Original Article

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Thumb pressure required to open containers and packages of daily commodities

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Abstract

Detailed guidance for rehabilitation patients in their daily activities can be provided by determining the thumb pressure required to effectively utilize daily commodities. In order to clarify the necessary pressure for opening the lid of food containers and packages, we targeted 20 healthy persons and 85 patients with a distal radius fracture to determine the thumb pressure required for opening four types of daily commodities using a small pressure sensor and examined the relationship with normal evaluated muscle pressure. For the containers of goods, we used two types of cup-type containers, a bag-type container, and a plastic bottle, and the four types of commodities were pudding, jelly, snacks, and plastic bottles. The results revealed that the less pressure required for opening in the following order: pudding, snacks, jelly, and plastic bottles. Furthermore, for patients with distal radius fractures, we analyzed the relationship with the capability of opening commodities and examined the cut-off value. As a result, the pressure indicated by the small sensor showed high sensitivity and specificity in the following order: pudding at 0.25 Mpa, snacks at 0.41 Mpa, jelly at 0.48 Mpa, and plastic bottles at 0.54 Mpa, with grip pressure revealing high discrimination accuracy in jelly at 14.5 kg and plastic bottles at 19.5 kg. The results of this study lead us to conclude that the opening of commodities is closely related to the pressure indicated in the small sensor and the grip pressure on the injured side and this is a useful indicator for implementing rehabilitation in the upper arms.

Key words

thumb pressure, daily commodities, health subjects, distal radius fracture
receiver operating characteristic curve

Introduction

Generally, using or manipulating daily commodities and opening or operating lids of food containers and packages often requires a lateral pinch[1-3]. In patients with motor system injuries such as a fracture of the wrist joints or hand fingers, patients with diseases such as rheumatoid arthritis or spinal cord injury, and the elderly among targets for rehabilitation, we often experience cases demonstrating difficulty in opening daily commodities and hear complaints of the inability to open food containers or drug packages due to decreased muscle pressure of the hand fingers[4-9]. As a goal of rehabilitation, recovery of the ability to use daily commodities is included. Generally, in order to evaluate the muscle pressure of hand fingers, measurements of grip strength and pinch strength are set as the degree of recovery[10-12], although a few reports exist with numerical values provided as the standard that indicate at which stage in recovery from diseases, usage of daily commodities should be permitted and when the goal should be regarded as having been accomplished[13-16]. Recently, it has become possible to measure the pressure applied on the

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hand fingers when in use by using a pressure sensor worn over a device or directly on the living body and thus, some reports evaluating the pressure when in use have been occasionally been published[17-19]. Direct measurement of the pressure when opening commodities by wearing such a sensor on the fingers makes it possible to provide detailed evaluations[20,21]. In consideration of hygiene, durability, convenience, etc., plastic or vinyl is frequently used for materials of lids of containers and packages. Because there are a wide variety of containers, it is believed that exposure to the pressure required for opening makes it possible to set a concrete goal and provide instruction on daily living activities.

Accordingly, in order to clarify the necessary pressure for opening the lids of food containers and packages, we targeted healthy persons and patients with distal radius fractures to determine the pressure required to open four types of daily commodities by using a small pressure sensor and examined the relationship with normal evaluated muscle pressure.

Methods

1. Subjects

The subjects consisted of 85 patients, excluding sensorial impairment and surgical cases, from a total of 90 patients with fractures. We targeted all right-handed and right-injured cases diagnosed with a distal radius fracture that had undergone treatment through conservative therapy. The subjects comprised 26 males and 59 females at an average age of 62.8±13.3 years old. The evaluation was conducted an average of 62.2±26.2 days following injury. Furthermore, we set 20 adult health males in their 20's to 30's (average 31.3±5.5 years old) that were all right-handed and had no history of diseases in the neural or muscle/bone systems of the upper arms as a healthy group.

