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# THE EFFECTIVENESS OF AN ELEMENTARY SCHOOL CHAIR DESIGN TO ENSURE EASE OF MOBILITY

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## ABSTRACT

The aim of this study was to evaluate the effectiveness of Indonesian elementary school chair modification and to determine the proper holding position when transporting chairs during class activities for children aged 6–8 years old. Participants included 14 healthy, right-handed Indonesian and Japanese children. The effectiveness of the modification was examined by comparing the original chair (OR) and modified chairs (MD), first in the lower (LHP) and second in the higher (HHP) holding positions using three measurements, namely task time, using an electromyography (EMG) technique while carrying a chair, and measuring success rates for proper lifting and turning a chair methods. The use of the chair (MD and LHP) significantly reduced task time and significantly decreased the activity of the middle fiber of the deltoid muscle. However, for lifting and turning a chair onto a desk, these strategies did not eliminate the influence of excessive chair weight and discouraged easy task completion.

*Keywords:* Chair transport; Elementary school children; Proper holding position; School chair modification

## 1. INTRODUCTION

An earlier study showed that the weight of an Indonesian elementary school chair was not appropriate to a particular children's ages; thus, decreasing the weight of Indonesian elementary school chair was recommended to encourage dynamic class activities (Purwaningrum et al., 2015). That study mentioned that in some developing countries such as Nigeria, Malaysia, and Vietnam, the weight of school furniture was similar to that in Indonesia. However, conventional school furniture producers in Indonesia are having difficulty in producing lightweight furniture by using strong and durable materials under good quality control. Alternative strategies to improve ease of transport of chairs in Indonesian elementary schools without decreasing weight have been proposed (Purwaningrum et al., 2017). One of the recommendations is the modification of parts that are usually grasped when children carry, lift, and turn the chair. The modification should also take into account that some of the parts are too thick for children's grip and the chairs' corners are too sharp. To minimize the burden of carrying the load and to provide comfortable handling, previous studies recommended that the load should have handles

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(Jung & Jung, 2003), that sharp corners and edges should be eliminated (Mital & Okolie, 1982), and that the size or diameter should fit the user's grip (Grant et al., 1992; Kong & Lowe, 2005). Accordingly, with the chairs' parts serving as carrying handles, they should be modified using rounded corners and sizes appropriate for children's grip.

Furthermore, the popular holding position, as found in our previous study (Purwaningrum et al., 2017), indicates two possible positions of a child's right hand (in Parts A and B) (Figure 1). Previous studies indicated that the muscle activities of the upper arm significantly affect upper arm positions during the holding positions (Alpert et al., 2000; Sigholm et al., 1983; Yasojima et al., 2008). Using electromyography (EMG), a study of scapular plane abduction with varied loads in hand was conducted, Yasojima et al. (2000) and Alpert et al. (2000) have found that rotator cuff and deltoid muscle activities were influenced by increasing loads and angles of shoulder abduction during this kind of experiment. According to Sigholm et al. (1983), in an activity that needs precision of hand positions, combined with carrying load, the effect of the arm position while having the load in hand is important, and they recommended that the arm should be close to the body during the activity. Proper upper limb position in carrying, lifting, and turning a chair is needed to improve ease of chair transport. This action is particularly difficult if the chair is too heavy for children; however this experiment only concerned the shape of the chair, neither the weight or materials were part of this research.


Figure 1 Main method (left); and popular holding position with grasping pattern when carrying a chair (right)

The encircled areas (Parts A, B, and J) indicate the parts of the chair that are usually grasped by children. Thus, carrying, lifting, and turning of elementary school chairs can be made easier by modifying the shape of the chair based on proper holding position. The aim of the present study was to evaluate the effectiveness of shape modification of chairs in Indonesian elementary schools in order to provide the proper holding position when carrying a chair, lifting and turning it onto a desk for children aged 6-8 years old. After modifying the chair for carrying, lifting, and turning in the previous study (Purwaningrum et al., 2017), this study examined their effectiveness by comparing original (Chair-OR) and modified chairs (Chair-MD) using three measurements, namely task time, electromyogram (EMG) while carrying a chair, and success rates for lifting and turning a chair.

