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Original Article

An exploratory study on the impact of static and dynamic sitting postures on lumbar and pelvic mobility during visual display terminal work

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Abstract. [Purpose] Limited studies exist on the impact of sustained work at a visual display terminal (VDT) on the position and motion of the pelvis and lumbar spine. We evaluated the changes in movement of the lumbar column and pelvis during VDT work. [Participants and Methods] We evaluated the sitting posture of 20 healthy adults while they performed VDT work. The effects of the sitting posture on lumbo-pelvic position and motion were captured using a three-dimensional accelerometer. Between-posture effects of VDT work were evaluated using an analysis of variance (ANOVA). A two-way ANOVA was used to assess the root mean square (RMS) values of the 80-min VDT work period for each posture. A one-way ANOVA was used to evaluate pre- and post-work changes in RMS values during the finger floor distance test (FFD). [Results] People in the dynamic sitting balance chair (DSBC)-based posture demonstrated significantly higher pelvic RMS values than those in reclining and upright sitting postures. The DSBC-based posture was also associated with significantly higher pre- and post-work lumbar and pelvic RMS values during the FFD than in the reclining and upright sitting postures. [Conclusion] The dynamic balance chair may be an effective method of establishing a pattern of spinal exercise during prolonged sitting.

Key words: Dynamic sitting posture, Visual display terminal, Acceleration sensor

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INTRODUCTION

Information technology in the industrial field has changed the ergonomics of the workplace environment. A 2008 field survey of technological innovation in the labor force, conducted by the local Ministry of Health, Labour and Welfare of Japan, reported that 97% of workplaces included computer equipment. Among workers using visual display terminals (VDTs), 68.6% reported experiencing physical fatigue and musculoskeletal symptoms, with low back pain being a common complaint[1)]. Static sitting postures, including slumped sitting, sustained over a prolonged period are a risk factor for physical pain, especially low back pain[2–4)]. Maintaining natural lumbar lordosis and pelvic tilt while sitting can prevent or reduce the risk for posture-related back pain when working at VDTs[5, 6)].

However, maintaining an ideal sitting posture during prolonged sitting is difficult[7, 8)]. Dynamic changes in the posture of the lumbar spine and pelvis during prolonged sitting provide an effective alternative to maintaining an ideal static posture to relieve posture-induced pain[9–11)]. Dynamic chairs with moving seat have been designed to facilitate such dynamic changes in posture during prolonged sitting. Annetts et al.[12)] compared effects of dynamic and static chairs on the angle of pelvic

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*Corresponding author. Hironori Tanoue (E-mail: tanohiro2@gmail.com) retroversion tilt, lumbar anteflexion, neck alignment, and head-tilt. They failed to find a uniform effect of either dynamic or static chairs, underlining the importance of selecting a chair based on an individual's needs.

The effects of VDT-based work on posture have been evaluated through the assessment of muscle activity and fatigue in the cervical spine and trunk. To our knowledge however, the effects of sitting posture during VDT work on post-exposure lumbar and pelvic mobility have not been evaluated. Inclusion of the pelvis is as important as including its alignment, because sitting directly influences trunk alignment and, therefore, may play an important role in lowering the risk of, or preventing, musculoskeletal pain and impairment with prolonged sitting[13)].

In patients with chronic low back pain, movements of the lumbar spine along the sagittal plane are correlated with the intensity of low back pain and functional disorders to a greater extent than movement along the frontal and transverse planes[14)]. In a previous study, we provided evidence that use of a dynamic chair that promoted pelvic movement during prolonged sitting posture improved post-work physical flexibility and pelvic mobility. However, the effects of pelvic movement on the lumbar spine were not specifically evaluated[15)]. Therefore, the aim of the present study was to determine time-dependent changes in the movement of the lumbar spine and pelvis during sustained VDT work, using a three-axis accelerometer, and to use this data to evaluate the impact of static and dynamic sitting postures on post-work lumbar and pelvic mobility. Findings will inform the selection of an optimal chair for VDT workers and, ultimately, may improve the health outcomes of VDT workers.