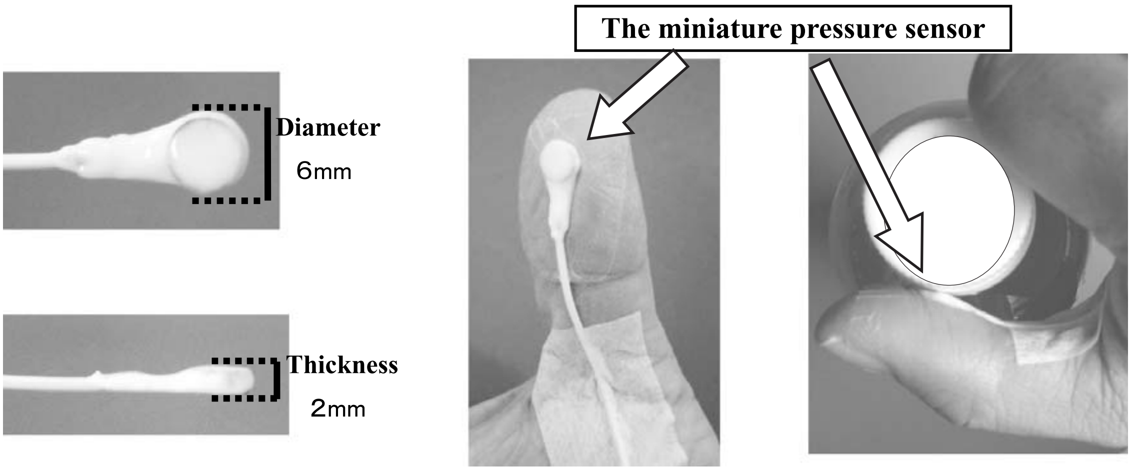
2. Measuring method and equipment used

For measurements, we used Bridge Unit DBU-120A, a small pressure sensor PS-50KAM260 (with a rating capacity of 5 Mpa; hereinafter referred to as "small sensor") manufactured by Kyowa Electronic Instruments Co., Ltd. The size of the pressure-receiving surface of the small sensor was 6 mm in diameter and 2 mm in thickness, and the pressure applied on the pressure-receiving surface was analyzed by Bridge Unit Control Software via Bridge Unit and calculated in Mpa. The pressure receiving part was covered with silicon rubber so as not to directly contact the skin and commodities. This small sensor was attached and fixed over the palmar surface of the right thumb finger with a transparent film (0.1 mm in thickness), and the code was fixed with tape so as not to interrupt the subject during each operation (Fig. 1). In addition, the reliability and validity of the small sensor used in this study has already been reported[21]. Furthermore, the pinch strength was measured on the lateral side by using a pinch dynamometer (Pinch Track Commander MF106A (unit: N) manufactured by Nihon Medix). The grip strength was measured at the second position by using a Jamar-type grip dynamometer (Grip Track Commander MF150A (unit: N) manufactured by Nihon Medix).

We previously provided evidence supporting the reliability and validity of this miniature pressure sensor, as briefly described below. While the miniature sensor was fixed on the pad of the thumb with an adhesive film, another pinch strength measuring device (Pinch Track Commander MF106A, Nihon Medix Co., Ltd.; unit of measurement, Nm) was used for taking measurement simultaneously. The correlation between the measurements obtained by the miniature sensor and pinch strength measuring device was found to be high ($r=0.969$; $p<0.01$). Moreover, the reproducibility of these values in repeated measurements was high (ICC (1,1)=0.908; $p<0.01$). These previous results demonstrated that the measurements obtained by the miniature sensor showed high reliability and reproducibility[21].

3. Experimental procedure

With the small sensor applied on the palmar surface of the right thumb of the subjects, we then had the subjects open daily commodities by lateral pinch and measured the pressure applied on the palmar surface of the right thumb (hereinafter referred to as "thumb pressure"). Clinically,



A. The miniature pressure sensor PS-50KAM260 (Kyowa Electronic Instruments Co., Ltd.)

B. Fixed using transparent tape onto the right thumb

C. Photograph of plastic bottle which is being measured by the device

Figure 1. Location of measurement and the miniature pressure sensor

patients complain about difficulty in opening daily commodities[13], and for the containers of goods, we selected cup-type containers, bag-type containers, and plastic bottles, which are all frequently used in Japan. We used easy peel film, which is the most commonly used adhesion system for materials for container lids and materials for bags, and the lid materials included plastic and aluminum. For the plastic bottles, we used those with caps with a diameter of 28 mm, which is the most frequently used diameter in Japan. Each of the containers of goods had a high sales quantity, and we selected types that could be obtained, thereby ultimately selecting the following 4 types: a) plastic bottles

	a) Plastic bottle	**b) Snack**	**c) Jelly**	**d) Pudding**
Production maker ; Contents	ITO EN LTD ; 500ml	Calbee foods CO., LTD ; 85g	Maruha Nichiro Foods, ; 250g	Glico dairy products CO.,LTD ; 180g
Appearance of the container				
Method of opening containers	 The outer diameter of the cap is 28 mm. Open by twisting counterclockwise.	 The horizontal length of the opening is 195 mm. The size of the central tab is 11 mm. Pull apart horizontally.	 The diameter of the lip is 94 mm. The maximum size of the central tab is 18 mm. Pull upward.	 The diameter of the lip is 87 mm. The maximum size of the central tab is 14 mm. Pull upward.

