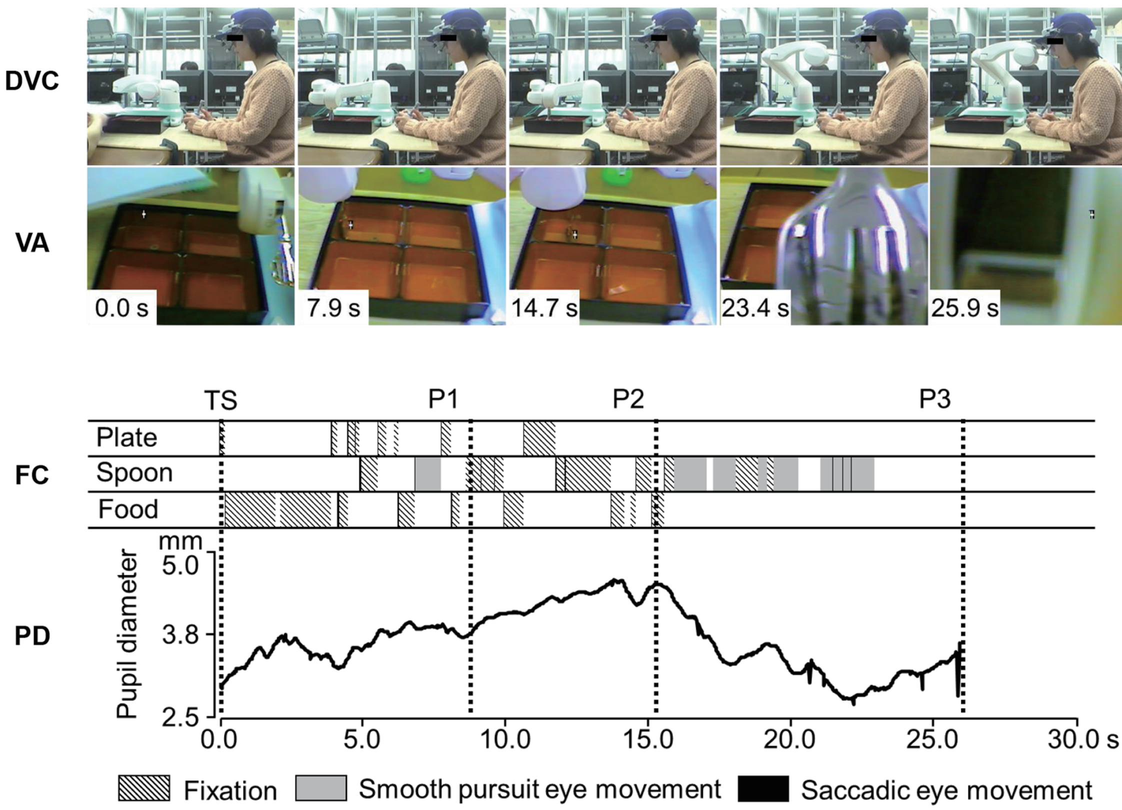

Fig. 3. Transition of visual axis and the pupil diameter during robot-assisted eating in subject A.

