Kawasaki Journal of Medical Welfare Vol. 10, No. 1, 2004 1–8

Original Paper

Effects of Sitting Posture on Sitting Pressures and Electromyograms

Masatomi MATSUMOTO*and Yoshinori SAITO*

(Accepted May 8, 2004)

Key words: sitting posture, sitting pressure, electromyogram, modular chair

Abstract

This study was designed to investigate the effects of sitting posture on sitting pressures and electromyograms to obtain baseline data for improving seating for the elderly. The subjects were ten healthy Japanese men, and nine sitting positions were tested utilizing an experimental modular chair. Pressures on the seat and back, and surface electromyograms of the tibialis anterior, soleus, vastus medialis, superior trapezius, and iliocostalis-lumborum for each sitting position were recorded. The results were as follows: 1) Pressure on the seat was significantly increased when the seat height was high and when the armrest height was high or low. 2) Pressure on the seat was increased at a back angle of 110 °, and pressure on the back was increased at back angles of 100 °and 120 °. 3) High seat height did not place a direct burden on the soleus, but affected the posture resulting in a burden on the legs. 4) Integral electromyograms were increased significantly at a high armrest height, and it is predicted that a poor armrest fit may place a burden on the shoulders.

Introduction

People spend much of their time during the course of a day sitting in a chair, particularly with elderly wheelchair users in care facilities. This has been confirmed in time study investigations of the residents in such facilities [1–2].

However, most elderly people use standard wheelchairs, and usually the seat or armrest height is not adjustable to the user's physique. For example, Ueno *et al.* (1992) reported that the average lower-thigh height of the elderly in Japan is 370 mm (men) and 340 mm (women), and the average sitting elbow height is 200 mm (men) and 180 mm (women) [3]. However, standard wheelchairs are designed for users with lower-thigh of 400∼470 mm and sitting elbow heights of 230 mm. Since these wheelchairs have inappropriate dimensions for the user, they cause forced posture and result in physical stress. As the population ages, improvements have been made in the living environment of nursing homes for the elderly, such as the trend toward single occupancy, but few changes have been made in seating. Several studies have been done on seating for driving or office work [4, 5], and effects of chair/wheelchair-accessories like cushions or backrests on sitting pressures, and positioning of wheelchairs [6, 7]. With regard to studies involving sitting pressures and electromyograms, Inagaki *et al.* (2000) reported on an evolutionary driving seat [8], and Yukawa *et al.* (2002) reported on an evolutionary wheelchair [9]. These studies dealt with

* Department of Medical Welfare Environmental Design, Faculty of Medical Welfare
Kawasaki University of Medical Welfare
Kurashiki, Okayama 701-0193, Japan

particular seating or products, but didn't cover general seating for the elderly.

The purpose of the present study was to obtain fundamental data to improve seating for the elderly by investigating (1) the effects of sitting posture on sitting pressures, and (2) the effects of sitting posture on electromyograms, utilizing a custom-ordered experimental modular chair.

Methods

(1) Subjects

Ten healthy Japanese men participated in this study. The physical characteristics of the subjects are shown in Table 1. The subjects were 20.2±0.9 years old (Mean ± SD), 172.3 ± 3.2 cm tall, and weighed 62.3 ± 10.6 kg (Table 1). They wore short pants and T-shirts during the experiments.

Table 1 Physical characteristics of subjects

	Age	Height (cm)	Weight (kg)	Lower-thigh height(cm)	Sitting-elbou height(cm)	sitting height(cm)	Hip breadth (cm)
Subject-1	20	174	85	44	28	93	37.5
Subject-2	20	173	57	45	24	94	33.5
Subject-3	20	174	55	47	26	92	32.5
Subject-4	21	166	55	43.5	25.5	91	32.5
Subject-5	20	170	52	43	27.5	92.5	31.5
Subject-6	22	175	54	47	22	91	31
Subject-7	21	175	72	44.5	27	98	36
Subject-8	19	171	60	45	26.5	93	34.5
Subject-9	20	176	72	47	26.5	96.5	36
Subject-10	19	169	61	43	23	89	34.5
Mean	20.2	172.3	62.3	44.9	25.6	93.0	34.0
SD	0.9	3.2	10.6	1.6	2.0	2.7	2.1