Figure 2. Overview of containers of goods and limb positions during the measurements

(content: 500ml of green tea; ITO EN LTD), b) snacks (content: 85 g; Calbee foods CO., LTD), c) jelly (content: 250 g; Maruha Nichiro Foods), and d) pudding (content: 180 g; Glico dairy products CO, LTD). As a measurement task, the subjects held one of the four types of the determined containers with their non-dominant hand and opened it with their dominant hand (Fig. 1). We encouraged them to pinch using the lateral sides of their fingers so as to vertically contact the operation part of the commodity where the small sensor was attached and open at normal speed. After several practice tries, we randomly selected a daily commodity and took measurements three times each for a total of 12 times. The thumb pressure was incorporated into a PC at a sampling frequency of 100Hz while opening a commodity, in which the maximum value during the opening operation per commodity was set as a representative value (Fig. 2). Furthermore, for the muscle pressure, lateral pinch strength and grip strength at the second position were measured according to ASHT[11] in a seated position on a chair, a slightly abducted shoulder joint position, a dependent position, a 90-degree bent cubital joint position, an intermediate position of the forearms, and a slight dorsiflexion wrist joint position. The measurement was conducted one time each on the non-injured side (left side) and injured side (right side) to obtain the maximum value.

4. Statistics

In both the healthy group and fracture group, age, gender, grip strength and pinch strength were compared in an unpaired t-test, and gender was compared using an χ^2-test in both groups. Subsequently, we classified the fracture group into a "possible group" in which each daily commodity could be opened and an "impossible group" in which they could not be opened, and examined each item of muscle pressure between the three groups, including the healthy group, by using one-way analysis of variance (ANOVA) and multiple comparison tests (Sheffe's post hoc test). Furthermore, in order to determine each relationship between the possible group and impossible group, we obtained Pearson's correlation coefficient.

Moreover, we examined each of the four types of commodities by using logistic regression analysis in which capability of opening was an objective variable and the period until measurement was conducted and muscle pressure were explanatory variables. Based on the calculated opening factors defined for daily commodities, we examined the relationship between threshold and discrimination accuracy for predicting the capability of opening. For the predicting factors extracted from a logistic regression analysis, we further created a receiver operating characteristic (ROC) curve and calculated the area under curve (AUC) of the ROC curve. Based on the evaluation of the ROC curve, we obtained the sensitivity and specificity, in which the cut-off value was determined to be the point where the product of sensitivity and specificity reached the maximum[22]. For the statistical analysis, we used the SPSS Ver. 11.5j software program. We set the criteria for discriminating the statistical significant difference to be less than 5% in any case.

Upon implementation of this study, we obtained approval from the Ethical Committee of Kanazawa University (approval number: 238) and approval from the Ethical Committee of Fuchinobe General Hospital (approval number: 09-006). When participating in this study, participants preliminarily received an explanation of the study purpose, details, and handling of investigation results, etc. and agreed to these. Furthermore, we made sure to place as little burden as possible on patients during the investigation.

Results

1. Comparisons between the healthy group and fracture group

Table 1 shows the breakdown of 20 cases in the healthy group and 85 cases in the fracture group as well as the results of the unpaired t-test and χ^2 test. The grip strength of right side, left side, the lateral pinch strength of left side, gender, and age showed a significant difference. The lateral pinch strength of left side showed no significant difference ($p = 0.774$).

