Recommended Maximum Holding Time of Common Static Sitting Postures of Office Workers

Somayeh Tahernejad
Shiraz University of Medical Sciences
Mohsen Razeghi
Shiraz University of Medical Sciences
Mohammad Abdoli-Eramaki
Ryerson University
Hossein Parsaei
Shiraz University of Medical Sciences
Mozhgan Seif
Shiraz University of Medical Sciences
Alireza Choobineh (alrchoobin@sums.ac.ir)
Shiraz University of Medical Sciences

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Abstract

Purpose: A posture maintained for a prolonged period can be harmful to the health of office workers. This study aimed to estimate the recommended ergonomic duration for maintaining different sitting postures.

Materials and Methods: Forty healthy male and female students participated in this experiment designed to measure perceived discomforts caused by the maintained common static sitting postures of office workers in a simple ergonomic set up for 4 minutes. The Borg CR10 scale was given to the participants to assess the discomfort in different body parts, before and after each experiment. Based on the mean group discomfort level of 2, the recommended holding time of each posture was estimated.

Results: The recommended holding time and its discomfort score for each studied posture was tabulated. The moderate neck flexion had the highest score of discomfort among different neck postures with recommended MHT of 1.61 minutes. The lowest discomfort score was obtained for neutral neck posture (recommended MHT = 2.37 min). The moderate forward trunk inclination (30°) showed the highest discomfort score with MHT of 1.78 minutes among different trunk postures. The lowest discomfort score was obtained for the backward trunk position (back supported) with recommended MHT of 5.92 minutes. Among the most common knee postures, while working at the workstation, the lowest discomfort score was obtained for the knee flexed about 90 degrees, with the recommended MHT of 5 minutes. The lower limbs position with crossing one leg over the other (leg crossing) received the highest discomfort score (recommended MHT = 1.88 min).

Conclusions: The recommended holding time in this study may help assess the risk of MSDs in office work and training proper sitting behavior to individuals involved in office tasks.

1. Introduction

Musculoskeletal disorders (MSDs) are a critical health problem among office workers (1). Some studies have shown that 20–60% of office workers suffer from MSDs (2). Office workers are a large occupational group vulnerable to musculoskeletal disorders (MSDs) due to prolonged sitting (3). Poor sitting behavior with various pains and other complications can cause a threat to human health (4). Consequently, to prevent health problems, mainly to prevent MSDs in office workers, the sitting behavior has to be improved (5).

In studies that have been conducted to reduce the side effects of sitting work, some efforts have been made to minimize sitting duration or improve sitting posture. Two systematic reviews of interventions to reduce sitting time using active workstations found insufficient evidence to support these workstations' effectiveness, particularly for workers' long-term behavior change (6, 7). Although the occupational sitting duration can be reduced to some extent, the workers in many jobs have to spend a lot of time sitting. To improve the sitting posture of workers in sedentary jobs, some interventions, such as ergonomic workstation adjustment (8, 9) and ergonomic training (10–12), have been proposed. However, in these interventions, usually only correcting the posture of individuals has been addressed (by persuading them to maintain one or two correct postures).

The correct sitting posture is assumed as an upright sitting posture with a straight back while the knees and hips form right angles (13). However, no average person can maintain such a posture during work time. Some studies have suggested other workstation configurations and sitting postures for office workers. The definition and measurement of correct sitting posture in adults are not properly described or understood (13, 14). Moreover, dynamic sitting behavior, which concerns posture change, is more popular than maintaining a perfect posture while sitting (13, 15, 16).

The postural lack of movement is itself further suspected to be a cause of MSDs. The movement factor is essential when the task to be performed requires extended periods of sitting (such as office tasks) (17).

A posture maintained for a prolonged period can harm health (13, 18, 19). Previous studies have reported insufficient nutrition of the intervertebral discs, increased height of spine, decreased range of lumbar motion, and increased lumbar spine stiffness as side effects of prolonged sitting (13). Low and relatively muscle activity during static sitting posture can lead to muscle discomfort and pain. It was shown that after 30 seconds of 2% of maximal voluntary contraction (MVC), the oxygen transport in erector spine muscle is significantly reduced (20). Therefore, a fixed or static sitting posture should not be maintained for a while. Correct sitting posture consists of a frequent change in the position of various body parts, which is another name for "dynamic sitting" (15).

