Effectiveness of adaptive silverware on range of motion of the hand (#7889)

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- Original primary research within **Scope of the journal**.
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- Rigorous investigation performed to a high technical & ethical standard.
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- Impact and novelty not assessed. Negative/inconclusive results accepted. *Meaningful* replication encouraged where rationale & benefit to literature is clearly stated.
- Data is robust, statistically sound, & controlled.
- Conclusion well stated, linked to original research question & limited to supporting results.
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Effectiveness of adaptive silverware on range of motion of the hand

Susan McDonald, David Levine, Jim Richards, Lauren Aguilar

Background:
Hand function is essential to a person's self-efficacy and greatly affects quality of life. Adapted utensils with handles of increased diameters have historically been used to assist individuals with arthritis or other hand disabilities for feeding, and other related activities of daily living. To date, minimal research has examined the biomechanical effects of modified handles, or quantified the differences in ranges of motion (ROM) when using a standard versus a modified handle. The aim of this study was to quantify the ranges of motion (ROM) required for a healthy hand to use different adaptive spoons with electrogoniometry for the purpose of understanding the physiologic advantages that adapted spoons may provide patients with limited ROM.

Methods:
Hand measurements included the distal interphalangeal joint (DIP), proximal interphalangeal joint (PIP), and metacarpophalangeal joint (MCP) for each finger and the interphalangeal (IP) and MCP joint for the thumb. Participants were 34 females age 18-30 (mean age 20.38 ± 1.67) with no previous hand injuries or abnormalities. Participants grasped spoons with standard handles, and spoons with handle diameters of 3.18 cm (1.25 inch), and 4.45 cm (1.75 inch). ROM measurements were obtained with an electrogoniometer to record the angle at each joint for each of the spoon handle sizes.

Results:
A 3 x 3 x 4 repeated measures ANOVA (spoon handle diameter by joint by finger) found main effects of ROM between joints ($P < 0.01$) and spoon handle diameter ($P < 0.01$), but not between fingers ($P = 0.264$). As the spoon handle diameter size increased, the range of motion utilized to grasp the spoon handle decreased in all joints and fingers ($P < 0.01$).

Discussion:
This study confirms the hypothesis that less range of motion is required to grip utensils with larger diameter handles, which in turn may reduce challenges for patients with limited ROM of the hand.

Effectiveness of Adaptive Silverware on Range of Motion of the Hand

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19 **Abstract**

20 **Background:** Hand function is essential to a person's self-efficacy and greatly affects quality of
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22 individuals with arthritis or other hand disabilities for feeding, and other related activities of
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40 **Discussion:** This study confirms the hypothesis that less range of motion is required to grip
41 utensils with larger diameter handles, which in turn may reduce challenges for patients with

limited ROM of the hand.

Introduction

Adaptive equipment is used by approximately 23 percent of older adults in the United States, indicating the importance of validating the efficacy and effectiveness of these assistive devices for optimal and appropriate evidence-based prescription (Kraskowsky & Finlayson 2001). Hand impairment can inhibit or reduce functional ability to perform many activities of daily living such as dressing, bathing, eating, and other self-care. It has been previously reported that the use of traditional utensils to feed oneself can be difficult and/or painful with impaired hand function (Brach et al. 2002). Objective assessment of hand joint range of motion required for functional activities can be valuable in prescribing adaptive equipment for individuals with impairments. A person with normal hand ~~range of motion (~~ROM~~)~~ should not feel discomfort in performing tasks such as gripping a standard sized eating utensil; the same task, however, can be difficult if hand range of motion is limited due to either injury or disability. Examples of conditions that commonly affect hand ROM include stroke, osteoarthritis, rheumatoid arthritis, and cerebral palsy (van Roon & Steenbergen 2006). According to the Arthritis Foundation 1 in 5 adults in the United States are affected by arthritis, indicating a great demand for methods to relieve associated complications (Foundation 2015). One intervention often used are increased diameter grip handles on eating utensils. These grips are typically made from a foam-like material and are available in varying sizes such as 3.18 cm (1.25 inch) and 4.45 cm (1.75 inch) diameters as seen in Figure 1.