Table 1. Charateristics of the study sample

average ± S.D. (range)

	Healthy group	Fracture group	P value
Number	20	85	NA
Female/Male	0/20	57/25	0.001**
Age ; years	28.5 ± 6.7 (20 − 39)	62.8 ± 13.3 (45 − 81)	0.045*
Time elapsed from the time of injury ; days	NA	62.2 ± 26.2	NA
Grip strength of right side ; kg	48.2 ± 9.4 (34 − 68)	14.7 ± 8.2 (0 − 40)	0.001**
Grip strength of left side ; kg	47.9 ± 10.8 (35 − 66)	31.7 ± 11.7 (16 − 69)	0.001**
Lateral pinch strength of right side ; kg	7.16 ± 1.30 (5.4 − 8.9)	3.97 ± 2.16 (0 − 12.1)	0.007**
Lateral pinch strength of left side ; kg	6.84 ± 1.27 (5.2 − 8.8)	6.68 ± 2.42 (3.1 − 13.8)	0.774

Abbreviaion: NA, not applicable. *P＜0.05, **P＜0.01

2. Comparisons among the healthy group, possible group, and impossible group using a small sensor as an indicator

Subsequently, based on the capability of opening each of the four types of commodities, we classified the fracture group into the possible group and the impossible group. Table 2 shows the breakdown of the three groups: healthy group, possible group, and impossible group and the results of one-way ANOVA and multiple comparison tests. A

Table 2. Comparison between the groups regarding the containers and packaging of each daily commodity tested

		Healthy group	Fracture		F value	P value of ANOVA
			Possible group	Impossible group		
pudding	Number	20	74	11		
	Grip Rt;kg	48.2 ± 9.4 ¶	16.3 ± 7.3 #	4.2 ± 5.6 $	127.0	0.001
	Grip Lt;kg	47.9 ± 10.8 ¶	32.2 ± 11.8	28.0 ± 9.7 $	40.3	0.001
	Pinch Rt;kg	7.16 ± .30 ¶	4.32 ± 2.05 #	1.53 ± 1.08 $	79.5	0.001
	Pinch Lt;kg	6.84 ± 1.27	6.68 ± 2.44	6.68 ± 2.40	0.41	0.96
	Pudding;Mpa	0.28 ± 0.14 ¶	0.11 ± 0.26 #	0.05 ± 0.01 $	211.0	0.001
Snack	Number	20	57	28		
	Grip Rt;kg	48.2 ± 9.4 ¶	18.5 ± 6.5 #	7.1 ± 5.4 $	178.9	0.001
	Grip Lt;kg	47.9 ± 10.8 ¶	34.4 ± 12.4 #	26.0 ± 7.2 $	23.1	0.001
	Pinch Rt;kg	7.16 ± 1.30 ¶	4.91 ± 1.89 #	2.03 ± 1.16 $	60.8	0.001
	Pinch Lt;kg	6.84 ± 1.27	6.89 ± 2.37	6.26 ± 2.58	0.78	0.46
	Snack;Mpa	0.54 ± 0.07 ¶	0.21 ± 0.54 #	0.08 ± 0.03 $	246.8	0.001
Jelly	Number	20	45	40		
	Grip Rt;kg	48.2 ± 9.4 ¶	19.7 ± 6.4 #	9.1 ± 6.0 $	178.5	0.001
	Grip Lt;kg	47.9 ± 10.8 ¶	36.8 ± 12.7 #	25.9 ± 6.9 $	31.2	0.001
	Pinch Rt;kg	7.16 ± 1.30 ¶	5.20 ± 2.02 #	2.58 ± 1.32 $	56.6	0.001
	Pinch Lt;kg	6.84 ± 1.27	7.09 ± 2.40	6.25 ± 2.39	1.67	0.19
	Jelly;Mpa	0.58 ± 0.09 ¶	0.26 ± 0.05 #	0.12 ± 0.05 $	265.7	0.001
Plastic bottle	Number	20	24	61		
	Grip Rt;kg	48.2 ± 9.4 ¶	23.6 ± 5.8 #	11.2 ± 6.1 $	227.0	0.001
	Grip Lt;kg	47.9 ± 10.8	42.1 ± 13.7 #	27.6 ± 7.6 $	40.3	0.001
	Pinch Rt;kg	7.16 ± 1.30	6.38 ± 1.94 #	3.02 ± 1.37 $	79.5	0.001
	Pinch Lt;kg	6.84 ± 1.27	7.13 ± 2.59 #	6.11 ± 2.12 $	8.15	0.01
	Plastic bottle;Mpa	0.85 ± 0.14 ¶	0.44 ± 0.11 #	0.16 ± 0.07 $	311.0	0.001

Abbreviation: Grip Rt, grip strength of rignt side; Grip Lt, grip strength of left side; Pinch Rt, lateral pinch strength of rignt side; Pinch Lt, lateral pinch strength of left side; Sheffe's post hoc test P＜0.05; ¶,significant differece between healthy group and possible group; #, significant differece between possible group and impossible group; $, significant differece between impossible group and healthy group.

