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Prevention of Deep Vein Thrombosis in VDU Work

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This paper introduces preventive measures against Deep Vein Thrombosis (DVT) during Visual Display Units (VDU) work. Four experiments were conducted in order to address this issue. The effectiveness of the preventative measures was evaluated by measuring foot swelling. The results indicated that the following 3 methods would be particularly effective: (a) occasionally adopting a reclining posture with a footrest, (b) 10-min walking every 50–60 min of VDU work, and (3) stretching. In addition we predicted that taking a deep breath could sometimes be effective. DVT is likely to occur in daily life and its incidence can be related to the long-term postures associated with VDU work. This paper suggests that VDU workers should be aware of the risk of DVT and take preventative measures.

Deep Vein Thrombosis foot swelling visual display units
long-term work

1. INTRODUCTION

Recently, with the growth of telecommunication technologies and changes in office organization the office worker's work environment has changed dramatically. For instance, working stress has become more complicated and diverse, resulting sometimes in mental fatigue. At the same time physical fatigue and discomfort due to long-term work have increased.

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Long-term Visual Display Unit (VDU) work has increased as VDU work has evolved into usage of personal computers (PC). Consequently, VDU work is increasingly a major component of work. This study addresses VDU work. A guideline for VDU operators (Waseda University, 1995) has recently been updated for portable PC use (Noro, 1994, 1999). In the guideline three postures were reported: upright, bent forward, and reclining posture.

According to further research by Tanaka and Noro (2000), more than 70% of VDU operators bend forward while they work. In order to avoid excessive periods of time in the forward-bending posture and upright posture, we proposed a reclining posture using a leg rest during a long-term evaluation of lower leg and foot discomfort. Our experiment examined foot swelling during VDU work together with subjective discomfort. It was found that the volume of the foot decreased with the reclining posture. A decrease also occurred when the participants took a 10-min rest between the upright posture and the reclining posture. This can be linked to the findings of Olszewski and Engeset (1980), who found that exercise, such as walking, makes blood flow upwards to the heart like a pump system and leg activity seems to increase lymph flow. In another example Winkel and Jorgensen (1986) investigated the effect of 2-min walking breaks after every 30 min of work. In this research it was found that 10-min rest every 1 hr of work was more productive. The second part of the work, experimented by comparing different rest durations, which were 5, 10, and 15 min.

Whereas Pottier, Dubreuil, and Monod (1969) found that prolonged sitting slows venous flow to the heart due to a reduction in muscle activity, we showed that the reclining posture decreased the swelling measured in the feet. Paul (1995) found that a sit-stand workstation caused less foot swelling. These reports show how foot swelling can be used to measure the effect of long-term VDU work on the body.

In addition to its association with long-term VDU work, foot swelling often occurs when one maintains a static posture on an airplane, train, and bus during long trips. Such conditions are known to give rise to Deep Vein Thrombosis (DVT) and its occurrences are reported frequently. Consequently the possibility of DVT during the VDU work has been investigated and effective methods for preventing foot swelling, as in experiment 3, are recommended. Scurr (2002) reported that graduated elastic compression stockings reduced the incidence of DVT. Generally, the activation of the muscle pump effect was effective in preventing foot discomfort. Sugimoto, Shiratori, and Sekido (1992) found a relationship between breathing and foot swelling.

Previous work has identified three methods for preventing foot swelling. The first method is a reclining posture used with a leg rest, the second is 10-min walking, and the third is occasional stretching. In the final part of the current work we investigated the relationship between heart rate and drawing in a deep breath, 10-min walking, and stretching respectively.

This study enables us to propose several approaches to the prevention of foot swelling and DVT. Nowadays VDU workers are unaware of the risk of DVT despite their long-term seated posture. This is an important problem for occupational safety. This study is the result of a long period of investigation and development of countermeasures. It is expected that this study will contribute to the assurance of a comfortable environment for VDU use in future offices.

2. METHODOLOGY

2.1. Experiment 1

2.1.1. Methods

Paul (1995) examined variations in foot volume for two kinds of VDU postures. This experiment reproduces his method.

2.1.2. Participants

Ten university students (4 males, 6 females).

2.1.3. Apparatus

1. Water tank (30 × 20 × 20 cm)
2. Graduated cylinder (1000 cc, 100 cc)
3. Pipette (10 cc)
4. Adhesive tape
5. Measuring tape

2.1.4. Procedure

We followed the procedure described in Pottier et al. (1969) and Winkel (1981). Foot swelling was measured using a water tank. The participant performed a task at a VDU seated in the upright posture for 50 min followed by a rest of 10 min. During the rest participants were free to move, walk around,

and so forth. After the rest the participant continued the same task but seated in the reclining posture with a leg rest for 50 min. The foot swelling measurement was recorded four times for each participant. To subjectively evaluate discomfort, a questionnaire was administered, in which participants were asked to rate their discomfort in the specific areas of foot swelling, dullness, discomfort, shoulder discomfort, hip discomfort, and overall body discomfort. The participant chose from a 10-point scale with 1 representing *least discomfort* and 10 representing *most discomfort.* Discomfort ratings were obtained twice: Once at the end of the VDU task seated upright and again at the end of the VDU task seated reclined with the leg rest.

