

LUMBAR DISC PRESSURE AND MYOELECTRIC BACK MUSCLE ACTIVITY DURING SITTING

IV. Studies on a Car Driver's Seat

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ABSTRACT. The myoelectric activity of several muscles of the back and the lumbar disc pressure have been measured simultaneously while healthy subjects were sitting in a driver's seat. Three support parameters, viz. backrest inclination, lumbar support, and seat inclination, and two driving manoeuvres, viz. depression of the clutch pedal, and shifting gear, were investigated.

The disc pressure and the myoelectric activity both decreased when the backrest was inclined backwards and when the lumbar support was increased. The seat inclination had a minor influence only. The disc pressure increased both when the gear was shifted and when the clutch pedal was depressed. When the gear was shifted there was also an increase in myoelectric activity. The lowest disc pressure and the lowest level of myoelectric activity were found when the backrest inclination was 120°, the lumbar support 5 cm, and the seat inclination 14°. Aiming at these values, it is suggested that the backrest and the seat inclinations should be variable and adjusted to the interrelations between the human body and the various dimensions of the workspace. Further, a variable lumbar support should be provided.

INTRODUCTION

The driver's seat should be suitable both for work and for rest. While driving involves only little physical work there is an intensive psychic stress. The situation of the driver has been described as one of physical rest in a permanent state of alert (78, 82). Obviously it is important that the seat is correctly designed for sitting, to avoid unfavourable postures and fatigue. This is particularly important as sitting is often extended over long periods, and as the position of the driver is delimited by the position of the controls and by the vision.

In previous studies the myoelectric activity of

several muscles of the back, and the lumbar intervertebral disc pressure, have been studied in three other types of chairs (Parts I, II, III). The purpose of the present investigation was to study simultaneously the disc pressure and the myoelectric activity when healthy subjects were sitting in a driver's seat. Different support parameters were studied as well as common driving manoeuvres.

METHODS

The car simula.

A standard Volvo driver's compartment and driver's seat were modified. As shown in Fig. 1, several parameters could be varied. These variations could be read directly from protractors and scales. The backrest, shown in Fig. 2, was 560 mm high, and had an opening to allow for exit of the disc pressure needle. The instrumentation of the car consisted of a steering-wheel, a gear lever, and a clutch pedal which was attached to a spring scale. By means of a mirror it was possible to observe the deflection of the spring as the pedal was depressed.

The recording equipment

The recording equipment was the same as was used in a previous investigation (I).

MATERIAL

The study was performed on four adult volunteers—three female and one male—with no history of back injury or back disease. Physical examination revealed no pathological condition of the trunk or extremities. All subjects had normal radiographic appearance of the lumbar discs. A summary of subject data is provided in Table I.

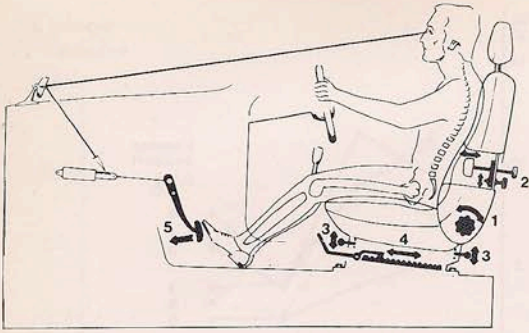


Fig. 1. The car simulator, which permitted adjustment of the backrest inclination (1), the position of the lumbar support (2), the seat inclination (3), and the distance seat to dashboard (4). The clutch pedal could be depressed (5) and was attached to a spring scale.

RECORDING PROCEDURE

The procedures for the insertion of the pressure transducer, and for the application of the electrodes, were described in previous papers (I, 4). The location of the electrodes was the same as in a previous investigation (II).