Although adaptive utensils with modified handles are commonly used, limited research quantifies the biomechanical effects of larger grips or describes how modified handles affect the

range of motion of hand joints. Of the prescribed eating and drinking adaptive devices, 35% are not utilized (Neville-Jan A 1993). Primary reasons for this noncompliance likely stem from the improper sizing of recommended device (Kraskowsky & Finlayson 2001; Neville-Jan A 1993). An in-depth review of the literature by (Thomas WN 2010) found the four most common reasons for non-compliance for using adaptive equipment are: the patient was not included in deciding on adaptive equipment; inadequate instructions were given; the medical condition improves so they no longer need the adaptive equipment; and the patient's environment is favorable to their condition so they no longer need the adaptive equipment. An individualized approach to prescribing assistive equipment that improves the quality of life for clients mirrors the client-centeredness of rehabilitation therapists. A client-centered approach to assistive equipment provision requires client input when deciding on equipment and to ensure its relevance and appropriateness for the client (Hoffmann & McKenna 2004). Determining the individuals range of motion can help with adaptive equipment prescription and may decrease pain associated with simple tasks of daily life and improve utilization and evidence-based rehabilitation outcomes. Bazanski (Bazanski 2010) suggested that a 50° lack of flexion in metacarpophalangeal joints, the most important joints during grip, causes a 24% increase in finger impairment.

Electrogoniometers have previously been found to be a valid and reliable tool for the measurement of range of motion (Bronner et al. 2010; Carnaz et al. 2013; Piriyaprasarth et al. 2008). One previous study used a biaxial goniometer to analyze thumb movements during the use of hand held devices, such as mobile phones, and found the electrogoniometer to be both clinically feasible and accurate (Jonsson et al. 2007).

Modified spoon handles can be beneficial while feeding and research has shown positive outcomes regarding the potential benefits of these utensils for patients with conditions

including rheumatoid arthritis, Parkinson's disease, and cerebral palsy (Ma et al. 2008; van Roon & Steenbergen 2006). Handle diameter and its relationship to spoon-use movement was examined in patients with Parkinson's disease. Handles of small (1.2 cm), medium (2.0 cm), and large (3.8 cm) diameter size were studied and the large handles significantly decreased task movement time and subjective scores of comfort and feasibility of use (Ma et al. 2008). This was likely seen as the hand aperture of the participants with Parkinson's disease was significantly smaller than that of the controls. This study provides evidence of the benefits of altering handle size, but accounts for only the overall movement of the hand as a single unit, and does not address how the grip affects individual joints within the hand.

The use of modified handles for daily activities in persons with rheumatoid arthritis suggests that these assistive devices can help to protect joint integrity by minimizing joint forces and avoiding tight grips (Shipham & Pitout 2003). Van Roon (2006) examined spoon grip-size and its effects on movement kinematics and food spilling for patients with cerebral palsy. Participants with tetraparesis performed quicker transportation of water from one bowl to another and with less spillage when using a 5~~.0~~ cm (2 inch) diameter modified spoon versus a 3~~.0~~ cm (1.18 inch) and 1~~.0~~ cm (0.40 inch) spoon.

While these studies show benefits that may result from using modified spoon handles, they do not study biomechanical changes that occur to individual finger joints when gripping the handles. This study aimed to determine the biomechanical differences in ~~range of motion~~ of the fingers when using three different spoon handles in young healthy subjects. These included a standard spoon, a 3.18 cm (1.25 inch) diameter modified handle and a 4.45 cm (1.75 inch) diameter modified handle. These sizes were chosen as they are commonly ~~available commercially for patients to obtain~~. The purpose of this study was to determine differences in the