PARTICIPANTS AND METHODS

Twenty students enrolled in a local Junior College of Health Science (13 males and 7 females; mean age, 21.8 ± 2.5 years; height, 166.4 ± 8.0 cm; weight, 60.1 ± 10.9 kg; body mass index, 21.6 ± 2.8 kg/m^2) participated in this study. The inclusion criteria were good general health (no current illness, ongoing treatment, physical pain, or unidentified complaints). Individuals with significant malalignment of the cervical and thoracolumbar spine and/or pelvis, a history of neck and lumbar pain, or visual acuity <1.0, regardless of use of correcting lenses, were excluded (n=2).

Three postural conditions were defined *a priori*, and VDT work was performed in each posture. The order of the postures was randomized across participants, with each participant evaluated for each of the three postural conditions, with a one-day rest period between postures. The following three postural conditions were evaluated: condition 1, upright sitting posture (control condition); condition 2, reclined posture; and condition 3, dynamic change in posture, using a dynamic sitting balance chair (DSBC, Finggal Link, Tokyo, Japan). In each sitting posture, the soles of the feet were fully planted on the ground, with the knees flexed to 90°. The distance between the monitor and the eyes was maintained at more than 40 cm, with the elbows kept away from the desk. The upper end of the monitor was set below eye level as per previously published recommendations[1)]. For conditions 1 and 2, we used an office chair without armrests, with the backrest fixed in 70° of retroflexion; participants were free to adjust the height of the sitting surface (ITOKI JOIFA 602, Itoki Corp., Osaka, Japan) (Fig. 1). For condition 1 (control), participants selected a comfortable posture without resting their back against the backrest. This free posture allowed subjects to avoid physical movement constraints during work. For condition 2, participants sat on the chair with the back against the backrest set at 70° of retroflexion. If the posture changed during work, verbal instruction was provided to correct the posture. For condition 3, a DSBC chair was used, with 15° of free tilt in the anteroposterior and left-right directions, based on self-generated center of gravity (COG) shifts (Fig. 1). Therefore, participants could move the seat freely when feeling fatigued during work.

Fig. 1. The chairs used in the study.
(A): standard office chair without armrests, used for conditions 1 and 2. (B): dynamic sitting balance chair (DSBC), used fir condition 3. The sitting surface and column of the DSBC are connected by a universal joint. The chair has a fulcrum in the middle of the seat allowing for anteroposterior and lateral tilting. Upon a shift in the position of the body center of gravity in the sitting, the seat tilts 15° in the anteroposterior and lateral directions.

Using a laptop computer, participants were instructed to type from an English-language manuscript. A bookrack for the English-language manuscript was installed on the left side, at the same height as the laptop screen. The examiner turned the manuscript pages for participants. The manuscript was not shown to participants until just prior to the experiment, and participants were instructed to use only the keyboard and computer screen, without the mouse, for 80 min. The examiner changed the work task every 10 min. If a participant was unfamiliar with the input keystrokes for special characters or symbols during typing, the participant was instructed to skip the letter.

Continuous movement analysis of the trunk and pelvis during work. Movement of the trunk and pelvis were measured using a small, 8-channel, wireless motion sensor (MVP-RF8-BC, MicroStone, Saku, Japan) during an 80-minute work period. The sensor weighed approximately 60 g. One sensor was taped over the third lumbar vertebra and another over the dorsal surface of the sacrum, to capture lumbar spine and pelvic movement, respectively; the position of each sensor was fixed with a belt. Data were transmitted to a computer (Dynabook, Toshiba, Tokyo, Japan; Windows XP, Microsoft, Redmond, WA, USA) using a wireless connection via a Bluetooth-USB adaptor (Parani-UD100, Micro Stone, Saku, Japan) at a 10 Hz frequency. The effective value of movement direction (root mean square [RMS]) was calculated from the acceleration data at each 10-min interval. The RMS value was used to identify the intensity of lumbar and pelvic mobility during task performance, with an increase in RMS being indicative of increased movement.