2.2. Experiment 2

2.2.1. Participants

Eight university students (4 males, 4 females).

2.2.2. Apparatus

1. Custom-designed water tank (30 × 13 × 13 cm)
2. Pipette (10 cc)
3. Measuring tape

2.2.3. Procedure

The participant performed a task at a VDU seated in the upright posture for 50 min followed by a rest period of either 15 or 5 min. As in experiment 1 participant could walk around during the rest period. Three measurements were taken for each participant. One was variation in foot volume using the water tank. The second was the circumference of lower thigh and instep using a measuring tape. Thirdly, the discomfort questionnaire was administered.

2.3. Experiment 3

2.3.1. Participants

Ten university students (5 males, 5 females).

2.3.2. Apparatus

1. Custom-designed water tank (Figure 1)
2. Measuring tape

2.3.3. Procedure

The experiments were conducted under the three different conditions. Firstly the participant was simply performing the same VDU task as in the previous experiments. Secondly, in addition to the VDU task the participant drank a cup of water twice at 25-min intervals. Thirdly, in addition to the VDU task the participant performed four kinds of stretching exercises twice at 20-min intervals. The measurements made were same as those in experiment 1 and 2 plus further measurement of forefoot circumference in two places.

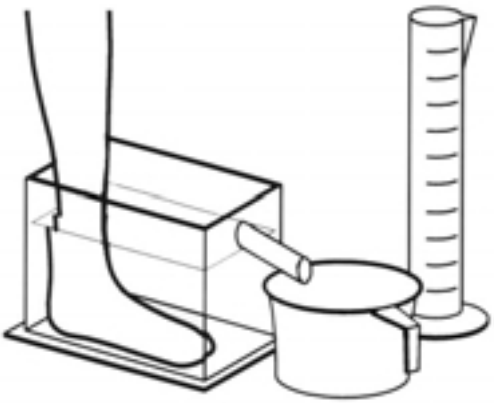

Figure 1. Water tank for measuring foot swelling (created by Mitsuya) *Notes.* Foot swelling is measured with overflow water from the tank.

2.4. Experiment 4

2.4.1. Method

In this experiment the three countermeasures examined in the preceding experiments were compared for their effect on heart rate. The counter-measures examined were drawing in a deep breath, adopting the reclining posture with a leg rest, and 10-min walking and stretching.

2.4.2. Participants

Two university students (1 male, 1 female)

2.4.3. Apparatus

1. Heart rate monitor (POLAR S810; POLAR Electro, Finland)
2. Stop watch

2.4.4. Procedure

Firstly the participants walked for 10 min with a heart rate monitor. Secondly they rested, in the reclining posture with a leg rest, drawing in a deep breath and extending their legs for 1 min. Finally they performed a stretching exercise, moving the heel and toe up and down alternately.

3. RESULTS AND DISCUSSION

3.1. The Result of Experiment 1

The accuracy of the foot volume measurement was 1 ml. This corresponded to an average of 0.1% of the foot volume. Figure 2 shows respectively the mean percentage of changes in the volume of the foot. The discomfort of the foot was correlated to foot swelling. The difference in volume change between the upright posture and the reclining posture had a 5% level of significance in a two-way ANOVA. The difference in discomfort rating between the upright posture and the reclining posture also had a 5% level of significance.

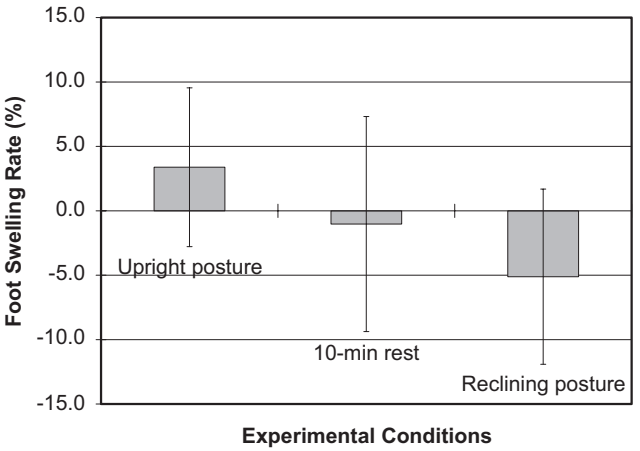

Figure 2. Mean percentage change in foot volume measured with wet system. *Notes.* This figure shows the reclining posture is the most effective method of decreasing foot swelling

