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Ergonomic Comparison of a Sit-Stand Workstation With a Traditional Workstation in Visual Display Unit Work

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Abstract: *Purpose*: To compare ergonomics of an electrically adjustable sit-stand workstation with a traditional workstation in video display unit (VDU) work.

Methods: Twelve female workers (aged 27-53 years) participated in this experimental study. Electromyography, wrist postures, subjective assessments, and productivity were used to make the ergonomic comparison.

Results: The muscle activity of the right trapezius (p=0.01) and left wrist extensors (p=0.02), extension of the right (p=0.05) and left (p=0.002) wrist, and perceived strain of the arms (p=0.05) were lower and productivity was better (p=0.02) when the workers used a low-sitting, high-sitting, or standing posture at the sit-stand workstation than when using a low-sitting posture at the traditional workstation. In the whole, the subjects were more satisfied (p=0.05) with the sit-stand workstation than with the traditional workstation.

Conclusions: Working both in sitting and standing postures was more productive and caused lower strain of the workers' upper limbs than work only in a sitting posture. The electrically adjustable sit-stand workstation offers the possibility to reduce the sedentary behavior and inactivity in VDU work.

Keywords: Ergonomics, sedentary work, sit-stand workstation, standing, visual display unit.

INTRODUCTION

Epidemiological evidence suggests that decrease in sedentary behavior is beneficial for health [1]. Objectively measured data show that people spend in USA and Australia on average 7.7 h/day and 8.1 h/day in sedentary behavior, respectively [2, 3]. Finni *et al*. [4] have shown that exercise for fitness, regardless of its duration, does not decrease the inactivity time during normal daily life. Further, different counseling interventions have been carried out to decrease sedentary behavior [5].

Sit-stand workstations offer one possibility of decreasing sedentary behavior and varying work postures during work day [6-9]. Workers can select low-sitting, high-sitting, and standing postures according to their needs and tasks and adjust the work station height easily [9, 10]. Ergonomic sitting and standing postures are typically used in the prevention of musculoskeletal disorders such as low-back pain and upper-limb disorders [6, 11, 12]. According to Callaghan and McGill [9], sitting resulted in higher (p<0.001) low back compressive loads than those experienced by the lumbar spine during standing.

Further, good forearm support has been shown to reduce the musculoskeletal exposure, and discomfort in VDU work [13-16] Dainoff *et al.* [7] reported about an ergonomic intervention, which included also a use of motorized adjustable workstations in VDU work, that musculoskeletal pain among the VDU workers reduced significantly. According to Schofield *et al.* [17] standing and typing produced an average of 13% higher energy expenditure than sitting and typing did, and it can therefore reduce the risk of weight gain. According to the review of Reid *et al.* [18] both prolonged standing and sitting can cause discomfort of the lower extremities. Leg swelling is also more typical during long-lasting standing [19].

The ergonomics of sit-stand workstations have been evaluated earlier for VDU work [6, 9, 20]. According to Wilks *et al.* [9], 60% of the workers used the sit-stand function of the table once monthly or less, and the frequency was even lower among the older participants. Also pain experienced during the past year and education on the use of the worktable increased the use of the adjustability function [8]. According to Straker *et al.* [6], use of sit-stand desks was associated with better sedentary behavior in call center workers, however ergonomics awareness did not enhance the effect. In other occupations, use of an electrically adjustable worktable in microscope work decreased the muscle strain of neck and upper limbs among laboratory workers [21]. Jung

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[22] and Koskelo *et al.* [23] showed that use of adjustable school furniture decreased muscular strain, developed general posture, and increased learning results of the students.

Electrically adjustable workstations have been used as workplace accommodations for workers with long-standing diseases or permanent physical disabilities [24]. Shen *et al.* [25] showed, that the cutout surface of the worktable provided forearm support in addition to improving writing performance among students with physical disabilities. New reclining/supine computer workstations have also been developed for workers with chronic low back pain who cannot work in sitting position [26].