We used the finger-to-floor distance (FFD) to quantify lumbo-pelvic flexibility. Participants stood atop a 20-cm platform, with both arms hanging, and were asked to move to their position of maximum trunk flexion and keep their knee in extension. The FFD was measured as the distance between the end of the third finger and the floor at the position of maximum trunk flexion. As a measure of lumbar and pelvic mobility, the accelerometers were again affixed over the third lumbar vertebra and dorsal surface of the sacrum, and participants were asked to move from a standing posture to maximum flexion of the trunk and back to a standing posture, with the feet maintained shoulder width apart, as described by Solomonow et al(16). Lumbosacral movements were also recorded during the following movement series. After standing still for 3 s, participants dropped both arms forward, with both knees fully extended, and maintained the anteflexed position of the trunk for 4 s. After maintaining the anteflexed trunk position for 4 s, participants returned to their standing posture and held this posture for 4 s. Using the recorded acceleration profiles (sampling frequency, 1,000 Hz), the RMS value from the starting point of trunk anteflexion back to the standing posture was calculated.

Prior to testing, participants were provided with a written explanation of the purpose of the study, its content, how personal information would be protected, and potential risk. Written consent was obtained from all participants prior to testing. The study was approved by the Ethics Committee of Gifu Junior College of Health Science (H23-3), and conducted in accordance with the ethical standards of the Declaration of Helsinki.

A two-way analysis of variance (ANOVA) was used to assess the RMS values at each 10-min interval of the 80-min VDT work period for each posture condition. If a significant difference or interaction was identified, a multiple comparison test was performed using the Bonferroni method. A one-way ANOVA was used to evaluate pre- to post-work change in self-reported fatigue (VAS score), FFD, and RMS values. If significant differences were found, comparisons between conditions were conducted using the Bonferroni method for multiple comparisons. All analyses were performed using SPSS 11.0 for Windows (IBM, Armonk, NY, USA), with the significance level of $p<0.05$.

RESULTS

RMS values increased during the 80-min VDT work time period for the three postural conditions. The time-depended changes in the lumbar and pelvic RMS values are shown in Tables 1 and 2, respectively, for all three conditions. A significant between-condition difference in the lateral movement component of the lumbar RMS was identified ($p<0.01$), with a multiple comparison test confirming higher lateral movement of the lumbar spine under conditions 1 and 3, compared with condition 2 ($p<0.01$).

The significant change in the RMS value of the lateral component means that the posture without backrest and the work in the chair where the seat surface moves, moved the lateral direction and the lumbar spine had increased. Significant between-condition differences were also identified for the vertical and anteroposterior components of the RMS ($p<0.01$), with greater vertical movement in condition 1 than in conditions 2 and 3 ($p<0.01$), as well as greater anteroposterior movement than in condition 2 ($p<0.01$). A significant between-condition difference was also identified for the total RMS of the lumbar spine ($p<0.01$), with conditions 1 and 3 having significantly higher values than condition 2 ($p<0.01$ and $p<0.05$, respectively). RMS values were significantly higher for the lumbar spine for condition 1 than for condition 3, during all 10-min intervals of measurement ($p<0.05$).

With regard to the RMS values for the pelvis, significant between-group differences were identified for the lateral and vertical components of the signals ($p<0.01$). Lateral RMS values were higher for conditions 1 and 3 than for condition 2 ($p<0.01$), while vertical component values were higher for condition 3 than for conditions 1 and 2 ($p<0.01$ and $p<0.05$, respectively). No effect of postural condition on the anteroposterior component of the RMS signal was identified. A significant between-condition difference was also identified for the total RMS of the pelvis, with condition 3 having significantly higher values than conditions 1 and 2 ($p<0.05$ and $p<0.01$, respectively).