Table 1. Elapsed time in respective phases of unassisted eating

Subject	Total	P1	P2	P3	
	Elapsed time	Elapsed time	Elapsed time	Elapsed time	CVP time
A	3.9 ± 0.7	1.1 ± 0.2	1.0 ± 0.4	1.8 ± 0.3	0.9 ± 0.2
B	3.3 ± 0.4	1.0 ± 0.1	1.1 ± 0.4	1.2 ± 0.1	0.7 ± 0.2
C	2.9 ± 0.3	0.9 ± 0.1	0.8 ± 0.2	1.2 ± 0.1	0.6 ± 0.1
D	2.5 ± 0.2	0.9 ± 0.2	0.6 ± 0.1	0.9 ± 0.1	0.5 ± 0.1
E	3.2 ± 0.4	1.2 ± 0.1	1.0 ± 0.4	1.0 ± 0.1	0.6 ± 0.1
F	2.8 ± 0.2	1.0 ± 0.1	0.9 ± 0.2	1.0 ± 0.1	0.6 ± 0.1
G	3.1 ± 0.3	1.3 ± 0.1	0.7 ± 0.1	1.1 ± 0.3	0.7 ± 0.1
H	2.2 ± 0.3	0.8 ± 0.2	0.5 ± 0.1	1.0 ± 0.1	0.5 ± 0.1
I	2.7 ± 0.2	0.9 ± 0.1	0.7 ± 0.2	1.1 ± 0.1	0.6 ± 0.1
J	4.0 ± 0.3	1.3 ± 0.2	1.1 ± 0.1	1.6 ± 0.2	1.1 ± 0.1
K	2.4 ± 0.1	0.9 ± 0.1	0.6 ± 0.1	1.0 ± 0.0	0.5 ± 0.1
L	3.7 ± 0.3	1.2 ± 0.2	1.1 ± 0.3	1.4 ± 0.1	0.9 ± 0.1

(s)

Table 2. Elapsed time in respective phases of robot-assisted eating

Subject	Total Elapsed time	P1 Elapsed time	P2 Elapsed time	P3 Elapsed time
A	25.5 ± 1.1	8.4 ± 0.5	5.4 ± 1.1	11.7 ± 0.4
B	27.2 ± 2.2	8.4 ± 0.2	6.8 ± 2.0	12.0 ± 0.4
C	26.4 ± 0.7	8.2 ± 0.1	5.6 ± 0.7	12.6 ± 0.3
D	26.4 ± 0.9	8.3 ± 0.4	6.8 ± 0.8	11.3 ± 0.6
E	25.9 ± 1.0	7.8 ± 0.1	5.5 ± 0.9	12.6 ± 0.3
F	25.4 ± 0.7	8.5 ± 0.1	5.5 ± 0.7	11.3 ± 0.2
G	26.2 ± 1.4	8.8 ± 0.3	6.9 ± 1.0	10.5 ± 0.6
H	25.3 ± 1.5	8.3 ± 0.6	6.6 ± 0.9	10.4 ± 0.8
I	24.7 ± 1.0	8.1 ± 0.1	5.5 ± 0.8	11.2 ± 0.5
J	25.2 ± 1.3	8.5 ± 0.6	5.3 ± 1.3	11.5 ± 0.2
K	26.6 ± 0.9	8.2 ± 0.3	5.5 ± 1.1	12.9 ± 0.5
L	26.4 ± 1.8	8.9 ± 0.8	5.0 ± 1.1	12.4 ± 1.0

(s)

of total elapsed times was 24.7−27.2 s. Furthermore, the elapsed times of each phase were 7.8−8.9 s, 5.0−6.9 s, and 10.4−12.9 s. In all subjects, CVP disappeared completely from all trials in P3.

Table 3 shows the min-to-max or max-to-min pupil diameters, differences, and changing counts for unassisted eating in all subjects of P3. For subject A, the min-to-max or max-to-min pupil diameters increased from 3.8 to 4.1 mm, decreased from 4.2 to 3.9 mm, and remained from unchanged at 3.9 mm. The pupil diameter difference was a 0.3 mm increase and a 0.3 mm decrease. The increase, decrease, and no change of pupil diameters were 5, 2 and 3, respectively. The near reflex value was 1.1 mm; from 3.8 mm to 2.7 mm. Five subjects showed an increase, decrease and no change of pupil diameter.

In subject G, the min-to-max or max-to-min pupil diameters increased from 4.3 to 4.4 mm and decreased from 4.6 to 4.3 mm. The differences of pupil diameter were a 0.1 mm increase and a 0.3 mm decrease. The pupil diameter changing counts showed increase of two and decrease of eight. The near reflex value was 1.2 mm; from 4.5 mm to 3.2 mm. Two subjects showed an increase and decrease of pupil diameter.

