Applied Ergonomics 1991, 22.6, 395–400

An investigation for determining the optimum length of chopsticks

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Chopsticks are one of the most simple and popular hand tools ever invented by humans, but have not previously been investigated by ergonomists. Two laboratory studies were conducted in this research, using a randomised complete block design, to evaluate the effects of the length of the chopsticks on the food-serving performance of adults and children. Thirty-one male junior college students and 21 primary school pupils served as subjects for the experiment. The results showed that the food-pinching performance was significantly affected by the length of the chopsticks, and that chopsticks of about 240 and 180 mm long were optimal for adults and pupils, respectively. Based on these findings, the researchers suggested that families with children should provide both 240 and 180 mm long chopsticks. In addition, restaurants could provide 210 mm long chopsticks, considering the trade-offs between ergonomics and cost.

Keywords: Hand tools, handles, chopsticks

Introduction

Chopsticks and knives and forks are fundamental hand tools used respectively by the Oriental and Occidental peoples in food serving. Though ergonomics studies on the knife handle have been performed by some researchers (e g, Riley and Cochran, 1980; Cochran and Riley, 1986a, 1986b), chopsticks, used by at least 1·5 billion people daily, have seldom been examined by ergonomists. It may be because Occidentals, who emphasise more on empirical research, do not use chopsticks, or because Orientals think that chopsticks are too simple to be studied. Nevertheless, from the ergonomics point of view, chopsticks, being used by a large number of people, deserve a systematic study.

There are many kinds of chopsticks used in Taiwan. They differ in various ways, such as in length, shape, material, colour and texture. Surprisingly, the length of the chopsticks is mainly designed for adults, with little consideration of the differences between adults and children. This research evaluated the effects of the length of chopsticks on the food-serving performance of adults and children and determined the optimal length of the chopsticks for adults and children, respectively.

Background

Hand tools can be considered as extensions of human hands. Human beings use chopsticks instead of hands to take food, because chopsticks can aid hand capabilities and supplement hand limitations. Chopsticks can help people to extend hand reach, to pick up food, and to protect hands from heat. Using chopsticks is more hygienic than using fingers. In addition, they can be used to cut and spear food as knives and forks do. Apparently, chopsticks are one of the simplest and most convenient and efficient hand tools ever invented by human beings, and they cannot be fully replaced by knives and forks because of the cultural differences in food serving.

When a person wants to pick up food with chopsticks, he usually has to manipulate a pair of chopsticks in a procedure roughly as follows: First, put one chopstick (named as 'fixed') into the crotch between the thumb and index finger, and support the chopstick at about its half way with the first knuckle of the ring finger and second knuckle of the thumb. Secondly, put another chopstick (named as 'movable') along the side of the index finger, grip it with the tip of the middle and first fingers, and then suppress it with the skin at the thumb base. Thirdly, pick up food by opening and closing the 'movable' chopstick with the index and middle fingers, and use the thumb and index finger as a fulcrum while keeping the 'fixed' chopstick steady. Therefore, the operation of chopsticks can be classified as third-class levers. Fig. 1 shows the operation procedure of chopsticks.

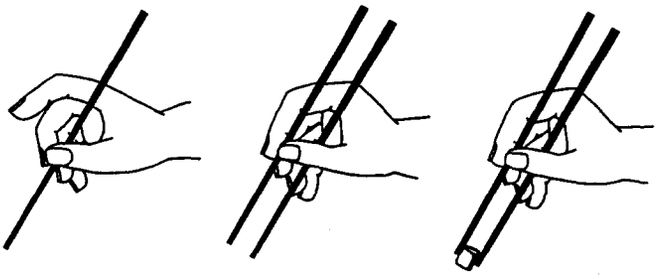

Fig. 1 The operation of chopsticks

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As a general rule, the grip of hand tools can be classified into the following basic categories (Napier, 1956; Bendz, 1974; Konz, 1986): (1) The pinch grip, in which the object is held between the thumb and the index finger, as one might hold a key; (2) The internal precision grip, a pinch grip plus the support of the tool handle at the base of the little finger, as one holds a table knife; (3) The external precision grip, a pinch grip plus the support of the tool handle between the thumb and the index finger, as one holds a pencil; (4) The power grip, in which the tool handle is perpendicular to the four fingers, and the fingers curl around the shaft with the thumb 'locking' on to the top of the first finger, as one holds a saw, a hammer or a cork-screw.

