Journal of Accessibility and Design for All

Volume 12, Issue 2. (CC) JACCES, 2022. ISSN: 2013-7087

LEFT-HANDEDNESS AND MUSCULOSKELETAL DISCOMFORT IN STUDENTS

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Received: 2020-08-16 | Accepted: 2022-11-21 | Published: 2022-11-30

***Abstract*:** School furniture design is based on the right-handed population since left-handedness is uncommon. In the classroom, left-handed students are forced to use the chair that was designed for the right-handed. The awkward posture caused by the improper chair may contribute to musculoskeletal discomfort. This study aimed to evaluate the benefit of using an ambidextrous chair to accommodate left-handed students. Nordic Musculoskeletal Questionnaire was given to 14 subjects to identify their health problems related to the chair in the classroom. The NMQ showed that students often perform awkward postures and experience pain afterwards. To validate the ambidextrous chair, the subjects were asked to perform writing while sitting on both the existing and modified chairs. Then, the angles of lateral flexion of their neck and lower back from upright sitting posture were compared. Paired t-test evaluation showed that the ambidextrous chair reduced lateral flexion. Developing proper school furniture based on user-centred design can increase the comfort of the students. However, it may be costly and too specific for general use.

Keywords: design, left-handed, Nordic musculoskeletal questionnaire, musculoskeletal discomfort, ambidextrous chair.

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Introduction

Musculoskeletal discomfort (MSD) is a common health problem in modern society (Albers & Estill, 2007). Symptoms of MSD include pain, aching, discomfort, numbness, tingling, and swelling that usually occur in the back, shoulders, neck, legs, wrists, fingers, elbows, and arms. Previous studies suggested that prolonged static sitting is associated with an increased risk of developing MSD in the back, neck, shoulders, arms, and legs (Naqvi, 1994; Winkel & Jorgensen, 1986).

Students spend much time in the classroom and sit in a static posture (Murphy et al., 2003; Dianat et al., 2013). Therefore, they are at risk of various factors associated with a long-term sedentary position and poor and static postures (Dianat et al., 2013). Prolonged sitting might cause MSD in the buttock and low back regions (Sondergaard et al., 2010). The discomfort from prolonged sitting is attributed to muscle fatigue from sustained contraction of back muscles during sitting (Hosea et al., 1986). Awkward postures during prolonged sitting increase the prevalence of MSD in students (Allegri et al., 2016). Previous studies found that neck and low back pain are common problems for students in the classroom (Whittfield et al., 2001; Trevelyan & Legg, 2003). In addition to physical discomfort, awkward body posture may cause students to lose interest in participating in the classroom regardless of how interesting the teaching material is (Hira, 1980).

The most significant cause that contributes to MSD in left-handed students is the usage of improper school furniture that is designed for right-handed students (Flatt, 1999). The chair in the classroom may be designed poorly, that in the end, would cause low back pain. Postures with prolonged flexion will cause the soft tissue to aggravate the backbones which will lead to low back pain (Allegri et al., 2016). Regardless of the handedness, bad posture will cause low back pain. Since the chairs in the classroom are designed for right-handed students, the impact of bad posture will be even more significant for left-handed students. Thus, the left-handed students have to adjust their body posture to write on the table, which may cause discomfort in the neck and back. The common chair forces left-handed students to adjust their posture to reach the table when they try to write. It may lead to MSD because they

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spend most of their time in the classroom sitting with static and unchanged postures (Murphy et al., 2003).

Given the above, we have developed an ambidextrous chair suitable for both right-handed and left-handed students. This study aimed to evaluate the impact of using an ambidextrous chair for left-handed students. With this chair, left-handed students do not need to adjust their sitting posture in the classroom. Herein, we report the MSD evaluation on left-handed students, details of the chair design, evaluation of the proposed chair compared to the typical chair in the classroom, and students' feedback regarding their experience using the chair. The ambidextrous chair could be an alternative for schools to enhance left-handed students' learning activities by helping them minimise musculoskeletal discomfort due to improper school furniture.

Methodology

Participants

A total of 14 left-handed Indonesian students (21.64 ± 1.67 years) with a height of 163.7 ± 4.85 centimetres and a weight of 63.98 ± 11.3 kilograms were recruited in this study. The subjects were free of neurological disorders based on self-report, and informed consent forms were signed before participation. The subjects were asked to fill out the Nordic Musculoskeletal Questionnaire (NMQ) for a screening of MSD symptoms (Dickinson et al., 1992). We wanted to examine whether left-handed students experienced any MSD symptoms. In addition, the subjects were asked to fill out personal information such as the class duration, sitting habits in the classroom, rest duration, and exercise duration per week. The purpose of this set of questions was to evaluate the factors affecting left-handed students' discomforts.

