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Original Paper

A Study of the Relationship between Sitting Environments and Physical Motion Activities in the Elderly

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Abstract

This study was done to provide reference materials for the improvement of the sitting environments of elderly people. Parameters studied included sitting pressure distributions in stationary sitting positions, postural change indices in prolonged sitting positions, and physical motion activities using the Actigraph, which measures the amount of physical activity based on accelerations along 3 axes. Ordinary-type wheelchairs and office chairs adjustable to postural change were utilized, and differences in sitting environments were evaluated. The results indicated that postural change activities did not significantly vary, although there were minor variations. However, office chairs had lower values of maximum sitting pressures than wheelchairs. In addition, the physical motion activities for office chairs were relatively low, indicating that the Actigraph could be useful for evaluating sitting environments.

1 . Introduction

The sitting postures of many elderly people are influenced by spinal deformities such as humpback and lateral curvatures due to these physical disorders, such as muscular weakness and articular contracture. When these people use ordinary wheelchairs, they often sit in a slanted position when changing their postures. This becomes a factor in causing secondary disorders such as back pain and decubitus. The authors discussed the influences of differences in sitting environments on sitting pressure and physical motion activities, and confirmed that adjustments for individuals can be ergonomically effective [1-5].

As a follow up to the previous studies, this study compared ordinary wheelchairs (Ordinary Type)[1] and office chairs with backs and seating surfaces adjustable to postural change (Functional Type)[2]. The influences of the differences in sitting environments on postural change indices and sitting pressure were examined and the data for small physical motion activities were compared utilizing the Actigraph[3], a three-

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[1] At nursing homes for the aged, wheelchairs are often used as chairs rather than devices of transportation. Thus, an Ordinary Type was used in this study as representative of chairs in nursing homes.

[2] An office chair employing the Ankle-Move Synchro-Locking System, which allows the seat and back to jointly lean backward with the ankle being the center of rotation. The seating surface can be moved forward when the person's trunk leans backward (produced by Itoki). This chair was used for comparison as representative of ergonomic chairs.

[3] Normally, the Actigraph (A.M. Inc., USA) is a 3-axial accelerometer used to measure sleep-wake rhythms. It is a wristwatch-like device that detects physical motion in units of 0.01G with a frequency of 10 times per second and records the data. They were attached to the extremities by velcro straps, and the accumulated data were transferred to a personal computer by proprietary interface.

axial accelerator. The effectiveness of this procedure as an objective evaluation method was examined, with the aim of obtaining reference materials for the improvement of the sitting environments of elderly people.

2. Methods

As a primary survey, 8 kinds of postures and behaviors[4] were selected, and analyzed their relationships to physical motion activities measured by an Actigraph mounted on the dominant hand of the subject.

The subjects of this survey were 9 males and 9 females in normal health age (average age: 20.7±0.9, height: 161.7±8.6cm, weight: 50.9±6.2kg). The following were studied for both the Ordinary Type and Functional Type chairs, (1) sitting pressure in the stationary sitting position[5], (2) physical motion activities of the subjects over a 2 hour period as measured with 4 Actigraphs (one on each hand and foot), and (3) the situation when the subjects changed their postures as observed by video camera[6]. The data collected was analyzed comparatively. The outline of the study is tabulated in Table 1, the chairs and wheelchairs are shown in Figure 1.

3. Relation between Physical Motion Activities and Each Posture

The relationship between physical motion activities and each posture (average of 10 people) is shown in Table 2.

In the basic sitting posture, physical motion activity was about 100, and when conversation was added, it increased 1.5 to 2 times. This indicates that the Actigraph was able to sense the slight oscillating motion of speech. When an activity that required concentration, such as watching TV, the value decreased to