The use of an adjustable workstation decrease musculoskeletal exposure of workers [27] and enhance work productivity [9, 10, 20]. Hasegawa *et al.* [28] reported the effects of a sit-stand schedule on a light repetitive task and concluded that a “change of posture” is useful to reduce the monotonous feelings of fatigue in a short-term, light, repetitive task.

The aim of this study was to compare ergonomics of an electrically adjustable sit-stand workstation with a traditional workstation in VDU work.

MATERIALS AND METHODS

Subjects

The subjects were 12 healthy female workers (aged 27–53 years) from one office (Table **1**). They were all right-handed and used a traditional mouse and keyboard. They were accustomed to work at both an electrically adjustable sit-stand workstation and a traditional workstation. During their normal work, the participants adjusted the height of their sit-stand workstation an average of 6 (0–20) times a week, mainly due to perceived tiredness and strain. The volunteer subjects were individually informed of the study, and they gave their written consent to participate before the study began. Before the measurements, the subjects were assigned to two study groups of six participants each, the groups having a different order for the use of the workstations.

Table 1. Background Factors of the Participants (n =12). The values are Means, Standard Deviations (SD), and Ranges

Variable	Mean	SD	Range
Age (years)	38	9	27 - 53
Height (cm)	169	6	158 - 180
Weight (kg)	64	8	50 - 76
Experience in VDU work (years)	9	4	3 - 15
Experience in using a sit-stand workstation (months)	14	13	2 - 48

Study Design

This study was a comparative experiment. The measurements of each subject were carried out during one day in a simulated situation (Fig. **1**). During the study the subjects worked at both workstations (sit-stand workstation, traditional workstation) for 42 minute (Fig. **2**). They worked at the sit-stand workstation in a low-sitting position (LS) for 14 minutes, in a high-sitting position (HS) for 14 minutes, and in a standing position (ST) for 14 minutes. At the traditional workstation they worked for 42 minutes in a low-sitting position. At both workstations, the same standardized mouse and typing tasks were conducted during the measurements, and the tasks were changed every 7 minutes. During the measurements, all 12 subjects worked for 42 minute at both work stations, six subjects first worked at the sit-stand workstation, and six first at the traditional workstation.

Methods

The sit-stand workstation was evaluated with the use of musculoskeletal exposure measurements (electromyography, wrist angles), subjective evaluations (perceived musculoskeletal strain, and satisfaction), and productivity (a mouse and a typing task).

Electromyography (EMG) was recorded from four muscles of the upper body bilaterally (m. erector spinae, m. trapezius pars descendes, m. extensor digitorum communis, m. erector spinae trunci) with a portable ME3000P device with a video option (Mega Electronics, Finland) [29]. The EMG was recorded using the averaged mode, a sampling frequency of 1000 Hz, a time interval of 0.1 seconds, and a bipolar setting of disposable surface electrodes (M-OO-S, Medicotest, Denmark). The positions of the electrodes were defined according to the recommendations of Zipp [30]. The maximal muscular activity of the three muscles was registered during their maximal isometric voluntary contractions (MVC) and standardized as the percentage of the MVC (%MVC). The studied worktasks were video-recorded with a Panasonic S-VHS-C video camera. The EMG data were transferred *via* an optic link to a computer. The analyses and calculations were performed by attached software.

Wrist extension/flexion and ulnar/radial deviation were measured using a two-channel electronic goniometer (Type XM110, Penny & Giles Blackwood Ltd, UK) attached to the wrists of the worker with skin adhesive tape [31]. The output from the goniometers was sampled with a portable device (ME3000P, Mega Electronics Ltd, Finland) at a frequency of 250 Hz, using the averaged mode and a time constant of 0.1 seconds, and stored on a computer for analysis with ME3000P software.

Visual analogue scales (VAS) were used to determine the musculoskeletal strain, and satisfaction with the sit-stand and the traditional workstation [32]. The workers rated their perceived strain on modified VAS, the result of each scale being reported in millimeters (range 0-100 mm with end points of “0 not at all strainful - 100 very strainful”). Satisfaction with the workstation was asked with the question “How satisfied you are with the workstation (VAS, “0 not at all satisfied – 100 very satisfied”)?