Chair Design

The design of school furniture is most likely made to accommodate the majority of the students. Thus, left-handed students, as the minority, may become frustrated and have difficulties in doing simple tasks such as sitting and writing in the classroom. User-centred design is a term used to describe a

wide range of design methods where end-users are involved in the process of creating a design (Abras et al., 2004). There are several methods to involve users in the development of a product: interviews/questionnaires, focus group discussion, direct observation, role-playing/simulations, and usability testing (Preece et al., 2002). The involvement of users in the design ensures that the product will be suitable for its intended use, and thus, the product will be safer, more effective, and more efficient. In this study, we started the design process by conducting interviews, questionnaires, and direct observation of the left-handed students while using the existing chair designed for the right-handed. There were 7 left-handed students (20±2.16 years) who participated in the preliminary study. The results of the preliminary study showed that left-handed students need to lean their bodies to the right with their neck and lower back deviated more than 40 degrees from the upright sitting posture. In addition, 6 out of 7 students experienced musculoskeletal pains in the last 7 days from the data collection date. From these findings, we devised an idea to modify the existing chair to reduce the neck and lower back deviations while writing.

The ambidextrous chair was designed based on the current chair in the classroom. As can be seen in Figure 1, the left-handed student has to adjust their body to reach the table to write. This awkward body posture might contribute to the MSD symptoms considering the duration students spend in the classroom. To overcome the discomfort of left-handed students caused by the current chair, we modified the chair to accommodate both right and left-handed students (Figure 2). For the modified chair model, an ordinary chair commonly used by Indonesian universities was selected. The chair was made adjustable due to left-handedness is not common in Indonesia. Thus, the chair can be used as usual if the student is right-handed. We did not specifically consider the chair dimensions, such as width, seat, and back angles because our purpose was to create an economical design to accommodate left-handed students. Therefore, we modified a chair already being used in the classroom. As can be seen in Figure 2, the proposed chair was designed with 3 table parts made of plywood. The table parts are connected using 2 hinges in each part with removable linkage to stabilise the table. The purpose of this design was to make sure that the table looks exactly similar when positioned on either

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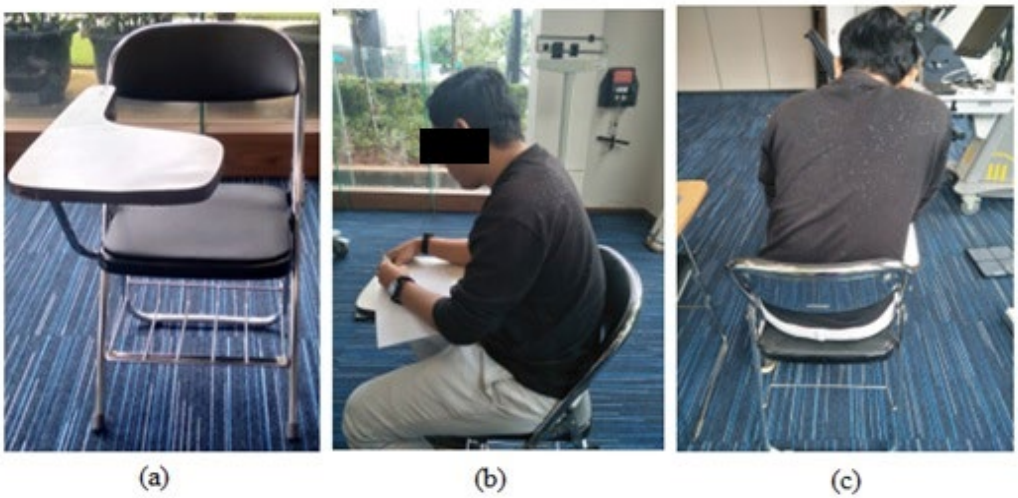
side of the chair. In order to evaluate the design, the subjects were asked to perform writing tasks for 2 minutes in both the current and proposed chairs.

