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# POSTURE OF THE TRUNK WHEN SITTING ON FORWARD INCLINING SEATS

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**ABSTRACT. Changes in posture during one hour of sitting were measured by a statometric method on ten subjects. Four seats were used, one horizontal and three with forward inclinations respectively of 5°, 10° and 15°. With increasing forward inclination of the seat, the spine moved toward lumber lordosis. A supplementary sample showed that 1/3 of the body's adaptation to the seat inclination took place in the spine and 2/3 in the hip joints. A tendency to a more vertical position of the trunk as a whole was observed on the 5° chair, but the posture of the cervical spine was not influenced by the seat inclination. During the hour of sitting a slight tendency was observed for the subjects to sit with the trunk in the most vertical position at the first measurements. The back curves did not change in any systematic way during the hour. A comfort evaluation showed the 5° forward inclination and the horizontal seats to be preferred.**

*Key words:* Sitting posture, spinal curve, forward inclining seat, long-term sitting

Many investigators (1, 12, 18, 27, 32) recommend that the seat surface should be inclined about 5° backwards; one has even suggested 15° backwards (29). Others suggest that the seat should be almost horizontal (20, 28), and in some committees (6, 10, 15) a range from 0° to 4°–5° backwards has been suggested. Another body of opinion focuses on the possible advantages of a forward inclination of either the whole seat (4, 7, 21, 24, 25, 30, 35), the posterior part (5, 31), or the anterior half (17). Mandal (24, 25) suggests a tiltable seat from −5° (backwards) to +15°, and Kroemer (20) an adjustable seat slope between −6° and +6°, to make it possible to change the position for different tasks.

Despite the fact that sitting posture may change during long-term sitting, almost all knowledge of the subject has been based on studies carried out on people sitting for a few minutes. Long-term sitting has been evaluated by means of varying parameters (3, 8, 13, 14, 16, 19, 22, 23, 27, 36) but the only published studies concerning spinal curves during long-term sitting are those of Eastman & Kamon (9) and Grall (11).

The purposes of this study were:

1. To compare spontaneously chosen posture when sitting one hour on each of the four seat inclinations—horizontal, 5°, 10° and 15° forward—and to estimate the adaptability of the trunk and hip joints to different forward inclinations of the seat.

2. To follow the changes of the spinal curves during one hour of sitting on one seat.

3. To evaluate comfort in relation to the different seat inclinations.

## MATERIAL

Ten healthy subjects were examined, six females and four males, aged 23–68 years (mean 33 years). Their weights ranged from 45 to 75 kg (mean 60 kg) and heights from 159 to 187 cm (mean 173 cm). None had back trouble or back abnormalities at the time of investigation.

Four experimental chairs were used with seats measuring 37 cm from front to back and 44 cm from side to side. The seats were sagittally straight, except for a downward curved front border, and slightly concave from side to side. They were covered with 4 cm of foam of moderate firmness (100 kg/cm$^3$) and upholstered with a cloth material. The seats were mounted on a base easily adjustable in height, the only difference being the horizontality or inclinations forward of the seat surface of 5°, 10° and 15°. The chairs had no back rest.

The experimental table had a top surface which was height adjustable. It was 2 cm deep and had no frame.

## METHOD

The following four points were marked on each subject with a speedmarker (Fig. 1*a*); 1) the sacral point (S) was the bony prominence nearest to the top point of the right-angled, isosceles triangle appearing in Fig. 2; 2) the lumbar point (L) and 3) the thoracic point (T) were the spinous processes nearest to the top points of the respective curves, when accentuated maximally during sitting; 4) the occipital point (O) was the external occipital protuberance.

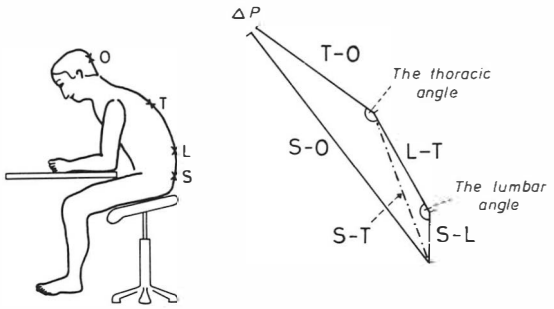


*Fig. 1.* The four back points are seen on the figure to the left. They are projected to the figure to the right, where the vectors and the thoracic and lumbar angles are illustrated. $\Delta P$ is the difference between the end points of the long vector and the three short ones.