The effect of posture conditions on the pre- to post-work change in FFD was significant ($p<0.01$; Table 3), with lower

Table 1. Time-dependent changes in lumbar root mean square values over the 80-min work period at the visual display terminal

	Condition 1			Condition 2			Condition 3		
Time (minutes)	Lateral component	Vertical component	Anteroposterior component	Lateral component	Vertical component	Anteroposterior component	Lateral component	Vertical component	Anteroposterior component
0–10	0.05 ± 0.03	0.02 ± 0.01	0.46 ± 0.10	0.01 ± 0.01	0.00 ± 0.00	0.17 ± 0.10	0.05 ± 0.03	0.01 ± 0.01	0.30 ± 0.42
10–20	0.07 ± 0.08	0.04 ± 0.04	0.77 ± 0.40	0.03 ± 0.01	0.01 ± 0.02	0.34 ± 0.29	0.09 ± 0.06	0.01 ± 0.01	0.45 ± 0.57
20–30	0.10 ± 0.05	0.06 ± 0.03	0.92 ± 0.05	0.04 ± 0.02	0.01 ± 0.02	0.31 ± 0.27	0.09 ± 0.06	0.02 ± 0.01	0.91 ± 0.98
30–40	0.14 ± 0.10	0.06 ± 0.03	1.00 ± 0.90	0.05 ± 0.04	0.01 ± 0.02	0.34 ± 0.30	0.10 ± 0.09	0.01 ± 0.01	0.78 ± 0.80
40–50	0.15 ± 0.20	0.06 ± 0.04	1.04 ± 0.05	0.05 ± 0.04	0.01 ± 0.01	0.33 ± 0.29	0.13 ± 0.09	0.01 ± 0.01	0.72 ± 0.79
50–60	0.14 ± 0.20	0.07 ± 0.05	1.12 ± 0.80	0.05 ± 0.03	0.02 ± 0.02	0.35 ± 0.30	0.12 ± 0.14	0.01 ± 0.01	0.63 ± 0.54
60–70	0.19 ± 0.20	0.09 ± 0.07	0.86 ± 0.50	0.05 ± 0.03	0.01 ± 0.01	0.47 ± 0.44	0.13 ± 0.22	0.01 ± 0.01	0.72 ± 0.65
70–80	0.20 ± 0.30	0.11 ± 0.09	0.89 ± 0.40	0.05 ± 0.04	0.02 ± 0.02	0.47 ± 0.45	0.13 ± 0.21	0.01 ± 0.01	0.73 ± 0.65

Values are mean ± standard deviation. Root Mean Square values (m/s^2). Condition 1 and 2: a standard office chair was used for the work task. Condition 3: a dynamic sitting balance chair was used for the work task.

(A) Lateral component: Condition: F=13.145, p<0.01; Time: F=2.508, p<0.05; Condition × Time: F=0.440, p=0.961; Multiple comparisons (Bonferroni test): Condition 3 > Condition 2 (p<0.01), Condition 1 > Condition 2 (p<0.01).

(B) Vertical component: Condition: F=36.916, p<0.01; Time: F=1.974, p=0.057; Condition × Time: F=1.251, p=0.235; Multiple comparisons (Bonferroni test): Condition 1 > Condition 2 (p<0.01), Condition 1 > Condition 3 (p<0.01).

(C) Anteroposterior component: Condition: F=8.597, p<0.01; Time: F=0.936, p=0.478; Condition × Time: F=0.2, p=0.999; Multiple comparisons (Bonferroni test): Condition 1 > Condition 2 (p<0.01).

(D) Total component Condition: F=11.97, p<0.01; Time: F=1.306, p=0.245; Condition × Time: F=0.192, p=0.999; Multiple comparisons (Bonferroni test): Condition 1 > Condition 2 (p<0.01), Condition 3 > Condition 2 (p<0.05), Condition 1 > Condition 3 (p<0.05).