Table 3. Correlation within the groups among the containers and packaging of each daily commodity

pudding

(Possible group n=74)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.51**				
Grip Lt	0.49**	0.52**			
Pinch Rt	0.46**	0.77**	0.65**		
Pinch Lt	0.29*	0.21	0.73**	0.56**	

(Impossible group n=11)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.19				
Grip Lt	0.06	−0.16			
Pinch Rt	0.31	0.62*	0.09		
Pinch Lt	0.34	−0.21	0.70*	0.17	

Snack

(Possible group n=57)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.57**				
Grip Lt	0.41**	0.48**			
Pinch Rt	0.51*	0.68**	0.63**		
Pinch Lt	0.39**	0.27	0.77**	0.70**	

(Impossible group n=28)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.59**				
Grip Lt	0.02	−0.22			
Pinch Rt	0.61**	0.69**	−0.03		
Pinch Lt	0.13	−0.32	0.70**	0.02	

Jelly

(Possible group n=45)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.54**				
Grip Lt	0.38**	0.45**			
Pinch Rt	0.58**	0.68**	0.60**		
Pinch Lt	0.44**	0.37	0.78**	0.79**	

(Impossible group n=40)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.58**				
Grip Lt	−0.02	−0.21			
Pinch Rt	0.66**	0.73**	0.01		
Pinch Lt	0.03	−0.36	0.72**	−0.04	

Prastic bottle

(Possible group n=24)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.52**				
Grip Lt	0.54**	0.27			
Pinch Rt	0.68**	0.51**	0.41**		
Pinch Lt	0.71**	0.18	0.73**	0.72**	

(Impossible group n=61)

	Thumb	Grip Rt	Grip Lt	Pinch Rt	Pinch Lt
Grip Rt	0.68**				
Grip Lt	0.20	0.05			
Pinch Rt	0.52**	0.72**	0.32*		
Pinch Lt	−0.05	−0.31	0.63**	0.06	

Abbreviations: Thumb, thumb pressure of Right side; Grip Lt, grip strength of left side; Grip Rt, grip strength of rignt side Pinch Rt, lateral pinch strength of right side; Pinch Lt, lateral pinch strength of left side. *$P<0.05$, **$P<0.01$

significant difference was observed in each item for pudding, snacks, and jelly, except for pinch strength on the left side.

Then, as a result of Sheffe's post hoc test, with regard to pudding, there was no significant difference between the possible group and impossible group in terms of grip strength on the left side. Furthermore, with regard to plastic bottles, there were no significant difference between the healthy group and possible group in terms of grip strength on the left side, pinch strength on the right side and pinch strength on the left side, while a significant difference was observed in the other items.

In the possible group, among the various groups the four commodities show no significant difference in the correlation coefficient between the grip strength on the right side and the pinch strength on the left side in the possible group, while a significantly high correlation coefficient was observed in the possible group.

In the impossible group, pudding showed a significant correlation between the grip strength on the right side and pinch strength on the right side, between the grip strength on the left side and the pinch strength on the left side. The three other commodities showed a significant correlation between the thumb pressure and grip strength on the right side, as well as between the thumb pressure and pinch strength on the right side. Moreover, a significant correlation was observed between the grip strength on the right side and pinch strength on the right side, and also between the grip strength on the left side and pinch strength on the left side (Table 3).

