Innovative Handle Design and Evaluation of Woks for Middle-Aged and Elderly People

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Abstract

With the enhancement of medical technology and human living standards, the world is showing a trajectory towards an aging society. The elders generally suffer from degeneration, which may cause problems in their daily lives. Aging has since become a major issue of scientific researches.

Elders in Taiwan mostly live alone or with a partner. Because eating out is not a habit, cooking often plays an important role in their lives. Due to the degeneration happening to their bodies, the danger during cooking activities increases. Therefore, it is necessary for them to seek help from assistive devices.

In this research, we will make assistive design models that help elders use woks. The designs are for the task we have chosen from our investigation. We will also evaluate the effect of the aids objectively using the EMG system, and collect the iEMG value for evaluation. The iEMG values were collected from four muscles (FDC, FCR, Biceps and Deltoids). Eight middle-aged participants who will become elders in the near future were invited to participate in the experiment. Four design solutions were chosen from seven working models. The design solutions were all helpful to the task, and the performances of the stove design solutions are significantly better than the original wok. The degrees of hand trembling while performing tasks were also measured, however the differences were not significant.

Keywords: Handle Design, Wok, Middle-Aged, Elderly people, Ergonomic Design

Degeneration is an inevitable problem associated with aging. The muscle mass of elder people will reduce 25% to 45%, while the muscle endurance will reduce about 20%. Furthermore, the muscle strength and muscle area will also reduce (Harih and Dolsak, 2014; Hyatt, 1990).

Due to their living habits for decades and the inconvenience in mobility, elder people do not eat out very often. Instead, they prefer cooking for themselves. Kitchen tasks involve many actions that require physical abilities. Also, associated with the danger accompanying high temperature, we need to place a focus on kitchen tasks. Due to the degeneration of elder people, they cannot deal with all the kitchen tasks smoothly. The decrease of upper body functions makes it difficult for elder people to operate kitchenware, rotate grips and perform certain fine actions (Holt & Holt, 2011). Concluding all the reasons mentioned above, it is necessary to come up with assistive devices that help elder people deal with daily kitchen tasks.

In this research, we have visited the homes of several elder people. We found that elder people tend to work with traditional kitchenware, especially with woks, saucepans and stockpots.
Traditional kitchenware appears to be durable but heavy. Elder people are generally frugal because of their life habit during the war era. According to our observation, most of the elder

people are still using the kitchenware from their old times. In addition, when elder people were younger, they had to cook for the whole family, so they tend to choose bigger woks or stockpots. But after their children grew up and left home, the heavy and old-style kitchenware remains in use; they are reluctant to disuse anything that still works, even if there are better, newer designs (Raven, 2006). Many elder people are still using big woks that can cook for four to five people.
The main purposes of this research are listed below:
(1) To design aids for traditional woks and saucepans.
(2) To evaluate the aids designed in this research by electromyogram (EMG) and subjective questionnaire for assessment of results.

1. Observation and Literature Review

In this research, wok tasks, which involve a lot of hand motions, will be focused.
When holding things, the force is mainly from our fingers and wrists (Goislard de Monsabert, Vigouroux, Bendahan, & Berton, 2014). With that said, discussing the aging of hand muscles and joints will help the research. We will observe and analyze the behaviors to uncover any common problems and find solutions to them.

There are two holding styles: (1) grip and (2) pinch. The serial analyses of these two motions are mentioned below.
(1) Gripping

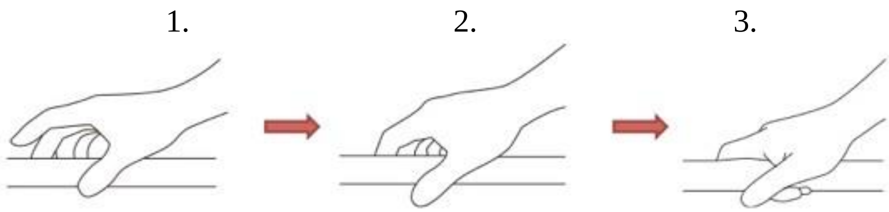


Figure 1 Motion of gripping

Table 1 Serial analysis of gripping

Motion description	Working Muscles
Placing fingers	Lumbrical muscles and extensor digitorum muscles.
Approaching	Finger flexor muscles control the bending of fingers; extensor carpi ulnaris and flexor carpi radialis fix the angle of wrist.
Gripping in static state	No movements at this stage. Muscles involved are isometric.