Table 2. Time-dependent changes in pelvis root mean square values over the 80-min work period at the visual display terminal

	Condition 1			Condition 2			Condition 3		
Time (minutes)	Lateral component	Vertical component	Anteroposterior component	Lateral component	Vertical component	Anteroposterior component	Lateral component	Vertical component	Anteroposterior component
0–10	0.03 ± 0.02	0.03 ± 0.02	0.21 ± 0.22	0.01 ± 0.00	0.02 ± 0.01	0.08 ± 0.06	0.05 ± 0.03	0.03 ± 0.01	0.31 ± 0.22
10–20	0.07 ± 0.05	0.05 ± 004	0.36 ± 0.35	0.02 ± 0.00	0.03 ± 0.01	0.35 ± 0.26	0.09 ± 0.07	0.17 ± 0.11	0.54 ± 0.34
20–30	0.11 ± 0.09	0.07 ± 0.06	0.60 ± 0.45	0.03 ± 0.01	0.06 ± 0.04	0.44 ± 0.31	0.10 ± 0.09	0.22 ± 0.15	0.71 ± 0.48
30–40	0.14 ± 0.21	0.11 ± 0.09	0.84 ± 0.89	0.02 ± 0.01	0.09 ± 0.05	0.53 ± 0.39	0.11 ± 0.09	0.29 ± 0.18	1.01 ± 0.95
40–50	0.15 ± 0.24	0.13 ± 0.11	0.80 ± 0.82	0.02 ± 0.01	0.08 ± 0.04	0.66 ± 0.44	0.16 ± 0.11	0.40 ± 0.25	1.24 ± 0.98
50–60	0.11 ± 0.22	0.17 ± 0.19	0.87 ± 0.90	0.02 ± 0.01	0.07 ± 0.04	0.81 ± 0.60	0.13 ± 0.10	0.50 ± 0.42	1.56 ± 1.23
60–70	0.16 ± 0.24	0.15 ± 0.16	0.72 ± 0.77	0.03 ± 0.01	0.07 ± 0.04	0.94 ± 0.72	0.15 ± 0.12	0.56 ± 0.44	1.43 ± 1.16
70–80	0.15 ± 0.24	0.16 ± 0.16	0.67 ± 0.70	0.04 ± 0.02	0.05 ± 0.03	1.23 ± 1.10	0.17 ± 0.13	0.79 ± 0.61	1.25 ± 1.30

Values are mean ± standard deviation. Root Mean Square values (m/s^2). Condition 1 and 2: a standard office chair was used for the work task. Condition 3: a dynamic sitting balance chair was used for the work task.

(A) Lateral component: Condition: F=25.462, p<0.01; Time: F=2.921, p<0.01; Condition × Time: F=0.545, p=0.906; Multiple comparisons (Bonferroni test): Condition 3 > Condition 2 (p<0.01), Condition 1 > Condition 2 (p<0.01).

(B) Vertical component: Condition: F=6.095, p<0.01; Time: F=0.816, p=0.575; Condition × Time: F=0.415, p=0.970; Multiple comparisons (Bonferroni test): Condition 3 > Condition 2 (p<0.05), Condition 3 > Condition 1 (p<0.01).

(C) Anteroposterior component: Condition: F=2.631, p=0.073; Time: F=2.264; p<0.05; Condition × Time: F=0.2036; p=0.998; Multiple comparisons (Bonferroni test): not significant.

(D) Total component: Condition: F=6.453, p<0.01; Time: F=2.807, p<0.01; Condition × Time: F=0.289, p=0.995; Multiple comparisons (Bonferroni test): Condition 3 > Condition 1 (p<0.05), Condition 3 > Condition 2 (p<0.01).

Table 3. Changes in post-work finger-to-floor distance (FFD) before and after visual display terminal work

		Condition 1	Condition 2	Condition 3	p-value
FFD (cm)	Pre-work	30.0 ± 12.2	28.6 ± 12.8	32.0 ± 11.0	0.28
	Post-work	29.4 ± 11.9	31.5 ± 12.8	30.5 ± 11.0	0.34
	Amount of change	−0.7 ± 3.7	3.0 ± 5.0^{*1}	−1.6 ± 3.5^{**2}	<0.01

Values are reported by their mean ± standard deviation; Condition 1, upright sitting posture; Condition 2, a reclined posture; Condition 3, a dynamic sitting balance chair; FFD, finger-to-floor distance.