111 ~~range of motion~~ required ~~from the joints in the hand~~ when gripping three different sizes of
112 adaptive spoon handles with various diameters.
113
114
115 **Materials & Methods**
116 **Subjects**
117 Thirty-four healthy females between the ages of 18 and 30 (x = 20.38 ± 1.67) years of age
118 voluntarily participated in this study. The average grip strength was 58.41 psi, consistent with
119 previously published normative values for females between the ages of 20-29 (Bohannon 2006;
120 Peters et al. 2011).
121 Exclusion criteria included previous hand injury, any neurological condition that would
122 impair hand movement, arthritis or any other condition that would prevent the subject from
123 having normal hand function and ROM. To reduce the amount of variables potentially affecting
124 or influencing results, all participants were right handed and only the dominant sides were
125 assessed, as the dominant hand is typically used to grasp utensils. All subjects read and signed an
126 informed consent form in accordance with the Institutional Review Board at the University of
127 Tennessee at Chattanooga (IRB #14-026). There were no incentives or rewards given for
128 participating. Subjects were recruited using online advertisements sent to students of the
129 University of Tennessee at Chattanooga.
130
131 **Equipment**
132 A Jamar hydraulic hand dynamometer[a] was used to take a total of 3 measurements of grip
133 strength, which were averaged. The electrogoniometer utilized[b] was comprised of an angle

134 display unit and a single axis goniometer with accuracy previously reported as +/- 0.1 degrees
135 (Christensen 1999). A foam arm rest (Figure 2) was used to provide a comfortable standardized
136 position for the subjects during data collection.
137
138 **Experimental Protocol**
139 Subjects were seated with their shoulder in the anatomical position, and their elbow at a 90
140 degree angle, with the hand dynamometer handle placed in the second grip position which is
141 recognized as the standard position for producing the most accurate results (Massy-Westropp et
142 al. 2011; Trampisch et al. 2012). Grip strength was tested and participants then placed their right
143 arm on a foam arm rest to standardize arm position (Figure 2). A single axis electrogoniometer
144 was used to measure the angles created at each joint of the hand (Figure 3).
145
146 For all finger joint measurements subjects were given the three spoons (standard handles, and
147 handle diameter of 3.18 cm (1.25 inch), and handle diameter of 4.45 cm (1.75 inch) in
148 randomized order and instructed to grip the spoon as if they were going to feed themselves while
149 keeping all fingers in contact with the spoon. In order to confirm that the subjects maintained a
150 solid grip on the spoon throughout the experiment, a small lightweight object was placed in the
151 spoon to ensure they could lift and balance an object with their grip. Hand measurements
152 included the distal interphalangeal joint (DIP), proximal interphalangeal joint (PIP), and
153 metacarpophalangeal joint (MCP) for each finger and the interphalangeal (IP) and MCP joint for
154 the thumb. Measurements were obtained for all joints and all fingers by placing one sensor on
155 the proximal bone and one sensor on the distal bone adjacent to the joint being measured (Figure

3 displays an example of the index finger PIP). The angle was displayed in real time on the display unit and was recorded. All measurements were made in triplicate.

Results

Mean values and standard deviations of ROM are reported for each finger, by joint and spoon handle size (Tables 1-5). A 3 x 3 x 4 repeated measures ANOVA (Spoon handle size by Joint by Finger) found main effects of ROM between joints ($P < 0.01$) and spoon handle size ($P < 0.01$), but not between fingers ($P = 0.264$). The pairwise comparisons showed that as spoon size increased, the range of motion needed decreased in all joints and all fingers ($p < 0.01$). In all five fingers the differences in ROM between the standard spoon and both adaptive spoons was statistically significant ($P < 0.01$), with the adaptive spoons requiring less ROM for grasp. In all five fingers the difference in ROM between the 3.18 cm (1.25 inch) diameter and 4.45 cm (1.75 inch) diameter spoons was statistically significant ($P < 0.01$) with the 4.45 cm (1.75 inch) diameter spoon requiring less ROM for grasp (Tables 1-5).

Discussion

This study quantified finger and thumb joint ROM needed for adult females to grip a standard spoon and two different adaptive spoon handle sizes. A statistical comparison between the ~~ranges of motion~~ for each finger, for each of the three spoons ~~illustrate~~ a significant difference between the angles ~~created~~ at each joint ~~in correlation~~ with the spoon handle size. The angle recorded can be thought of as the distance the joint moved from its original position in order to grasp the spoon handle. Increased joint angles recorded when subjects gripped the standard spoon handle compared to the decreased joint angles across all fingers when participants grasped the handles

of the modified spoons indicate a potential challenge for someone with limited hand ROM to grasp a standard sized spoon handle. The data listed in Tables 1-5 and the statistical analyses confirm less range of motion is required to grip spoons with modified handles. Patients who benefit from the use of such utensils include those diagnosed with conditions that commonly restrict hand ~~range of motion~~, such as patients diagnosed with carpal tunnel, stroke, cerebral palsy, or rheumatoid arthritis (van Roon & Steenbergen 2006) as well as older adults (Kraskowsky & Finlayson 2001). Knowing the ROM required by the hand to attain certain grasps may help reduce trial-and-error approach and improve the prescription of ADL utensils and could be a clinically relevant consideration for occupational therapists who often fit patients with such assistive devices.