Kitchenware includes a lot of hand tools, and due to the high temperature of cooking tasks, gripping stably is very important in order to reduce the risks of possible accidents.
Table 1 and Figure 1 are the serial analysis of gripping. We can see that the muscles involved are mostly located in the forearms. Muscles in the forearms are fine and complicated.

(2) Pinching
Comparing to gripping, the muscles working for pinching are finer and more complicated. Pinching is to hold objects with pulps, and is mostly used to hold finer and smaller objects, such as chopsticks and clips. We also use pinching to deal with some special cooking tasks like pinching the edge of a pot of hot soup.
Table 2 and Figure 2 are the serial analysis of pinching. We can see that the ways the muscles

work are pretty much the same with that of gripping with minor differences.

1. 2. 3.

Figure 2 Motion of pinching

Table 2 Serial analysis of pinching

Motion Description	Working Muscles
Opening	The number of fingers open depends on the shape of the objects and the intention of the action. Thu, there are unlimited combinations between lumbrical muscles and extensor digitorum muscles.
Placing fingers	Unlike gripping, when pinching, thumb is always on the opposite side of other fingers, and objects will be held by the first knuckles of fingers.
Approaching	Finger flexor muscles control the bending of fingers; extensor carpi ulnaris and flexor carpi radialis fix the angle of wrist. Usually, index fingers, middle fingers and ring fingers stay curved, and little fingers might be curved or straight.
Pinching	No movements at this stage. Muscles involved are isometric.

The analyses of Table 2 show that, regardless of the opening motion, the main muscles used when holding objects, with either the gripping or pinching motion, are the finger flexor muscles that bend our fingers and the extensor carpi ulnar sand flexor carpi radials that fixes our wrists,. In this research, tasks done with woks and pans will be our focus. When using such kitchenware, the main motion of our hands will be holding. Thus, when collecting EMG data for evaluation, the muscles mentioned above will be emphasized.

Because the muscle composition of forearm is complicated, our hands can do many fine motions. Besides the holding motion mentioned in the previous chapter, forearms can also perform rotating motions. Forearm rotates randomly when working in a kitchen, which means that there is not a standard procedure for the rotating motion. In that case, we list movements and muscles that are possibly involved, shown in Figure 3.

When working in the kitchen, we often have to lift objects. Biceps, brachialis, brachioradialis are mainly involved when lifting objects. Figure 4 shows the position of these muscles.
When our arms flex, biceps provide the most power, and brachialis and brachioradialis do fine adjustments. When our arms flex with palm downwards, brachialis and brachioradialis bare an especially heavy loading.

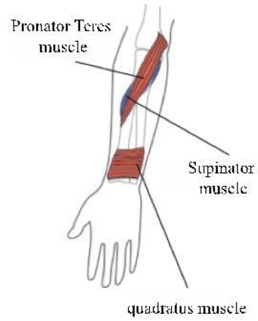


Figure 3 Muscle distributions of forearms

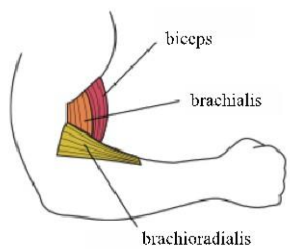


Figure 4 Muscle distributions of upper arms

In this research, we focused on woks and pans. Woks and pans have different forms of handles. In this section, handles will be emphasized to gain parameters for design.

Working with bending wrist for long periods will cause pain and chronic diseases, or even permanent damages (Tichauer, 1966). Grip force performs the best when wrists are kept central (Kadefors et al., 1993). Thus, it is important to keep wrists central when designing handles. In that case, the handle not only eases the pressure on wrists but also enhances the efficiency of work. Thickness influences the pressure on palms. Besides adjusting thickness, changing the shape of handles is also a solution to make gripping easier. Previous findings show that compared to cylindrical handles, people feel more satisfied with the handles that fit their hands (Lewis, 1993; Harih and Dolsak, 2014).