The volume of the foot decreased with the reclining posture. A decrease also occurred when the participants took a 10-min rest between the two tasks. This can be linked with the findings of Olszewski and Engeset (1980) who

found that exercise, such as walking, made blood flow upwards to the heart like a pump system and leg activity seemed to increase lymph flow. In another example Winkel and Jorgensen (1986) investigated the effects of 2-min walking breaks after every 30 min of work. Further research is needed to find an optimal rest time. The result of experiment 2 indicates the research needed.

Whereas Pottier et al. (1969) found that prolonged sitting slowed the venous flow to heart due to a reduction in muscle activity, it is shown here that the reclining posture decreased the swelling measured in the feet. The condition that Pottier showed suggested the possibility of DVT (see also experiment 3). Paul (1995) found that a sit-stand workstation caused less foot swelling.

The current work shows a leg rest to be effective in VDU work. The effectiveness may also be affected by the height of the leg rest or the type of shoes worn. The former factor appears to be the more important (in experiment 4, we made an adjustment of the height of the leg rest). As for the latter, Hansen, Winkel, and Jorgensen (1998) investigated the significance of mat and shoe softness during prolonged work in an upright position. The hypothesis that a still more-reclined posture with a higher foot position might be more suitable for longer periods of VDU work could be investigated by measuring foot swelling.

3.2. The Result of Experiment 2

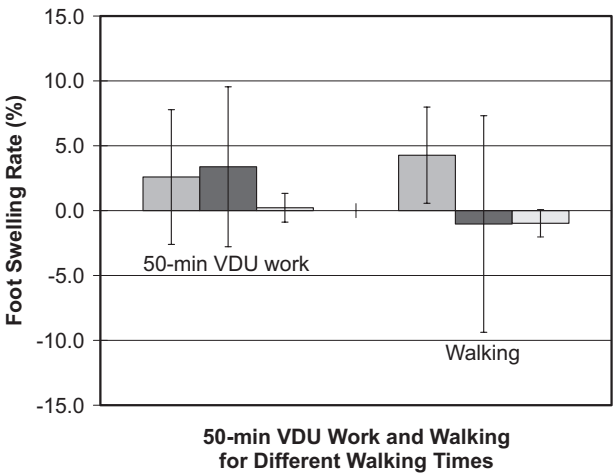

Figure 3. Foot-swelling rate for each walking time during the rest. *Notes.* This figure indicates 10-min walking is the most suitable method for decreasing foot swelling. VDU—visual display unit.

Figure 3 shows the amount of foot swelling immediately after VDU work and then following the walking rest periods of different duration. The values increased in the case of 5-min walking. The values for 10- and 15-min walking were not very different. Therefore we propose 10-min of walking after 50 min of VDU work.

3.3. The Result of Experiment 3

Figure 4 and Table 1 show the results of the foot-swelling change for different parts of the foot. The swelling change was greatest for condition 1 (VDU work only). With a two-way ANOVA a significant difference was shown for the maximum circumference of the lower leg between VDU work only and VDU work with stretching ($p < .05$) The lower swelling rate is indicated in the case of the lower leg and forefoot.

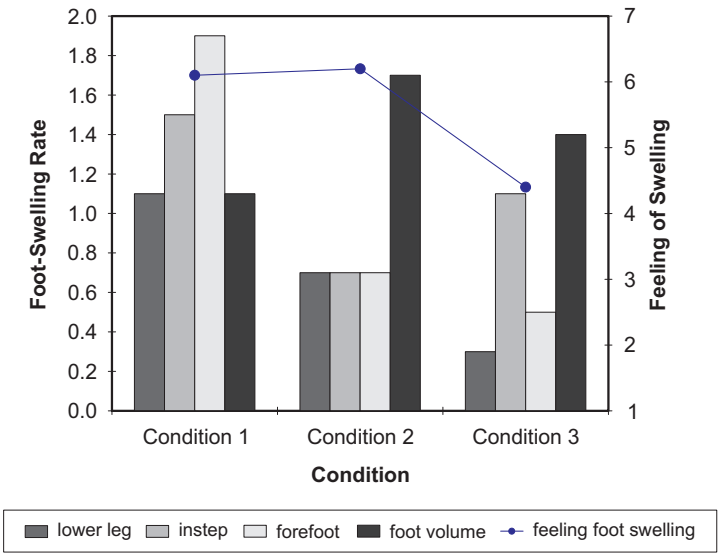

Figure 4. Foot swelling rate for different parts of the foot, and feeling of swelling. *Notes.* Vertical axis on the left indicates foot-swelling rate, on the right it indicates the mean score of feeling foot swelling. The highest score of feeling foot swelling is 7 points.

