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Investigating the Effect of Backrest Angle and Lumber Prominence on Low back Muscle Activity in the Automobile: A Nigeria Perspective

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Abstract

Six male subjects volunteered for a study into the effects of automobile seat backrest angle (110^0 and 120^0) and lumbar prominence (0 mm and 50mm). There were 2 x 2 possible factor-level combinations in this experimental design. Each subject participated in each experimental session twice. The sessions lasted for 1-hr. The root mean square (RMS) variation of the EMG was used to assess the stress imposed on the low back musculature. The dependent variable was the change in RMS (RMS) over time. By definition, the RMS value becomes more positive as low back muscle activity decreases. Backrest angle was found to have a statistically significant main effect ($p<.05$). For the selected vehicle package, a 120^0 backrest angle was optimal. Lumbar support prominence was not found to affect low back muscle activity.

Keyword: backrest, lumber support, low back, design, muscle.

1. Introduction

In the context of automotive seating, it is rather obvious that traditional lumbar support recommendations are failing the consumer. To combat this problem, new features are constantly being developed to address the muscle activity common in sitting postures. Massaging lumbar mechanisms are an example. Backrest angel and lumbar support prominence are two factors that, independent of feature, affect the occupant.

Andersson et al (1974) found that an increase in automobiles seat backrest angle was accompanied by a decrease in myoelectirc activity. The explanation is simple. When the backrest angle is increased, a larger proportion of the occupant’s body mass is transferred to the backrest and thus the stress on back musculature is reduced.

Even though the aforementioned rationale is fairly well understood, there is, to data, no universally accepted research that definitively outlines an optimal backrest angle. Vehicle package is, obviously, the limiting factor. More specifically, the backrest angle is restricted by the need for a good field of view. That is, the eyes must be suitably placed in relation to the automobile body so that vision is not obscured. When the backrest angle is too large the head must be flexed to enable the driver to see the road.

The appropriate design of a lumber support, in terms of prominence, is one of the most widely discussed issues in the ergonomics of seating. A lumbar support is a structure that contacts the lower back in the area of the lumbar spine during sitting. In traditional automotive seats, the lumbar support is integrated into the backrest contour. The general purpose of the lumbar support is to stabilize the occupant’s torso and, thereby, improve postural stability. This is accomplished by restricting the rearward rotation of the pelvis that normally accompanies sitting while at the same time reduces flexion (forward bending) of the lumbar spine. Rearward rotation leading to flexion causes the lumber spine to move from lordosis towards kyphosis.

Automobile seat designers have, for a long time, attempted to preserve or induce, to the extent possible, a lordotic lumbar spine curvature by providing a firm, longitudinally convext lumbar support in the lower part of the backrest. The deflected contour of such a support, based on general design practice, should mate with the lordsis of the occupant's lower back, providing relatively even contract pressure behind the pelvis and lumbar spine. Conventional design wisdom states that if the design of the lumbar contour does not induce lordosis, there is often, a mismatch between the occupant's back and the seat. According to Reed et al (1991) this mismatch may produce uncomfortable pressure concentrations or a lack of support in the lower levels of the lumbar spine (i.e the region where discomfort is most frequently reported). In addition to crating discomfort, it is also possible to infer that this mismatch may lead to increased muscle activity.

By the mid-1970s, most lumbar support recommendations were strongly influenced by philological studies of the load on the lumbar spine. Anderson et al (1974) found the lowest level of myoelecirc activity with an automobile seat lumber support prominence of 50 mm. Based on the assumption that low myoelectirc activity is favorable, Anderson et al (1974) recommend a lumbar support prominence of 50mm.

In view of this body of work, one might question the need for future research into lumbar support design. However, some recent investigations have suggested that current lumbar support recommendations based on physiological considerations do not adequately take into account the behavior of the occupant in the driving environment (Reed et al, 1991).

As an example, Porter and Norris (1987), noting that the lumbar support specifications in the literature are based primarily on physiological rationales, constructed a wooden laboratory seat to compare the lumbar support specifications recommended by Anderson et al (1974) with occupant preferences. Porter and Norris (1987) found that people preferred postures with substantially less lordosis (i.e., 20mm).

More drastically, some researches have even questioned whether a lordotic lumbar spine posture is described when seated. Adams and Hutton (1985) argue that the advantages of a flexed spine posture outweigh the disadvantages. They cite increased transport of disc metabolites with changing pressure levels as a factor in favor of flexed-spine postures. In summary, questions have started to surface regarding the role of lumbar support in automotive seating.

With the quantity and quality of research done in the area of automobile seat backrest design, the lack of consensus is surprising. This study was conducted with the purpose of attempting to establish, for a specific vehicle package and experimental protocol, the most advantageous combination of backrest angle and lumber support prominence (assuming that low myeolectirc activity is favorable).

2. Method

2.1 Experimental set-up

In order to investigate the effect of backrest angle and lumbar prominence on low back muscle activity, six healthy male subjects volunteered to sit (for a series of one hour sessions) in an experimental, luxury-level automobile seat (leather trim and power adjusters) that was mounted on a wooden base. The experimentation was spread over a period of a few months. At the beginning of the experiment, each subjects signed a consent form to indicate that he did not have any musculoskeletal disorders (particularly with reared to the lower back) that would make participation in the study inadvisable.

The muscle group of interest was the erector spinae (sacrospinalis). This muscle group stretches from the sacrum to the base of the skull. Since it is the most superficial muscle of the back, it is best suited to surface EMG evaluation mythologies.