In subject H, the min-to-max pupil diameters increased from 4.2 to 4.6 mm. The difference of pupil diameter was 0.4 mm. The pupil diameter increased in all trials. The near reflex value was 1.8 mm; from 5.1 mm to 3.3 mm. Two subjects showed an increase in pupil diameter.

In subject J, the max-to-min pupil diameters decreased (from 5.2 to 4.3 mm). The difference of pupil diameter showed a 0.9 mm decrease. The pupil diameter decreased in all trials. The near reflex value was 1.9 mm; from 4.5 mm to 2.6 mm. Three subjects showed a decrease in pupil diameter.

Table 4 shows the pupil diameters from min-to-max or max-to-min, difference and changing counts in robot-assisted eating of all subjects in P3.

In subject A, the max-to-min pupil diameters decreased from 4.4 to 2.9 mm. The difference of pupil diameter was 1.5 mm. A decrease in pupil diameters appeared in all trials of all subjects.

Discussion

Characteristics between visual axis and pupil diameter during unassisted eating

Fig. 2 shows that the visual axis was placed only on the spoon and the food from task start to CVP. The pupil diameter increased slowly from task start to the end of P2. In addition, the pupil diameter at P3 increased slightly with CVP. The subject in Fig. 2 showed three types of pupil diameter transitions; increase, decrease, and no change (Table 3). However, the difference of pupil diameter in each type was less than the near reflex.

Table 3. Pupil diameter of unassisted eating in phase 3

Subject	Pupil diameter (mm)						Near reflex (mm)		
	Max (Min)	to	Min (Max)	Type	Dif.	Counts	Max	Min	Dif.
A	3.8		4.1	Inc	0.3	5	3.8	2.7	1.1
	4.2		3.9	Dec	0.3	2			
	3.9		3.9	No	0.0	3			
B	5.8		5.9	Inc	0.1	2	4.9	3.4	1.5
	6.2		5.8	Dec	0.4	4			
	5.7		5.7	No	0.0	4			
C	4.5		4.6	Inc	0.1	6	4.8	2.7	2.1
	4.7		4.5	Dec	0.2	2			
	4.5		4.5	No	0.0	2			
D	5.2		5.4	Inc	0.2	5	4.4	3.2	1.2
	5.2		5.1	Dec	0.1	3			
	5.5		5.5	No	0.0	2			
E	3.6		3.7	Inc	0.1	2	3.4	2.3	1.1
	3.7		3.5	Dec	0.2	7			
	3.5		3.5	No	0.0	1			
F	3.6		3.7	Inc	0.1	2	3.2	2.7	0.5
	3.9		3.6	Dec	0.3	8			
	−		−	No	−	0			
G	4.3		4.4	Inc	0.1	2	4.5	3.2	1.3
	4.6		4.3	Dec	0.3	8			
	−		−	No	−	0			
H	4.2		4.6	Inc	0.4	10	5.1	3.3	1.8
	−		−	Dec	−	0			
	−		−	No	−	0			
I	4.8		5.1	Inc	0.3	10	4.3	3.4	0.9
	−		−	Dec	−	0			
	−		−	No	−	0			
J	−		−	Inc	−	0	4.5	2.6	1.9
	5.2		4.3	Dec	0.9	10			
	−		−	No	−	0			
K	−		−	Inc	−	0	5.0	3.3	1.7
	5.4		5.0	Dec	0.4	10			
	−		−	No	−	0			
L	−		−	Inc	−	0	3.5	2.4	1.1
	4.0		3.6	Dec	0.4	10			
	−		−	No	−	0			

A near reflex test is an examination to look at about 100 mm front of a subject immediately from a far-off place. The pupil diameter decreases in healthy subjects. The phenomenon results from an accommodation reflex and a convergence reflex (Bando, 1996; Leigh & Zee, 1991). The near reflex differs from light reflex in terms of pathways (Tazaki & Saito, 2013). The CVP of the subject was more distant than the near reflex. Reportedly, the recorded distances of CVP in the 19 subjects were large among the subjects, ranging from 157−471 mm in the performance of 0.1 spoon. The CVP distance of each subject was reduced slightly when the amount of juice in the spoon was increased (Sasaki et al., 2013).