## 2. METHODOLOGY

### 2.1. Participants

This study included 14 healthy, right-handed Indonesian (n = 8) and Japanese (n = 6) children (7 boys and 7 girls), aged 6, 7, and 8 years, which correspond to the first, second, and third grades of elementary school. Participant data were as follows (mean ± standard deviation): age, 6.7±0.8 years; height, 119.3±23.1 cm; weight, 21.9±3.1 kg; grip strength, 7.8±1.6 kgf; hand length (wrist to middle finger), 12.9±4.0 cm; grip inside diameter (diameter from the thumb to the middle finger), 28.0±3.0 mm. The Ethics Committee of the Faculty of Design, Kyushu University, Japan, approved this study (approval number 125).

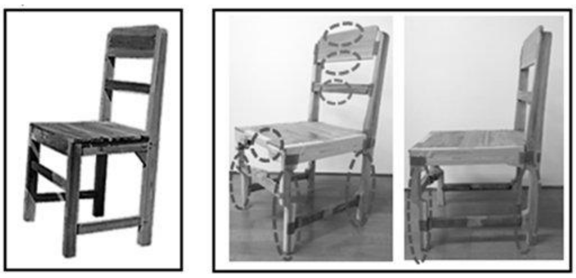
## 2.2. Furniture Types

Representative furniture from Indonesian and Japanese public elementary schools were used as the main equipment in this experiment, including one Indonesian chair, two Japanese chairs, and one Japanese desk.

Two chairs, Chair–OR and Chair–MD, were examined in this experiment to evaluate the effectiveness of chair modification. Chair–OR, the same chair used in previous studies (Purwaningrum et al., 2015; Purwaningrum et al., 2017), is the typical chair used in most public elementary schools in Indonesia (dimension, 400×400×420 mm, width×depth×seat height; weight, 5.0 kg) (Ministry of National Education of Republic of Indonesia, 2007; Purwaningrum et al., 2011; Rosyidi et al., 2014). The weight (5 kg) was the lowest in the weight range of elementary school chairs, based on a pilot study of chair weight in 11 public Indonesian elementary schools (Rosyidi et al., 2014). The seat height of the chair was the usual height adopted in Indonesian elementary schools (Ministry of National Education of Republic of Indonesia, 2007; Purwaningrum et al., 2011; Rosyidi et al., 2014).

Chair–MD was a Chair–OR adjusted by: (1) cutting its holding part and curving off its sharp corners, based on the popular grasping pattern revealed in the previous studies (Purwaningrum et al., 2017). Figure 2 displays the modified parts of the chair, which included the modification of the front seat and legs based on the size of the children's grip and rounded edges (Figure 2, shape of the chair's legs and front seat); and (2) curving the edge of the main and middle backrests (Figure 2, shape of the chair's back).

The weight of Chair–OR was maintained in Chair–MD, despite the removed parts, by attaching an additional weight that is equal to the lost weight to a hidden part of Chair–MD.



Original Chair (Chair–OR) Modified Chair (Chair–MD)

Figure 2 Details of the modified elementary school chair. The feet and front seat became smaller and curvy and the back became curvy

A desk with a height 580 mm was used in this study, which is appropriate for the participants in this experiment (age, 6-8 years; height, 131-144 cm) and meets ISO 5970 (ISO, 1979).

## 2.3. Experimental Conditions

The participants in the present study performed the tasks of carrying the two chair types (Chair–OR and Chair–MD) and lifting and turning a chair onto a desk using two holding positions: a higher holding position (HHP) and a lower holding position (LHP). The holding positions were derived from two popular holding positions in our previous study (Purwaningrum et al., 2017), which indicated two popular grasping patterns, AJ (the right hand grasp Part A and the left hand grasp Part J) and BJ (the right hand grasp Part B and the left hand grasp Part J).