*1= Condition 1 vs. Condition 2; *2= Condition 3 vs. Condition 2; *p<0.05, ** p<0.01.

change values identified for conditions 1 and 3 than for condition 2 ($p<0.05$ and $p<0.01$, respectively).

No differences in pre- and post-work lumbar in the lateral component of the RMS values were identified for the movement from standing posture to maximum trunk anteflexion position, or for the movement from anteflexion to standing posture. However, significant effects of postural condition were identified on the vertical and anteroposterior components of the RMS during this movement series ($p<0.01$; Table 4). Multiple comparison testing identified higher vertical and anteroposterior component values for condition 3 than for conditions 1 and 2 ($p<0.01$). Similarly, between-condition effects were also identified on the vertical and anteroposterior components of the RMS signal at the pelvis during the same movement series, with values again being higher for condition 3 than for conditions 1 and 2 ($p<0.05$ for the vertical component; $p<0.01$ for the anteroposterior component).

DISCUSSION

We found that the DSBC chair maintained—even increased—flexibility of the trunk during VDT work. However, the RMS values increased during the 80-min work period for all conditions, with the total component of the lumbar RMS values after 80 min being significantly lower for the reclined posture than for the upright sitting posture. Moreover, changes in pre- and post-work FFD and RMS values were significantly higher and lower, respectively, for participants in the reclined posture, compared with those in the upright sitting posture.

Previous studies have reported that prolonged sitting decreases lumbar lordosis and increases intradiscal pressure, pressure on the ischium, and muscle activity[17, 18]. In our study, we also found that prolonged sitting in a static posture decreased physical flexibility. Therefore, correction of sitting posture over sustained periods of VDT work may significantly influence the treatment and prevention of spinal problems[19]. Proposed corrections to sitting posture include auxiliary treatments to maintain a natural lumbar lordosis and increased anterior pelvic tilt, as well as improving muscle strength to maintain this postural alignment[19–21]. Despite interventions, maintaining an optimal static sitting posture over a prolonged period of time is difficult. When time-depended changes in lumbar and pelvis RMS values for the reclining and DSBC chairs were compared, the lateral and total components of the RMS signals were significantly higher when sitting on the DSBC chair, which supported easy changes in lumbo-pelvic posture during the 80-min work period. Notably, there were significantly lower and higher changes in FFD values and RMS values, respectively, from trunk maximum anteflexion to standing posture after VDT working with the DSBC chair, compared with the reclining chair. Therefore, dynamic sitting positions were better for post-work lumbar and pelvic mobility than static sitting positions.

Since the chair has a direct influence on body alignment, individuals with musculoskeletal symptoms related to prolonged sitting are often advised to change the chairs at their workstations[22–25]. Although dynamic changes in posture during sitting have been suggested to provide the same benefits as sitting on a ball[10, 11], our data confirm previous findings of the benefit of dynamic chairs over fixed chairs for maintaining lumbar and pelvic mobility[26]. Moreover, our analysis demonstrated that sitting condition did not uniformly affect all three components of the lumbar and pelvic mobility, with effects of dynamic sitting being most evident on the lateral component of the RMS signal.

Different chairs also influenced the sitting strategy. During the 80-min VDT work period, the upright sitting posture was associated with a time-dependent increase in movement of the neck and trunk, while greater movement in the DSBC chair was centered on the hip, with the amount of change in RMS values pre- and post-work being significantly greater for both