Although Konz (1983) classified the holding of chopsticks as an external precision grip, obviously, the grip of chopsticks is different from holding other hand tools. When a person picks up an object with chopsticks, he must hold the two separated handles of the chopsticks. This requires higher dexterity and takes a longer time for learning and practice than using other hand tools. In addition, since the operation of the chopsticks applies the principle of third-class levers, the lever or moment arm distance of the longer chopsticks is longer than that of the shorter ones, and since the distance between fulcrum and exertion point is fixed, the longer chopsticks require more force to pick up the same object. Thus, the length of the chopsticks may affect the food-serving performance significantly. For this reason, the primary objective of this investigation was to verify the effect of the length of chopsticks on the food-pinching performance of adults and children. A second objective was to determine the optimal length of the chopsticks for children as well as adults. It is believed that these data would be useful as a given premise in the subsequent studies related to chopsticks ergonomics.

Experiment 1

The objective of Experiment 1 was to determine the optimal length of chopsticks for adults.

Subjects

Thirty-one male junior college students aged between 17 and 21 years (mean 19·0 years), volunteered to participate in this experiment. These subjects were right-handed and were quite experienced in the use of the chopsticks. At the beginning of the experiment, subjects were briefed about the purpose and requirements.

Experimental design

A randomised complete block design was utilised. Each subject was considered as a block. The length of the chopsticks was varied at six levels and was considered as a fixed factor. Each subject was asked to perform four tasks with six different length levels presented in a random order.

Experimental chopsticks

Six pairs of chopsticks were made of bamboo and levels of length were set at 180, 210, 240, 270, 300 and 330 mm to cover the range of length encountered in Taiwanese markets. Each pair of chopsticks has two parts: the handle and the tip. The diameter of the handle is 6 mm, and the dimensions (length and slope) of the tip is 80 mm and 1° as shown in Fig. 2.

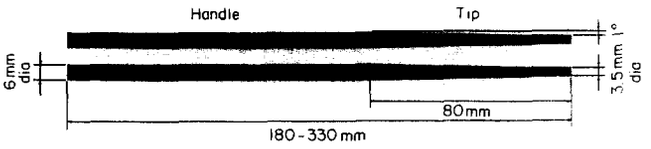

Fig. 2 The experimental chopsticks

Konz (1983) suggested that, in some situations for example, using a pencil – rotation is neither good nor bad, for the cross-section of the handle should be circular to minimise sharp edges. Therefore, it is reasonable that the cross-section of the handles of chopsticks is round. In addition, for the purpose of cutting and spearing food, the diameter of the tip part decreased from 6 mm to 3·5 mm.

Experimental procedure

Before the test, each subject was asked to report his personal data on gender, age, height, weight and preferred hand. The subject was allowed to adjust his seat to a comfortable height, and to practise picking the peanuts using his preferred hand for 1 min.

During picking, the subject was instructed to put his unused hand on his lap. Furthermore, to minimise the effect of fatigue, the subject was given a 2-min rest period between successive measurements.

After the practice, the subject was asked to remain seated and used his preferred hand to complete the following tasks: (1) pick up peanuts for 1 min, (2) pull a simulated food (eraser) three times, (3) 'answer' semantic-differential scales, for each pair of chopsticks. Finally, the subject was asked to rank his preference from 1 (favourable) to 6 (unfavourable) for the 6 pairs of chopsticks.

Four criterion measures – food-pinching efficiency, food-pinching force, subjective rating and subjective ranking – were used for each of the aforementioned tasks. The detail of the experimental tasks and criterion measures are as follows:

(1) Food-pinching efficiency. The subject would sit on an adjustable seat, and was required to pick up peanuts from a dish (150 mm diameter) in front of the subject (450 mm) to a cup (200 mm high and 70 mm diameter) under the mouth for 1 min. During pinching, the experimenter counted the numbers of peanuts in the cup. The reason for using peanuts was that it was difficult to pick them up and hence was more representative as a measure of the effect of the length of the chopsticks on food-pinching efficiency. Fig. 3 demonstrates the workplace layout and task of the food-pinching.

(2) Food-pinching force. The subject was required to use chopsticks to grip a simulated food (a rubber eraser with 60 mm in length, 20 mm in width and 5 mm in height) in front of the subject (450 mm) and pull it toward the mouth until it slipped off, and the experimenter read the numbers in the push-pull scale (model ATTONIC) tied with this simulated food. Since the pulling force was related to the food-pinching performance, it was used as one of the criterion measures. Each subject was asked to repeat the same task three times, and the average of the three readings was used in the analysis.