However, a study of furniture types used by elementary school children (Purwaningrum et al., 2015) indicated that the weight and dimension of elementary school chairs in Indonesia are too heavy and oversized for younger children. Consequently, the position of the right hand in Part

A, which is the part usually grasped, is critical. From the biomechanical point of view, grasping Part A is riskier for children when carrying a heavy and oversized chair because they would need to abduct their shoulder over 90° to grasp that part, which is not recommended (Sigholm et al., 1983). Moreover, the down-facing direction of the hand while grasping the heavy chair can lead to the loosening of grasp and thus dropping chair. This study discarded Part A and recommended that Part B should be grasped instead to eliminate the constraints. Alternatively, Part O was used as an additional part to grasp. The children can grasp Part O in the same direction as Part B, when the hand is facing up. Moreover, in our previous study (Purwaningrum et al., 2017), the children grasped Part O when carrying a chair.

In summary, the present study used two holding positions modified from the holding position in our previous study (Purwaningrum et al., 2017). The first was HHP of the right upper arm which was used the grasping pattern BJ, wherein the right and left hand each grasped Parts B and J, respectively, and had a higher position in the right upperarm. The second was LHP, which used the grasping pattern OJ, wherein the right and left hand each grasped Parts O and J, respectively, and had a lower position in the right upper arm.

Furthermore, according to our previous study (Purwaningrum et al., 2017), lifting and turning a chair involved two steps. In the first step, while lifting the chair, HHP was adopted, which was the same position used in carrying the chair. In the second step, when turning the chair onto the desk, the right or left hand each grasped the chair legs (Parts K, L, M, or N; Figure 3).

Figure 3 The method of carrying a chair using two holding positions of right upper limb: (1) higher holding position (left): shoulder abducted 60°-90° and neutrally rotated, elbow flexed at 45°-90°; (2) lower holding position (right): shoulder abducted 30°-60° and neutrally rotated, elbow flexed at 45°-60°

### 2.4. Experimental Procedures

The experiment was conducted for 6 days in August to September 2014 in a large and flat experimental room of the Faculty of Design, Kyushu University, under temperate conditions. To compare the differences between Chair−OR and Chair−MD, the following tasks were performed by the participants: (1) carrying a chair; and (2) turning and lifting a chair onto a desk.

For each task, all participants practiced before the actual experiment. A brief instruction was given to help them perform the protocol completely. To prevent injury, they used nonslip shoes and gloves. An adult assistant accompanied them for safety and told them when to stop if they were in a dangerous situation and if the condition looked impossible to continue. After finishing each task, participants were asked about conditions, such as pain, fatigue, lack of motivation, etc. to anticipate task difficulty.

In the task of carrying a chair, participants brought Chair−OR and Chair−MD from the start to the finish line (distance, 5 m) using the recommended carrying method (Purwaningrum et al., 2017), which was carrying the chair in front of the child's body with two hands on two parts of the chair and with the chair oriented laterally (Figure 3). Then, according to the above experimental conditions, the participants carrying Chair–OR and Chair–MD used two holding positions in random order (Figure 3).

In the tasks of lifting and turning a chair upside down, the present study adopted the recommended carrying method (Purwaningrum et al., 2017), which was carrying the chair in front of the child's body with two hands on two parts of the chair and the chair oriented laterally, using two popular holding positions (HHP and LHP). The holding positions and grasping patterns were defined according to the above experimental conditions. Participants used two steps to turn and lift the Chair–OR and Chair–MD upside down in a random order.

### 2.5. Measurements

In the task of carrying a chair, three methods were used to measure task time. First, a manual stopwatch measured the real time of the task. Second, the task time was measured by a frame-by-frame playback of movies that were recorded by a digital video camera (HC-V 300 M; Panasonic, Tokyo, Japan). Third, to monitor the chair movement, a pressure sensor (S120, PH-463; diameter, 12 mm, thickness, 0.5 mm; Nihon Kohden, Tokyo, Japan) was attached to the bottom of one chair leg. The output of the sensor was monitored by a computer. The task period was defined as the time point when one chair leg bottom was raised off the floor to the time point when the chair touched the floor. The combination of the three methods was used to ensure accurate time measurement.

Furthermore, surface EMG was measured using a multichannel telemetry system (WEB-7000; Nihon Kohden, Tokyo, Japan). EMG electrodes (ZB-150H; Nihon Kohden, Tokyo, Japan) were attached to six muscles of the right and left arms, which were the middle fibers of the deltoid (DMF), biceps brachii (BB), and finger flexors (FF). EMG data used a sampling frequency of 1 kHz with low-cut filtering at 15 Hz. The WEB 1000/7000 application program (QP-700H; Nihon Kohden, Tokyo, Japan) recorded the EMG data synchronized with the pressure sensor.