*Fig. 3.* The inclinometer in use.

Four vectors were drawn to connect these points: The sacro–lumbar (S–L), the lumbo–thoracic (L–T), the thoraco–occipital (T–O) and the sacro–occipital vector (S–O). After measuring their inclinations and lengths, these vectors could be plotted on paper as shown in Fig. 1 (right). A fifth vector, the sacro-thoracic (S–T), was calculated, as were the angles between the short vectors. These angles were called the thoracic and lumbar angles.

Ideally the end point of the long vector S–O should be identical to the end point of the sum of the three short ones. By calculating the distance between them, an expression for the accuracy of the measurements should be obtained: The shorter the distance, the better the accuracy. The four points were covered with tape at the end of a day's testing to make it possible to use them again the next day.

The apparatus used to measure the vectors was the inclinometer introduced by Mølhave (26) and shown in Fig. 3. The scale for measuring the inclinations was divided into 0.5 degrees.

## PROCEDURE

To accustom the subjects to a forward inclining seat their homes were furnished with a tiltable office chair at least two weeks before the experiment. The seat could tilt from 5° backward to 15° forward.

The sitting position was defined in the following way: The subject was seated with the hindmost gluteal point touching a line perpendicular to the rear edge of the seat. To ensure that the thighs conformed to the seat surface, height adjustment was effectuated by placing the seat at first a little too high, with the legs hanging freely, and later lowering it until the stockinged feet rested on the floor with the lower part of the legs vertical. Approximately 2/3 of the thighs were resting on the seat. The height of the seat was defined as the distance from the floor to the midpoint of the seat surface, just above the axis for tilting when adjusting the four seat inclinations.

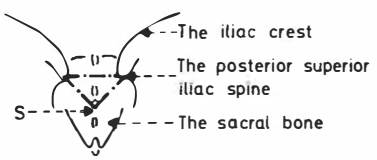


*Fig. 2.* The sacral area seen from behind. The position of the sacral point *S* is illustrated.

The table height was adjusted so that its surface was 21 cm higher than that of the seat.

In each position the subjects were asked to sit in a comfortable position with the elbows placed on the table and read a horizontally placed text. The horizontal distance from the border of the table to the rear edge of the seat was measured to ensure it was identical for the separate subject at the different examination days.

Each subject was examined on four consecutive days, each day on a different seat inclination. The sequence of the four seat inclinations was taken at random for the different subjects. During the one hour of sitting, the backcurves were measured after approximately 5, 15, 25, 35, 45 and 55 min. The subjects did not know when a measurement was going to take place.

When it was time for a measurement the subject was asked to hold the posture. A forehead indicator was then moved toward the forehead to minimize changes in the posture during the two to three minutes of measuring (Fig. 3).

At the end of the period of sitting all subjects were asked to estimate the degree of comfort on each specific seat inclination, using a scale from one (poor) to five (excellent). The same scale was used to rate the tiltable chair they had used for two weeks in their home.

*Supplementary sample I*

The inclination of the T–O vector did not change with head movements only, but did so with different positions of the hip joints and/or the lumbar spine as well, even if the cervical spine was not flexed or extended. Therefore, to estimate the position of the head in relation to the trunk, the T–O length was assessed. To correlate this length to the approximate extent of nodding movements, the T–O vector was measured in two different positions of the head: at a spontaneously chosen reading position and at

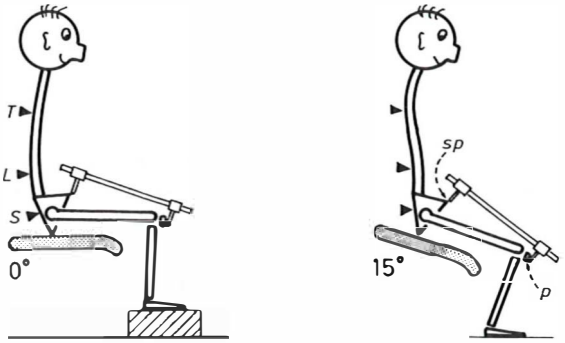


*Fig. 4.* The supplementary study II where the change of the lumbar angle was measured in relation to a 15° forward tilting of the seat, thighs and pelvis. The degree of flexion in the hip joints was identical in the two positions controlled by reproducing the distance sp-p.