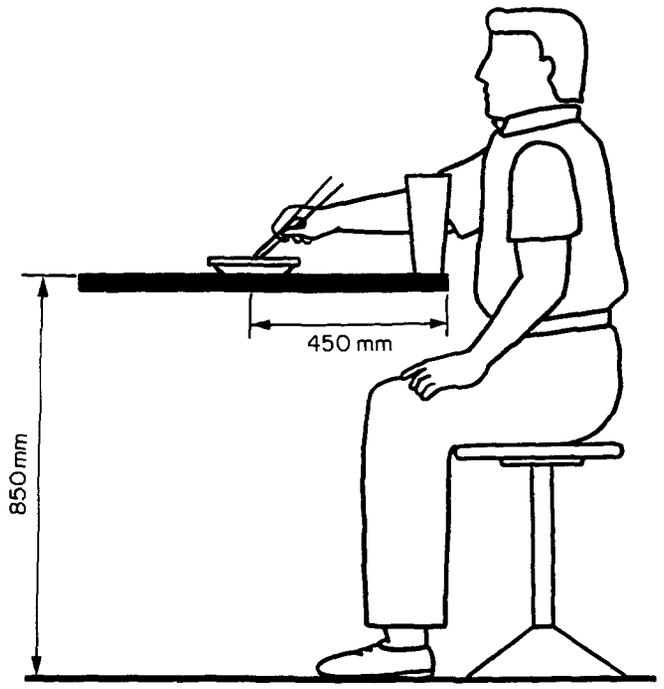

Fig. 3 Arrangement of the workplace layout for the task of 'pinching' food

(3) Subjective rating. After the subject had finished the aforementioned two tasks with each level of the length of the chopsticks, he was asked to complete a semantic-differential scale comprising five adjective pairs: arm aching–arm unaching, gripping easily–gripping difficultly, exerting easily–exerting difficultly, comfortable–uncomfortable, and too short–too long. Each pair had an unmarked scale from one to nine; arm unaching, gripping easily, exerting easily, and comfortable were scored as 9 (i e, 1, 2, 3, 4, 5, 6, 7, 8, 9). Too short–too long was scored with 1 for two extremes and 9 for the middle location (i e, 1, 3, 5, 7, 9, 7, 5, 3, 1).

(4) Subjective ranking. The subject was also asked to rank his overall preference for the six pairs of the experimental chopsticks at the end of the testing. Subjective preference ranking can be used to cross-validate with other performance measures.

Results

The mean value of all criterion measures for all subjects is presented in Table 1. In addition to the subjective ranking data, the other criterion measures were subject to the analysis of variance and Duncan test. The subjective ranking data were analysed by the Wilcoxon test. Table 2 showed the results of the Duncan and Wilcoxon test for four criterion measures.

(1) Food-pinching efficiency. From the analysis of variance on the food-pinching efficiency data of adults, the length of the chopsticks had a significant effect on the food-pinching efficiency (F (5,150) = 5·05; $P < 0·0003$), and significant differences were found among subjects (F (30,150) = 17·93; $P < 0·0001$). The Duncan Multiple Range Test in Table 2 illustrates the significant differences ($P < 0·05$) among the various lengths of the chopsticks. The efficiency produced by the 240 mm long chopsticks was significantly superior to those 300, 180, 270, and 330 mm long – which did not differ among themselves. However, the 240 and 210 mm long chopsticks did not differ significantly from each other. Additionally, the 210 mm long chopsticks were also significantly better than those 270 and 330 mm long, but not significantly different from those of 300 and 180 mm length.

(2) Food-pinching force. From the ANOVA on the food-pinching force of adults, the result showed that the length of the chopsticks affects the food-pinching force significantly (F (5,150) = 17·75; $P < 0·001$), and that significant differences were found among subjects (F (30,150) = 7·54; $P < 0·001$). The subsequent Duncan Test (Table 2) indicated that the force produced by the 180 mm long chopsticks was significantly greater than that of those 240, 270, 300 and 330 mm long, but not significantly different from that of the 210 mm long chopsticks, and the force produced by those 330 mm long was the smallest.