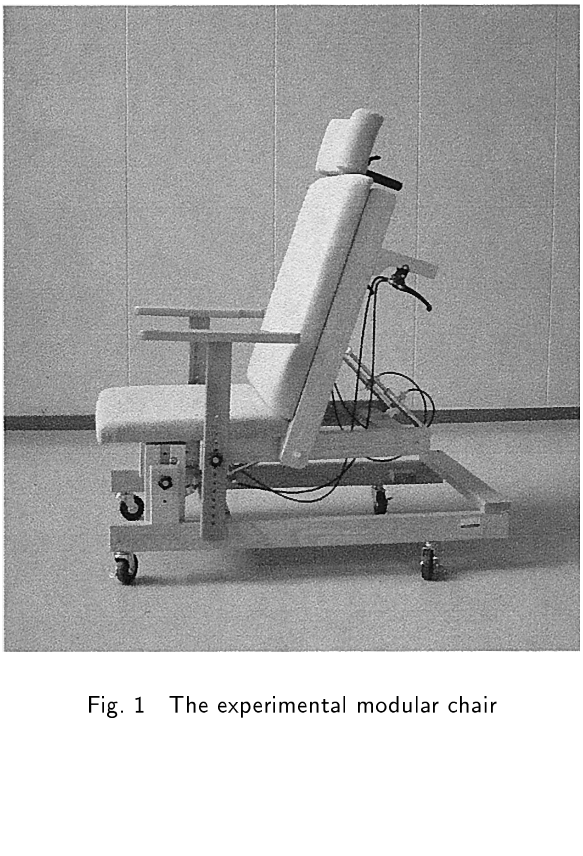

Fig. 1 The experimental modular chair

(2) Experimental modular chair

A modular chair was custom ordered for this experiment (Figure 1). The sitting height, armrest height, seat depth, back angle, and seat tilt were adjustable. The specifications are shown in Table 2.

(3) Procedures

The experiments were performed between July and August 2003 in an air-conditioned room at Kawasaki University of Medical Welfare. After the experimental routine was explained fully to each subject, their physical measurements were taken. Sitting pressures and surface electromyograms were measured for each subject while sitting in a relaxed manner in each of nine positions (Table 3).

(3–1) Sitting pressures

The measurement system (apparatus and analysis software) used was Force Sensing Array Ver.3.1 (Takano, Nagano, Japan). This system was capable of recording the pressure on the seat and back at 5 frames/second. After the sitting posture of each subject had stabilized, data were obtained for 20 seconds (100 frames). The middle 50 frames were selected, and the total contact areas (the area which the sensor detects the body pressure) and the average pressures were calculated.

Table 2 Specifications of the experimental modular chair

	Adjustable range	Adjustable interval
Seat height	H=290～510mm	30mm
Armrest height	H=200～460mm	20mm
Seat depth	D=300～480mm	20mm
Back angle	A=0～45°	no-interval
Seat tilt	A=0～25°	no-interval

Table 3 Nine seating positions of the experimental modular chair

No.	Code	Seating Position
1	basal s. (basal seating)	seat height = lower-thigh length armrest height = elbow height back angle = 100° seat depth = buttock-popliteal length − 40mm seat tilt = 0°
2	sh-90	seat height = lower-thigh length − 90mm
3	sh+90	seat height = lower-thigh length + 90mm
4	sh+180	seat height = lower-thigh length + 180mm
5	ah-60	armrest height = elbow height − 60mm
6	ah+60	armrest height = elbow height + 60mm
7	ah+120	armrest height = elbow height + 120mm
8	ba 110	back angle = 110°
9	ba 120	back angle = 120°

□All positions were the basal seating exept for the change in the seating position column.

□Each setting value was determined by referring to other studies [10,11] and a previous pilot study.

(3–2) Surface electromyograms (EMGs)

EMGs were recorded with a Multi Telemeter MT11 (NEC Medical Systems, Tokyo, Japan). After cleaning the skin with alcohol, surface electrodes were attached with conducting paste to the tibialis anterior, soleus, vastus medialis, superior trapezius, and iliocostalis-lumborum at the L3 level on the left side of the body. The time constant was 0.03 s, the high-cut filter was 100 Hz, and the notch filter to cut off the ham was 60 Hz. The analytical software used was Bimitus II (Kissei Comtec, Nagano, Japan). Data were taken over a period of 90 seconds and the middle 30 seconds of data were used for analysis. The baselines were corrected and integral EMGs (iEMGs) were calculated.