As for spatulas, to prevent subjects from touching the edge of a hot pan, a spatula with a 25 cm handle length and 25° lifting angle is suggested (Wu, 2002). However, the research did not change the form of spatulas, but only the sizes and angles. In this research, we try to develop innovative design solutions without the limitations to the existing forms.

2. Method

2.1. Observation

We invited a woman of age 81 to be the model for observation. Slow motion videos were recorded, and the result of the observation would be the foundation of the design process. The participant was asked to repeat the task we assigned for several times, and videos were recorded from behind the participant, as well as her left and righthand sides. Circle stickers will be placed on the joints of the participant as marks (shown in Figure 5), to help with the observation. Table 3 shows the details of the observation.

In this research, six people (with an average age of 25.6 years old) with design backgrounds were invited to participate in the focus group process. Before the process, participants were asked to gain knowledge of our issue and background information.

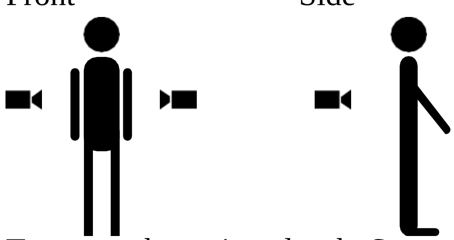
There were two stages of the focus group.

(1) Observation:

Participants were asked to watch the three slow motion videos recorded during observation. The video was repeat continuously, and each participant was asked to share their thoughts on each video with other participants and to discuss amongst the group.

Figure 5 Circle stickers placed on participants

Table 3 Details of observation

	Content	Notes
Participant	Ms. Hung	80 years old/ Female/ Well experienced on cooking/ No upper body diseases
Environment	Kitchen	
Camera set	Front Side 	Videos will be recorded from the participant's back, left-hand and right-hand side.
Task	To repeat the assigned task: Scoop up ingredients into dishes	Repeat for at least five times
Apparatus	Apple iPhone 5s 16G	Slow motion video

2.2. Focus Group

With the observation in the previous stage, participants would understand what the problems are. For the task we focused on, woks and stoves are involved. We separated the wok into handle and wok parts. Along with the stove, we have a total of three parts of the object. Participants were asked to develop ideas based on the problems they pointed out, and to propose solutions to redesign.

(2) Design Development

We chose three handles (thick handle, hollow handle and upright handle), one wok (anti-flipping wok) and three stoves (stove plate, rounded stove and stove stand) as our solutions. The reasons we chose these solutions are due to the feasibility and our technology limitations. Figure 6 are the final solutions of our aid design. Objects shown in the chart are composed for evaluation.

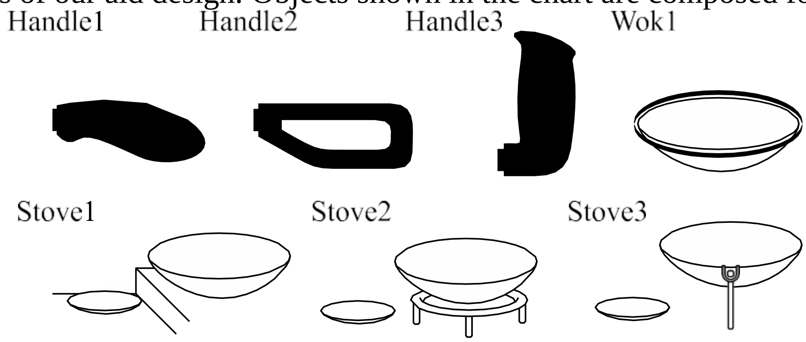


Figure 6 Final solutions of aid design

The concept handle models are made with PU foam. With the concept models we can make little adjustments to the handle shape so as to fit the hands. As for the sizes, Seo and Armstrong (2008) mentioned that if the hand optimal size is bigger than the handle diameter, which is the common situation for woks that are available nowadays, grip force decreases with decreasing handle diameter. Therefore, we made our model with a diameter bigger than common-found handles and try our best to fit the optimal sizes of hands. We then made 3D handle models with Solid Works. Working models are made by Up Plus 3D printer using ABS as our material. The thickness of layer was 0.2 mm, and the print speed was medium. Figure 7(a) is the wok used in this research. The diameter is 38 centimeters, and the weight is 1.5 kilograms. The handle is replaceable, so we can change the handles we printed to evaluate their effectiveness.