Productivity was evaluated using the number of right strokes per 42 minutes during the standardized mouse and typing tasks. In the mouse task (Fig. **3**), developed for this study, the participants used the mouse to delete the middle digit from each item in a special order (111>11, j0j>jj,

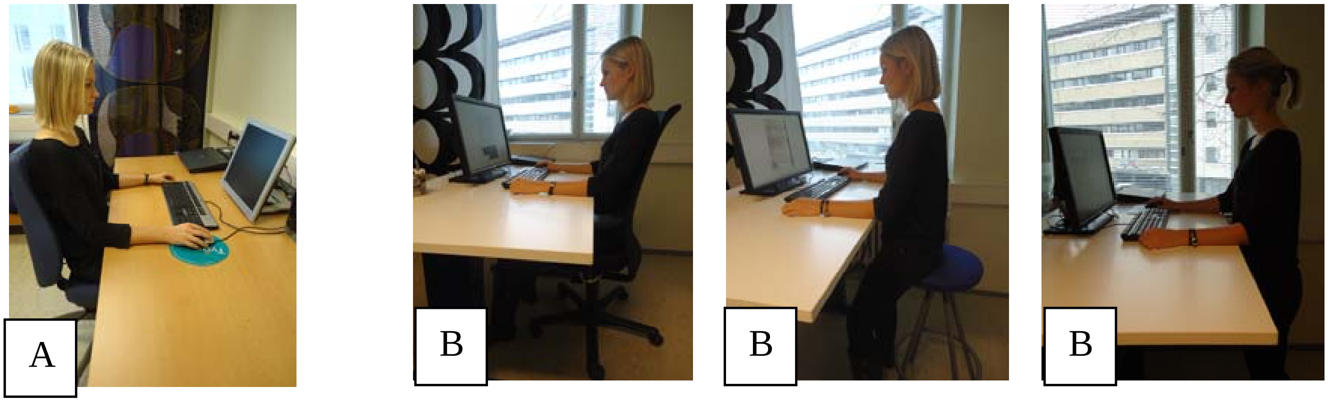


Fig. (1). The traditional workstation (**A**), and the electrically adjustable sit-stand workstation (**B**).