(3–3) Statistical Analysis

Statistical analysis was by paired t-test.

Differences were considered significant at $p<0.05$.

Results

(1) Sitting pressures

Figures 2–1,2 show sitting pressures for each seat height. Raising the seat height resulted in increased total contact area on the seat, and the differences compared to basal seating were significant. However, setting the seat height lower or higher than basal seating increased average pressure on the seat. Figures 3–1,2 show the results for each armrest height. There were no significant differences in total contact area. However, just as in the case for seat height, both lowering and raising the armrest from basal seating increased average pressure on the seat.

Figures 4–1,2 show the results for each back angle. Both the total contact area and the average pressure on the seat were higher at a back angle of 110 °than at angles of 100 °or 120 °. The pressure on the back was lower, however, at a back angle of 110 °.

(2) Surface electromyograms

The average iEMGs of ten subjects for each sitting position are shown in Figure 5. The iEMGs of the superior trapezius were increased at armrest heights of +60 and +120, but were decreased at back angles of 110 ° and 120 °. Among these differences, the values for the armrest height of +120 were especially significant. The iEMGs of the soleus were increased at sh+90 and sh+180, but the differences were not significant. No other differences were detected in the other muscles.

Figure 6 shows the soleus iEMGs for each subject. The iEMGs of subject-1 at sh+180 and subject–3 at sh+90 were especially high.

Figure 7 shows the superior trapezius iEMGs for each subject. More than half of the subjects showed increased iEMGs at ah+60 and ah+120. These results indicated that armrest height had a particularly marked effect on iEMGs.

Discussion

(1) Relationship between sitting position and pressure

Generally, sitting pressure is concentrated on the ischium when the seat height is low, and it is dispersed over the undersurface of the thigh when the seat height is high [11]. In this investigation, the total contact area increased significantly as the seat height was increased from –90 to basal seating, +90 and +120. The average pressure on the seat increased in both cases when seat height was lowered and raised, which showed the burden on the seat increased under these opposite conditions. As stated in the introduction, many elderly people use wheelchairs with seat heights higher than their lower-thigh length, which has negative effects on the muscles of the posterior thigh. As there were no clear changes in the total contact area or the average pressure on the back, the increased burden caused by raising the seat height was shifted from the weight on the plantar. However, the experimental equipment used in this study was only capable of recording pressure in two places simultaneously which precluded obtaining pressure data from the plantar. This problem will be examined in a future study.

The average pressures on both the seat and the back were increased significantly when armrest height was lowered to –60, suggesting that part of the weight on the armrest was shifted to the pressure on the seat and back. However, the average pressure on the seat also increased when the armrest height was raised from the basal level to +60 and +120. Thus, setting the armrest to the sitting elbow height apparently is moderately effective in dispersing sitting pressure.

The pressure on the seat was increased at a back angle of 110 °, and that on the back was increased at back angles of 100 °and 120 °. Noro *et al.* (1991) reported that a sitting posture of 110 °is the most comfortable [12], implying that decreasing the pressure on the back is effective in promoting comfort. These results indicate that shifting the back angle around 110 °is effective in controlling the dispersion of pressure. For example, if the back angle of the chair/wheelchair is adjustable, this fact would make it easy to adjust the pressure on the seat and back for the elderly who have difficulty in shifting their sitting position by themselves.

(2) Relationship between sitting position and surface electromyograms

The iEMGs of the soleus showed a marked increase when the seat height was increased from the basal level to +180 (subject–1) and +90 (subject–3). Both subjects extended their toes to reach the floor at that time, which was considered to be an unconscious desire to attain a stable posture. That is, the high seat position itself does not stress the soleus, but the halfway seat height affects posture by placing a burden on the leg.