TABLE 1. Mean Value of Foot Swelling Rate (%) for Each Part of the Foot

Part of the Foot	Condition 1	Condition 2	Condition 3
Lower leg	1.1	0.7	0.3
Instep	1.5	0.7	1.1
Forefoot	1.9	0.7	0.5

The results of a subjective rating of the physical discomfort in specific parts of the body are shown in Table 2 (the highest score was 7). A one-way ANOVA found that the discomfort score was highest in the VDU work only condition ($p < .1$). The foot discomfort score was also highest in the VDU work only condition.

TABLE 2. Mean Values of Subjective Rating of Discomfort in Specific Parts of the Body

Part of the Body	Condition 1	Condition 2	Condition 3
Head	3.1	3.0	3.2
Neck	4.1	3.8	4.6
Shoulder	4.5	4.5	4.5
Forearm	3.9	3.2	3.1
Elbow	3.5	2.8	2.4
Upper arm	3.3	2.7	2.8
Abdomen	3.6	2.8	2.6
Back	4.6	4.2	4.8
Lumber	4.9	4.9	4.5
Buttocks	5.3	5.2	4.0
Thigh	4.3	4.5	3.5
Knee	4.0	3.4	2.7
Lower leg	5.1	4.1	3.2
Foot	5.2	4.2	3.2

For 60-min VDU work, work with stretching was effective for workers to reduce foot-swelling rate, which was concluded in this experiment. By approaching from subjective evaluation, we obtained knowledge that long-term static posture in VDU work only affected physical discomfort, especially the lower leg and buttocks, which were causes of foot swelling. In this experiment we predicted that the risk factor of DVT in VDU work was long-term static posture as well as the factor of the Economy Class Syndrome.

3.4. The Result of Experiment 4

The results for the two participants are shown in Table 3 and Figure 5.

TABLE 3. Heart Rate for Two Subjects in Each Condition

	Heart Rate (M ± *SD*)	
Condition	1 Female	1 Male
10 min-walking	92.7 ± 3.72	95.6 ± 4.34
Deep breath, reclining with a leg rest	93.0 ± 12.15	85.1 ± 8.24
Stretching	84.1 ± 3.30	82.8 ± 3.40

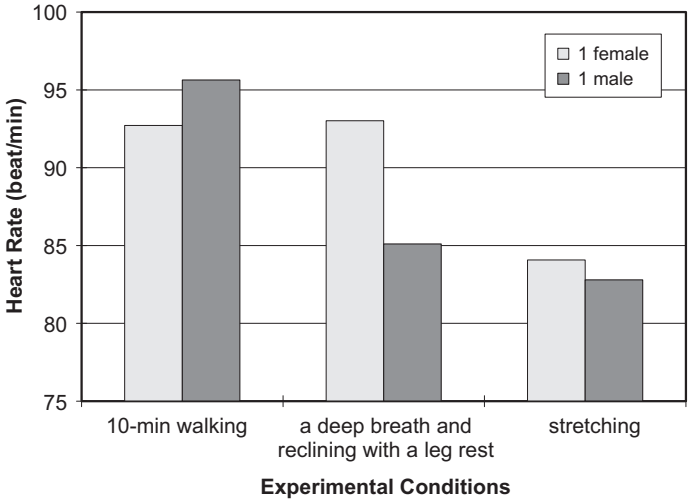

Figure 5. Heart rate for the 2 participants in each condition. *Notes.* This figure shows stretching requires less exercise than the two other conditions.

A one-way ANOVA showed no significant difference between the conditions. The finding indicated that stretching may be sufficient exercise. In the case of the male participant heart rate in the 10-min walking condition was almost the same as when drawing in a deep breath and extending the legs. However in this experiment there were only two participants so we could not confidently propose drawing in a deep breath and extending the legs as an effective rest activity to decrease discomfort during VDU work. It is further noted that during 10 min of walking the participants would have also stretched and taken deep breaths.

4. CONCLUSION

With the growth in the use of information technology (IT), the working environment of the office has greatly changed. DVT is likely to occur in daily life, especially associated with VDU work in a modern office where IT is widely used. Sometimes excessive air conditioning and maintaining the same seated posture for a long time might trigger off DVT. Tezuka, Sato, Igarashi, and Sugishita (1996) found that stretching is effective in decreasing foot swelling during VDU operation. In this study some preventive measures were proposed: sitting in a reclining posture and occasionally using a footrest, deep breathing and resting the legs on an adequate leg rest, and 10 min of walking during a break. Further research will follow.

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