Figure 1. Current chair in the classroom: (a) current chair, (b) side view, (c) back view of a left-handed student sitting



Results

Table 1 shows the significant correlation between NMQ items and subjects' personal information ($p<0.05$). From this data, it can be seen that the subjects have signs of MSD due to their habit inside and outside of the classroom. Subjects with heavier weights reported having bad sitting posture ($p=0.032$) and pain in the neck ($p=0.035$) and knees ($p=0.036$). Interestingly, the subjects with longer exercise and rest duration admitted having better sitting posture ($p=0.027$). Additionally, enough rest could reduce the problem in the neck ($p=0.013$) and pain in the wrists ($p=0.038$). Subjects with long class duration experienced pain in the neck ($p=0.01$), wrists ($p=0.026$), and lower back ($p=0.021$). Similarly, bad sitting posture caused pain in the neck ($p=0.022$). However, prolonged sitting reduced the pain in the knees. The correlation analysis also showed the relationships among the items in the NMQ questionnaire, such as the pain in the neck is related to the pain in the wrists ($p=0.015$) and the shoulder ($p=0.13$).

Figure 2. Proposed chair: (a) for right-handed students, (b) for left-handed students, (c) top view for left-handed students, (d) front view of a left-handed student sitting, (e) side view of a left-handed student sitting, (f) back view of a left-handed student sitting

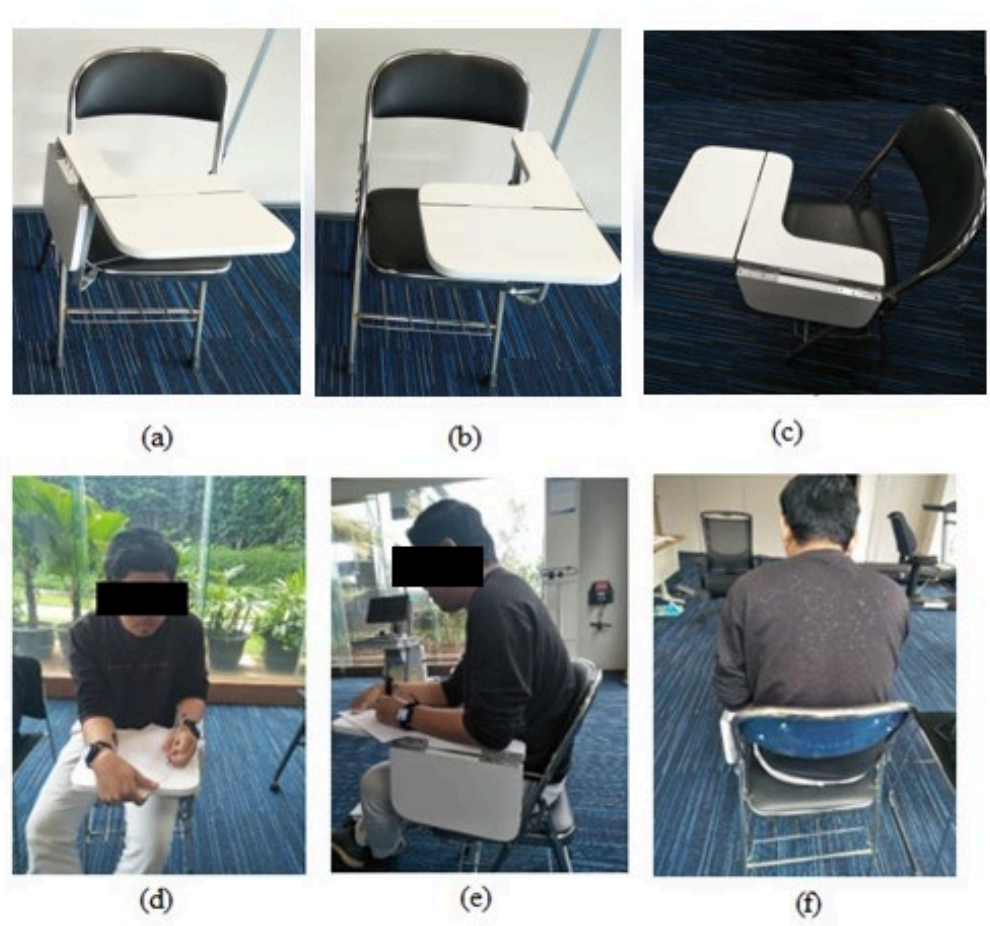


Table 1. Pairwise Pearson correlation of NMQ questionnaire

Category 1	Category 2	Correlation	p-value
Bad sitting posture	Weight	0.575	0.032
Pain in last 7 days_Neck	Weight	0.565	0.035
Pain in last 12 months_Knees	Weight	0.563	0.036
Bad sitting posture	Exercise duration	-0.589	0.027
Bad sitting posture	Enough rest	-0.603	0.022
Class duration	Enough rest	-0.591	0.026
Problem in doing activities_Neck	Enough rest	-0.645	0.013