Figure 7(b) is the wok design. This structure is expected to make users avoid flipping the wok. Figure 8 is the illustration of how the wok is expected to work. Figure 8(a) is to make the dish lower than the stove. The height of the plate is 9 centimeters. Figure 8(b) is to add a circle base around the stove so that the wok can rotate smoothly along the base. The height of the base is 6 centimeters. Figure 8(c) is to provide a standing stand so that users can place the wok after they lift them in the air, which could make flipping woks easier to accomplish. The height of the stand is 18.5 centimeters, which should be approximately the same with the wok radius so that the wok would not knock against the stove while flipping. These three objects are aimed to help users accomplish the task without too much force.

(a) (b)

Figure 7 (a) Wok and replaceable handles; (b) Wok design

(a) (b) (c)

Figure 8 (a) Stove plate; (b) Circle base around the stove; (c) Standing stand

In sum, table 4 is the list of all the design models from this research. Names are given to each model, and statements of each design concepts are also in the table.

2.3. Pretest

A pretest was performed to eliminate the models with unsatisfactory results. Originally, we had 3 handles, 1 wok and 3 stoves, a totally of 7 design solutions as our design development. For the pretest, we invited 7 participants to perform the task. Participants for the pretest were an average age of 23.5 (SD=0.957). Each participant was asked to perform the task for 8 sets, one for the original wok and stove, and the other seven for the 7 design solutions. Cookies are placed to simulate ingredients, and participants were asked to scoop up the cookies into an iron pot.

Table 4 the list of all the design models of this research

Thick handle	Hollow handle	Upright handle	Anti-flipping wok
			
The streamline shape is to fit the hands well. Also thicker for easier gripping	Another specific shape for handle, aiming to decrease the chance of the wok dropping.	Change type of gripping. The handle is expected to eliminate ulnar deviation.	This structure is made to avoid the wok from flipping.
Stove plate	Rounded stove	Stove stand	
			
To make the dish lower than the stove so that limited lifting is required.	To add a circle base around the stove so that the wok can rotate smoothly along the base.	To provide a standing stand so that users can place the wok after they lift them in the air.	

Participants were asked to practice with all the design solutions for several times, so as to ensure that they fully understand how the aids work. When the participants can smoothly perform the task with all the aids, they were asked to fill out a questionnaire.

The questionnaire is a scale of subjective feelings towards the design solutions. For hand tools, Kuijt-Evers, Twisk, Groenesteijn, De Looze, and Vink (2005) proposed the CQH (Comfort Questionnaire for Hand Tools). The questionnaire asks participants to rate their feelings for the hand tools with Likert scale, so as to evaluate the subjective feelings. We selected some appropriate questions for our questionnaire to evaluate the handles designed.

Table 5 Results of pretest questionnaire

Items		Pavg	Navg	Pavg/Navg	Rank
Thick handle		4.81	2.333	2.061	3
Hollow handle		5.27	2.667	1.976	4
Upright handle		4.524	3.238	1.397	6
Anti-flipping wok		4.679	3.982	1.175	7
Stove plate		6.071	1.911	3.178	1
Rounded stove		4.964	3.107	1.598	5
Stove stand		6.179	2.036	3.035	2

The questionnaire is composed with positive questions and negative question. Participants were asked to answer all the questions in Likert scale. We calculated the average score of both positive (Pavg) and negative questions (Navg), and obtained the ratio of the two average scores

(Pavg/Navg). The results are shown in Table 5. According to table 5, we can see the Pavg/Navg ratio of the 7 design solutions. The top four of the ranking (stove1, stove3, handle1 and handle2) was selected for the final evaluation.