The subject was subsequently positioned in the car simulator. The distance between the seat and the dashboard was adjusted to match different joint angles when the backrest was 90°. The approximate angles for the ankles, knees, and elbows were 90°, 120°, and 80° respectively. Three support parameters were investigated, all defined in Fig. 3. The backrest was inclined to either 90°, 100°, 110° or 120°. The lumbar support was always

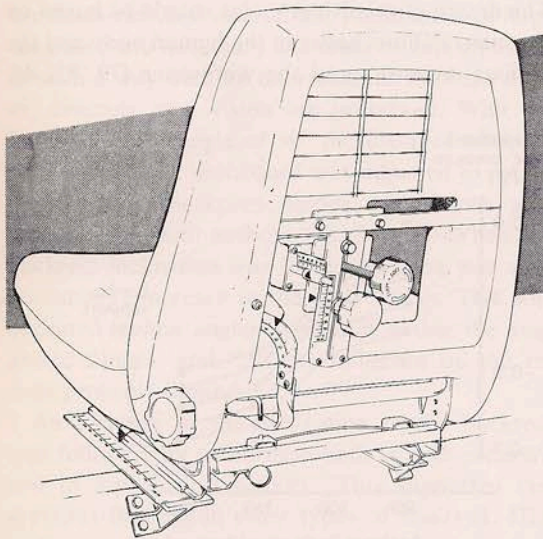


Fig. 2. The backrest had an opening to allow for exit of the disc pressure needle. All variations could be read from protractors and scales.

Table I. Summary of subject data

Subject no.	Age (yrs)	Sex	Weight (kg)	Body weight above level measured (kg)	Height (cm)
1	23	F	65	37.5	177
2	23	M	68	38.8	182
3	27	F	57	32.5	169
4	39	F	59	33.6	167

located at the level of L3 and was increased perpendicular to the backrest, from 0 to 5 cm in increments of 1 cm. The seat inclination was either 10° or 14°. All combinations of the three support parameters were investigated. In addition, studies of two common driving manoeuvres were made, viz. shift of gear, and depression of the clutch pedal against a resistance of 300 N.¹ When these manoeuvres were performed the lumbar support was always 0 cm, but the backrest and seat inclinations were varied. The arms were always on the steering-wheel. The head was directed forwards, and the subjects instructed to fix their eyes straight ahead. In each position recordings were made for 12 seconds.

DATA ANALYSIS PROCEDURE

Detailed descriptions of the analysis procedures were given in previous papers (I, 4). The disc pressure data were normalized to the relaxed sitting position in which the backrest inclination was 90 degrees, the lumbar support 0 cm, and the seat inclination 10 degrees.

RESULTS²

When sitting relaxed, only minor differences in myoelectric activity were found between the right and the left side of the trunk. The interindividual variation in myoelectric activity was larger for the trapezius muscles than for the other muscles. An increase in backrest inclination was found to reduce the myoelectric activity in all muscles investigated. The activity was always low at C4 level, however, and thus the decrease was limited. The lumbar support influenced the activity mainly at thoracic (T5, T8, and T10) and lumbar (L1 and L3) levels; activity decreasing with an increase in lumbar support. Fig. 4 shows the combined effect of changes in backrest inclination and

¹ Newton (N) is the name of the force unit in the International System of Units (SI). 1 N is defined as the force necessary to give a mass of 1 kg the acceleration 1 ms/s². 1 N=0.102 kp=0.225 lbf.

² Tables of the results can be obtained on request from the Department of Orthopaedic Surgery I, Sahlgrenska sjukhuset, S-413 45 Göteborg, Sweden.

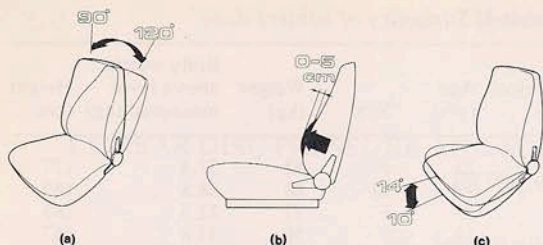


Fig. 3. Definitions of the three support parameters. (a) The backrest inclination was defined as the angle between the seat and the backrest. (b) The lumbar support was defined as the distance between the original plane of the backrest, and the anterior convexity of the lumbar back pad. (c) the seat inclination was defined as the angle between the seat surface and the horizontal.