The iEMGs recorded from the trapezius showed significant increases when the armrests were high. As mentioned previously, existing wheelchairs are generally too large especially for elderly people. Furthermore, this tendency is exacerbated in patients with kyphosis. A poor fitting wheelchair in which the armrest is too high results in a burden on the shoulders and could cause neck stiffness, *etc.*

In this experiment, EMGs were measured on five muscles, and a significant correlation with posture was observed only for the trapezius. It appears that there is no great burden on muscles involved directly in the sitting posture, such as those of the waist, the back, and the legs. However, Inagaki *et al.* (2000) reported that stress caused by prolonged seating raised the iEMG of the psoas [8]. Therefore, further studies will be performed on the effects of sitting for prolonged periods.

Acknowledgments

This study was supported by grants-in-aid for Project Research from the Kawasaki University of Medical Welfare in 2001. The authors would like to express their gratitude to Prof. Sho ONODERA of Kawasaki University of Medical Welfare for helpful discussions and Mr. Takeru TANIGUCHI for his assistance with the experiments.

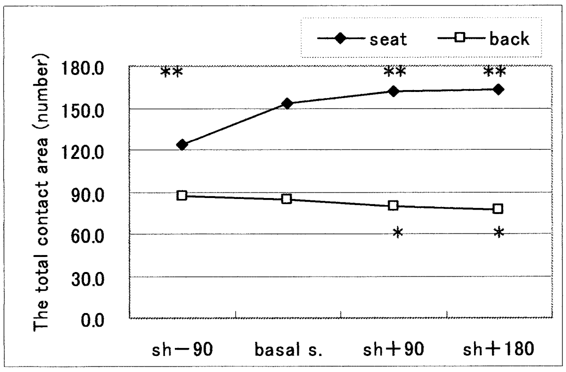

Fig.2–1 Total contact area at each seat height (Significantly different from basal seating, *:p<0.55, **:p<0.01)