Future Research

The aim of this study was to provide quantifiable data to support the common practice of employing adaptive equipment such as spoons with increased handle diameter to reduce ROM required to grip a standard spoon handle and thereby increase independence with feeding activities of daily living. Although this concept was successfully confirmed, different research hypotheses could be formed and tested using similar methods. For example, information recorded during the data collection process such as measurements of hand size could be investigated to show possible correlations between variables of hand size and the range of motion required to grip the different spoon handle diameters. This would require interpretation of individual results as opposed to the overall group analysis run for this particular study. Advances in biomodeling may present the opportunity to provide custom silverware and other tools based on the individual's hand size, strength, and functional needs. Other variables could be introduced

such as questioning the subject for a subjective rating of comfort to establish what may be the ideal handle size as decreased ROM does not necessarily correlate to increased comfort levels or increased efficiency. A more diverse study population including patients with hand deficits likely to use adaptive equipment could be included in future studies. Certain variables such as grip strength may also be a factor in determining the effectiveness of adaptive utensils when the study population has pre-existing hand impairment, as grip strength performance is highly related to the ability of a subject to use their hand functionality

Conclusions

The study quantified the hand range of motion needed for adults to use a standard spoon and two commonly available commercial adaptive spoons. It was hypothesized that it would require less range of motion to grip the spoons with modified handles. An electrogoniometer was used to determine range of motion data for 34 healthy subjects. Statistical analysis found significant differences in range of motion between joints and confirmed the hypothesis that less range of motion is required to grip the modified utensils.

Footnotes

a. Patterson Medical, Warrenville, IL, USA

b. Biometrics Ltd, Ladysmith, VA, USA

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Legend for illustrations

Figure 1. Adaptive Utensils with Modified Handles. These images, from left to right depict a standard spoon, a spoon with a 3.18 cm (1.25 inch) diameter handle, and a spoon with a 4.45 cm diameter handle (1.75 inch).

Figure 2. Foam arm rest to support the forearm.

Figure 3 Single axis goniometer used to measure the Proximal Interphalangeal Joint (PIP) of the index finger. Sensor 'A' is placed on the intermediate phalanx and sensor 'B' is placed on the proximal phalanx of the index finger. (Source: *Goniometer and Torsiometer Operating Manual*. Biometrics Ltd)

Table legends

Table 1. Comparison of thumb (first digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

Table 2. Comparison of index finger (second digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

296

297 Table 3. Comparison of middle finger (third digit) ROM using a standard spoon, and two
298 commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-
299 inch]).

300

301 Table 4. Comparison of ring finger (fourth digit) ROM using a standard spoon, and two
302 commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-
303 inch]).

304

305 Table 5. Comparison of pinky finger (fifth digit) ROM using a standard spoon, and two
306 commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-
307 inch]).

308

1

Adaptive Utensils with Modified Handles

Figure 1. Adaptive Utensils with Modified Handles. These images, from left to right depict a standard spoon, a spoon with a 3.18 cm (1.25 inch) diameter handle, and a spoon with a 4.45 cm diameter handle (1.75 inch).