in lumbar support. The seat inclination had an influence on the myoelectric activity in the muscles of the lumbar region only. When the backrest inclination was 90° or 110° the lowest activities were found with the seat inclined to 10°. When the backrest inclination was 100° or 120°, however, the lowest activities were found when the seat was inclined to 14°. Thus, as a rule, the lowest levels of activity were found when the backrest inclination, the lumbar support, and the seat inclination were all as large as possible. The mean value of the non-normalized disc pressure in the reference position was 0.513 MPa¹ (standard deviation 0.160 MPa). A decrease in disc pressure was found both when the backrest inclination and the lumbar support were increased. As shown in Fig. 5, there was, in general, less effect of both support parameters the more the backrest-seat angle was increased. When the seat inclination was increased from 10° to 14° there was a systematic decrease in disc pressure, provided the backrest inclination was 100° or 120°. When, on the other hand, the backrest inclination was 110° there was a systematic increase in the pressure. Thus, the lowest disc pressure was found when the backrest inclination, the lumbar support, and the seat inclination were all as large as possible.

When the driving manoeuvres were compared with relaxed sitting, differences were found both in the myoelectric activity and in the disc pressure. When the gear was shifted there was a slight increase in myoelectric activity in the trapezius mus-

¹ Pascal (Pa) is the name of the pressure unit in the International System of Units (SI). 1 Pa = 1 N/m² (Newton per square metre). 1 MPa = 10⁶ Pa = 10.2 kp/cm² = 145 lbf/in².

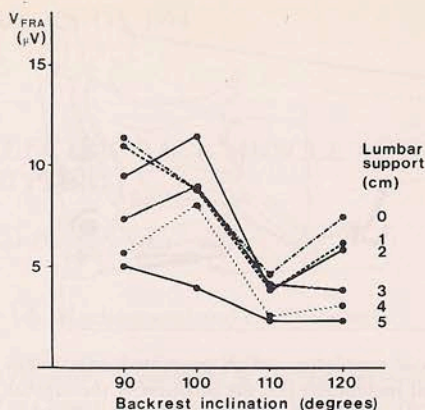


Fig. 4. Mean full-wave rectified and averaged values of myoelectric activity at L1 level. The seat inclination was 10°.

cles. An increase was found also at T5 and T8 levels on the left side of the back. The depression of the clutch pedal had only minor influence on the myoelectric activity. The disc pressure increased when the gear was shifted and even more when the clutch pedal was depressed (Fig. 6). In both manoeuvres there was a decrease in myoelectric activity and in disc pressure when the backrest inclination was increased. The seat inclination had no systematic influence.

DISCUSSION

The design of the driver's seat should be based on the interrelations between the human body and the various dimensions of the workspace (79, 81, 84,

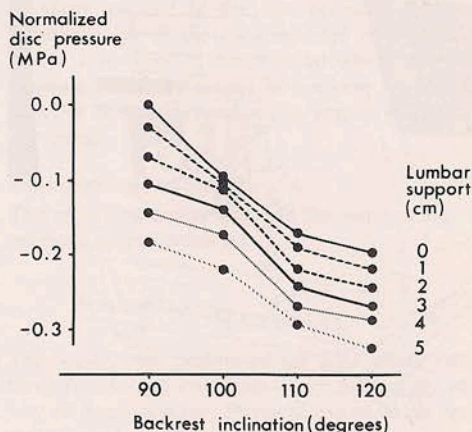


Fig. 5. Mean normalized disc pressure values when the backrest inclination and the lumbar support were varied. The seat inclination was 10°.