Category 1	Category 2	Correlation	p-value
Pain in last 12 months_Wrists	Enough rest	-0.559	0.038
Pain in last 7 days_Knees	Prolonged sitting	-0.679	0.008
Pain in last 7 days_Neck	Bad sitting posture	0.603	0.022
Problem in doing activities_Neck	Class duration	0.664	0.01
Pain in last 12 months_Wrists	Class duration	0.592	0.026
Pain in last 12 months_Lower Back	Class duration	0.609	0.021
Pain in last 7 days_Wrists	Pain in last 12 months_Neck	0.632	0.015
Pain in last 7 days_Shoulder	Pain in last 7 days_Neck	0.645	0.013
Pain in last 12 months_Elbows	Problem in doing activities_Shoulder	0.548	0.043
Problem in doing activities_Elbows	Problem in doing activities_Shoulder	0.65	0.012
Problem in doing activities_Hips	Problem in doing activities_Shoulder	0.645	0.013
Problem in doing activities_Hips	Seeing doctor in last 12 months_Shoulder	0.679	0.008
Pain in last 7 days_Ankles	Pain in last 7 days_Shoulder	0.548	0.043
Pain in last 7 days_Lower Back	Pain in last 12 months_Upper Back	0.559	0.038
Pain in last 12 months_Wrists	Pain in last 12 months_Elbows	0.559	0.038

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Category 1	Category 2	Correlation	p-value
Pain in last 12 months_Knees	Pain in last 12 months_Elbows	0.548	0.043
Problem in doing activities_Hips	Pain in last 7 days_Elbows	0.782	0.001
Pain in last 7 days_Hips	Pain in last 7 days_Elbows	0.782	0.001
Pain in last 12 months_Ankles	Pain in last 7 days_Elbows	0.576	0.031
Pain in last 7 days_Wrists	Problem in doing activities_Wrists	0.632	0.015
Problem in doing activities_Hips	Problem in doing activities_Wrists	0.645	0.013
Problem in doing activities_Hips	Seeing doctor in last 12 months_Wrists	0.679	0.008
Problem in doing activities_Hips	Seeing doctor in last 12 months_Lower Back	0.679	0.008
Pain in last 7 days_Knees	Pain in last 12 months_Knees	0.645	0.013
Pain in last 7 days_Knees	Problem in doing activities_Knees	0.679	0.008

Based on the correlation analysis, the left-handed students showed signs of MSD due to improper sitting posture in the classroom. The modification of the existing chair was done to help students in minimizing this problem. To evaluate the experience of left-handed students in using the proposed chair, the degree of the neck and lower back deviation from the upright sitting posture was measured. The purpose of this measurement was to see the sitting posture improvement when the subject sits on the proposed chair. Table 2 shows the comparison between the current and proposed chair in terms of the neck and lower back degree deviation from the upright sitting posture. The proposed chair reduced the deviation significantly in both the neck ($p<0.001$) and lower back deviation ($p<0.001$).

Table 2. Neck and lower back degree deviation from the upright sitting

Parameter	Current chair	Proposed chair	p-value
Neck deviation	28.52±10.71	3.42±3.42	p<0.001
Lower back deviation	38.55±8.91	5.95±3.94	p<0.001

Discussion

MSD in left-handed students

Life is never easy for left-handers in Indonesia since everything is designed to be used for the right-handed population. Thus, they need to work harder to comprehend and remain in the classroom. One of the struggles of left-handed students is using the writing armchair designed for right-handers. In order to write, they need to adjust their bodies to reach the table on the right side of the chair. Left-handed students need to maintain this awkward body posture constantly during writing activities in the classroom. This awkward body posture in the classroom may lead to spine deformities such as thoracic hyperkyphosis (Nissinen et al., 1995) and scoliosis (Milenkovic et al., 2004).