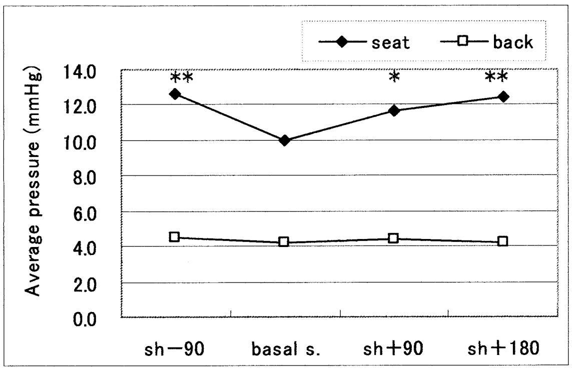

Fig.2–2 Average pressure at each seat height

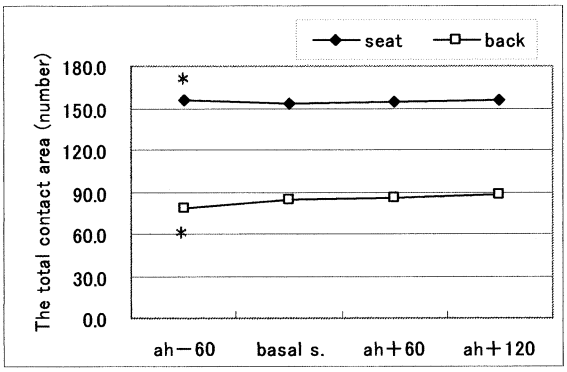

Fig.3–1 Total contact area at each armrest height

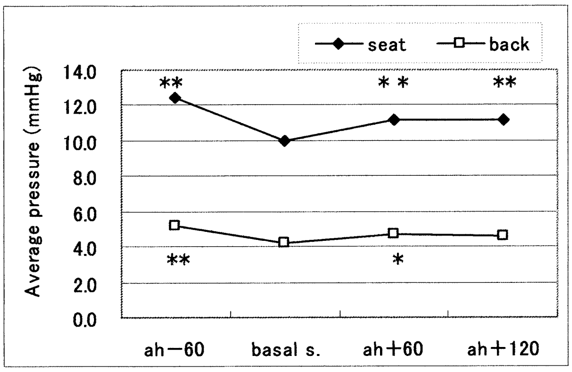

Fig.3–2 Average pressure at each armrest height

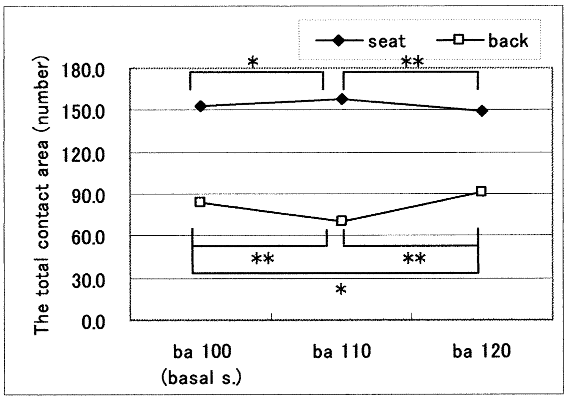

Fig.4–1 Total contact area at each back angle

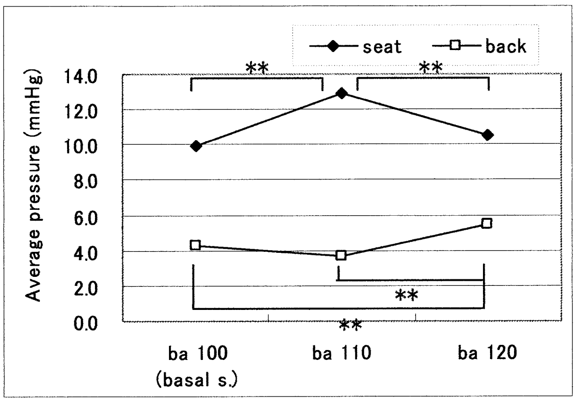

Fig.4–2 Average pressure at each back angle

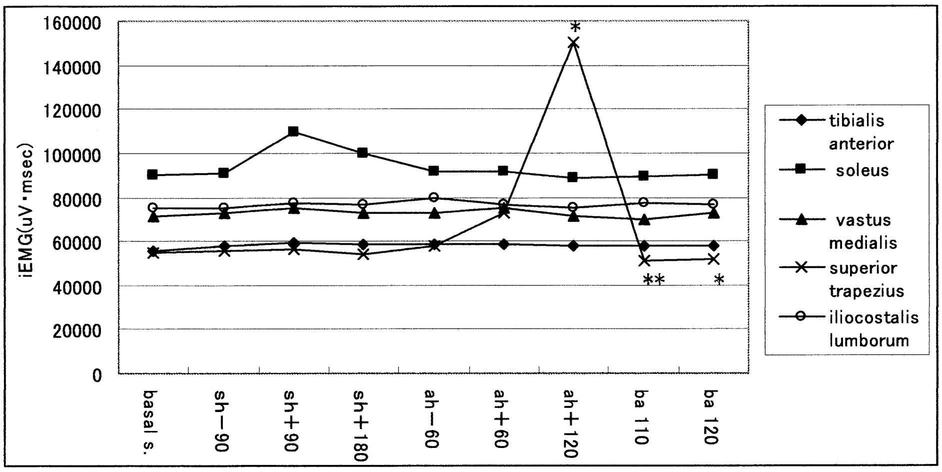

Fig.5 Average iEMG for each seating position
(Significantly different from basal seating, *:$p<0.05$, **p:<0.01)