(3) Subjective rating. Table 3 shows the mean rating scores for various lengths of the chopsticks. The analysis of variance for these rating data shows that the length of the chopsticks had a significant effect on the rating scores ($P < 0·01$) in either individual mean scores (adjective pair) or total mean scores. The rating scores of the chopsticks 240 mm long was significantly better than those of the 270, 300, 180 and 330 mm long chopsticks, but not significantly different from those 210 mm long. In addition, those of the 330 mm long chopsticks were the poorest (Table 4).

(4) Subjective ranking. The mean rank data of all subjects for six pairs of chopsticks was listed in Table 1. Through

Table 1: Summary statistics of average value for four criterion measures (adults)

Lengths of chopsticks (mm)	Food-pinching efficiency (*)	Food-pinching force (kg)	Subjective ratings (**)	Subjective rankings
180	24·935	0·7097	4·56	5·09
210	25·484	0·6452	6·79	2·67
240	26·323	0·6097	7·07	1·38
270	24·323	0·5419	5·68	2·38
300	24·968	0·4817	4·78	3·80
330	24·000	0·4129	3·47	5·48

*Quantity of peanuts picked ** The greater the score, the better

Table 2: Summary results of the Duncan and Wilcoxon tests for four criterion measures (adults)

Rank	Food-pinching efficiency (Duncan test)	Food-pinching force (Duncan test)	Subjective rating (Duncan test)	Subjective ranking (Wilcoxon test)	
1	24	18	24	24	Best
2	21	21	21	27	
3	30	24	27	21	Middle
4	18	27	30	30	
5	27	30	18	18	Worst
6	33	33	33	33	

a Wilcoxon test on the rank data, the length of the chopsticks was found to have a significant effect on subjective preference ($P < 0{\cdot}0001$). Furthermore, the six pairs of chopsticks were grouped into the Best, Middle, and Worst, depending on whether their estimated median was significantly smaller or greater than 3·5. It can be seen from Table 2 that the 240 mm long chopsticks were the Best, the 270, 210 and 300 mm long were the Middle, and the 180 and 330 mm long were the Worst.

Experiment 2

The objective of Experiment 2 was to determine the optimal length of the chopsticks for children.

Method

A total of 21 (13 boys and 8 girls) primary school pupils aged between 7 and 10 years (mean 8 years) volunteered to participate in this experiment. The subjects were right-handed, and were accustomed to eating with chopsticks. The experimental design was the same as in Experiment 1.

In consideration of the smaller hands of children, the 330 mm long chopsticks for adults were replaced by the 150 mm ones, and the 150, 180, 210, 240, 270 and 300 mm levels of length were used in Experiment 2. The other dimensions of the chopsticks used in Experiment 2 were similar to those used in Experiment 1.

The pulling force was found in Experiment 1 to be inversely related to the chopsticks' length and the pupils cannot well comprehend the semantic-differential scales; therefore, only the food-pinching efficiency and subjective ranking were used in Experiment 2 as the criterion measures. The experimental procedure was similar to Experiment 1 except that the reach distance between the dish and the subject was 350 mm.

Table 3: Mean scores data of subjective rating for all five adjective pairs of adults

Lengths (mm)	Arm unaching	Grip easily	Exertion easily	Comfortable	Too long/ too short	Total
180	4·17	5·03	5·52	4·36	3·23	4·56
210	5·29	6·54	8·58	5·93	7·58	6·79
240	6·06	7·16	6·97	6·81	8·42	7·07
270	4·80	5·64	5·81	5·80	6·32	5·68
300	5·00	5·32	5·13	5·00	4·48	4·78
330	4·38	3·61	3·63	3·23	2·48	3·47

Table 4: Results of the Duncan test on the rating data for all five adjective pairs individual and overall of adults

Rank	Arm unaching	Grip easily	Exertion easily	Comfortable	Too long/ too short	Total
1	24	24	21	24	24	24
2	21	21	24	21	21	21
3	30	27	27	27	27	27
4	27	30	18	30	30	30
5	18	18	30	18	18	18
6	33	33	33	33	33	33

Results

Table 5 shows the mean statistics for the food-pinching efficiency and subjective ranking data of children, and Table 6 shows the Duncan and Wilcoxon tests on these data.