In addition to the higher risk of spine deformities, left-handed students also are at greater risk of MSD (Murphy et al., 2003). The screening of MSD symptoms using the NMQ showed that left-handed students experienced pain in the neck, shoulder, wrists, lower back, hips, knees, and ankles in the last 7 days. These discomforts may be caused by their bad sitting posture in the classroom. As shown in Table 1, that bad sitting posture is correlated with neck pain (p=0.022). Whereas neck pain is linked to pains in the shoulder (p=0.013) and wrists (p=0.05). Neck, upper back, and lower back pains are common in students (Azuan et al., 2010). However, left-handed students may experience more musculoskeletal discomforts because they need to lean to the right in order to write due to the position of the table being on the right side of the chair. This condition forces their bodies, especially the neck,

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shoulder, and lower back, to be in an awkward position. The average lateral flexion of the neck and lower back of the left-handed students while using the existing chair were 28.52±10.71 degrees and 38.55±8.91 degrees, respectively. Past studies reported that lateral flexion of the lower back of more than 25 degrees will cause pain in the spine (Todd & Vaccaro, 2016). In addition, lower back pain is associated with upper back, neck, shoulder (Daraiseh et al., 2010), hip, and knee pains (Urits et al., 2019).

The students also reported having pain in their wrists and lower back in the last 12 months, and the Pairwise Pearson correlation analysis showed these issues were linked to the class duration. When writing on the table, left-handed students not only need to flex their bodies laterally but also need to curl their wrists. This non-neutral posture, when performed frequently, will cause discomfort. A past study found that non-neutral postures and prolonged sitting can lead to the development of MSD symptoms (O'Sullivan et al., 2012). Since the students need to be in the classroom for several hours almost every day, the sustained awkward posture of the left-handed students further enhanced the symptoms (Lis et al., 2007). In left-handed students, preventive interventions such as improving writing techniques, body posture while writing, and specially created school supplies such as school furniture might reduce spine deformities and MSD symptoms (Paul, 1994).

Modified chair

The consideration of modifying the current chair was because left-handers are the minority in Indonesia. Using the modified chair, the right-handed students are still able to use the chair. The modified chair was designed to make it possible for the writing armchair to be put on either side of the chair. We modified the chair that is frequently used at universities in Indonesia. This modification is considered more economical than preparing a special chair for left-handed students.

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Figure 3. Details of proposed chair: (a) isometric view, (b) left-side view, (c) right-side view, (d) top view, (e) isometric-bottom view, (f) bottom view