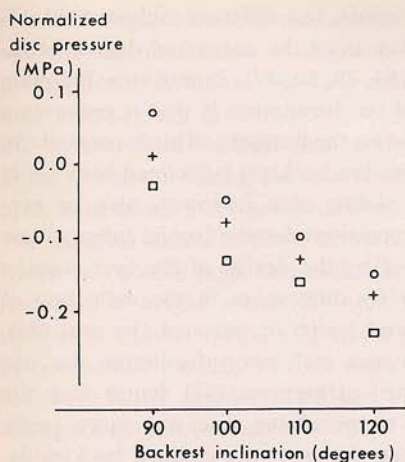


Fig. 6. Mean normalized disc pressure values, when the backrest inclination was varied. The lumbar support was 0 cm and the seat inclination 10°. □, relaxed sitting; +, shifting gears; ○, depression of clutch pedal.

86, 87). It is necessary to know not only the body measurements, but also the space measurements, which are aimed at defining the areas within reach of the driver. Obviously, the main purpose of the seat is to create opportunities for good driving conditions. The field of vision and the reach of different controls are therefore the most important design criteria. Limited by these factors the seat should be correctly designed for sitting. One of the main problems is the difference in body measurements between individuals. Possibilities of large variations are necessary and must be accomplished in such a way that the interrelations between driver, controls, and vision are preserved. With the backrest at an angle of 90° the distance between the seat and the dashboard was adjusted to match the angles of the knees, ankles, and elbows, suggested by several authors (79, 86, 87). When the backrest inclination was increased there was a simultaneous increase in the joint angles. This was accepted as the angles were still within the suggested ranges, and thus the influence on the results probably limited.

An increase in the inclination of the backrest was followed by a decrease both in disc pressure and in myoelectric activity. This supported our previous findings in other types of chairs (I, III), and was consistent also with previous myoelectric investigations (4, 83, 88, 90). When the backrest inclination increased, a larger proportion of the body weight was transmitted to the backrest and

thus the stresses on the spine were reduced. Consequently, the more the backrest was inclined the less was the disc pressure and the myoelectric activity. The effect was, however, less pronounced at a larger backrest inclination. The main limiting factor of the inclination is the need for a good field of view. The eyes must be suitably placed in relation to the car body so that vision is not obscured (79, 80, 81, 84, 87). When the backrest inclination is too large the head must be flexed to enable the driver to see the road (89). Previous studies have shown an increase in the myoelectric activity of the muscles of the neck when the head is flexed (38, 50). These studies were, however, made when sitting upright where the force of gravity on the head had to be counteracted. In the present investigation a decrease in myoelectric activity at C4 level was found when the backrest inclination was increased, and similar findings were made also by Rosemeyer (88). Obviously the situation in the car seat was different; the position of the head was controlled mainly by the anterior muscles of the neck. The backrest inclination is limited also by the length of the coupé, by the distance between the trunk and the controls, and by the angle of the hip joints. When the backrest inclination increases, a larger part of the coupé is occupied by the seat. The arms must be extended, thus flattening the lumbar curve (21, 22) and perhaps even preventing adequate contact between the backrest and the thoracic part of the trunk. Rosemeyer (88) found an increase in the activity of the muscles in the thoracic region when the backrest-seat angle was large (140°) and the seat horizontal. Although the maximum inclination of the backrest from the horizontal, the sum of the seat and backrest inclinations, was 134°, no such findings were made in this study. The angle of the hips is of course influenced by the backrest inclination. A large backrest-seat angle increases the angle of the hips and forces the pelvis to rotate backwards; the lumbar spine moves towards kyphosis. A hip angle of 95–120° has been suggested as suitable (22, 86, 87). This would limit the backrest-seat angle to 120–130°. Too low backrest inclinations on the other hand places the driver in a more upright position and increases the joint angles. Thus the decision of the degree of backrest inclination to be used must be based on knowledge of the interrelation between several factors. An increase in the lumbar support had a decreasing