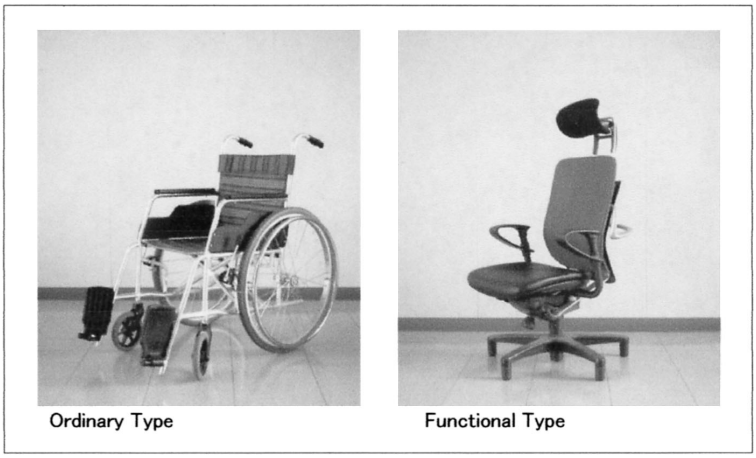


Fig. 1 Types of chairs

[4] "Conversation" was by a voluntary basis.

[5] The FSA Version 3.1 (produced by Takano) was used to measure. The number of sensor responses (total contact area), sitting pressure distribution [mmHg], and maximum sitting pressure [mmHg]. Values were an average of 20 measurements over a 4 second period. Because the upper limit of maximum sitting pressure that could be measured was 100.0 mmHg, measurements that exceeded this limit were recorded as "more than 100.0 mmHg".

[6] In analyzing for motion, the videotape was stopped when a subject changed his/her posture and the number of body parts that changed position was counted. Categories of body parts were the trunk, head, arms, hands, feet, and bottoms of feet. Two investigators made judgments to make the data as objective as possible.

Table 1 Methods of investigation

Survey item	Date	Contents
Preliminary survey	Jun. 2004	Physical motion was measured with the Actigraph mounted on the dominant hand of each subject. Total of 8 kinds of postures and behaviors.
① Sitting Pressure	Jul. 2003	The number of sensor responses, sitting pressure distribution, and maximum sitting pressure were measured with the FSA Version 3.1.
② Physical Motion Activity	Jul. 2003	Physical motion activity when sitting for 2 hours was measured with the Actigraph mounted on each hand and foot.
③ Postural Change	Jul. 2003	Behavor of subjects sitting for 2 hours was recorded by video and analyzed.

Table 2 Physical motion activities of each posture

Posture	Posture conditions	Avarage of PMA (number/minute)
Stationary sitting position	Clasping hands on the abdominal region, and restricting other motion to maintain this posture.	23.6
Stationary sitting position + conversation	Keeping the stationary sitting position, and engaged in free conversation.	142.2
Basic sitting position	Allowing only postural change (stretching and re-crossing legs, etc.) when tired, and restricting other motion.	109.2
Basic sitting position + conversation	Engaged in free conversation in the basic sitting position.	185.3
Basic sitting position + TV watching	Watching television in the basic sitting position.	49.4
Stationary standing position	Clasping hands behind (standing at ease), restricting other motion to maintain this posture.	67.7
Stationary supine position	Clasping hands on the abdominal region, and restricting other motion to maintain this posture.	31.6
Gait	Continuous walking at an ordinary speed	245.3

about 50. In addition, when motion was restricted, such as in stationary sitting or position, etc, the value became 20-40. Less than 40 is at sleep level[7].

The Actigraph detects even minor motions produced by a person who is awake, so it was predicted that there would be no differences between behaviors. However, the results of this study indicate a difference in measurements between behaviors. Therefore, it was thought that such differences might be used as an index for observing the changes of behaviors and postures.

4. Comparison of Sitting Environments from the Perspective of Sitting Pressure

Table 3 shows the results of total contact area, average sitting pressure, and maximum sitting pressure[8] measurements. A statistical comparison between the Ordinary and Functional Type chairs was conducted using the paired t-test.