It is worth mentioning that if the ergonomic adjustment leads to a more comfortable posture, corresponding to smaller loads on various structures, then the person will instead tend to sit in a more constrained posture for a more extended period and by another route again reach the area of pain/injury (buffer effect) (15).

Many ergonomic studies have focused on correct sitting posture (13, 15), while others emphasize on the implementation of the principle of dynamic sitting. There is no study presenting ergonomic recommendations for the duration of static sitting postures. The absence of these recommendations ignores the course of static sitting postures in assessing the risk of MSDs in office jobs.

Miedema et al. determined the maximum holding time (MHT) in their study to prevent the discomfort of static standing postures (21). Grandjean determined the recommended holding time of static posture at three levels based on the amount of force required to maintain the posture (22). However, since the recommended time limits in these studies and similar studies are not specific to sedentary jobs, they cannot be used for sitting postures in office work. This is because postures of the trunk, neck, and legs are significantly different in non-sedentary occupations in terms of postural angles and flexion, degree of muscle activity, and static work (23, 24).

As explained above, knowing the maximum holding time (MHT) in common static sitting postures and for office workers in an ergonomically adjusted workstation is essential. It helps prepare ergonomic instructions, especially for training office workers about the principle of dynamic sitting, and it might prevent musculoskeletal discomfort in sitting.

Our project's long-term goal is to develop a smart system for improving sitting behavior of office workers. This paper aimed to estimate the recommended ergonomic duration for maintaining different sitting postures of office workers in an ergonomically adjusted workstation as a preliminary study.

2. Method

2.1. participants

A quasi-experimental study was designed to evaluate the mean recommended holding time in common postures of different body parts in office jobs. This cross-sectional study was performed in the laboratory during the first quarter of 2021.

orty student volunteers (20 male and 20 female) participated in the study. Inclusion criteria included having a normal BMI in the range of (18.5 to 24.9 kg/m^2) (25) and no apparent physical and mental problem (self-reported). Before the study, participants signed an informed consent form approved by the ethics committee of Shiraz University of Medical Sciences.

2.2. Data gathering tools

- **Demographic questionnaire:**

The questions asked in this survey covered personal details such as age, gender and level of education.

- **Borg CR10 scale for recording body discomfort:**

The 10-point rating scale for recording body discomfort is commonly used in ergonomics studies for rating the perceived discomfort. This study used this scale to assess the perceived discomfort in different body parts (trunk, neck, and legs) from 0 (no discomfort) to 10 (extreme discomfort, almost maximum) (21).

2.3. Procedure

Volunteers were invited to attend the laboratory to complete a demographic questionnaire and then their weight and height were measured for body mass index (BMI). The musculoskeletal health of the individuals was assessed based on their description of any pain and movement limitations during physical activities at work, home or leisure time and based on examining the movement of their body parts.

After selecting the participants, they were informed about the objectives of experiments, postures to be studied, duration of experiments, experiment settings, and the Borg CR10 scale.

The workstation used for the experiment was equipped with an office chair with adjustable height and footrest. The chair's backrest was at an angle of about 95 degrees concerning the chair seat (if the trunk reclined against the backrest, the angle would increase up to 110 degrees). All participants were adjusted to an upright position, which means that the upper arms were almost vertical, the lower arms were close to the body and were horizontally laid on the table, the thighs were approximately horizontal, the lower legs were vertical, and the knees were at approximately 90° of flexion (13).

After setting up the workstation, the Borg CR10 scale was used to assess the discomfort in different body parts before starting the experiments as a reference.

The experimented postures were common static sitting postures of the trunk (seven postures), neck (six postures), and legs (four postures) during office work and working at an office computer in an ergonomically adjusted workstation presented in Table 1.

This study used a within-subject design in which the subjects participated in all posture experiments (17 postures). Consequently, counterbalancing was conducted to eliminate the order and carry-over effects, which can act as disturbing external variables and make it difficult to interpret the results of within-subject experiments. In this process, the order of presenting different postures to the participants changed. Therefore, each participant's order and carry-over effects were counterbalanced by the order and carry-over effects on the other participants. In this way, each of the 17 postures was selected randomly based on drawing.