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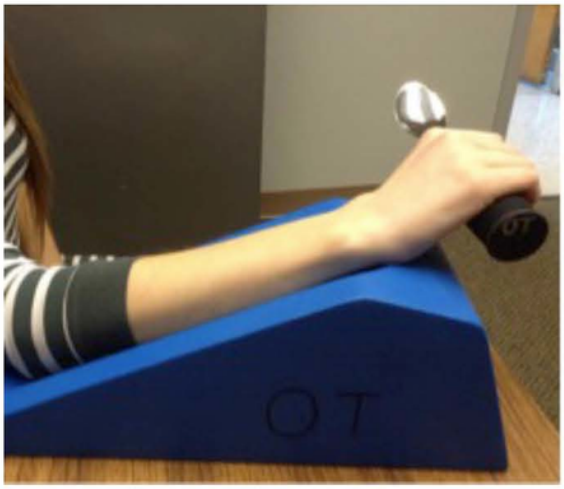
2

Foam arm rest to support the forearm

Figure 2. Foam arm rest to support the forearm.


OT

3

Single axis electrogoniometer

Figure 3 Single axis electrogoniometer. Image is demonstrating measuring the proximal Interphalangeal Joint (PIP) of the index finger. Sensor ‘A’ is placed on the intermediate phalanx and sensor ‘B’ is placed on the proximal phalanx of the index finger. (Source: *Goniometer and Torsiometer Operating Manual*. Biometrics Ltd)