2.4. Experiment

Four models were chosen from the pretest, and the evaluation of this research is the EMG data for using these models. Eight middle-aged participants were invited as the participants. Participants were asked to perform the task we chose from the questionnaire. This research aims to find out whether the aids help with the task or not and the change of muscle loading, so the data before and after equipping the aids will both be collected.

After the pretest, we chose four solutions, including two handles and two stoves. With the original handle, a totally of five sets of experiments were conducted. Participants were asked to repeat the task three times for each set. The task was divided into three movements. For each set, 10 seconds for lifting the wok, five seconds for flipping the wok and 15 seconds for putting the wok back and rest. Thus, each trial of EMG data was 90 seconds long, and a total of five trials of data were collected from each participant. Figure 9 shows the correspondence between movements and the timeline. This specification is to make sure that participants do the same movements at the same time. In that case, comparisons from data to data would be more sensible.

Stability was also measured. Yan and Downing (2001) mentioned that stability is also a criterion of firm gripping. To measure stability, an app was applied to detect the position information.

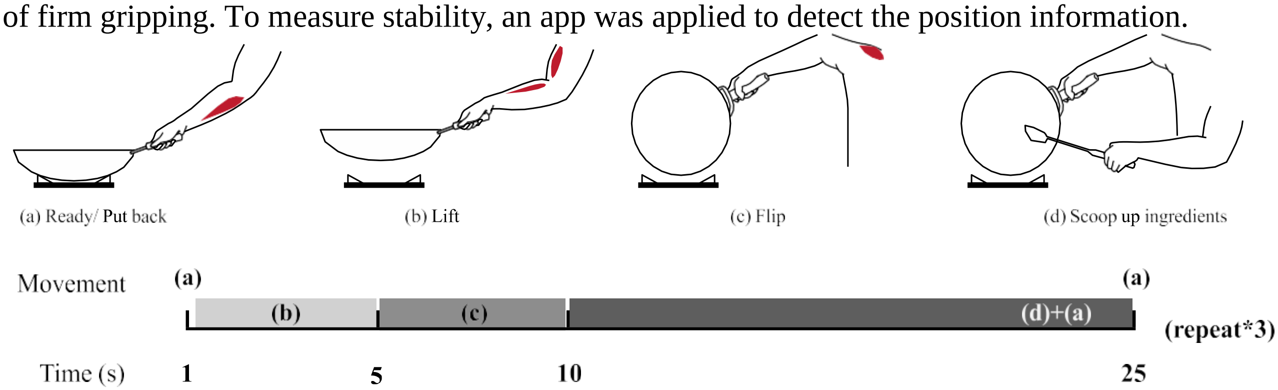


Figure 9 Correspondence between movements and the timeline

Before the EMG measurement, participants were asked to fully understand what they were going to do. Due to the fact that these aid design solutions are innovative, participants may not know how to use these new designs from first sight, needless to say to manipulate the aids. In that case, participants were asked to practice for several times before the measurement. Data collecting did not start until the participants were fully aware of the aids and their tasks.

The data of handles were compared with others from the handles, and data of stoves were compared with that of the woks. Since we only have two design solutions remained for each category after the pretest, we chose the better one from each category and combined them into a system.

(1) Participants

Eight participants were invited to the experiment (four males and four females). Participants were an average age of 51.25, right handed, and were all experienced with cooking. Participants

are healthy and have never suffered from hand diseases.
There are two main reasons for us to invite middle-aged participants rather than elder participants:

(a) Due to the muscle degeneration that happens to elders, it would be easier to collect accurate muscle data from middle-aged participants.

(b) Middle-aged participants will become elders in the near future. However, some musculoskeletal problems like trigger finger, tennis elbow and De Quatrain's disease begin during middle-aged. The aids designed can also be considered as a prevention of their degeneration.

(2) Apparatus

(a) Electromyography (EMG)
The device used to measure muscle action potential is BioRadio 150 by CleveMed. The device is composed by a user unit, a computer unit, wires, electric patches and a computer with Windows operating system.