After the skin was cleaned with alcohol, electrodes were placed on the skin surface of the selected muscles according to the previous studies (Basmajian & Blumenstein, 1980; Criswell, 2010; Ervilha, 2012).

Before the task, a test of maximum voluntary contraction (MVC) was conducted for the normalization of EMG activity. Participants performed an MVC against static resistance of each muscle for 3 sec. The MVC of the six muscles was according to previous studies and handbook tests (Herberts et al., 1980; National Institute of Advanced Industrial Science and Technology, 2014; Research Institute of Human Engineering for Quality Life, 2010). After the completion of the MVC test, the EMG measurement of task was undertaken.

The signals of EMG were rectified and averaged across the data collection period, which was from the start to the end of the task. For each participant, the mean EMG data of each muscle were normalized relative to the mean MVC EMG data, namely the percentage of EMG (% EMG).

In the task of lifting and turning a chair, the criteria of success and unsuccessful task completion were the same as the criteria used in the lifting and turning of a chair in the study of Purwaningrum et al. (2015). A task was considered successful if the task was completed without dropping the chair or stopping, and unsuccessful if the chair is dropped or the task was stopped.

### 2.6. Statistical Analysis

IBM SPSS Version 21.0 (2012) for Windows was used to perform statistical analysis. A repeated–measure using a two-way analysis of variance (ANOVA) examined the effects of two types of the chairs and two holding positions on task time and EMG activities. The success rates between chair types and between carrying patterns for the lifting and turning task were compared using Fisher's exact test (Field, 2013; Sheskin, 2004). The level of significance was set at $p < 0.05$.

# 3. RESULTS

## 3.1. Carrying a Chair

All participants (n = 14) completed four tasks: Carrying the Chair–OR using HHP (Chair-OR_HHP), Carrying the Chair–OR using LHP (Chair–OR_LHP), Carrying the Chair–MD using HHP (Chair–MD_HHP), and Carrying the Chair–MD using LHP (Chair–MD_LHP) (task time, mean±SD: Chair-OR_HHP, 7.9±1.3 sec; Chair-OR_LHP, 7.8±1.0 sec; Chair–MD_HHP, 7.5±1.3 sec; Chair–MD_LHP, 7.1±1.1 sec). Repeated–measures of a two–way ANOVA showed significant effects of chair types and holding positions ($p < 0.05$). Figure 4 displays the task time comparison of carrying a chair. The task time of Chair–MD was significantly shorter than that of Chair–OR, and the task time of LHP was significantly shorter than that of HHP ($p < 0.05$).

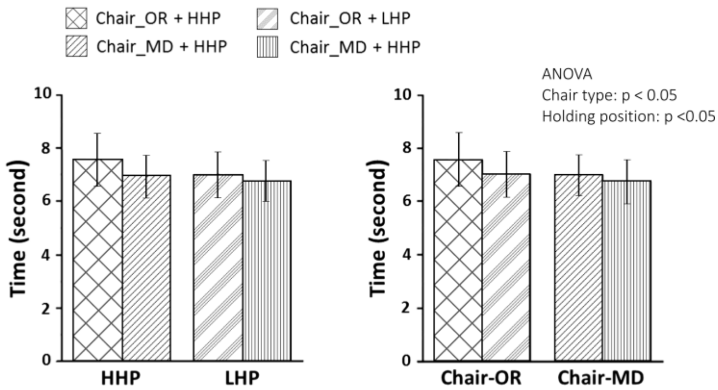



Figure 4 Task time comparison of carrying a chair: The effects of (left) two chair types (Chair-OR and Chair-MD) and (right) two holding positions (HHP and LHP) on task time

Table 1 displays the result of the % EMG of each muscle when carrying a chair. ANOVA showed that only the right DMF has a significant effect on % EMG (Table 2). Figure 5 displays the % EMG of the DMF when comparing both holding positions. The % EMG of the DMF when using Chair-MD was significantly lower than that when using Chair–OR ($p < 0.05$). In both chair types, the % EMG of the DMF using LHP was significantly lower than that when using HHP ($p < 0.05$).

