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Low Back Muscle Activity in an Automobile Seat with a Lumbar Massage System

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This investigation was conducted to determine the effects of a massaging lumbar support system on low back muscle activity. The apparatus included a luxury-level automobile seat, six 10-mm diameter bipolar surface electrodes, an amplifier, an analog-to-digital conversion board, data acquisition software, and a personal computer. Six experimental conditions, each involving a variation of massage time, were considered. The dependent variable was the change in the root mean square variation of the EMG signal. One minute of lumbar massage every 5 min was found to have a beneficial effect on low back muscle activity (as compared to no massage). This may prove to be an extremely important result in the quest to combat low back pain attributable to automobile seating.

automotive seating electromyography low back pain

1. INTRODUCTION

It is clear that low back pain is one of the most frequent and disabling conditions affecting people in their productive years. Very few people are exempt from experiencing this most annoying and, at times, incapacitating

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malady at some point in their lives. The need for prevention is, therefore, significant. Before preventative measures can be instituted, it is essential to understand that an automobile seat can, and does, impact the onset of low back pain. This was insinuated by Porter's (1994) claim that automobile drivers are affected at a rate of approximately 34%. Traditional lumbar support recommendations, used by the automotive seating industry, may be the culprit. This research work was focused specifically on a lumbar massage system (incorporated into an automobile seatback) designed with the intent of combating the detrimental effects of static sitting postures thought to be associated with low back pain.

From as early as 1968, low back pain has been thought of as a disease of the automotive age (Coventry, 1968). Since this time, several studies have tended, in some way, to imply that sitting in an automobile seat plays a role in the onset of low back pain. In this context, perhaps the most influential studies were those of Kelsey (1975) and Kelsey and Hardy (1975). In their case-controlled studies of the epidemiology of acute herniated lumbar intervertebral disc pain, they found that (a) men who spend half or more of their on-the-job time driving a motor vehicle were about three times as likely to develop an acute herniated lumbar disc as compared to those who did not hold such jobs and (b) persons of either sex who said that they drove a car, either away from work or at work, were more likely to develop an acute herniated lumbar disc than those who did not drive at all. The strength of these associations in individuals aged 35 and older and the lack of association in those who were under that age suggested that a certain amount of time in sedentary occupations was necessary for an effect to be seen. These associations could not be attributed to any confounding variables considered in their studies. However, as sitting associated with driving was not thought of as a risk factor when the studies began, the findings were plagued by various limitations (all of which were acknowledged by the authors). The most significant of which included (a) the lack of a control group from the general population, (b) the relatively small sample size, and (c) the tendency of cases to be weighted towards hospitalized patients. Nevertheless, this research work was important because, prior to these studies, there was a total absence of epidemiological evidence to suggest that prolonged sitting in a driving environment was related to low back injuries.

The exact reason for the aforementioned association could not, according to Kelsey (1975) and Kelsey and Hardy (1975), be stated with any degree of certainty. It is, however, not difficult to think of possible explanations for this effect. In fact, Keegan (1953) speculated that back pain was associated with an increased risk of disc herniation because driving for long periods of time requires prolonged sitting in a position that offers insufficient support for the low back. Keegan's (1953) opinion was based on his observations of people with low back pain who had difficulty sitting comfortably in motor vehicles and straightening their backs on rising despite the purported comfort of the seats.

There have been numerous studies detailing the many factors related to low back pain. Andersson (1981), based on his extensive work in this area, wrote a summary paper from which it is possible to infer that the most important automobile seating factors are (a) individual, (b) vibration, and (c) static postures.

With respect to individual factors

- Delin, Hedenrud, and Horal (1976) found that the maximum frequency of low back pain symptoms appears to occur between the ages of 35 and 55 years.
- Westrin (1970), when comparing back-pain patients with a control group found psychological factors to differ significantly. More specifically, a poorer intellectual capacity, less ability to establish emotional contacts, and a sociophilic attitude were characteristic of the back pain patients.
- A high incidence of social problems has also been found in back pain patients. Their general social and economic situation is, on average, not as good, and there is a greater proportion of back pain patients suffering from drug and alcohol abuse than would normally be expected (Magora, 1973; Westrin, 1970).