(1) Food-pinching efficiency. From the analysis of variance on the food-pinching efficiency of pupils, it was found that the length of the chopsticks did affect the performance significantly ($F(5,100) = 4{\cdot}18; P < 0{\cdot}0017$), and significant differences were found among subjects ($F(20,100) = 12{\cdot}49; P < 0{\cdot}0001$). The Duncan Test was performed to reveal significant differences ($p < 0{\cdot}05$) among the various lengths of the chopsticks (Table 6). It was found that the efficiency produced by the chopsticks 180 mm long was significantly better than those 210, 240, 270 and 300 mm long – which did not differ among themselves, but was not significantly different from those 150 mm long. Furthermore, the efficiency of the 150 mm chopsticks was significantly better than that of the 300 mm long ones, but not significantly different from that of the 210, 240 and 270 mm long ones, and the 330 mm long ones were the worst.

(2) Subjective ranking. The mean rank data of all subjects for six pairs of chopsticks was listed in Table 5. Through a Wilcoxon test, it was discovered that the length of the chopsticks affected subjective preference ($P < 0{\cdot}0001$) significantly, the 180 mm long chopsticks were most preferred by pupils, and the 270 and 300 mm long ones the least preferred by pupils (Table 6).

Table 5: Summary statistics for food-pinching efficiency and subjective rankings (children)

Lengths of chopsticks (mm)	Food-pinching efficiency (Mean)	Subjective rankings (Mean)
150	26·000*	2·76
180	27·524	1·85
210	24·857	2·28
240	24·857	3·33
270	24·333	4·92
300	23·714	5·85

*Quantity of peanuts picked

Table 6: Summary results of the Duncan and Wilcoxon tests for food-pinching and subjective ranking (children)

Rank	Food-pinching efficiency (Duncan test)			Subjective rankings (Wilcoxon test)		
1	18	|		18	|	Best
2	15	|	|	21	|	
3	21	|	|	15	|	Middle
4	24	|	|	24	|	
5	27	|	|	27	|	Worst
6	30	|	|	30	|	

Discussion

One of the main factors which affect the food-serving performance of the chopsticks is their length, and this was verified in this study. The length of the chopsticks did affect the food-pinching efficiency, food-pinching force and subjective rating significantly.

Table 2 is the summary results of Experiment 1, and Fig. 4 shows the data for four of the criteria for the six levels of the length of the chopsticks. The criterion scales in Fig. 4 had been converted to fairly arbitrary values, and only the 'desirable' and 'undesirable' directions were indicated (Siegel and Brown, 1958). It can be seen, however, that three criteria were the best for the 240 mm long chopsticks, and all four criteria were the worst for the 330 mm chopsticks. Although the 180 mm long chopsticks produced the largest pulling force, they were undesirable in subjective ranking and rating.

Why are the 240 mm long chopsticks better than others in the food-pinching efficiency? According to the viewpoint of motion and time analysis, both the shorter and the longer chopsticks require more time in food-pinching. The shorter the chopsticks, the greater the distance to reach, and consequently the more time it takes. Furthermore, the shorter chopsticks limit the range of opening and closing of the two tip parts, and thus reduce the efficiency of pinching. The longer the chopsticks, the more the handle parts remain over the crotch of the thumb and the first finger. Thus the more likely the handle parts of the chopsticks would collide with each other and influence the pinching performance. Therefore, chopsticks 240 mm long were the optimum length for adults.

As the operation of the chopsticks can be classified as a third-class lever system, the shorter chopsticks such as those of 180 mm length generate the largest food-pinching force. But when a person picks up food with the longer chop-

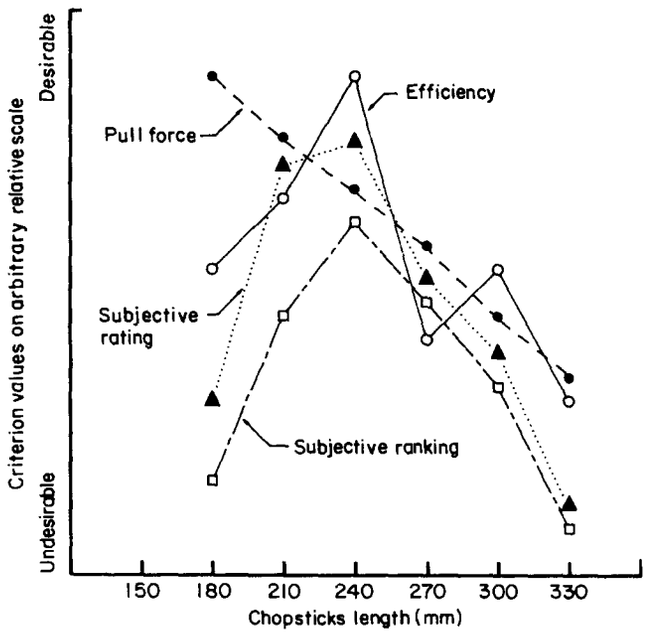

Fig. 4 Criteria values relating to the length of the chopsticks (adults). The criteria values are all converted to an arbitrary scale for comparison purposes