The muscle action potential signal are transmitted to the computer unit via Bluetooth. The computer unit is connected to a Windows operating system computer. The software of the device called BioCaptureshould is installed on the computer. The waveform of the muscle action potential signal are shown on the screen. After the data collection process, the data can be exported as a csv. File form, which can be opened by excel. The electrode patch is Medi-Trace 200 by Kendall. The Kendall Medi-Trace 200 series electrode EG200 is made with foam, adhesive gel and an Ag/Ag chloride conductor. It is latex free and 3.6cm in diameter (Danlee Medical Products, 2014).

(b) Short-focused projector
The projector is used to play a demonstration video on the white board. Mirrored output videos were played while participants perform their tasks. The videos were used to remind the participants of their tasks. In the videos, the demonstrator made cues for the participants to follow. This allowed us to control the tempo of tasks, which made it easier to analyze the EMG data.

(3) Environment Setting

The experiment was held in the Interaction Laboratory of Department of Industrial design, NCKU. The table height is 85 centimeters, which is the same with the standard stove height in Taiwan. On the left of the table is the computer for collecting EMG data, and all the design models are put on the table. On the top left of the white board is the user unit of the EMG device. Also, a demonstration video was played synchronously when the experiment was in progress. Participants were asked to follow the video displays. To allow the participants to imitate the movements and catch the tempo easier, the video was mirrored output. This is to enhance the compatibility (Sanders & McCormick, 1987) and avoid unnecessary mistakes. Fig 10 shows the situation of mirrored output video.

Figure 10 Mirrored output video

2.5. Evaluation of Design

The main evaluation of this research is via the EMG equipment. By comparing the data before and after the use of the aids from this research, we determine whether the design ideas were helpful.

The data collected by EMG equipment are numbers that cannot be analyzed directly. Therefore, the data have to be transferred into iEMG value by Matlab, and the iEMG value is then used to do statistical analysis. The original data has to go through six steps to be transferred into iEMG value.

3. Results

3.1. EMG Data Analyses of Handles

With the result of the description data shown in Table 6, FDS (Flexor Digitorum Superficialis) shows the easiest loading when working with the thick handle. Here we can see that both of the two design solutions performed better than the original one. The design solutions all eased the pressure of FDS. The sequence of the effect to FDS would be (from better to worse): Thick handle>Hollow handle>Original handle.

Table 6 Description data of FDS (handles)

Designs	Mean	Std. Deviation	95% confidence interval of the difference	
			Lower	Upper
Original handle	3.47E+06	5.85E+05	2.09E+06	4.85E+06
Thick handle	2.17E+06	3.74E+05	1.29E+06	3.06E+06
Hollow handle	2.67E+06	3.14E+05	1.92E+06	3.41E+06

$P<0.05$

3.2. EMG Data Analyses of Stoves

The differences between the two stove design solutions and between muscles were significant ($p<0.05$). Also, mutual effect happened during the experiment. Table 7 shows the descriptive data of the experiments for stoves. A brief trend can be seen from the mean value which shows that the two stove design solutions are lower than the original one.

Table 7 Descriptive data for design solutions (stoves)

Designs	Mean	Std. Deviation	95% confidence interval of the difference	
			Lower	Upper
Original stove	2.42E+06	3.58E+05	1.58E+06	3.27E+06

Stove plate	1.37E+06	2.13E+05	8.64E+05	1.87E+06
Stove stand	1.73E+06	1.68E+05	1.33E+06	2.12E+06

Table 8 is the LSD (Least Significant Difference) analysis among design solutions. By the one on one comparison among the stoves, we can see that the mean iEMG values of both two stoves were significantly lower than that of the original stove. As for the comparison between the stove plate and the stove stand, there was no significant difference. But according to the descriptive data shown in table 8, the stove plate performed slightly better than the stove stand. This shows that the two stove design solutions did help the task significantly.

Further, with the result of the description data shown in Table 9, FDS shows the least loading when working with stove plate. Here we can see that both two design solutions performed better than the original one. That is to say, the design solutions all eased the pressure of FDS. The sequence of the effect to FDS would be (from better to worse): Stove plate>Stove stand >Original stove.