Vibration is a risk factor for low back pain because it causes repetitive small traumas that give rise to permanent spinal damage. Junghanns, as reported by Andersson (1981), accumulated statistics that showed an increase in low back symptoms in different populations subjected to various types of vibration. These populations included drivers of all types of motor vehicles. Frymoyer, Pope, Clements, Wilder, MacPherson, and Ashikaga (1983) also found vibration to be the main vocational factor associated with back pain, as did Sandover (1983) and Wilder, Woodworth, Frymoyer, and Pope (1982).

Individual factors and vibration are definitely important and should, therefore, not be underestimated. They are, however, not the focus of this research work. Instead, this investigation is concentrated on the static postures created by sitting in a driving environment. Sitting, due to its static nature, restricts blood flow. This can be contrasted with most other activities of daily living that provide a useful function of pumping blood into and out of the muscles. This combats fatigue and discomfort attributable to aches and cramps by providing nutrients and removing waste products.

According to Troup (1978), spinal stress in a given posture stems from the gravitational forces acting on the body and from the forces that arise from the muscular activity needed to maintain it. The stress is greater while sitting than when standing erect. In standing, sitting, and lying, the posture will be optimized by nature, which means that the stabilization function of muscles and ligaments requires a minimal amount of energy (Keegan & Radke, 1964). Less energy can be equated with less blood flow. A person in an unstable posture, due for instance to an improperly located or poorly contoured lumbar support, requires more energy. Unfortunately, the unstable posture restricts blood flow. The end result is fatigue or, more seriously, painful stress of the highly activated muscles. Repeated long-term exposure to unstable sitting posture may lead to irreparable defects.

To assess the role of static postures in the origin and occurrence of low back pain, it is necessary to measure, in some reliable fashion, low back muscle activity. It is known that direct muscle effort is reflected in large amplitude myoelectric signals. Fatigue at the muscle level usually leads to a decrease in the mean power frequency and an increase in myoelectric amplitude for equal function (Moritani, Ngata, & Muro, 1982). Said another way, the quantity of the muscle activity describes the proportions of the unstable posture. In the context of this investigation, an unfavourable lumbar posture causes lasting muscular tension. Surface electrodes allow for the evaluation of this type of muscle activity.

Even though the study results are somewhat inconclusive, electromyography (EMG) is probably the most frequently employed objective measurable of surface muscle activity in the automotive seating industry. As an example, Bush, Mills, Thakurta, Hubbard, and Vorro (1995), based on preliminary data, concluded that gross changes of the seating system, specifically contours, affect posture, which in turn affect muscle activity and are detectable by EMG analysis. Similarly, Sheridan et al. (1991) found that there are quantifiable changes in EMG measures of muscle activity and fatigue as a result of a long-term driving task. Furthermore, the changes were directly affected by automobile seat design. On the other hand, an analysis conducted by Reed, Saito, Kakishima, Lee, and Schneider (1991) was not sufficiently conclusive to allow the exploration of relationship between the EMG data and the subjective discomfort evaluations. In other words, the EMG data did not provide a clear view of muscle activity during their driving simulation. In like manner, Hosea, Simon, Delatozky, Wong, and Hsieh (1986) could not identify EMG evidence of fatigue even after 3.5 hrs of driving.

Andersson, Ortengren, Nachemson, and Elfstrom (1974) conducted arguably the most influential EMG study dealing with automotive seating. This research team showed that various aspects of the seated position could, in brief periods of time, affect both the EMG activity of the paravertebral muscles and lumbar intervertebral disc pressure. They found the automobile seat position that minimizes EMG activity and disc space pressure was 120° of backrest inclination, 14° of seat cushion inclination, and 5 cm of lumbar support.

It is, unfortunately, quite clear that, despite all of this work, there has not been an appreciable decrease in low back pain attributable to automobile seating. Even a peripheral examination of the aforementioned studies makes it immediately apparent that none of the cited studies dealt specifically with the lumbar region. All of the studies took more of a macro approach. That is, the onset of low back pain was studied in relation to the complete seatback.