After drawing and determining a posture for the experiment, participant was asked to maintain the posture at the workstation for 4 minutes suggested by Grandjean, as a maximum holding time of a comfortable static posture(22). Although in most studies, the duration of discomfort tests is considered one minute or less (26, 27),given that most of the postures studied are in the comfortable category, this study used the 4 minutes limit prescribed by Grandjean. Also, the short test duration caused the subject to feel very minimal discomfort, which increased the error in expressing the discomfort score by the subject. Excessive test duration could also cause harm to the participant or cause an error in defining the score due to the boredom.

A goniometer was used to adjust the angles of the trunk, neck, and legs. The proximal (fixed) arm and the center of the goniometer were placed on a joint, while the distal (moving) arm was aligned with the target limb (23) (The adjustment of the angles of different body parts will be explained in the next section (2-4)).

The participants were asked to look straight ahead during the experiment (4 minutes) and place their hands on the desk to mimic working with a computer with no task to prevent the cognitive workload from distracting their focus on the perceived discomfort.

In each experiment, a specific posture had to be maintained for a body part, and the participant was asked to maintain the other body parts in a neutral position. However, keeping the other body parts in a neutral position was not obligatory, and the participant was allowed to change the positions.

The Borg CR10 scale was given to the participant after 4 minutes to specify the discomfort in different body parts (trunk, neck, and legs) due to the discomfort in the target part after the experiment.

Each experiment was followed by a one-minute walk to relieve the potential fatigue and boredom. The experiments were performed for all postures (17) in two morning and afternoon sessions.

The difference between the degrees of discomfort in the target part before and after each experiment was used to obtain the net discomfort caused by the maintained posture.

Previous studies have shown that body part discomfort measured by the Borg CR10 scale [1982, 1990] at group level increases linearly with increasing holding time and is independent of the MHT magnitude (21, 28).

Miedema et al. have recommended that the mean discomfort of a group of participants working in static postures must not exceed a score of 2 based on the Borg CR10 scale (low discomfort) (21). In the present study, based on the same criteria, the recommended holding time of a posture was estimated for each body part based on the linear relationship of discomfort and the duration of maintaining the posture.

By obtaining the difference between the discomfort scores before and after the experiment, the time (T) for a discomfort score of 2 was estimated assuming the linear increase of discomfort score with time, as follows:

$T = (4\times2)/(\text{Net Discomfort Score})$ (21). The time was an estimate of the recommended holding time for trunk, neck, and legs in static posture experiment.

A flow diagram of the study process is shown in (Fig.2).

2.4 Adjusting angles of different body parts of subjects

For neck postures (except for neck rotation), the goniometer center was approximately placed on the seventh cervical vertebra (C7). With the neck in an upright position, the proximal arm was aligned with the imaginary line that connects the nasion and the inion. The distal arm was rotated simultaneously with the head to the desired angles. For the rotated neck posture, the center of the goniometer was placed over the center of the cranial aspect of the head, which was considered the middle of the imaginary line connecting nasion and inion (29, 30). The examined neck postures are shown in Fig.3.

To adjust the trunk angles, the participant was first asked to maintain his/her lower back (lumbar spine) in a neutral position so that the angle between the thigh and the trunk was approximately 90 °. Then, a point was marked on the iliac crest extending from the anterior superior iliac spine (ASIS) to the posterior superior iliac spine (PSIS). The proximal arm was placed along the imaginary line from the marked point, perpendicular to the chair seat. The distal arm was then rotated to the desired angles, and the participant was asked to bend so that the marked point was below the distal arm. To adjust the trunk angle in lateral flexion position, the proximal arm was placed between the spinous process of the twelfth thoracic vertebra (T12) and the beginning of the sacral curve perpendicular to the chair seat. The distal arm was then rotated to the desired angle and the subject was asked to bend so that the marked point was under the distal arm (29, 30). The examined trunk postures are shown in Fig.3.