Table 1 % EMG when carrying a chair using two chair types and two holding positions (mean±SD)

| Side | Muscle | N | Chair-OR HHP (M ± SD) | Chair-OR LHP (M ± SD) | Chair-MD HHP (M ± SD) | Chair-MD LHP (M ± SD) |
|---|---|---|---|---|---|---|
| Right | DMF | 7 | 41.3 ± 24.1 | 28.0 ± 18.7 | 34.1 ± 22.8 | 25.1 ± 19.3 |
| | BB | 7 | 41.3 ± 25.5 | 55.4 ± 39.8 | 47.5 ± 28.9 | 55.7 ± 26.6 |
| | FF | 7 | 71.4 ± 36.3 | 73.1 ± 34.1 | 78.8 ± 49.2 | 79.3 ± 46.1 |
| Left | DMF | 6 | 9.8 ± 6.4 | 12.5 ± 9.6 | 11.1 ± 9.4 | 14.3 ± 11.3 |
| | BB | 4 | 59.4 ± 15.0 | 52.7 ± 15.6 | 56.9 ± 11.6 | 57.4 ± 5.0 |
| | FF | 7 | 44.7 ± 26.4 | 63.4 ± 42.0 | 55.2 ± 50.7 | 60.6 ± 44.5 |

DMF: deltoid middle fiber; BB: bicep brachi; FF: finger flexor

Table 2 Result of repeated-measures two-way ANOVA of muscle activities in carrying a chair using two chair types and two holding positions (mean±SD)

| Effect | Right side | | | Left side | | |
|---|---|---|---|---|---|---|
| | DMF | BB | FF | DMF | BB | FF |
| Chair type | F = 6.56<br>P < 0.05 | n.s | n.s | n.s | n.s | n.s |
| Holding position | F = 5.27<br>P < 0.05 | n.s | n.s | n.s | n.s | n.s |
| Interaction | n.s | n.s | n.s | n.s | n.s | n.s |

DMF: deltoid middle fiber; BB: bicep brachii; FF: finger flexor; n.s: not significance

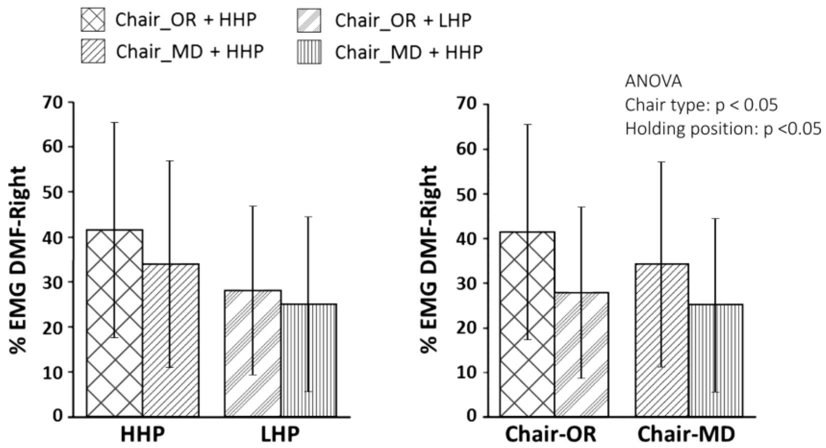



Figure 5 Effects of chair types and holding positions on the % EMG of the right deltoid middle fiber (right DMF) activity when carrying a chair

### 3.2. Lifting and Turning a Chair

Table 3 shows the success rate (percentage) of the participants in lifting and turning a chair in all conditions. Participants ages 6 and 7 years old did not succeed in any chair type or holding positions. In contrast, participants almost 8 years old could lift and turn the chair successfully (success rate, 67%). In the Fisher exact test, lifting and turning by all participants in all conditions (between Chair-OR and Chair-MD or between HHP and LLP) did not reveal any significant difference in success rate (p = 1.00).

