OBJECTIVE COMPARISONS OF VARIOUS TYPES OF CHAIR FOR STANDING WORKS

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INTRODUCTION

Local fatigue of lower back and legs in work performance is predominantly induced in a standing posture compared with a seated posture. When a state of mental and physical strains continues, severe fatigue is often accompanied by mental stress. This leads to various unwanted effects on the living system, such as a decline in concentration of work performance. To relieve such an undesirable situation, a chair for standing work would be useful.

Having a comfortable seating position would afford an effective avenue in reducing physical and mental burden without losing work flexibility. When seated on a high-seated chair, the thighs hang down. This seating posture increases the trunk-thigh angle, decreases the load supported by the spinal column and its musculature compared with seating on standard designed chair. However, because one can not sit deeply on this high-seated chair, the weight of the trunk is concentrated onto a certain part of the ischial tuberosity, beside exerting pressure on the posterior thigh region that comes into contact with the edge of seat.

We thought the pressure on the posterior thigh region would be reduced by tilting the front of seat slightly downward. In this way, the trunk-thigh angle is additionally increased to further relieve the spinal load. Moreover, the load that concentrates on the ischial tuberosity may be dispersed to the legs as well. However, changing these loads may affect the arousal level and work performance. The present study examined and compared the effects of using various types of chair designed for standing work on muscular loads of lower back and legs, arousal level, and posture. The chair was designed to afford variable seating slope with and without addition of a lumbar support.

METHODS

Subjects and experimental design

Seven healthy male subjects with an average age of 22 years (age range: 21-23yr) volunteered for this study. The chairs were designed with four seating conditions. Seating slopes employed were 90° 100° and 110° to the vertical plane, and the lumbar support was only added in chair with the 100° seating slope. The height of seating position was adjusted to stand the lower legs perpendicular onto the floor after matching a gluteal fold with the edge of seat. At this seating posture, the pressure on the posterior thighs region in contact with the edge of chair would be reduced (Fig.1).

Subjective evaluation

Subjects were asked to fill in a seven-rank subjectivity evaluation about their psychological states and discomfort levels in 13 body parts related to physical local fatigue and pain in visual display terminal (VDT) tasks.

Observation of the posture

During the experiment, the lateral version of posture of subjects was taken with a video camera at 1-min intervals during VDT task performance. Four demarcation points (the acromion, iliac crest, greater trochanter and head of fibula) with two lines linking either the acromion and iliac crest or greater trochanter and head of fibula were plotted. The intersection angle (i.e. the obtuse angle) where the two lines crossed each other was defined as the trunk-thigh angle. (Fig.1)

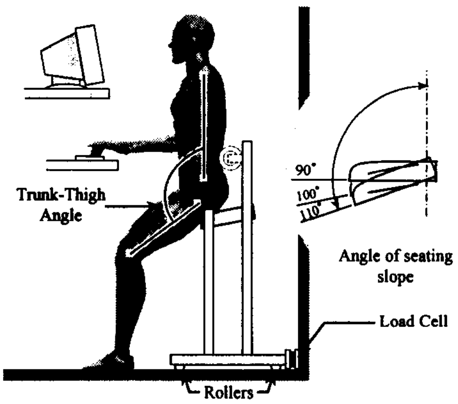

Fig.1 Experimental conditions indicating various angles of seating slope with a lumbar rest, and trunk-thigh angle.

Electromyogram (EMG)

Bipolar surface EMG were recorded from the muscles of spine, straight muscles of thigh, biceps of the thigh, gastrocnemius muscle and soleus muscle to investigate muscle activities of the legs and lower back. The mean amplitude of EMG was calculated and used as an index for measuring muscle activities.

Load Meter

When subjects were seated on the inclined seat of chairs, muscular loads on the legs prevented the hip from slipping off. To evaluate muscular loads exerted on the legs, the horizontal thrust against the chair was measured with a load。cell fixed to the hind side of bottom of chairs. (Fig.1) Each session consisted of a 10-min VDT task and followed by 5-min rest repeated over a series of four cycles on a continuous basis.

The VDT task was a simple approach in measuring the reaction time. Each subject was asked to make a quick motor response by pressing a clicking device between the initial preparatory stimulus (S1) and subsequent response stimulus (S2). The inter-stimulus interval (ISI) and inter-trial interval (ITI) were

Tab.1 Factor loading of main variables with two PCA-derived factors.