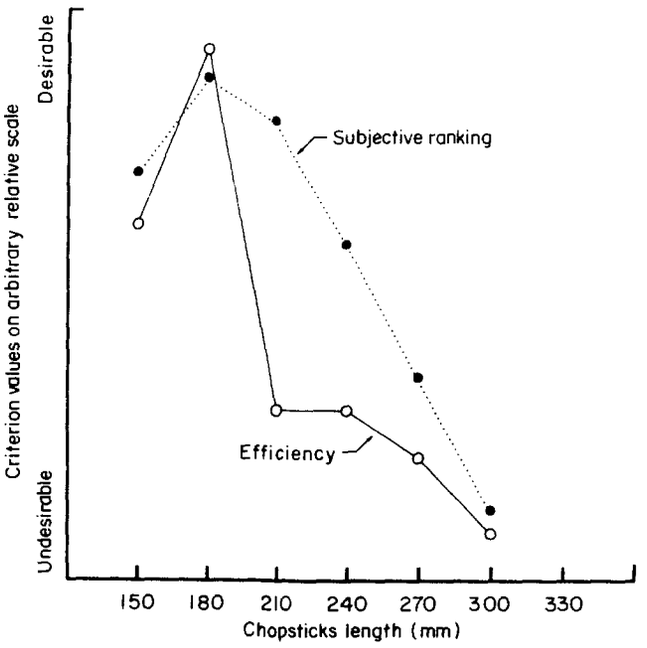

Fig. 5 Criteria values relating to the length of the chopsticks (children)

sticks, he requires greater pulling force, and may hold the chopsticks at a lower position to sustain a greater pinching force. In such a way, the chopsticks which are longer than 180 mm can be used to exert a force as much as those of 180 mm long. Furthermore, two subjective response measures all confirmed the results of the food-pinching efficiency. For this reason, we can conclude that 240 mm long chopsticks were the best for adults.

For children, it can be seen from Fig. 5 that for both criteria 180 mm long chopsticks were best. Because the hand sizes and strengths of the children were smaller than those of adults, the chopsticks they preferred were, understandably, shorter than those preferred by adults.

Conclusions

In summary, this research evaluated the effects of the length of chopsticks on the food-serving performance of adults and children. The following major conclusions were drawn as a result of this study:

1. The length of chopsticks had a significant effect on food-pinching efficiency. Both the shorter and the longer chopsticks were inferior to those chopsticks of middle length. The chopsticks about 240 mm long were the optimal for adults, and those about 180 mm long were the optimal for children.
2. The length of the chopsticks also had a significant effect on the food-pinching force. The shorter the chopsticks, the stronger the pulling force. This result verified that the operation of the chopsticks can be classified as third-class levers.
3. Subjective rating and ranking measures confirmed food-pinching efficiency measures. When a person picks up food with the longer chopsticks, he may hold the chopsticks at a lower position to obtain a greater pulling force. Thus the food-pinching efficiency was a reliable predictor for determining the optimal length of the chopsticks.

Recommendations

The following recommendations are made:

1. Since the operation of the chopsticks is more difficult for novices than many other hand tools, it is suggested that families with children should provide chopsticks both 240 and 180 mm long.
2. Longer chopsticks cost more than shorter ones. Adults and children ranked the 210 mm long chopsticks second. Thus, in considering the trade-offs between cost and ergonomics, restaurants can provide 210 mm long chopsticks for both adults and children.
3. Aforementioned suggestions are suitable for Oriental peoples. Nevertheless, it is necessary to verify if the conclusions could generalise to Occidental peoples.

Finally, it is recommended that future research should take into account the effects of shape, diameter, weight and material of the chopsticks.

Acknowledgements

The authors wish to acknowledge the support of Prof Manlai You (Mingchi Institute of Technology, Taiwan) and Prof C.F. Chi (National Taiwan Institute of Technology) for this research.

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