3. Cut-off values of four commodities

Subsequently, when examining the factors predicting capability of opening based on logistic regression analysis, for pudding and snacks, thumb pressure was extracted (pudding: odds ratio; 11.48, $p<0.01$, snacks: odds ratio; 21.82, $p<0.01$). For

Table 4. The odds ratio and, the 95% confidence intervals for the factors predicting the capability of opening each daily commodity

Daily commodity	factors	Odds ratio	95% Confidence interval (CI)		p value
Pudding	Thumb pressure of right side	11.48	24.41	20.98	0.001**
Snack	Thumb pressure of rignt side	21.82	7.90	60.79	0.001**
Jelly	Grip strength of right side	4.36	1.23	15.41	0.001**
	Thumb pressure of right side	43.90	6.23	109.21	0.001**
Plastic bottle	Grip strength of right side	1.38	0.98	1.95	0.001**
	Thumb pressure of right side	15.34	8.07	29.1	0.001**

**P＜0.01

Table 5. The sensitivity and specificity of the cutoff values for the containers and packaging of each daily commodity tested

Daily commodity	Factors that predicts the ability of opening the container/package	Cut-off	AUC, %	P value	Sensitivity, %	Specificity, %
Pudding	Thumb pressure of right side	0.25 Mpa	97.4	0.001**	90.9	86.0
	Grip strength of right side	11.5kg	91.3	0.001**	90.9	71.3
Snack	Thumb pressure of right side	0.41 Mpa	96.7	0.001**	81.0	90.1
	Grip strength of right side	13.5 kg	91.2	0.001**	67.7	82.3
Jelly	Thumb pressure of right side	0.48 Mpa	93.6	0.001**	78.1	88.6
	Grip strength of right side	14.5kg	89.1	0.001**	62.2	78.9
Plastic bottle	Thumb pressure of right side	0.54 Mpa	98.5	0.001**	90.1	95.1
	Grip strength of right side	19.5kg	95.4	0.001**	79.2	89.2

Abbrevition: AUC, area under curve. **P＜0.01

jelly and plastic bottles, grip strength on the right side and thumb pressure were extracted (jelly: odds ratio; 4.36, p＜0.01, odds ratio; 43.90, p＜0.01, plastic bottle: odds ratio; 1.38, p＜0.01, odds ratio; 15.34, p＜0.01) (Table 4). Then, the cut-off value of thumb pressure for predicting capability of opening daily commodities based on the ROC curve for each of the four commodities showed pudding: 0.25 Mpa (sensitivity: 90.9%, specificity: 86.0%, AUC: 97.4%), snack: 0.41 Mpa (sensitivity: 81.0%, specificity: 90.0%, AUC 96.7%), jelly: 0.48Mpa (sensitivity: 78.1%, specificity: 88.6%, AUC: 93.6%), and plastic bottle: 0.54 Mpa (sensitivity: 90.1%, specificity: 95.1%, AUC: 98.5%), (p＜0.01). Similarly, the grip strength on the right side showed pudding: 11.5kg (sensitivity: 90.0%, specificity: 71.3%, AUC: 91.3%), snack: 13.5kg (sensitivity: 67.7%, specificity: 82.3%, AUC: 91.2%), jelly: 14.5kg (sensitivity: 62.2%, specificity: 78.9%, AUC: 89.1%), and plastic bottles: 19.5kg (sensitivity: 79.2%, specificity: 89.2%, AUC: 95.4%) (p＜0.01) (Table 5).

Discussion

We measured the pressure applied on the thumb finger side when using daily commodities using a small and light sensor with high reliability and reproducibility[20,21]. The fracture group showed lower sensor pressure than the healthy group in all four commodities, with the average values of the healthy group as follows: 1) pudding; 0.28 Mpa, 2) snacks; 0.54 Mpa, 3) jelly; 0.58 Mpa, and 4) plastic bottles; 0.85 Mpa.

Furthermore, the sensor pressure of the healthy group, possible group and impossible group showed significant differences according to the four commodities (p = 0.001), thus implying that difficulty of opening commodities would be due to the difference in the measured pressure (Table 2). Regarding the differences of sensor pressure observed among the three groups, the grip and pinch strength and shape of the packages and containers were suggested to affect the results. The small sensor used in this study showed characteristic changes in pressure depending on commodities as shown in Fig. 3 and it could be provided a detailed evaluation of the opening operation. The thumb pressure indicated bimodality in plastic bottles, and that this is because the caps have a double stair structure taking proof of safety content into consideration[23,24]. Moreover, the