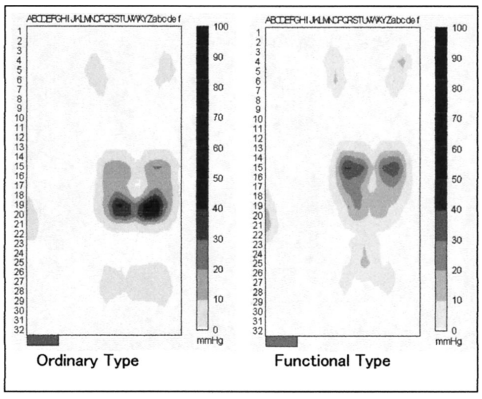
[7]Cole-Kripke Equation: $S = 0.0033\ (1.06\times an4 + 0.54\times an3 + 0.58\times an2 + 0.76\times an1 + 2.3\times a0 + 0.74\times a1 + 0.67\times a2)$, where the subject is judged as sleeping if $S < 1$, and the subject is judged as being awake if $S \geq 1$. (an4, an3, an2, and an1 are physical motion activities 4, 3, 2, and 1 minute before, respectively, and a1 and a2 are physical motion activities 1 and 2 minutes after, respectively. Using this equation, when physical motion activities are less than 40, the subject can be judged to be sleeping.)

[8]In the sitting pressure measurement experiment, the data for the S-7 case was judged to be invalid due to wrinkles on the FSA sheet.

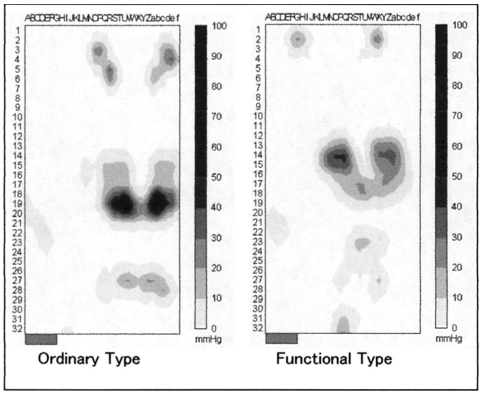
Table 3 Results of sitting pressure

No.	Total contact area (number)		Average pressure (mmHg)		Maximum pressure (mmHg)	
	Ordinary type	Functional type	Ordinary type	Functional type	Ordinary type	Functional type
S-1	121.1	123.2	9.8	9.9	34.3	27.6
S-2	141.0	157.4	13.1	13.3	55.3	60.8
S-3	138.6	145.4	10.4	10.5	100.0	30.7
S-4	109.8	127.7	10.7	13.7	53.4	36.5
S-5	164.3	166.7	13.2	10.5	46.8	29.6
S-6	153.8	155.1	12.9	11.6	55.6	37.7
S-7	-	-	-	-	-	-
S-8	159.4	151.0	14.6	9.3	75.2	58.3
S-9	160.7	162.4	13.8	10.1	87.8	41.5
Average	143.6	148.6	12.3	11.1	63.6	40.3
t-test						*

※ means improved case. Significantly different from Ordinary type: *<0.05



Flg. 2 Sitting pressure of S-6



Flg. 3 Sitting pressure of S-9

1) Total contact area was higher for the Functional Type in 7 of 8 subjects but the differences were not significant. However, the p-value was 0.071 indicating a tendency to be higher for the Functional Type.
2) Average sitting pressure was higher for the Functional Type in 4 subjects and lower in 4 subjects. No statistically significant differences were found between the two types.
3) Maximum sitting pressure was higher for the Ordinary Type in 7 of 8 subjects. The averages were 63.4 and 47.0 mmHg, the difference was significant. In general, maximum sitting pressure was concentrated at the buttocks for the Ordinary Type and dispersed to the femoral region for the Functional Type [Figure2, 3] .

It was thought that the significantly lower maximum sitting pressure was due to a decrease in maximum sitting pressure at the ischial region after the subject's trunk leaned backward using the adjustable seat back. This indicated that the mechanism for adjusting the seat and back of the Functional Type to postural change was useful for the dispersion of sitting pressure.

5 . Comparison of Postural Change Indices

The results of postural change indices are shown in Table 4.

This value was higher for the Ordinary Type in 7 of 9 subjects. The averages were 117.6 and 104.7, but the variation was large, and no significant differences were found between the Ordinary Type and Functional Type.

6 . Comparison of Physical Motion Activities

The average physical motion activities for 2 hours are shown in Table 4 and the distribution of physical motion activities are shown in Figure 5. After discussion, it was concluded that lower values of physical motion activities indicated a more stable posture.