Table 3 The number of successful lifting and turning of a chair

| Age (years) | N | Chair-OR (N) | | Chair-MD (N) | |
|---|---|---|---|---|---|
| | | HHP | LHP | HHP | LHP |
| Chair type | 6 | 0 | 0 | 0 | 0 |
| Holding position | 5 | 0 | 0 | 0 | 0 |
| Interaction | 3 | 2 | 2 | 2 | 2 |
| Total | 14 | 2 | 2 | 2 | 2 |

## 4. DISCUSSION

### 4.1. Carrying a Chair

Modifying the parts that are popularly grasped by children was recommended to ease the task of carrying of an Indonesia elementary school chair without decreasing its weight (Purwaningrum et al., 2017). First, a curved edge was adopted on Parts B and O, which are at the bottom of the main backrest and the middle backrest of the chair, respectively. Second, a curved edge and a smaller size were adopted for Part J (bottom of the front seat). Curving the sharp edge of the

Chair-OR was done to improve comfort and safer handling of the chair by children. Furthermore, the diameter of Chair-MD was based on the inside grip diameter of the children who participated in this research (average, ≤25 mm). Even though children could not fully grasp Part J due to the direct mounting on the chair's seat, the decrease in size was expected to be comfortable when the chair was carried.

A positive result was achieved in the present study, that is, the task time of carrying Chair-MD was statistically significantly faster than that of carrying Chair-OR. It indicates that the modifications made the chair more satisfactory for children and carrying the chair became easier for them. The curved shape of Chair-MD in this study was close to the cylindrical shape preferred during carrying activity, as recommended by Mital and Okolie (1982). Drury (1980) also recommended the elimination of sharp corners, edges, ridges, and finger grooves to reduce excessive loading. Accordingly, even though the weight of Chair-MD was the same as that of Chair-OR, the curved edge encouraged the children to grasp the chair's parts easily and comfortably and to continue walking and carrying the chair with a better balanced posture, which indicates that the task time could be shortened by shape modification.

The result showed that modifying Parts B and O significantly decreased the % EMG of the right DMF. The lower muscle activities indicated a lower burden placed on muscle for comfortable handling (Sigholm et al., 1983), whereas, according to previous studies (Roman-Liu et al., 2001; Sigholm et al., 1983; Sporrong, 1995; Yasojima et al., 2008), the lower burden placed on the DMF was strongly affected by the angle of shoulder abduction. Furthermore, the results of a previous study (Sigholm et al., 1983) showed that increasing the load in the hand could increase the activity of the deltoid. This can be attributed to the increase in the torque of the glenohumeral joint (Sharkey et al., 1994) due to the increasing load in the hand, which acts as a stabilizer of the complex shoulder joint (Sigholm et al., 1983). This can induce shoulder abduction and increased DMF activity. Accordingly, in the present study, decreasing right DMF activity by curving Parts B and O leads to the reduction of the excessive weight of the chair as a compensation for the decrease in the angle of abduction due to decreasing torque of the glenohumeral joint. Thus, this study shows that the comfortable handling brought about by the curved edge compensates for the excessive weight.

In addition, modifying the shape significantly influenced the % EMG of the right DMF, but not that of the left side. It may be caused by the position of the right hand on the chair, which was higher than the left hand, in the carrying activities. Consequently, participants tend to abduct the right shoulder rather than the left shoulder, and the left hand was more relaxed.

The results of the present study showed that the task time of carrying a chair using LHP was significantly faster than using HHP, i.e., the time for completing the task became faster, owing to high upper limb position. It can be explained by the finding that the higher position of the children's upper limb on a chair led to greater arm abduction, which in turn led to greater muscle activity and force (Mital & Okolie, 1982; Sharkey et al., 1994). Consequently, with the higher burden of carrying a load, walking effort became higher as well and task time became longer because of the need to maintain stability. In addition, early studies reported that a significant interaction between speed and load height position when carrying a heavier load (Anderson et al., 2007) and a higher load position on the body led to longer time for carrying a load (Mital & Okolie, 1982; Snook & Ciriello, 1991). Thus, the decreasing the burden of the load in carrying a chair using the lower position of upper limb would shorten task time.