effect both on the disc pressure and on the myoelectric activity. This effect on the pressure of a change in the posture of the lumbar spine towards lordosis supported the findings of a previous investigation and was discussed in detail in that paper (I). The decrease in myoelectric activity in the thoracic region was consistent with the previous studies (I, 4). The simultaneous decrease in the activity in the muscles of the lumbar region was, however, contrary to these investigations. The differences between the investigations may well be explained by the fact that in the experimental chair the small lumbar support acted directly on the back; it served as an indicator rather than a support. In the car seat the lumbar support was well padded and supported the back in a better way. The support was always located at the level of L3. The level is important. Too high a support forces the lumbar spine in kyphosis, while too low a support pushes the occupant forwards on the seat (I). It is equally important to provide an opening, or recess, below the support to accommodate the pelvis. Obviously, it would be desirable not only to permit variation of the support perpendicular to the backrest, but also in height. The height and the configuration of the backrest were the same throughout the investigation. The height should be sufficient to support the thoracic part of the back. The configuration should include a lateral support to improve stability. When the trunk is not sufficiently stabilized there is more stress on the spine and the arms. The inclination of the seat had a minor influence on the disc pressure and the myoelectric activity. As the variation was as small as 4° it is well possible that the method of investigation was not sensitive enough. An interdependence between the seat inclination and the backrest inclination was found, however. When the backrest inclination was 100° and 120° the lowest myoelectric activity and the lowest disc pressure were found with the seat inclined to 14°. When, on the other hand, the backrest inclination was 110° the lowest values were found when the seat inclination was 10°. As the increase in seat inclination was achieved by tilting the whole of the chair backwards there was a simultaneous increase in the inclination of the backrest. This changes the interrelations between the driver and the controls and may explain the observed differences. There is fairly good agreement in the literature that the car seat should be

inclined backwards, but different authors hold different opinions as to the suggested degree of inclination (22, 64, 79, 86, 87). In our view the main importance of the inclination is that it prevents a sliding forward on the buttocks. This is particularly important when the backrest is inclined backwards (I). Forward sliding can, however, also be prevented by depressions for the ischial tuberosities, either provided by the design of the seat cushion (1, 36, 85) or by differences in the deflection of the anterior and posterior parts of the seat (84). A backward seat inclination facilitates the use of the backrest. Umezawa (67) found that the physiological shape of the disc was more easily preserved when the seat was inclined backwards. Yamaguchi et al. (90) performed myoelectric studies of the abdominal and sacrospinal muscles and found a decrease when the backward seat inclination was increased. To some extent these findings were confirmed, because the lowest disc pressure and the lowest myoelectric activity were found when the seat inclination was 14°. To preserve the suggested hip angles it is necessary to increase the inclination of seat and backrest simultaneously. The greatest possible seat inclination will therefore be limited by the greatest possible backrest inclination. Other restricting factors are the increase in the pressure on the underside of the thighs, when the seat inclination is large, and the distance to the steering-wheel and the pedals.

When the clutch pedal was depressed a compressive force acted on the spine, and the lumbar spine was moved towards kyphosis. This explains the considerable increase in disc pressure observed. The probable increase in the activity of the iliopsoas and the abdominal muscles also contributes to the increase in pressure. In the posterior muscles of the back no increase in myoelectric activity was found. Gear shift was performed by stretching the right arm slightly forwards and in a lateral direction. This increased the torque on the shoulders and on the trunk, which accounts for the increase in disc pressure and in myoelectric activity. With respect to the position of the gear lever it is considered important that it should be placed in such a way that the driver need not bend forwards, removing the back from the backrest.

CONCLUSIONS

The lowest level of myoelectric activity, and the lowest disc pressure were found when the back-

rest-seat angle was 120°, the lumbar support 5 cm and the seat inclination 14 degrees. Based on the assumption that low myoelectric activity and low disc pressure are favourable, it is suggested that the backrest and the seat inclinations should aim at these values, taking the interrelations between body dimensions and workspace into consideration. The backrest should be fitted with a lumbar support which is variable both perpendicular to the backrest and in height above the seat. The depression of the clutch pedal and shifting of the gear both increased the disc pressure and also influenced the myoelectric activity. This can be avoided by the use of automatic transmission.

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