10° of further flexion of the head. The trunk was fixed by holding the contact with two bars, one touching the seventh cervical spinal process, the other touching a low thoracic one. The position of the head was determined by measuring the inclination of a pointer mounted approximately perpendicular to the forehead.

Twelve subjects—nine males and three females—were examined, greatly different from the subjects in the main study. Their heights ranged from 159 to 188 cm (mean 179 cm), weights from 50 to 86 kg (mean 69 kg) and ages from 24 to 37 years (mean 31 years).

*Supplementary sample II*

Because an increase of the lumbar angle with increasing forward inclination of the seat was demonstrated in the main study, a supplementary study was performed, where the interaction between movements of the lumbar spine and the hip joints when inclining the seat forward was estimated. This was accomplished by two measurements (Fig. 4). First *LL* was measured while the subject sat on a horizontal seat, and simultaneously the distance between the apex of the patella (p) and the anterior superior iliac spine (sp) was determined. Secondly *LL* was measured after the seat, thighs and pelvis were tilted 15° forward. The degree of flexion in the hip joints was reproduced by rotating the pelvis forward, until the p-sp distance was the same as in the previous determination. The degree of flexion in the knees was also reproduced in the second position, and a check was made that the upper trunk was in the same position in both measurements. This was done by controlling that the upper arms were in the same position when the subjects were resting their elbows on the table. Twenty measurements were carried out on ten subjects, greatly different from the participants in the main study. Five were male and five female aged 24 to 37 years (mean 30 years). Their heights ranged from 159 to 188 cm (mean 175 cm) and weights from 50 to 76 kg (mean 66 kg).

*Statistics*

The following seven variables were treated statistically: The inclination of the four vectors S–L, L–T, S–T and T–O, the length of the T–O vector and the thoracic and lumbar angles. Standard deviations (SD) of each variable were calculated and averaged for all seat inclinations and subjects (Table II). These estimated SDs were calculated for measurements obtained in the course of one hour.

When estimating the changes of a separate variable in relation to the different seat inclinations, two-way analysis of variance was performed on the averaged values for each subject and seat inclination. The lumbar angle showed a tendency to increase with increasing seat inclination. Therefore comparisons of the regression lines were also made regarding that variable. Comfort was evaluated by Friedman two-way analysis of variance on ranks for possible correlation with seat inclinations.

Table I. *Mean seat heights for the ten subjects in relations to the four seat inclinations*

| Seat inclination | Seat height (cm) | |
|---|---|---|
| | Mean | SD |
| 0° | 50.9 | 3.8 |
| 5° | 55.8 | 4.4 |
| 10° | 57.3 | 4.0 |
| 15° | 60.6 | 4.0 |

## RESULTS

The mean distance between the end points of the long vector S–O and the end point of the sum of the three short vectors was 1.09 (SD=0.64). Of the 240 measurements planned, 226 were performed. The missing 14 were mostly due to technical problems.

As expected the seat heights given in Table I show an increase with increasing forward inclination of the seat, due to the method of height adjustment. The SD of the spinal curve variables measured after 5, 15, 25, 35, 45 and 55 min on each of the four seats are given in Table II. During the hour of

Table II. *Estimated overall standard deviations (SD) for each of the seven spinal variables*

These SDs represent the variation between six different measurements within the course of one hour

| Variable | SD |
|---|---|
| S–L inclination | 5.2 degree |
| L–T inclination | 5.4 degree |
| S–T inclination | 5.2 degree |
| T–O inclination | 4.6 degree |
| T–O length | 0.7 cm |
| *LT* | 2.8 degree |
| *LL* | 1.4 degree |

essentially in the same direction. Furthermore, as the upper thoracic spine above the T point is just as fixed as the lower part, the thoraco–lumbo–sacral curve could only account for minor variations. Therefore, the variations of the vectors mainly originated from tilting the whole trunk over the ischial tuberosities (34) and from movements in the cervical spine. Nodding movements estimated from the T–O length seem to explain the larger variation of the thoracic angle compared to the lumbar angle.

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