To simulate lumbar curvatures, the subject was first asked to maintain a neutral lumbar posture. The angle between the thigh and the trunk was approximately 90° (forward hip rotation to maintain neutral lordotic posture). For the second posture, the subject was asked not to exert any muscular force by the back and abdominal muscles so that the trunk was flexed and the hip rotated backward (kyphotic or slumped posture). The studied lumbar spine curves are shown in Fig.4.

To adjust the angles of the knee, the center of the goniometer was placed over the lateral epicondyle of femur and the distal arm was almost over the lateral midline of fibula (23, 25).

2.6. Statistical analysis

IBM SPSS, version 22, was used to calculate the mean, standard deviation, maximum and minimum of discomfort scores for each posture. In addition, MS Excel was used to calculate MHT.

3. Results

The participants’ demographic characteristics are shown in Table 2. Accordingly, the participants' age, BMI mean, and Standard Deviation (SD) were 28.5$\pm$1.8 years and 23.5$\pm$2.5 kg/m^2, respectively.

Table2: Some demographic characteristics of the participants (N = 40)

Demographic characteristics Variables	
Age (years) (Mean ± SD)	28.5 ± 1.8
Body Mass Index(kg/m²) (Mean ± SD)	23.5 ± 2.5
Education Level (No. (%))	
Bachelor	28 (70)
Master	12 (30)
Sex (No. (%))	
Male	20 (50)
Female	20 (50)

The estimated recommended holding time of each posture is given in Table 3 according to the score of the perceived discomfort. The moderate neck flexion had the highest score of discomfort among different neck postures with MHT of 1.61 minutes. The lowest discomfort score was obtained for neutral neck posture.

Table 3: Perceived discomfort score in each posture and the corresponding recommended holding time (discomfort from 0 (nothing at all) to 10 (extreme discomfort))

Body Part	Sitting postures	Min - Max perceived discomfort	Mean perceived discomfort	SD	Recommended maximum holding times (min)
	Neutral Neck Posture(0°)	1.5 - 6.7	3.37	1.33	2.37
	Mild Neck Flexion (15°)	1 - 7	4.01	1.44	1.99
Neck	Moderate Neck Flexion (30°)	2 - 8	4.94	1.48	1.61
	Neck Extension (20°)	1.5 - 7	3.94	1.41	2.03
	Neck Lateral Bending (15°)	1.5 - 6	3.71	1.24	2.15
	Neck Rotation (15°)	1 - 6	3.52	1.21	2.27
	Middle Trunk Position (0°) (Short Lordosis)	1 - 5	3.13	1.16	2.55
	Middle Trunk Position (0°) (Slump Curve)	0.7 - 5	2.50	0.99	3.2
Trunk	Mild Forward Trunk Inclination (15°)	1.2 - 5.5	3.16	1.09	2.53
	Moderate Forward	1 - 8.5	4.48	1.74	1.78

	Trunk Inclination (30°)				
	Backward Trunk Position (Back supported)	0 - 3	1.35	0.65	5.92
	Trunk Lateral Bending (15°)	1.5 - 6	3.65	1.25	2.19
	Trunk Rotation (15°)	1.5 - 7	3.68	1.37	2.17
	Knee Flexion (60°)	0 - 3	1.24	0.91	6.45
Knee	Neutral Knee Position (90°)	0.5 - 4.7	1.66	0.95	4.81
	Knee Extension (120°)	0.5 - 4	1.60	1.03	5
	Leg Crossing	2 - 8	4.25	1.47	1.88

The moderate forward trunk inclination (30°) showed the highest discomfort score with MHT of 1.78 minutes among different trunk postures. The lowest discomfort score was obtained for the backward trunk position (back supported). The recommended MHT of this posture was found to be 5.92 minutes. For the middle trunk position, the natural posture had a higher discomfort score than slumped posture, while a slight difference between the two postures.

Among the most common knee postures, while working at the workstation, the lowest discomfort score was obtained for the knee flexed about 90 degrees, with the recommended MHT of 5 minutes. The lower limbs position with crossing one leg over the other (leg crossing) received the highest discomfort score.

4. Discussion

To our knowledge, this is the first study that addresses the recommended ergonomic holding time of common static postures of body parts of office workers while sitting in an ergonomically adjusted workstation.