Table 4. Lumbar and pelvic root mean square values pre- and post-work

		Lumbar			p-value	Pelvis			p-value
		Condition 1	Condition 2	Condition 3		Condition 1	Condition 2	Condition 3	
Lateral component (m/s^2)	Pre-	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.2	0.75	0.2 ± 0.2	0.2 ± 0.4	0.2 ± 0.2	0.87
	Post-	0.3 ± 0.2	0.3 ± 0.2	0.3 ± 0.3	0.61	0.2 ± 0.2	0.3 ± 0.4	0.2 ± 0.2	0.79
	Amount of change	−0.007 ± 0.2	0.03 ± 0.2	0.03 ± 0.3	0.24	0.01 ± 0.2	0.06 ± 0.2	0.01 ± 0.2	0.22
Vertical component (m/s^2)	Pre-	33.3 ± 22.6	34.2 ± 20.5	26.7 ± 17.5	0.29	10.2 ± 17.4	8.6 ± 10.7	8.2 ± 10.3	0.33
	Post-	24.1 ± 16.2	23.1 ± 16.4	34.3 ± 28.3	0.12	8.2 ± 12.3	6.3 ± 8.0	11.8 ± 17.9	0.29
	Amount of change	−9.2 ± 10.7	−11.1 ± 11.2**^{1}	7.6 ± 13.6**^{2}	<0.01	−2.0 ± 5.7	−2.3 ± 5.4*^{1}	3.6 ± 8.0*^{2}	<0.05
Anteroposterior component (m/s^2)	Pre-	40.9 ± 11.7	40.2 ± 10.2	33.2 ± 6.0	0.68	27.0 ± 13.4	25.5 ± 16.1	23.7 ± 11.5	0.68
	Post-	32.7 ± 7.2	32.2 ± 6.2	38.7 ± 9.0	0.55	23.1 ± 10.9	21.0 ± 10.8	27.9 ± 15.5	0.41
	Amount of change	−8.2 ± 8.0	−8.0 ± 7.9**^{1}	5.5 ± 6.5**^{2}	<0.01	−3.9 ± 6.1	−4.5 ± 9.4**^{1}	4.1 ± 6.2**^{2}	<0.01

Values are reported as the mean ± standard deviation; Condition 1, upright sitting posture; Condition 2, a reclined posture; Condition 3, a dynamic sitting balance chair.
*1= Condition 3 vs. Condition 2; *2= Condition 3 vs. Condition 1; *$p<0.05$, ** $p<0.01$.

the lumbar spine and pelvis. Therefore, movement of the lumbar spine and hips (pelvis) during prolonged sitting can enhance post-work flexibility.

Biomechanical studies have indicated that an incorrect sitting posture can affect the posterior rotation of the pelvis, resulting in decreased lumbar lordosis and sacral inclination, and consequently increased forces applied to the intervertebral discs[27]. As the position of the hips and lumbar spine during sitting affects the posture of all linked-segments, including the head and neck[13, 28, 29], preventing pelvic retroversion is important for maintaining lumbar lordosis during sitting. However, using the DSBC chair, we provided evidence that movement along the vertical and lateral planes is also important. Lumbar and Pelvic movement is widely used in the treatment of low back pain[30], and the effectiveness of spinal stability exercise in patients with low back pain has become clear[31, 32]. We propose that increasing lumbar and pelvic movements by adopting a dynamic sitting posture could help to prevent VDT-related low back pain.

Japanese industrial health guidelines underline the importance of physical exercise, stretching, relaxation, and light exercise before, during, and after work to prevent VDT work-related adverse effects on body function and accumulated fatigue[1]. The DSBC chair could be an effective method for establishing a pattern of spinal exercise during prolonged sitting, which could reduce the need for special exercises.

The sample size of this study was small and did not meet our expectations. The 20 participants included males and females, but gender, age, proficiency of performing VDT work, the length of the break time during the work, and exercise habits may have affected task activity. Each measurement was only performed once, but the data were collected repeatedly every other day, which may be helpful in correcting for measurement variability. We used a work period of 80 min. However, there is a need to clarify the time-dependent effects of different sitting conditions to identify reliable cut-offs for research and safe work practice. Future studies are needed to address these problems. Lastly, we did not consider sex-specific differences in sitting posture and effects of prolonged sitting posture on spinal posture and movement. Yet, gender differences in trunk flexibility are expected and would be an important factor to consider.

In this study, we compared a standard office chair to the DSBC chair, providing evidence that the lumbar and pelvic mobility allowed by the DSBC chair improve post-work flexibility.

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None.

Conflict of interest

The authors state there are no conflicts of interest to declare.

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