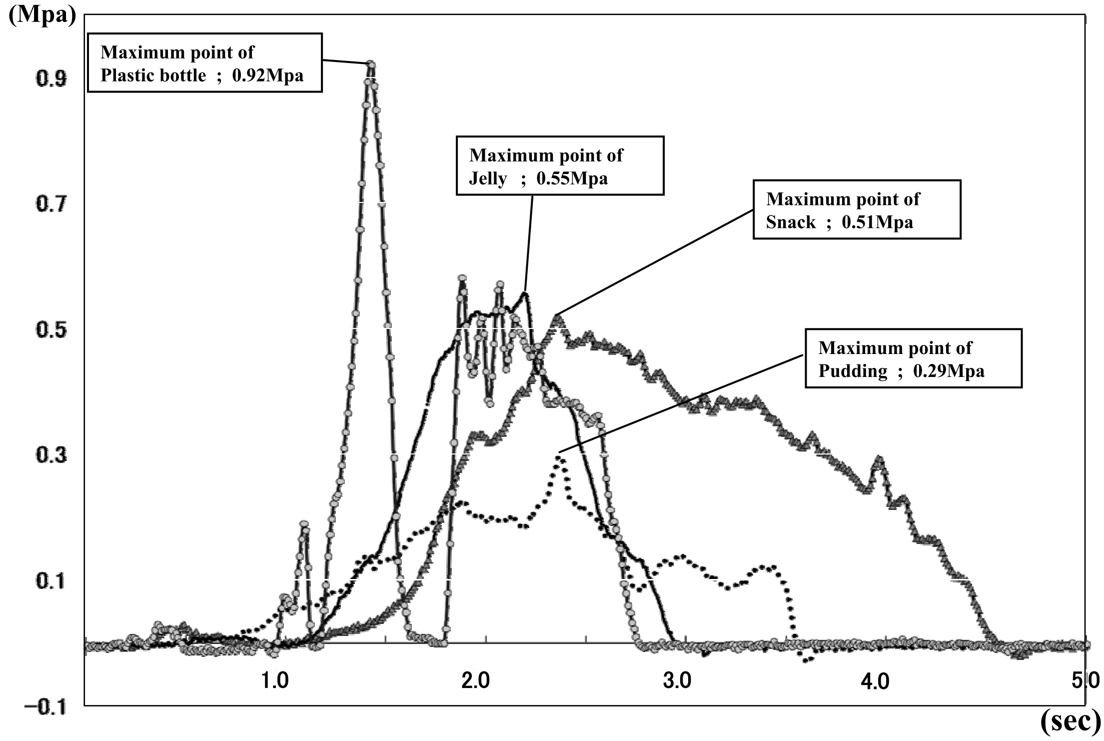


Figure 3. Typical examples regarding the intergradations of the strength required in order to open the packages of daily commodities

reason for the large differences observed in the thumb pressure between the healthy group and the possible group in opening commodities is considered to be due to the differences of the muscle strength between two groups (Table 2). Regarding to the difference in sensor pressure between the jelly and pudding, because the material used for the pudding lid was aluminum, it was less susceptible to stretching than the plastic of the jelly lid, the latter would be easier to apply thumb pressure and open the container.

We investigated the thumb pressure required to open the four commodities and examined the cut-off value. An evaluation of the ROC curve showed high sensitivity and specificity in pudding: 0.25 Mpa, snacks: 0.41 Mpa, jelly: 0.48 Mpa, and plastic bottles: 0.54 Mpa, and the grip strength indicated high discrimination accuracy in jelly: 14.5 kg and plastic bottles: 19.5 kg. When converting the pinch strength with the simple regression liner equation $y = 0.094x$ and $9.81Nm = 1 kg$ for thumb pressure and pinch strength according to a prior study[28,29], the average values were estimated as follows: 1) pudding; about 2.7 kg, 2) snacks; about 4.4 kg, 3) jelly; about 5.2 kg, and 4) plastic bottles; about 5.8 kg. Based on the examination of the ROC curve, the thumb pressure showed higher values in ACU, sensitivity, and specificity than those of the grip strength on the right side, and it was found that this was useful as an indicator for opening daily commodities (Table 5).