The recommended holding time for each studied posture was tabulated according to the perceived discomfort score. Because of the lack of quantitative data on exposure effects, ergonomic recommendations to prevent these risks cannot yet be based on long-term health effects. Discomfort can also be considered as an independent evaluation criterion for static postures. Since discomfort and MSDs are both related to exposure to biomechanical load, minimizing discomfort will presumably reduce the risk of MSDs as well (21).

According to the experimental results, the recommended holding times of all postures for different body parts (while sitting in an office chair) were more than 1.5 minutes. The shortest holding times were obtained for moderate neck flexion (1.61 min), moderate forward trunk inclination (1.78 min), and leg crossing (1.88 min), respectively.

Grandjean quantified static loading in three categories relating to the forces required. Based on his results, if a high force is exerted, the static muscle activity should be less than 10 s, for moderate force, less than 1 min, and for low force, less than 4 min (22). Because the recommended holding times in this study were considered for individuals at a workstation adjusted for their body dimensions, the awkward postures in which the body parts deviate significantly from the neutral posture were not examined. The authors believe that awkward postures are not common among users who use such adjustable workstations. In other words, there is no need to exert much force to maintain the studied postures. Therefore, the recommended holding times can be more than one minute, and the results of this study do not contradict the Grandjean's recommendations.

Miedema et al. examined static standing postures. In their study, the postures with recommended holding times between 1 and 2 minutes were classified as moderate, and those with recommended holding times between 2 and 7 minutes were classified as comfortable (21). In the present study, the method of Miedema et al. was adopted to estimate the recommended holding times of sitting postures. According to the classification of Miedema et al. study, the results of the present study except for the moderate neck flexion (1.61 minutes), moderate forward trunk inclination (1.78 minutes) and leg crossing (1.88 minutes), which were classified as moderate postures, the other sitting postures were classified as comfortable ones.

Among trunk postures, the MHT was obtained 5.92 minutes for the backward trunk position (back supported), more than twice the neutral trunk posture. This shows the importance of the chair backrest in sedentary work. In many studies, the positive effect of the chair backrest has been confirmed (31), and the back-supported posture has been considered the ideal posture in various studies (13). Therefore, the results of the present study are in good agreement with the results of previous studies.

In the middle trunk position with natural posture, the mean discomfort score was 3.1, and accordingly, the MHT was estimated 2.55 minutes for this posture. These results are not considerably different from the results of mild forward trunk inclination (15°) posture with a discomfort score of 3.16 and a holding time of 2.53 minutes. Kee et al. and Genaidy et al. also examined the relative discomfort score of some sitting postures. The discomfort scores were considered the same for postures in which the trunk flexion in the sagittal plane was between 0 and 20 degrees (26, 27). The same result was also obtained in the present study. However, Kee et al. and Genaidy et al., studied the discomfort of the moderate forward trunk inclination (30°), and lateral trunk bending (15°) postures was estimated to be three times larger than that of the trunk rotation (15°) posture and twice the middle trunk position with lordotic back. However, in the present study, no such considerable difference was found. It is worth mentioning that Kee et al. set the duration of discomfort experiments to one minute, and Genaidy et al. set it to 30 seconds, while in the present study, the course of discomfort experiment was considered 4 minutes.

Moreover, in the present study, the discomfort score of the middle trunk position with lordotic back was higher than that of slumped posture. However, different studies and standards have emphasized maintaining a natural lumbar curve while sitting (13). In a sitting posture with trunk flexion, in addition to the tensile load exerted to the posterior spinal ligaments, sacroiliac joint ligaments, etc., the disc's nucleus moves backwards. The long-term consequence of this backward movement may contribute to the development of radial fissures in the posterior annulus fibrosus (23, 32–34). According to these findings, it is recommended to maintain the natural curvature of the back while sitting. However, it is worth noting that in the case of maintaining the natural curvature of the spine for a long time, the intervertebral discs are not fed due to static posture. This is by itself another cause of disc damage. Moreover, the side effects of prolonged sitting are not limited to intervertebral disc damage. Low and relatively static muscle activity during sitting can cause muscle discomfort and pain (20, 34–36).