1) In only one case (S-3) , the values of the upper and lower extremities significantly increased when changing from the Ordinary Type to the Functional Type. Two other cases also increased slightly. In 5 other cases, physical motion activities of both the upper and lower extremities decreased by about 15 on average and more than 40 in one case, indicating great individual variation.
2) Observations showed that physical motion activities of the upper extremities significantly decreased when changing from the Ordinary Type to the Functional Type. There were no significant differences in the values of the lower extremities, but p-value was 0.052, which indicated a tendency to be slightly lower.
3) Physical motion activities of the upper extremities were concentrated between 200-240 for the Ordinary Type, and between 180-220 for the Functional Type, a difference of about 20. In addition, the distribution of physical motion activities of the lower extremities was concentrated between 120-180 for the Ordinary Type, and between 40-160 for the Functional Type, indicating a lower tendency for the Functional Type.

Table 4 Results of postural change

No.	Postual change index (number)	
	Ordinary type	Functional type
S-1	110	96
S-2	127	84
S-3	49	42
S-4	108	136
S-5	149	128
S-6	153	88
S-7	128	160
S-8	94	86
S-9	140	122
Average	117.6	104.7
t-test		

Table 5 Results of physical motion activity (average)

Upper extremities (number)		Lower extremities (number)	
Ordinary type	Functional type	Ordinary type	Functional type
193.5	172.2	109.9	102.9
217.9	176.0	127.7	88.5
176.5	200.5	185.2	213.2
218.0	208.6	142.0	150.0
158.2	167.5	118.4	63.8
179.9	135.9	72.2	61.6
229.2	200.4	155.0	141.7
234.0	211.2	168.8	143.5
185.6	172.1	122.1	102.5
199.0	183.0	133.0	119.0
	*		