	First factor	Second factor
will to do	**0.8468**	-0.0344
cheerful	**0.8212**	-0.021
interesting	**0.8134**	0.0868
be able to concentrate	**0.7815**	0.0901
delightful	**0.7785**	0.1808
feel fine	**0.7331**	0.3459
dynamic	**0.718**	-0.1919
.	.	.
.	.	.
.	.	.
loose	0.3329	**0.7495**
easy	-0.3362	**0.7113**
relieved	0.2167	**0.6721**
natural	0.0657	**0.6003**
easy to work	0.2739	**0.5879**
.	.	.
.	.	.
eigenvalue	**7.0369**	**3.0351**
Contribution Rates	**35.1849**	**15.1754**
Accumulation C.R.	**35.1849**	**50.3603**

designated at 2.5 and 11 sec respectively with the task encompassing 40 trails per session. The reaction time in this task was also measured. Subjects were tested on an individual basis under every condition at random. The scores on subjective evaluation on physical discomfort, trunk-thigh angle, EMG, the value of load meter and reaction time were categorized into 4 sessions for each condition. Statistical evaluations were verified by three-way ANOVA (4 levels of condition ×4 levels of session×7 levels of subject) and paired students t-test.

RESULTS

Subjective evaluation

Principal component analysis (PCA) performed with 20 questions about the psychological state of subjects while working, and varimax rotation was done with two extracted factors (Tab.1). The first factor was interpreted as the will to do task, while the second factor signified the difficulty in task performance. Factor scores were averaged at every condition for the respective factor. The 90° seating slope scored a value significantly higher than the means of other three conditions for the first factor.

In addition, three-way ANOVA verifications of each mean score of subjective evaluations on physical discomfort revealed that the main effects were statistically significant at the posterior thigh region and calf. As for the posterior thigh region, the condition with added lumbar support to 100° seating slope afforded significantly higher discomfort than the other conditions. As for the calf, the 11 0° seating slope offered significantly higher discomfort than the other conditions.

Trunk-thigh angle

Three-way ANOVA of the each score revealed significantly beneficial effects of the sloping of chairs. In short, the inclination of seating slope of chair was favorably proportional to comfort derived from the trunk-thigh angle.

Furthermore, when the lumbar support was added, the trunk-thigh angle increased significantly even with the same seating slope.

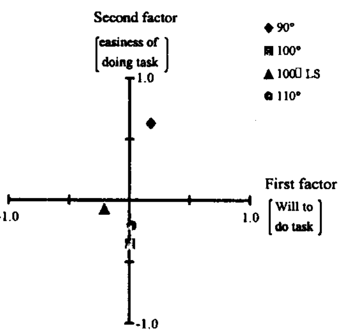

Fig.2 The distribution chart of the first and second factors (extracted by PCA).

Mean amplitude of EMG

Three-way ANOVA verification of each score illustrated a major significant effect on the muscle of spine. By adding the lumbar support to the 100° seating slope, significantly higher values, more than those of the other two conditions of 100° and 110° seating slope, were produced (Fig.3). This suggests that the trunk inclined against the lumbar support and probably used it effectively.

Load Meter

When the subjects tried to straighten their legs to prevent the rear hip from slipping off the eat, the muscles of anterior thigh region and

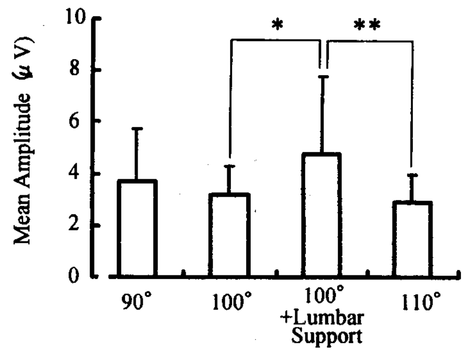

Fig.3 Comparisons between 4 conditions of the mean amplitude of the muscle of spine's EMG. Values are means ± SD. (*p<0.05, **p<0.01 by t-test)

calves contracted. Therefore, the values indicated by the load meter reflected the load was exerted on the legs, and there were significant linear relationships between the load meter and mean EMG amplitude of both the straight muscle of thigh (Fig.4) and soleas muscles.

Three-way ANOVA evaluation of the scores revealed significantly beneficial effects were derived from the seating condition. The inclination of seating slopes enhanced the values of load meter significantly.

In addition, with the lumbar support added, the value increased significantly even with the same seating slope. (Fig.5)

Moreover, there was a significant interaction between seating conditions and sessions, and the value was inconsistent between each session at the 100° seating slope. (Fig.6)

Reaction Time

The main effects of conditions were not statistically significant on the reaction time of subjects tested.