Consequently, a sitting posture that maintains the natural curvature of the spine causes the faster perception of muscle discomfort and pain due to the increased activity of the spinal muscles. However, injuries such as disc protrusion or ligaments and ligamentous tissues damage may occur years after (34). Therefore, in this study, which considered discomfort experiments as criteria for determining the recommended holding times of sitting postures, maintaining the natural curvature of the spine was resulted in higher discomfort in the subjects and the recommended holding time of this posture was less than that of slumped one.

In studies conducted by Karwowski et al. and Genaidy et al. and even in RULA observational method, which is commonly used to assess sedentary tasks, the middle trunk with slumped posture has not been considered. In these studies, experiments were only conducted for natural upright posture. The RULA and LUBA methods do not classify unnatural back postures, while the upright posture is the only item that is considered in the classification (22, 26, 27). However, slumped postures are often maintained during office work. Indeed, some other papers have investigated both slumped and upright postures by employing various techniques (37–39). For example, Wong et al. found that slumped sitting posture accounts for less trunk muscle activity than back supported and upright postures. However, proprioception and pain intensity were not significantly different in upright posture (37).

Among neck postures, the lowest discomfort score, and therefore, the longest recommended holding time were obtained for the neutral neck posture. In other studies, neutral neck posture was determined as the most comfortable posture (13, 22, 26, 40).

Among leg postures, the lowest discomfort score was given to the posture with the knee at a 90-degree angle, which was in agreement with the results of previous studies (13).

In the present study, the upper limbs were considered fixed, and their effects were not examined for the following reasons. 1) Upper limbs one usually involved in dynamic work during office tasks. Furthermore, the upper limbs are also exposed to significant risk factors, such as repetitive work, during office tasks (2), but these risk factors are not within the scope of this study. 2) Due to various office tasks, simulating common postures of upper limbs was difficult and required designing a dedicated comprehensive study. 3) For the upper limb posture, there was no much difference between sitting and standing tasks. Therefore, the same interventions that have been proposed to improve upper limb conditions can also be used to improve the conditions of office workers.

5. Conclusion

This study estimated the recommended ergonomic holding times for common static sitting postures of office workers at an ergonomically adjusted workstation. The recommended holding time limits in this study may be useful for assessing the risk of MSDs in office work and training the office workers to correct their sitting behavior. For example, smart systems developed to assess or improve sitting behavior using biofeedback can also evaluate the principle of dynamic sitting according to the recommended holding time limits.

Moreover, limiting the holding time of a posture can alleviate musculoskeletal discomfort in different body parts and thus reduce the MSDs in office workers. The results of this study can be used to determine occupational exposure limits (OEL) for the physical workload on office workers.

Declarations

Ethics approval and consent to participate: Participants signed an informed consent form approved by the ethics committee of Shiraz University of Medical Sciences.

Consent for publication: Not applicable

Availability of data and materials: The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

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Authors' contributions: AC and MR managed and planned the project. Experiments were performed by one researcher (ST). MS as a statistician, she re-checked statistical analysis. AC was a major contributor in writing the manuscript. All authors read and approved the final manuscript.

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Table

Due to technical limitations, table 1 is only available as a download in the Supplemental Files section.

Figures

Figure 1

Some examples of adjusting the angles of different parts of the subjects' bodies (A: Adjusting the neck angles in horizontal plane; B: Marking a point on the iliac crest; C: Adjusting the angle of the knee)