Table 8 LSD analysis among design solutions (stoves)

(I) designs	(J) designs	Mean Difference (I-J)	Std. Deviation	Sig.	95% confidence interval of the difference	
					Upper	Lower
Original stove	Stove plate	1.06E+06	3.16E+05	0.012*	3.07E+05	1.80E+06
	Stove stand	6.97E+05	2.57E+05	0.03*	8.94E+04	1.30E+06
Stove plate	Original wok	-1.06E+06	3.16E+05	0.012*	-1.80E+06	-3.07E+05
	Stove stand	-3.59E+05	2.17E+05	0.142	-8.72E+05	1.55E+05
Stove stand	Original wok	-6.97E+05	2.57E+05	0.03*	-1.30E+06	-8.94E+04
	Stove plate	3.59E+05	2.17E+05	0.142	-1.55E+05	8.72E+05

Table 9 Description data of FDS (stoves)

Designs	Mean	Std. Deviation	95% confidence interval of the difference	
			Lower	Upper
Original stove	3.47E+06	5.85E+05	2.09E+06	4.85E+06
Stove plate	1.50E+06	2.52E+05	9.06E+05	2.10E+06
Stove stand	1.99E+06	2.90E+05	1.30E+06	2.67E+06

The differences of the FCRiEMG values between the original stove and the two stove design solutions are significant ($p<0.05$). The differences of the BicepsiEMG values between the original stove and the two stove design solutions are significant ($p<0.05$). Further, with the result of the description data shown in Table 10, Biceps shows the least loading when working with stove plate. Here we can see that both design solutions performed better than the original one. That is to say, the design solutions all eased the pressure of Biceps. The sequence of the effect to Biceps would be (from better to worse): Stove plate>Stove stand >Original stove.

Table 10 Description data of Biceps (stoves)

Biceps			95% confidence interval of the difference	
			Lower	Upper
Original handle	2.19E+06	4.72E+05	1.07E+06	3.30E+06
Stove plate	1.01E+06	1.35E+05	6.94E+05	1.33E+06
Stove stand	1.73E+06	2.27E+05	1.19E+06	2.26E+06

3.3. EMG Data Analysis of Combination of Handles and Stoves

Through the comparison conducted, thick handle and stove plate performed better in their groups. Thus, we combined them together and run the same experiment process to see whether the combination works better. Table 11 is the description data of the four muscles. According to the description data (mean iEMG value), the combination of thick handle and stove plate did not show better performance than using the stove plate alone.

Table 11 Descriptive data for design solutions (combination)

Designs	Mean	Std. Deviation	95% confidence interval of the difference	
			Lower	Upper
Original stove	2.42E+06	3.58E+05	1.58E+06	3.27E+06
Thick handle	2.11E+06	2.86E+05	1.43E+06	2.79E+06
Stove plate	1.37E+06	2.13E+05	8.64E+05	1.87E+06
Thick handle* Stove plate	1.46E+06	2.94E+05	7.60E+05	2.15E+06

3.4. Subjective Questionnaire

Participants were asked to fill out the same subjective questionnaire as the one in the pretest. The results are shown in Table 12. The Pavg/Navg ratio all decreased for the four design solutions, which means that participants of the experiment were less satisfied with the design solutions than participants of the pretest. The rank among the design solutions also changed a little; according to Table 6, participants felt that hollow handle was better than thick handle.

Table 12 Results of experiment questionnaire

Items		Pavg	Navg	Pavg/Navg	Rank	Pavg/Navg (pretest)	Rank (pretest)
Thick handle		3.711	3.733	0.994	4	2.061	3
Hollow handle		4.111	3.133	1.312	3	1.976	4

Stove plate		4.95	2.975	1.664	1	3.178	1
Stove stand		4.35	2.7	1.611	2	3.035	2

4. Discussion

Since the design solutions of this research are all based on a traditional wok, we chose a wok with a changeable handle. There were two problems with the wok: (1) an awkward angle of handle. (2) Too heavy. As Figure 11 shows, an angle exists between the wok and the handle. This angle made the handles higher than expected, which made lifting more difficult for participants; they had to lift higher than they usually do. Moreover, the higher handle might keep the handles designed from performing their expected functions. More severe ulnar deviation happened, and Figure 12 tells why. Additionally, participants complained about the weight of the wok. These two problems might be the reasons why the iEMG value of FCR tended to be higher than other muscles measured.