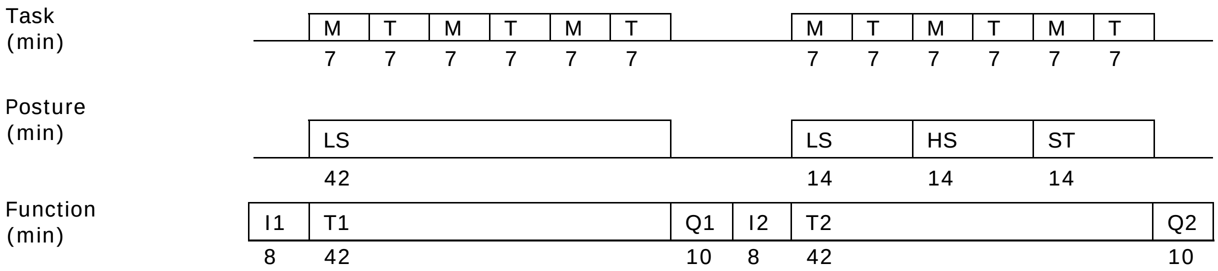
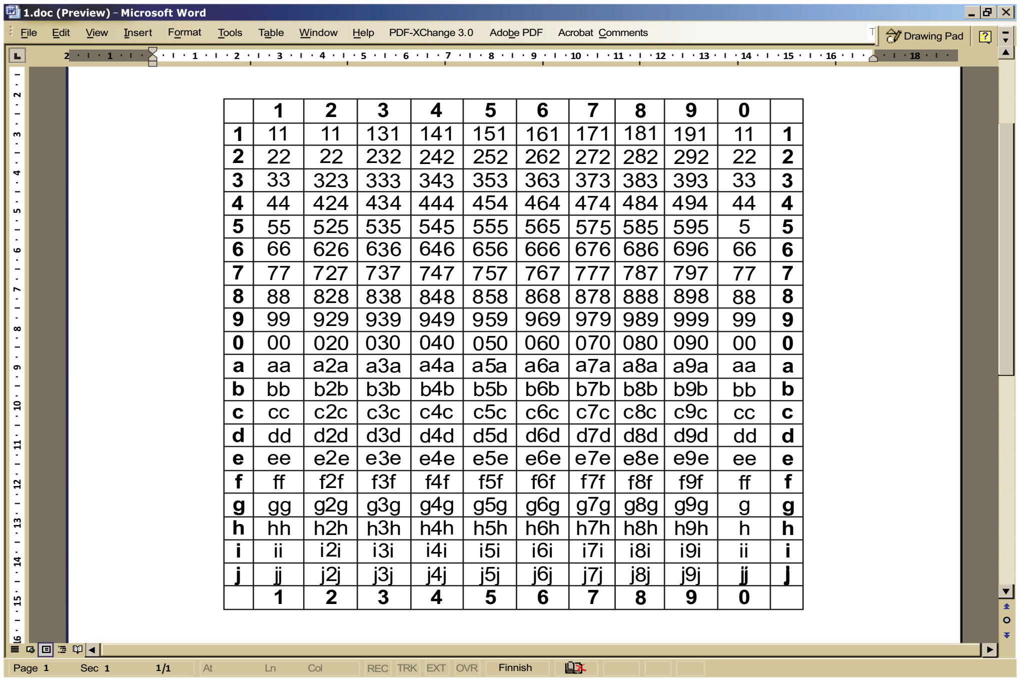


Fig. (2). The test schedule of each participant (n=12) (I1 = Information 1, T1 = Test 1, Q1 = Questionnaire 1, I2 = Information 2, T2 = Test 2, Q2 = Questionnaire 2, LS = low-sitting, HS = high-sitting, ST = standing, M = mouse task, T = typing). Function shows the phases of the experiment. The three scales (Task, Posture, Function) have time in common.



	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	
1	11	11	131	141	151	161	171	181	191	11	**1**
2	22	22	232	242	252	262	272	282	292	22	**2**
3	33	323	333	343	353	363	373	383	393	33	**3**
4	44	424	434	444	454	464	474	484	494	44	**4**
5	55	525	535	545	555	565	575	585	595	5	**5**
6	66	626	636	646	656	666	676	686	696	66	**6**
7	77	727	737	747	757	767	777	787	797	77	**7**
8	88	828	838	848	858	868	878	888	898	88	**8**
9	99	929	939	949	959	969	979	989	999	99	**9**
0	00	020	030	040	050	060	070	080	090	00	**0**
a	aa	a2a	a3a	a4a	a5a	a6a	a7a	a8a	a9a	aa	**a**
b	bb	b2b	b3b	b4b	b5b	b6b	b7b	b8b	b9b	bb	**b**
c	cc	c2c	c3c	c4c	c5c	c6c	c7c	c8c	c9c	cc	**c**
d	dd	d2d	d3d	d4d	d5d	d6d	d7d	d8d	d9d	dd	**d**
e	ee	e2e	e3e	e4e	e5e	e6e	e7e	e8e	e9e	ee	**e**
f	ff	f2f	f3f	f4f	f5f	f6f	f7f	f8f	f9f	ff	**f**
g	gg	g2g	g3g	g4g	g5g	g6g	g7g	g8g	g9g	g	**g**
h	hh	h2h	h3h	h4h	h5h	h6h	h7h	h8h	h9h	h	**h**
i	ii	i2i	i3i	i4i	i5i	i6i	i7i	i8i	i9i	ii	**i**
j	jj	j2j	j3j	j4j	j5j	j6j	j7j	j8j	j9j	jj	**j**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**0**	

Fig. (3). The standardized mouse task in which the middle digit was deleted from each cell in systematic order (111 > 11, j0j > jj, 212 > 22, i0i > ii, etc.).