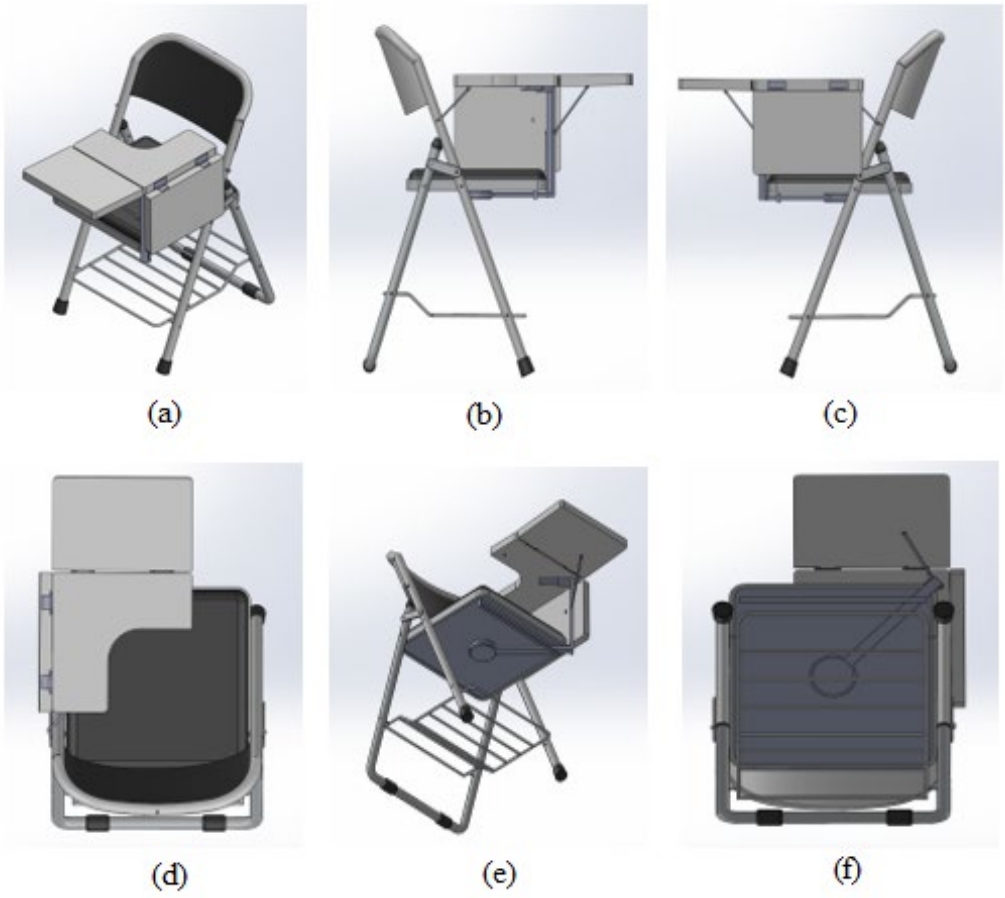

Figure 3 shows the detailed design of the chair. The table was made of high-pressure laminated plywood. It consists of 3 parts (2 parts are rectangular, and 1 part has a slope). The part with slope is the main table, while the rectangular parts are the additional tables to make writing possible. The main table and each of the additional tables are connected by 2 hinges to ensure the writing armchair will exactly look the same regardless of which side of the chair the writing armchair will be put. Depending on the user, a swivel is put under the chair to turn the table right and left. When the right-handed student uses the chair, the main table should be moved to the right side, and the rectangular part on the right side will be used. Similarly, when the left-handed student uses the chair, the main table should be positioned on the left side, and the rectangular part on the left side shall be used. To support the table, there is a linkage made of a steel bar on each side of the chair to mimic the

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function of the window stopper. When the chair is used for left-handed students, then the linkage on the left side should be used.

Based on the comparison analysis between the current and modified chairs, the results showed that the modified chair significantly reduced the deviation degree of both the neck and lower back from the upright sitting position. Furthermore, the subjects admitted that the modified chair was more convenient. They do not need to adjust their bodies to reach the writing armchair. However, some students with larger bodies felt the chair would be better with a wider seat. In order to develop an ergonomic chair for students, it is essential to measure the anthropometric data of the students, such as elbow height, buttock to popliteal length, popliteal height, and knee height (Tunay & Melemez, 2008). The development of a chair based on students' anthropometric data might be more convenient for students, but it will be more costly for the school. Furthermore, the school furniture may need to be frequently adjusted after the previous cohort of students graduated and the new cohort of students enrolled. We modified the existing chair based on our direct observation of the posture of left-handed students during the writing task. We aimed to reduce the students' lateral flexion of the neck and lower back to minimise the MSD symptoms in left-handed students. This study did not consider the anthropometric data for the chair design, considering that changing the whole design of the chair would be too costly for the school. Future studies developing the chair design using anthropometric data will be beneficial to give a better understanding of the impact of the improper chair on MSD in students. Especially if the school is willing to invest in school furniture to minimise the potential of MSD in students.User-centred design is beneficial to create safer school furniture for students, however, it is costly and takes more time to develop. In addition, the furniture could be too specific for general use. Therefore, it may not be readily transferable to the next cohort of students.

Conclusion

We modified the existing school chair widely used by the universities in Indonesia to reduce the lateral flexion of the neck and lower back of left-handed students during writing tasks. The modification was done based on the evaluation in the preliminary study. Our modified chair has shown that it could be used to help left-handed students in maintaining better body posture during the writing activity in the classroom. This modified chair was expected to reduce musculoskeletal discomfort (MSD) in left-handed students due to improper furniture in the classroom. In this study, we did not evaluate the spine deformities of the subjects. Only the MSD symptoms were evaluated. From the comparison between the existing and the modified chairs, our modified chair significantly reduced the lateral flexion of the neck and lower back of the left-handed students. However, the modified chair was developed by only considering the sitting posture of the students during observation. We did not consider students' anthropometric data in this study. Future studies developing ergonomic chairs for left-handed students with appropriate anthropometric measurements will be beneficial if cost is not an issue. The development of a user-centred design chair would greatly increase the comfort of the students, regardless of their hand preference. However, it would be very costly since the too specific design may not be able to be used for general students.

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Volume 12, Issue 2. (CC) JACCES, 2022. ISSN: 2013-7087

How to cite this article:

Nurwulan, N. R.,& Selamaj, G., (2022). Left-handedness and musculoskeletal discomfort in students, 12(2), 320-334. Journal of Accessibility and Design for All. https://doi.org/10.17411/jacces.v12i2.281

The Journal of Accessibility and Design for All, ISSN 2013-7087, is published by the Universitat Politècnica de Catalunya, Barcelona Tech, with the sponsoring of Fundación ONCE. This issue is free of charge and is available in electronic format.

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