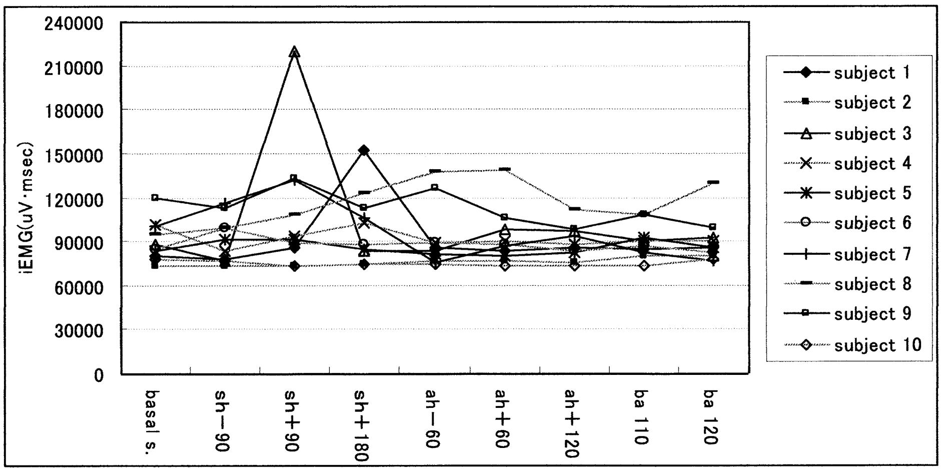

Fig.6 Soleus iEMG for each subject

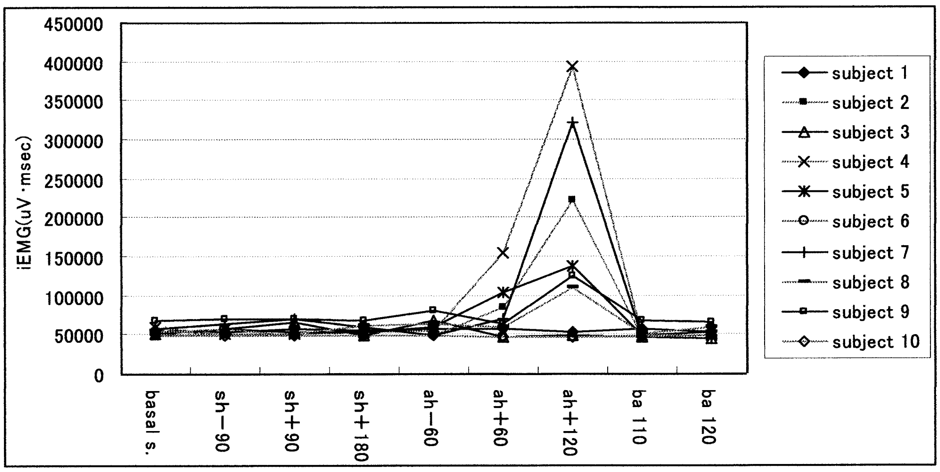

Fig.7 Superior trapezius iEMG for each subject

References

1. Toyama, T., Ichikawa, T., Saito, Y., Miura, K., Matsumoto, M., et al : *Research Report about Life Improvement of Elderly People in Care Facility by Developing their Living Environment*, Health, Labour and Welfare Ministry contract research report, 2002.
2. Taniguchi, T., Matano, S., Saito, Y., Matsumoto, M.: A Case Study on Effect of Adaptation for Elderly Wheelchair Users on Behavioral Pattern in Nursing Home, *Journal of Japanese Conference on Rehabilitation Technology*, 18, 157–158, 2003.
3. Kohara, J., Uchida K., Ueno, Y., Hatta, K.: *Human Physical Measurement.* Nippon Syuppann Sarvice, Tokyo, 1992.
4. David Ng, Tom Cassar, Clifford M. Gross: Evaluation of an Intelligent seat System, *Applied Ergonomics*, 26(2), 109–116, 1995.
5. E. Grandjean: VDT Workstation Design-Preferred Settings and their Effects, *Human Factors*, 25(2), 161–175, 1983.
6. Ehara, Y., Matsuo, K., et al: Development of wheelchair cushion that is a combination of air and urethane, *Summaries of Japanese Conference on the Advancement of Assistive and Rehabilitation Technology*, 15, 165–168, 2000.
7. Matsuoka, T., Nishimatsu, T., et al: Influence of Angle of Backrest for Sitting Comfort of Wheelchair, *Summaries of Japanese Conference on the Advancement of Assistive and Rehabilitation Technology*, 15, 211–214, 2000.
8. Inagaki, H., Taguchi, T., Yasuda, E., Doi, S.: Evaluation of Seat Kansei Quality. *Toyota Central Institute R & D review*, 35(4), 9–14, 2000.
9. Yukawa, T., Kawaguchi, A., et al: Evaluation of Wheelchair Seat Comfort Level, *Summaries of Japanese Conference on the Advancement of Assistive and Rehabilitation Technology*, 17, 57–60, 2002.
10. Hirose, H., Oyama, H.: A Study on the Design of a Chair for the Elderly, *Research Reports of National Rehabilitation Center for Persons with Disabilities*, 15, 1–6, 1994.
11. Kohara, J., Uchida, Y., Uno, H.: *Architecture Interior Human-Engineering.* Kajima Syuppankai, Tokyo, 1993.
12. Noro, K., Adachi, K., Hattori, T., Yamamoto, T.: *Ergonomics Design.* Nikkagiren Syuppansya, Tokyo, 1991.