212>22, i0i>ii, etc.) In the typing task, the same Finnish text was used to determine the writing speed [33].

The results were analyzed using the GLM procedure of SAS (Statistical Analysis System v6.12). The means, standard deviations, and ranges were used for the descriptive evaluation. The independent variable in all of the analyses was the workstation model (sit-stand workstation, traditional workstation). The dependent variables were the muscular activity of the three muscles, the angle of the wrists, the perceived musculoskeletal strain in different body parts, satisfaction, and the number of correct strokes. The differences between the sit-stand and traditional workstations and the testing order were tested using a paired *t*-test. The differences were considered statistically significant if p<0.05.

RESULTS

The test order of the workstation (sit-stand, traditional) had no statistically significant effect on the outcome variables. There were statistically significant differences in the %MVC values when the workstations are compared. The muscle activity of the right trapezius (p=0.01) and the left extensor digitorum communis (p=0.02) were lower when the participants worked at the sit-stand workstation than when they worked at the traditional workstation (Table **2**). There were no statistically significant differences in the activity of the other muscles when the subjects worked at these two workstations.

The extension of both wrists was significantly lower when the subjects worked at the sit-stand workstation compared to the traditional workstation (Table **3**). No differences were found in wrist deviation of the subjects when the two workstations were compared.

There was a statistically significant difference in perceived musculoskeletal strain of two body parts between the workstations. The subjects perceived lower (p=0.05) strain in their arms when they worked in different postures (low-sitting, high-sitting, standing) at the electrically adjustable sit-stand workstation than in work at the traditional workstation (Table **4**). However, work at the sit-stand workstation caused higher (p=0.01) perceived strain in lower limbs than work in low-sitting posture at the traditional workstation. No statistical differences were found in other body parts between the workstations. In the whole, the participants were more satisfied (p=0.05) with the sit-stand workstation than with the traditional workstation.

Productivity measured with the correct strokes per 42 minutes (mouse task and typing task) was 10% better (p=0.02) at the adjustable sit-stand workstation than at the traditional workstation.

DISCUSSION

With increasing VDU work in most jobs, sitting has become a main part of most working environments. Accordingly, any activity that decreases inactivity time, like sitting, may benefit health [1-5, 13].

This study showed that work productivity and satisfaction were better and musculoskeletal exposure was lower during VDU work alternately in low-sitting, high-sitting, and standing positions than during the work in the sitting position. Especially the muscular strain and perceived strain in the upper limbs was lower at the sit-stand workstation.

Table 2. Mean Muscle Activity (Electromyography, EMG, %MVC) in Four Muscle Groups Bilaterally During the Standardized VDU Worktasks of the Participants (n=12) at the Electrically Adjustable Sit-Stand Workstation (in Low-Sitting, High-Sitting and Standing Positions) and at the Traditional Workstation (in Low-Sitting Position)

Body Part/Muscle	Body Side	Sit-Stand Workstation	Traditional Workstation	p
Neck/Musculus Erector Spinae	Right	5.5	5.2	ns
	Left	5.3	4.8	ns
Shoulder/Musculus Trapezius	Right	7.0	9.7	0.01
	Left	5.9	5.2	ns
Arm/ Musculus Extensor Digitorum Communis	Right	10.1	10.4	ns
	Left	9.1	9.8	0.02
Back/ Musculus Erector Spinae Trunci	Right	2.1	1.2	ns
	Left	2.0	1.2	ns

Table 3. Mean Wrist Extension and Ulnar Deviation (Degree) of the Participants (n=12) During the Standardized VDU Worktasks at the Electrically Adjustable Sit-Stand Workstation (in Low-Sitting, High-Sitting and Standing Positions) and at the Traditional Workstation (in Sitting Position)

Wrist Posture	Body Side	Sit-Stand Workstation	Traditional Workstation	p
Extension	Right	22	24	0.05
	Left	18	21	0.002
Deviation	Right	10	11	ns
	Left	13	14	ns

Table 4. Mean Perceived Musculoskeletal Strain (Visual Analogue Scales, VAS, mm, 0=Not at all Strainful - 100 Very Strainful) for Different Body Parts of the Participants (n=12) After the Standardized VDU Worktasks at the Sit-Stand Workstation (Low-Sitting, High-Sitting and Standing Positions) and at the Traditional Workstation (Low-Sitting Position).