※ ▒ means improved case Significantly different from Ordinary type: *<0.05

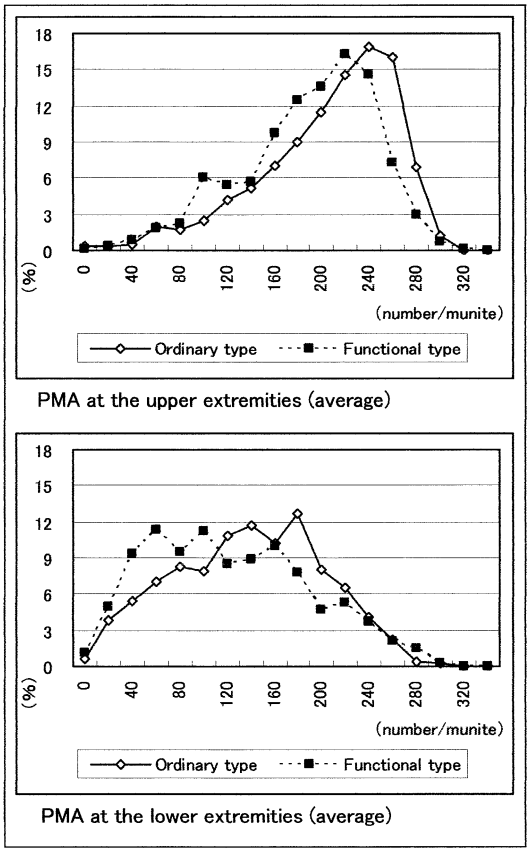


Fig. 4 Distribution of physical motion activities

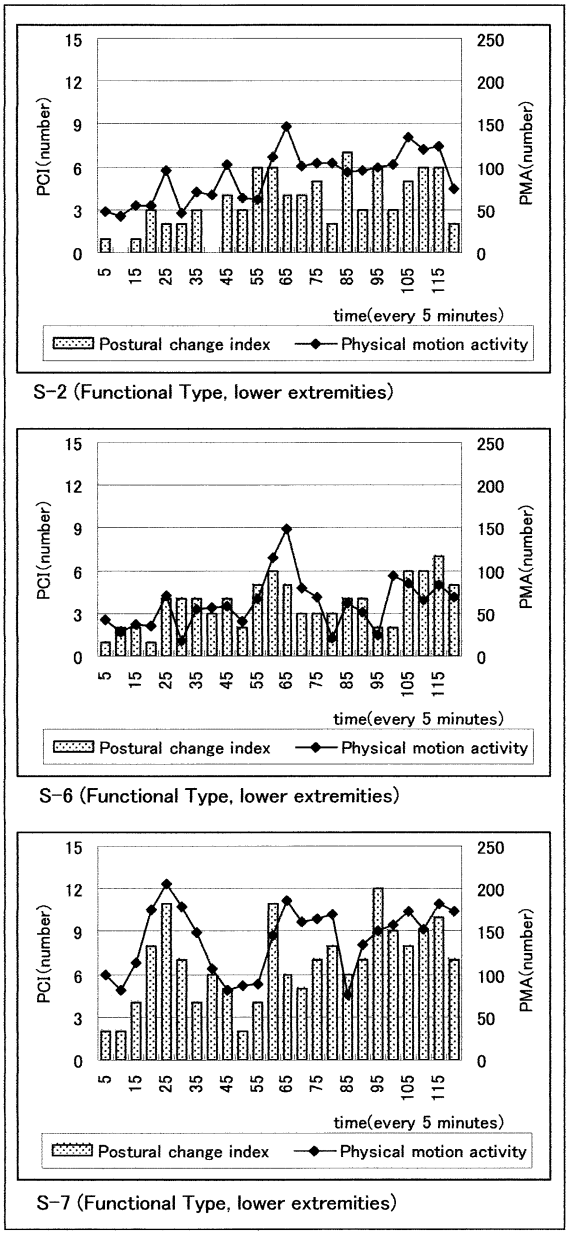


Fig. 5 Change of Physical motion activities and postural change indices

7. Relation between Physical Motion Activities and Postural Change Indices

Table 6 shows the correlation between physical motion activities and postural change indices measured at 10-minute intervals in each case. Figure 5 shows the time-series changes of physical motion activities and postural change indices for cases S-2, 6, and 7, in which correlations for the lower extremities were observed for the Ordinary Type.

With regard to the upper extremities, no significant correlations were found between physical motion activities and postural change indices. As for the lower extremities, a relatively high correlation was observed in 1 case for the Ordinary Type and in 3 cases for the Functional Type.

A general correlative tendency was not found, but as can be seen in Figure 6, some correlations were apparent in individual cases.

Table 6 Correlation between physical motion activities and postural change indices

No.	Ordinary type		Functional type	
	Upper extremities	Lower extremities	Upper extremities	Lower extremities
S-1	0.06	-0.12	0.23	0.16
S-2	-0.04	0.67	0.23	0.61
S-3	-0.11	-0.40	0.26	0.08
S-4	0.07	-0.21	-0.08	0.33
S-5	-0.08	-0.07	-0.02	0.19
S-6	0.05	0.08	0.31	0.56
S-7	0.13	-0.01	0.31	0.67
S-8	-0.16	-0.01	0.08	-0.04
S-9	-0.10	-0.09	0.06	-0.04

※ means correlation more/less than ±0.5

8. Summary

The intent of this study was to provide reference materials to improve the wheelchair-sitting environments of elderly people. The following were investigated: (1) the influence of differences in sitting environments on postural change indices and sitting pressure, (2) the effectiveness of using the Actigraph for sitting position evaluation. The findings are summarized as follows:

1) It was found that sitting pressure located at the buttocks was dispersed to the femoral region and the maximum sitting pressure decreased when changing from the Ordinary Type to the Functional Type. This indicated that adjusting the position of the seat and back of the Functional Type used in this study was useful for dispersing of sitting pressure.
2) The postural change index varied from individual to individual and no clear differences were found between the Ordinary and Functional Type.
3) In contrast, physical motion activities decreased in both the upper and lower extremities, when changing from the Ordinary Type to the Functional Type.

The fact that a change in sitting environment when changing from the Ordinary Type to the Functional Type induced a decrease in both maximum sitting pressure and physical motion activities indicated that improvements in sitting environments could be assessed by measuring physical motion activity, and that the Actigraph could be used for this purpose. On the other hand, no clear relationship was confirmed between postural change indices and physical motion activities. It is our intent to review the results of this investigation of analysis methods, etc. and devise other methods for evaluating the sitting environments of elderly people in the future.

Acknowledgements

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