The eight participants substantially performed the five-set experiment smoothly. With the demo video played in front of them, the motion tempo was well controlled so that the data collected could be compared directly. For EMG data collection, data of all male participants were collected successfully in one time. But for the female participants, the signals were not as strong and steady as the signals from the male participants', which made the experiment sets re-run for a few times.

Figure 11 Awkward angle of the traditional wok

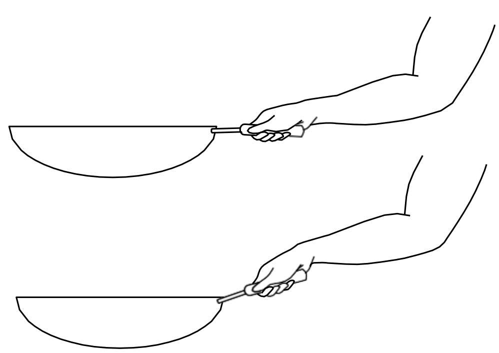


Figure 12 Ulnar deviation caused by the angle of handle

With all the situation and environment factors controlled, the factor that influenced the signal quality might be the difference between male and female. Generally, females have more subcutaneous fat, and this makes their muscles more difficult to show. Relatively, males not only have less subcutaneous fat but also stronger muscles. In that case, it was easier to place the electrodes at the right places when collecting data from males. However, weaker muscle performance may cause weak signals, and plus the cut off caused by subcutaneous fat, sometimes data were lost for a while because there was nothing measured.

Design solutions for handles are to change the way muscles works, and design solutions for stoves are to change working modes. From the highlights of the focus group observation, for the 17 highlights, changing the way muscle works were mentioned 13 times, and changing working modes were mentioned 6 times. These two principles took the first and second place among all the principles. From the description data of mean iEMG value, stove plate and stove stand apparently helped more than thick handle and hollow handle. This may be because when using stove plate and stove stand, participants did not have to lift a great range. Without the load of Biceps and fewer loads of FDS and FCR, the iEMG values decreased significantly. The result tells that changing working modes might be the more efficient way to help users when designing aids, which appears to be a little different from the highlights of the focus group observation. From the aspect of muscles, during the task of scooping ingredients into dishes, FCR loaded the most through the handle design solutions. Qin, Chen, and Dennerlein (2013) mentioned that the loading of FCR corresponds to ulnar deviation, which means that the design solutions of this research did not solve the problem of ulnar deviation. FDS took the second place of loading. Thus, we can say that the main loading of this task was on the forearms. According to the results, we can easily see that thick handle performed better than hollow handle, while stove plate performed better than stove stand.

5. Conclusion

All the design solutions helped with performance improvement of the task in this research. Among the four design solutions of this experiment, stove plate showed the most significant improvement. Besides the performance on EMG experiment, stove plate also got the highest Pavg/Navg ratio from subjective questions. Design solutions for stoves both performed significantly better than design solutions for handles. Thus, changing the working mode is the most efficient way of designing aids. Mutual effects happened to handles, and the loading of FDS decreased while the loading of FCR increased for both handles. This shows that the handles did help with the gripping movement, but did not help with the ulnar deviation. Future works can be focused on changing more parameters like handle diameters and angles to find the best size and shape for the handles.

Differences of hand trembling among all the design solutions are not significant, and this might be because the tasks performed in this experiment were not tiring enough to make hands tremble. Through this research, higher stove plate is strongly recommended. Higher plate for stoves not only helps with the task but is also better for tasks that require a high degree of concentration, especially for the stove related tasks that are associated with high temperature. Also, users do not have to bend down low to check the fire. Stove stand was also a creative solution that significantly decreased the loading on muscles, but the process of hanging the stove onto the stand caused extra muscle loading. Despite the fact that stove stand performed worse than stove plate in EMG analysis, further adjustment and development may still be worthwhile.

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