Body Part	Sit-Stand Workstation	Traditional Workstation	p
Neck-Shoulder	27	34	ns
Upper limbs	33	42	0.05
Back	30	32	ns
Lower limbs	41	26	0.01

The productivity of the participants was 10% better when the same tasks were done at the sit-stand workstation than it was at the traditional workstation. This finding is in line with the results of previous studies [9, 20]. However, in this study the productivity was measured using a quantitative method developed for this study in co-operation with the experts of technical ergonomics and psychology.

The participants were more satisfied (p=0.05) with the sit-stand workstation than with the traditional workstation. The adjustability offers the possibility to have an influence on own work behavior. The better satisfaction can also be due to the lower exposure and strain of upper limbs and possibility to vary the work postures according to the task and perceived strain.

The subjects perceived lower (p=0.05) strain in their arms and higher (p=0.01) strain in their lower limbs when they worked in different postures (low-sitting, high-sitting, standing) at the sit-stand workstation. The lower strain in the arms is obviously due to the lower static exposure of the arms. The electrically adjustable table offers possibilities to adjust the table height so that it is good for supporting the arms in different tasks. Resting the arms on the table surface has been found to be associated with a reduced risk of neck and shoulder pain and lower discomfort [13-16]. Possibility to support arms also increases the function of arms among persons with disabilities [25].

The subjects perceived higher strain in the lower limbs when they worked at the sit-stand workstation although they changed their working posture every 14 minutes and they had no overweight. This result is in accordance with the review of Reid *et al.* [18]. This shows that moving and dynamic movements are important both in standing and sitting postures [12, 18]. It would be important to develop new solutions to do activities in standing positions during VDU work.

The extension of both wrists was significantly lower when the subjects worked at the sit-stand workstation. This is an important result, because the bent postures of the wrists are main causation of carpal tunnel syndrome [7]. However, no differences were found in wrist deviation when the two workstations were compared. The suitable height of the working surface enabled the participants to keep their wrists in a more neutral position. This finding agrees with the results elicited during the use of arm rests [13]. It is obvious, that too low working surface in VDU work will cause greater extension of the wrists.

This study evaluated an electrically adjustable sit-stand workstation by comparing it with the traditional workstation. The study was planned in cooperation with researchers, workstation manufacturers, and experienced office workers in a participative way. The evaluation was made using the quantitative (EMG, wrist angle, VAS, productivity) methods. The 42-minute VDU task duration was chosen because it seemed to correspond to an average continuous VDU task in an actual work situation. All 12 subjects worked for 42 minute at both work stations and they had a pause between the workstations. The participants represented typical female workers in Finland and they were accustomed to using both of the tested workstations.

Sit-stand workstation offers the possibility to reduce the sedentary behavior and inactivity during the work day. These possibilities should be used when new office environments are designed or old offices are redesigned. Easily adjustable workstations are especially important in open offices where the same workstations are shared by several workers. However, the correct use of technical accessories such as adjustable workstations requires that all of the workers involved be well educated and systematically motivated. Sit-stand workstations can be used in the primary prevention when working comfort will be increased. In secondary prevention, the possibility to work also in high-sitting and standing positions is important, for example, for workers with acute back pain. In tertiary prevention, electrically adjustable workstations are proper workplace accommodations among persons with permanent disabilities [24].

CONCLUSIONS

Working both in sitting and standing postures was more productive and caused lower strain of the workers' upper limbs than work only in a sitting posture. The electrically adjustable sit-stand workstation offers the possibility to reduce the sedentary behavior and inactivity in VDU work.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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