Two subjects showed both an increase and decrease. Three subjects showed only a decrease. In addition, the difference of pupil diameters was smaller than the near reflex in each subject. A recent report described that CVP occurs in eating motions using a spoon and chopsticks (Nito, 2011). The report suggests that the role of the visual axis to the CVP reflected monitoring of the food during eating motions. However, other reports described that the motion carrying the spoon with the juice did not need to constantly maintain the visual axis on the cup of the spoon (Suzuki, Fujii & Nikara, 2009;

Table 4. Pupil diameter of robot-assisted eating in phase 3

Subject	Pupil diameter (mm)						Near reflex (mm)		
	Max (Min)	to	Min (Max)	Type	Dif.	Counts	Max	Min	Dif.
	−		−	Inc	−	0			
A	4.4		2.9	Dec	1.5	10	3.8	2.7	1.1
	−		−	No	−	0			
	−		−	Inc	−	0			
B	6.1		4.6	Dec	1.5	10	4.9	3.4	1.5
	−		−	No	−	0			
	−		−	Inc	−	0			
C	4.2		3.0	Dec	1.2	10	4.8	2.7	2.1
	−		−	No	−	0			
	−		−	Inc	−	0			
D	5.6		3.9	Dec	1.7	10	4.4	3.2	1.2
	−		−	No	−	0			
	−		−	Inc	−	0			
E	3.6		2.8	Dec	0.8	10	3.4	2.3	1.1
	−		−	No	−	0			
	−		−	Inc	−	0			
F	3.9		3.1	Dec	0.8	10	3.2	2.7	0.5
	−		−	No	−	0			
	−		−	Inc	−	0			
G	4.9		3.2	Dec	1.7	10	4.5	3.2	1.3
	−		−	No	−	0			
	−		−	Inc	−	0			
H	5.4		3.7	Dec	1.7	10	5.1	3.3	1.8
	−		−	No	−	0			
	−		−	Inc	−	0			
I	5.2		3.4	Dec	1.8	10	4.3	3.4	0.9
	−		−	No	−	0			
	−		−	Inc	−	0			
J	4.9		2.9	Dec	2.0	10	4.5	2.6	1.9
	−		−	No	−	0			
	−		−	Inc	−	0			
K	6.0		3.8	Dec	2.2	10	5.0	3.3	1.7
	−		−	No	−	0			
	−		−	Inc	−	0			
L	4.3		3.0	Dec	1.3	10	3.5	2.4	1.1
	−		−	No	−	0			

Suzuki et al., 2011). Therefore, the motion carrying the spoon is mainly performed using a motor program that is readily acquired in the brain. In addition, a recent study using dominant and non-dominant hands has shown that CVP had the same role as the eating motion (Takahashi, 2013). The report implied that CVP affects monitoring with a conscious guide of food. However, the relation of the visual axis and pupil diameter during eating motions has not previously been reported. These findings suggest that the pupil diameter transition during fixation on the visual axis of a spoon is not only done in the monitoring of the food.

Characteristics between visual axis and pupil diameter during robot-assisted eating

Fig. 3 shows that the visual axis is placed among the plate, the spoon, and the food from task start to the end of P2. First, the visual axis moved to the food early in P1. Next, the visual axis on the plate was equivalent to the position at which the spoon of My Spoon arrived. Finally, the visual axis shuttled back and forth among the plate, the spoon, and the food in P1. Although the visual axis moved to the plate from a distant place from the spoon of My Spoon, the pupil diameter increased slowly. In early P2, the order of the visual axis position on the spoon, the food and the plate was transitory. Results suggest that the visual axis of the subjects serve the role of monitoring during eating motions in robot-assisted eating. These findings suggest that the visual axis is used for adjustment between the spoon and the food position.