The erector spinae was targeted by placing six 10mm diameters bipolar surface electrodes (in pairs) at the L3, L4, and L5 levels on the right and left sides of the subject's back at a distance of approximately three centimeters from the centre of the spine. Each pair of electrodes corresponded to a channel. The exact attachment sites were determined based on the level of the palpable part of the spinous processes. To ensure that the EMG signal was free from noise, the attachment sites were carefully cleaned. When hair was found to cover the intended sites it was first removed. In order to achieve better conductivity, an electrolyte paste was used between t he surface of the electrodes and the subject's back. The electrodes were secured to the subjects using tape.

The subjects were always seated so that the sacrum, lumbar, and thoracic spine contacted the backrest. The subjects were instructed to keep their heads directed forward and to fix their eyes straight ahead. The approximate angles for the ankles, knees, and elbows were 90' 120^0, and 90^0, respectively. A cushion angle of 12^0 was adopted. This setup is typical of a luxury car package.

Data were collected, from each channel, in 15-minute intervals. Although subjects were asked to refrain from any strenuous physical activity prior to their participation in a particular test session, a reading was not taken at time equal to zero because it was assumed that subjects would arrive with varying levels of muscle activity. In this way, the first 15 minutes of the session (plus the minimal set-up time) were used to stabilize the subject's muscle activity to some normal, resting level. In summary, data were collected at four distinct time periods (i.e., 15minute mark, 30 minute mark, 45 minute mark, and 60minute mark).

2.2 Experimental design

There were two main factors in this experiment. They were backrest angle (measured as the angle between the horizontal and the front surface of the backrest) and lumbar support prominence (measured perpendicular to the backrest). The backrest angle was set to two levels: 110^0 and 120^0. The lumbar support prominence was also set to two levels: 0mm (i.e, flat or full-off) and 50 mm (full-on). The amount of lumbar prominence was varied using an adjustable lumbar support mechanism. As a result, there were four (i.e.2x2) different experimental conditions. Each subject participated in each conditions twice making this a full factorial, repeated measures design.

Root mean square (RMS) values were used in the analysis. The dependent variable was the difference between the maximum RMS value obtained during the first 30 minutes and minimum RMS values obtained during t he last 30 minutes. This measure will, from this point on, be referred to as RMS. At each time interval the RMS values were averaged across all six channels.

3. Results and discussion

3.1 Demographics and anthropometry

The subjects were from 25 to 35 years of age. The mean standing height was 176.17cm (SD =4.07) and mean body weight was 79.50kg (SD = 16.16).

3.2 Main effects and interaction

A two factor ANOVA was used to reveal that (1) backrest angle has a statistically significant effect on RMS values ($F(1, 44) = 5.860$, $p<.05$), (2) lumbar support prominence did not produce a statistically significant effect on RMS value, and (3) there was no statistically significant interaction.

In particular, a 120^0 backrest angle (mean RMS value=0.002740) was found to produce a larger decrease in erector spinae muscle activity over time than a 110^0 backrest angle (mean RMS value = 0.00196).

3.2.1 Explanation of study results

It is acknowledged that, in this investigation, when the backrest angle was increased from $110^0$to 120^0 there was a small change in torso, hip, knee, and foot angles. This was accepted as the influence on the results was, probably, limited. With the said, the decrease in erector spinae muscle activity observed with a 120^0 backrest angle can be attributed to the increasing transfer of body weight to the backrest. In other words, the amount of support needed to balance the trunk was minimized as part of the body weight was transferred to the back support. As previously mentioned, the limiting factor is the need for a good field of view. This supported previous findings with other automotive seats (Andersson et al, 1974).

The fact that lumbar support prominence does not affect erector spinae muscle activity can be attributed to the influence of the hamstrings. The hamstring muscles connect the pelvis and leg across the knee and hip joints and produce a restriction on pelvis orientation that varies according to knee angle (Stokes and Abery, 1980). When the knees are extended beyond 90^0, as was the case in this study, the erect pelvic angle necessary to produce substantial without hamstring discomfort. In other words, hamstring tension resulting from the extended knee angle restricted forward pelvis rotation, which reduced the possibility of achieving a substantially lordotic spine posture. As a result, erector spinae muscle activity was, relatively, unaffected.

The absence of significant effect dealing, with lumbar prominence implies that automobile backrests should be designed for driver' preferred postures rather than for postures with a large degree of lordosis, which are typically prescribed. In this context, Reed et al (1995) showed that lordoitc lumbar curvatures are not prevalent even when the seat is designed to accommodate them. If this is indeed the case, then the purpose of lumbar supports in automobile seats need to be reconsidered because the apparent physiological benefits of lumbar lordosis cannot be realized if occupants do not select such postures.

The findings from this study suggest that backrests with fixed lumbar supports should provide support for nearly flat spine profiles, rather than for the standing spine curvature typically recommend. Providing a four-way (up-down and in-out) adjustable lumbar support can accommodate those people who prefer to sit with substantial lordosis.

4. Recommendations for future work

Rather than arbitrarily selecting a pre-existing piece of work dealing with backrest angle and lumbar support prominence and incorporating the recommendations of control variables in future studies designed to evaluate new lumbar support innovations (which will use the same experimental to evaluate new lumbar support innovations (which will use the same experimental set-up), it was decided that another, separate investigation was warranted. It was felt that this prefatory study would lend credibility to the planned lumbar support research by arriving at backrest angle and lumbar prominence recommendations that can confidently be applied to the selected vehicle package and experimental protocol.

The planned research, using this work as the starting point, will (1) evaluate two different types of lumbar support mechanism separately with hopes of identifying optimal settings for control system variables, (2) compare the two different types of system to determine if there is a measurable difference tin muscle activity, and (3) compare EMG results to subjective perceptions of comfort.

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