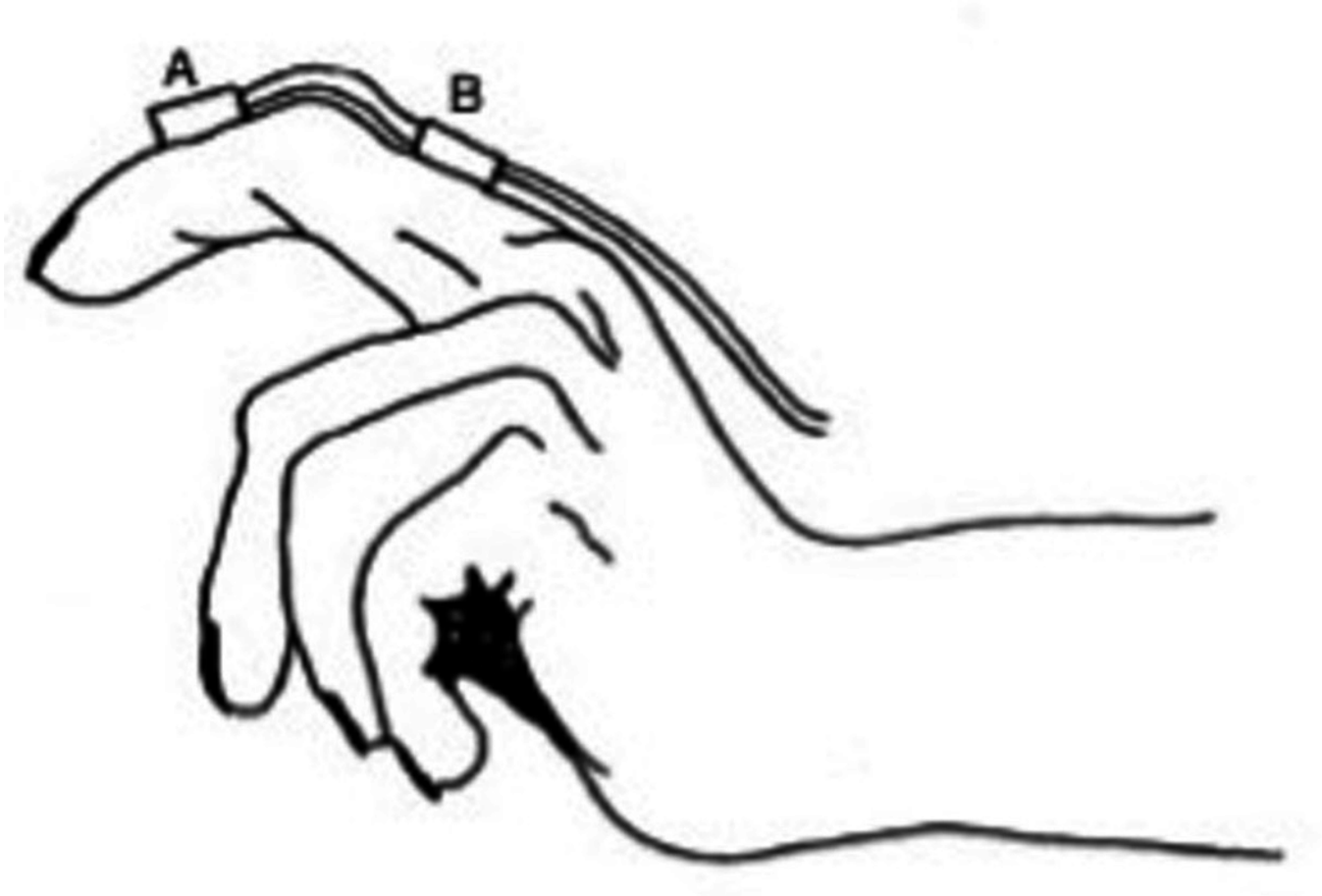


Table 1(on next page)

Comparison of thumb (first digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch])

Table 1. Comparison of thumb (first digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

	MCP	IP
Standard handle	30.62° ± 16.08°	45.7° ± 19.61°
3.18 cm (1.25 inch) handle	26.46° ± 14.50°*	42.28° ± 10.93°*
4.45 cm (1.75 inch) handle	16.53° ± 14.57°*#	36.43° ± 12.13°*#

*Difference between modified handles and standard handle ($P < 0.01$)

#Difference between 3.18 and 4.45 cm handles ($P < 0.01$)

Table 2(on next page)

Comparison of index finger (second digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch])

Table 2. Comparison of index finger (second digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

	MCP	PIP	DIP
Standard handle	87.47° ± 12.12°	106.59° ± 7.70°	63.58° ± 11.33°
3.18 cm (1.25 inch) handle	56.98° ± 13.28°*	70.73° ± 6.36°*	45.86° ± 6.80°*
4.45 cm (1.75 inch) handle	40.68° ± 11.77°*#	55.01° ± 8.13°*#	35.59° ± 6.96°*#

*Difference between modified handles and standard handle ($P < 0.01$)

#Difference between 3.18 and 4.45 cm handles ($P < 0.01$)

Table 3(on next page)

Comparison of middle finger (third digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch])

Table 3. Comparison of middle finger (third digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

	MCP	PIP	DIP
Standard handle	93.66° ± 10.12°	104.53° ± 5.51°	71.31° ± 11.01°
3.18 cm (1.25 inch) handle	67.42° ± 12.89°*	67.1° ± 5.78°*	50.93° ± 7.07°*
4.45 cm (1.75 inch) handle	52.98° ± 12.23°*#	53.68° ± 4.94°*#	39.71° ± 7.43°*#

*Difference between modified handles and standard handle ($P < 0.01$)

#Difference between 3.18 and 4.45 cm handles ($P < 0.01$)

Table 4(on next page)

Comparison of ring finger (fourth digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch])

Table 4. Comparison of ring finger (fourth digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

	MCP	PIP	DIP
Standard handle	81.07° ± 11.79°	108.9° ± 5.84°	68.17° ± 11.66°
3.18 cm (1.25 inch) handle	54.89° ± 15.09°*	68.05° ± 6.22°*	45.98° ± 6.90°*
4.45 cm (1.75 inch) handle	42.33° ± 14.81°*#	54.82° ± 7.21°*#	33.03° ± 5.02°*#

*Difference between modified handles and standard handle ($P < 0.01$)

#Difference between 3.18 and 4.45 cm handles ($P < 0.01$)

Table 5(on next page)

Comparison of pinky (fifth digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch])

Table 5. Comparison of pinky (fifth digit) ROM using a standard spoon, and two commercial spoons with enlarged diameter handles (3.18 cm [1.25-inch] and 4.45 cm [1.75-inch]).

	MCP	PIP	DIP
Standard handle	77.28° ± 19.23°	96.08° ± 8.21°	75.76° ± 11.04°
3.18 cm (1.25 inch) handle	51.96° ± 20.83°*	51.71° ± 9.39°*	39.73° ± 7.49°*
4.45 cm (1.75 inch) handle	39.06° ± 20.07°*#	42.7° ± 8.76°*#	31.28° ± 9.78°*#

*Difference between modified handles and standard handle ($P < 0.01$)

#Difference between 3.18 and 4.45 cm handles ($P < 0.01$)