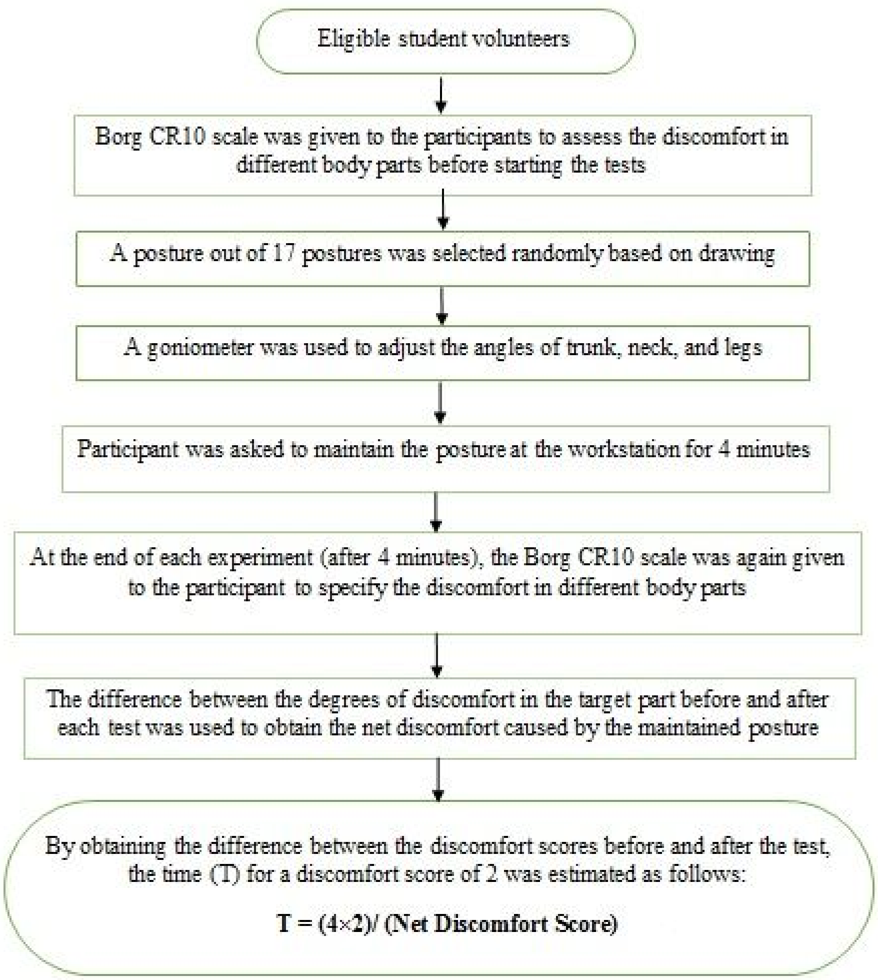

Figure 2

Flowchart of the study process

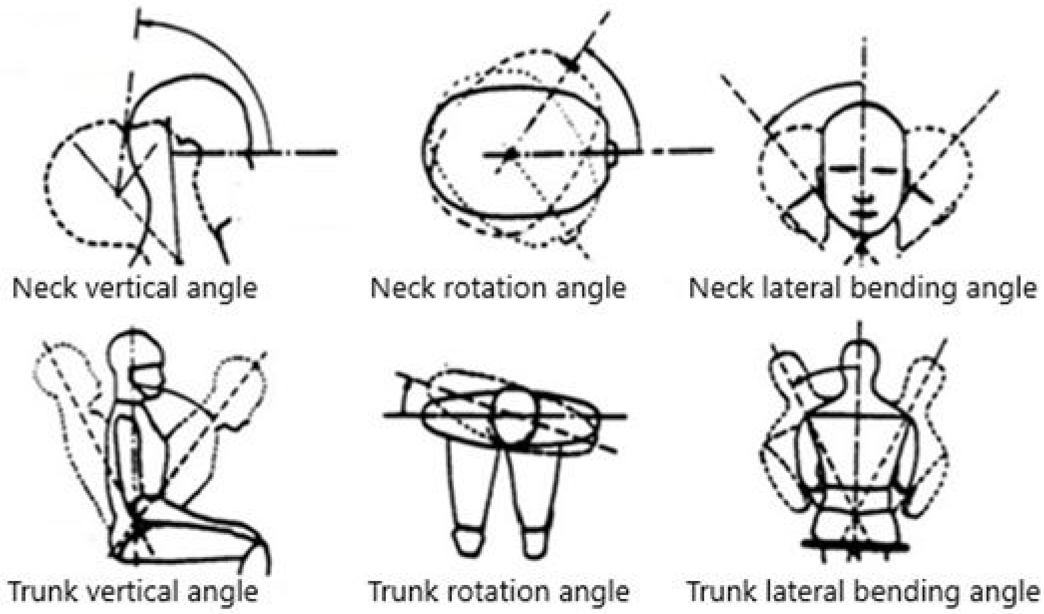

Figure 3

Examined neck and trunk postures taken from Hsiao et al study (39).

Figure 4

Studied lumbar spine curves in sitting positions (21).

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table1.docx