Finally, the visual axis moved to the food, and the subject gave an order to lift the food using the joystick. During P2, the distance from the left eye to the plate did not change, but the pupil diameter increased gradually from P1 to P2 for reasons that remain unclear. In P3, the visual axis is placed only on the spoon. The pupil diameter decreased 1.7 mm, from 4.5 mm to 2.8 mm using My Spoon. The visual axis position between the spoon tip of My Spoon and the subject was nearer than the CVP of unassisted eating. Furthermore, the difference of the pupil diameter in robot-assisted eating was greater than that for unassisted eating. Therefore, the pupil diameter in robot-assisted eating was less than that during unassisted eating. The minimum pupil diameter in robot-assisted eating resembles that of the near reflex. These data show that the subject looked carefully at the food and/or the spoon using accommodation convergence reflexes. The transitions of the visual axis and the pupil diameter were clear in all subjects. Results show that the visual axis approached the spoon from the plate to near the mouth. Using My Spoon, all subjects showed a similar transition of the visual axis and the pupil diameter. When the subjects have no somatosensory information, they depend only on visual information. Therefore, robot-assisted eating must identify the distance to the spoon from the mouth using visual information.

Differences between unassisted eating and robot-assisted eating

As described above, the visual axis showed a difference between unassisted eating and robot-assisted eating. The maximum difference was the presence of CVP. In unassisted eating, CVP is present, and the visual axis is located on the food or the spoon from P3 start to CVP. However, robot-assisted eating has no CVP. The visual axis is located on the food or the spoon from start until the end of the eating motion in P3. A recent report described similar results of the visual axis in caregiver-assisted eating (Saitou, 2006). In addition, unassisted eating showed numerous types of pupil diameter changes in 7 out of 12 subjects. Conversely, robot-assisted eating showed a pupil diameter decrease in all subjects. Even if the visual axis is applied to the food, the pupil diameter changes differ. Unassisted eating has a visual axis that did not monitor the food. However, it has been suggested that the pupil diameter decreases to the same degree as the near reflex when the visual axis shows careful monitoring of the food. During robot-assisted eating the distance between the spoon and the subject mouth must be measured visually. In robot-assisted eating, somatosensory information is not obtained. Therefore, anxiety occurs among all subjects when the spoon tip nears the subject.

These findings show that unassisted eating and robot-assisted eating elicit different physiological responses in healthy subjects.

Practical application of occupational therapy

In this study, unassisted eating and robot-assisted eating showed clear differences in physiological responses. Because of influences such as head injury and spinal cord injury, a challenged person might use a meal support robot. In robot-assisted eating, characteristics of physiological responses are important. However, voluntary eating with voluntary timing of the subject is necessary to improve QOL. OTRs must teach subjects to use meal support robots for QOL improvement. Therefore, it is necessary for OTRs to understand motion guidance methods and characteristics of physiological response using assistive technology.

Study limitations

Findings of this study demonstrated that unassisted eating and robot-assisted eating elicit different physiological responses in healthy subjects. Nevertheless, no comparison was made with challenged persons during unassisted eating or robot-assisted eating. In the future, the authors would like to investigate unassisted eating and robot-assisted eating with challenged persons.

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Asian Journal of Occupational Therapy
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The Asian Journal of Occupational Therapy (Asian JOT) which is published by the Japanese Association of Occupational Therapists publishes articles to promote occupational therapy in Japan and Asian countries. It is accessible to the public through an internet. This journal is particularly aimed at disseminating the aspects of clinical, research and education of occupational therapy in Asian region as well as Japan to the rest of the world.

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