The effect of the right LHP, wherein the right hand is grasping Part O, is same as the effect of shape modification, which significantly decreased the % EMG of the right DMF. Although the increase in muscle activity in the shoulder was influenced by the increased weight in the hand (Sigholm et al., 1983), the lower position of the upper limb with the same load in the hand significantly decreased the activity of the DMF muscles as a lifter muscle (Sigholm et al., 1983; Yasojima et al., 2008). Thus, decreasing the burden of this muscle is indicated (Sigholm et al., 1983). Work in the lower upper limb decreases the torque of the glenohumeral joint and leads to the abduction and decrease of its main function, owing to the rotator cuff muscles acting as stabilizer of the shoulder joint, thus possibly increasing its stabilization with increasing hand activity (Anderson et al., 2007; Kronberg et al., 1990; Sharkey et al., 1994; Sigholm et al., 1983). Decreasing the activity of the DMF muscles also prevents overloading (Sigholm et al., 1983). In addition, to reducing the risk due to overloading in the shoulder muscles, working with the hand above the shoulder level is not recommended (Chaffin, 1973; Herberts et al., 1980). It can be derived from the present study that it is safer for children to carry a chair by grasping Part O, which usually places strain on the lower shoulder muscle, thus minimizing the excessive weight of the chair.

### 4.2. Lifting and Turning a Chair onto a Desk

To encourage comfort when grasping a chair and to improve the ease of transport of the chair, two strategies were adopted in the task of lifting and turning elementary school chairs: first was modifying the part of the chair usually grasped to a curved rectangle edge (Drury, 1980; Mital & Okolie, 1982) and the second was adapting the diameter to suit the average grasp of the children (Grant et al., 1992; Kong & Lowe, 2005). According to the National Institute of Advanced Industrial Science and Technology (2014), the ratio of mean adult hand length to its grip inside diameter (182.6–44.4 mm) is 4.11. Using this ratio, the grip inside diameter in children with mean age of 7 years and mean hand length of 126 mm (Research Institute of Human Engineering for Quality Life, 2010) is 30.7 mm. The diameters of Parts K, L, M, and N, which were adapted to the grip inside diameter of the participants (≤ 25 mm), were smaller than the above calculations. Second, an LHP of the first step was adopted to decrease the burden of the heavy chair (Sigholm et al., 1983). However, the children were unsuccessful in completing the task despite adopting proper shape and holding positions, indicating that those strategies did not encourage the children in lifting and turning a chair.

The heavy weight might be the main reason why the children were discouraged from completing the task. It can be explained by the fact that when turning a chair, the child’s hands grasped Parts K, L, M, or N (the leg of the chair), which were upside down, and then lifted up those legs before putting the chair’s seat, which is opposite to the legs, onto the desk. This condition induced a higher angle of abduction in the upper limbs of the children, which would be located above the shoulder level. According to previous studies (Sigholm et al., 1983; Yasojima et al., 2008), lifting heavy weight using the higher-angle abduction could significantly increase the burden of stress and strain on the muscle. The torque of the glenohumeral joint would be increased because of effect of the load on the higher part of the arms (Inman & Abbott, 1996; Kronberg et al., 1990; Sharkey et al., 1994; Sigholm et al., 1983). Moreover, working with the hand above the shoulder level is risky because of the excessive load on the shoulder muscles (Chaffin, 1973; Herberts et al., 1980). Accordingly, a comfortable grasp and a proper holding position on the chair did not counter the heavy chair weight and its additional muscle burden.

### 4.3. Limitation and Future Research Priorities

The result of the present study provides alternative solutions in reducing the burden of carrying heavy chairs in children ages 6–8 years old without decreasing the weight. However, the participants involved in the present study are very few. The body sway of the children when walking during the completion of the task, for instance, can cause inaccurate measurement and contribute to the noise factor in the EMG result, which possibly affected the accuracy of the EMG results. Because of these limitations, this study failed to determine the effectiveness of carrying a Chair−MD using the FF and FB muscles in proper holding positions. Thus, it is necessary to add more participants and isolate the problems related to EMG measurement.

## 5. CONCLUSION

Two effective methods adopted include: (1) modifying the shape of the popular grasping pattern with a curved rectangle edge and based on the size of children's grasp; and (2) carrying a chair in the LHP or below the shoulder level, which makes it easier for children to carry chairs.

## 6. ACKNOWLEDGEMENT

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