DISCUSSION

The condition with a 90° seating slope offered stable seating condition because it presented a level position. From the results of subjective experience on the psychological state of subjects under this condition (Tab.1), the VDT task was performed without feeling difficult. The result of subjective evaluations on physical discomfort did not reveal any complaints at the posterior thigh region. This was probably

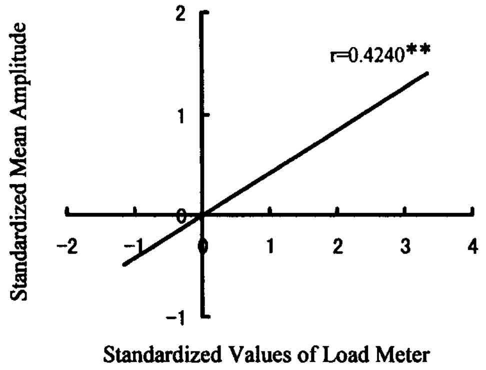

Fig.4 The correlation between the value of load meters and mean EMG amplitude of straight muscle of thigh. As vast differences to amplitude existed in EMG and the values of load meters, the values were therefore standardized accordingly measured value - mean value)/SD. (**p<0.01)

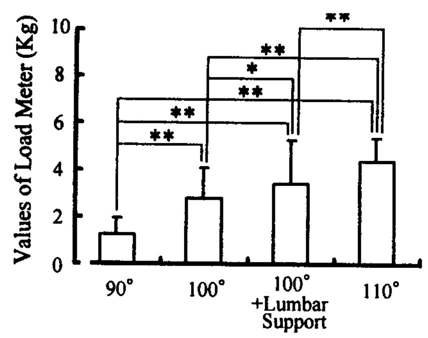

Fig.5 Comparisons between 4 conditions of the value of Load Meters. Values are means ± SD. (*p<0.05, **p<0.01 by t-test)

due to reduced pressure exerted on the posterior thigh region by the effective method in determining of the height of seats.

Increasing the trunk-thigh angle by increasing the seating slope was supposed to decrease the spinal load. However according to findings with the load meter, there was an increase in load on the legs when the seating slope was increased. With a seating slope of 100° , significant fluctuations in the value of load meter between sessions were registered, suggesting that the seating condition was unstable. While inclining at a 110° seating slope, these fluctuations ceased, and the load on the legs had increased.

We focused on establishing an ideal posture on leaning rather than randomized sitting in our study. The condition of inclining a 110° seating slope secured higher stability than that of 100° . These two postures are formed on seating on a chair for standing work, and selecting the seating condition much depends on the working situation (e.g., the time ratio of seating posture, frequency of sit-stand movement, etc).

Furthermore, in a seated posture with the added lumbar support limited the frequency in backward rotations of the pelvis. The trunk-thigh angle thus increased significantly compared with a seating condition without lumbar support even at the same seating slope. However, the seated posture became shallower. Therefore, many complaints on discomfort at the posterior thigh region that came into contact with the edge of seat rather than the condition without lumbar support were received from the subjects.

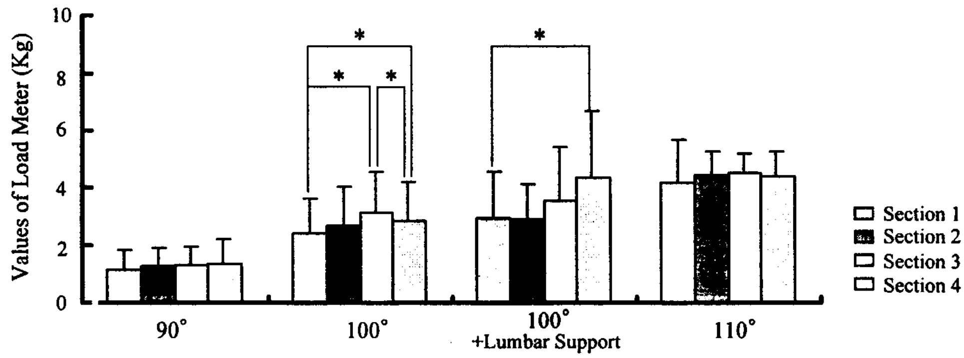

Fig6 Changes in the value of load meter over 4 sections of each condition. Values are means ± SD. (*p<0.05 by t-test)