The study investigating the normal value of grip strength and pinch strength[10,25-29] indicated normal values per age bracket in addition to reporting that the grip strength required for daily living was 4 kg and the pinch strength was 1 kg. In the study measuring the pinch strength by using a robot arm wearing a pressure sensor that was conducted by Smaby et al.[30,31], 14 types of pressure (pressing remote control buttons, opening and closing zippers, inserting and extracting into and out from an outlet, inserting and extracting a key, inserting and extracting an ATM card, stabbing food with a folk, etc.) were measured. The results revealed that the minimum pressure was for the operation of pressing remote control buttons: 1.4 kg and the maximum pressure was for the operation of inserting a socket into an outlet: 3.14 kg, thus leading to the conclusion that the pressure of operation varied in commodities. Furthermore, it has been reported that is possible to predict approximately 80 percent of targets when investigating patients with cervical cord injuries. In addition, the prior study with the small sensor used in this study reported that 0.2 Mpa or more pressure was required when measuring the pressure applied on the second finger at the time of opening a divided package of drug formulation and indicated that research and development of opening with less pinch strength were necessary[20]. For the thumb pressure when opening the daily commodities used in this study, all four commodities required a strong pressure of 0.25 Mpa or more, showing a difference in results among the commodities. In particular, it was found that the opening of plastic bottles required substantially strong pressure. To this end, in order to operate and open commodities, it is believed that it is necessary to target improving lateral pinch strength and grip strength as well as provide instructions on the use of a self-help device or a compensation method until recovery.

The Japanese Industrial Standards (JIS) provide the standards of a method for testing the capability of opening packages and containers as a guideline for the elderly and disabled[23,24], in which the torque value required for opening is to be measured. The measurements are conducted by each company for the values of healthy persons or the healthy elderly but there are no standard values, so each company must strive to make them easily available without divulging the contents. Because the data in this study was obtained from subjects who were patients with distal radius fractures and it was possible to indicate the pressure required for opening along with the grip strength and pinch strength, it is believed that this will contribute to establishing good standards for food manufacturers and container manufacturers. Based on the transitions in pressure over time shown in Fig. 3, both the plastic bottles and jelly require the maximum muscle strength in the initial phase of opening movements, thus indicating that there is room for structural adjustments for the initial phase of opening.

The results of this study suggested that because difficulty of opening varies in daily commodities when implementing rehabilitation of the upper arms, it is necessary to check the recovery of pinch strength and grip strength and provide concrete daily living instructions.

Limitation of this study

In this study, because a small pressure sensor was used and an analysis was conducted -using the maximum value that is normally used as a representative value and persons without sensational disorders were targeted as the subjects, it is impossible to refer to a cut-off value in the subjects with sensational disorders. Moreover we discussed the relationship between skin friction and material friction.

Conclusions

We measured the pressure applied on the thumb side required for opening four types of daily commodities by using a small sensor. The results revealed that the pressure required for opening varies in the following order: pudding, snacks, jelly, and plastic bottles. Furthermore, we targeted patients with distal radius fractures to analyze the relationship with capability of opening commodities and examined the cut-off value. As a result, thumb pressure showed high sensitivity and specificity as follows: pudding; 0.25 Mpa, snacks; 0.41 Mpa, jelly; 0.48 Mpa, and plastic bottles; 0.54 Mpa, and grip strength indicated high discrimination accuracy in jelly: 14.5 kg and plastic bottles: 19.5 kg. The results of this study revealed that the opening of commodities is closely related to thumb pressure and grip strength on the right side and it is believed that this is a useful indicator to be implemented during rehabilitation of the upper arms.

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日常物品開封時に必要な母指圧力に関する研究

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要　　旨

食料品の容器の蓋や袋の開封に必要なつまみ力を明らかにするために、健常者20例と、橈骨遠位端骨折患者85例を対象に小型圧力センサーを用いて、４種類の日常物品開封時に必要な力を明らかにし、通常評価している筋力との関連性について検討した。物品の容器は、カップ型２種類と袋型、ペットボトルを用いて、プリン、ゼリー、お菓子、ペットボトルの４種類とした。結果は、プリン、スナック菓子、ゼリー、ペットボトルの順で開封に必要な圧力が増加することがわかった。また、橈骨遠位端骨折患者を対象に、物品の開封可否との関連性について分析し、カットオフ値を検討した。その結果は、小型センサー力は、プリン0.25 Mpa、スナック菓子0.41 Mpa、ゼリー 0.48 Mpa、ペットボトル0.54 Mpaで感度、特異度が高く、さらに握力は、ゼリー 14.5 kg、ペットボトル19.5 kgで高い判別精度を示していた。今回の研究結果により、物品の開封には、小型センサー力や受傷側握力との間に密接な関連性をみとめ、上肢のリハビリテーションを進めていく上での有用な指標であると考えられた。