The significance of the present contribution lies in its focus on the effects of a specific seat feature (i.e., massage system) that targets a specific body region (i.e., lumbar). This micro approach is unique and should help to resolve the problem of low back pain attributable to prolonged sitting in an automobile seat.

The introduction, which was crafted to express the lack of knowledge and need for the present investigation, is appropriately concluded in the highlighted portion of the theoretical framework shown in Figure 1.

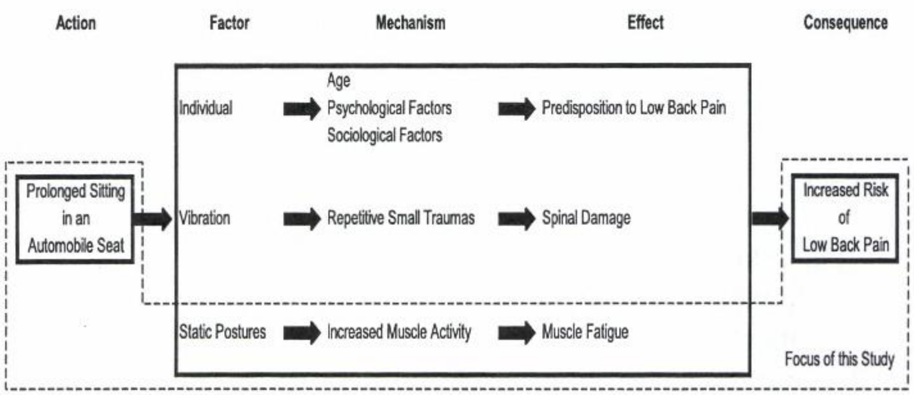

Figure 1. Theoretical framework.

The aim of this study was to determine if a lumbar massage system built into an automobile seatback can combat the detrimental effects of static postures common in prolonged sitting.

2. METHODS

2.1. Experimental Setup

A complete luxury-level (i.e., leather trim and power adjusters) automobile seat, equipped with a lumbar massage system, was used for this study. The experimental seat was mounted on a wooden base. The seatback assembly included a massaging lumbar mechanism attached directly to the frame, a molded foam pad that covered the frame (including the lumbar mechanism), and a leather trim cover that was pulled over both the frame and the foam. A motor, located underneath the seat cushion assembly, controlled the mechanism's massaging action. The massage was performed with the aid of rollers situated in the lumbar portion of the seatback.

Six 10-mm diameter bipolar surface electrodes were used to measure low back muscle activity. A high performance amplifier was used to amplify the measured EMG signals. Data were captured using an analog-to-digital conversion board. The routine, which was run through data acquisition software loaded onto a 486-based personal computer, was set to capture 45 readings per second from six channels. The software also allowed for data storage and manipulation. To prevent the possibility of electromagnetic interference, which would have affected the EMG signals, both the amplifier and the automobile seat were kept away from all other equipment.

2.2. Target Muscle Group

The muscle group targeted in this study was the sacrospinalis. This muscle runs almost parallel to and on each side of the spinal column. It is a large, superficial muscle mass that covers the lower and posterior part of the sacrum, the rear part of the iliac crests, many of the lumbar, and two of the thoracic vertebrae. The function of the sacrospinalis muscles is to maintain an erect posture against the force of gravity.

2.3. Experimental Design

In order to control the position of the occupant, seatback angle (measured from the seatback to the horizontal), lumbar support prominence (measured perpendicular to the backrest with the reference line being the flat contour), and seat inclination (measured from the seat cushion to the horizontal) were held constant. Seatback angle was set to 120°. The apex of the lumbar support prominence was set to protrude 5 cm into the occupant's lower back. Seat inclination was set to 12°. These levels were selected to facilitate the use of the seatback.

Six different experimental treatments were evaluated. Five of the six conditions involved massage whereas one condition involved no massage. More specifically, the five massage conditions were: (1) 5 min of preliminary

TABLE 1. Descriptive Statistics for Participant Anthropometry

Condition		Height (cm)	Mass (kg)
0	*M*	174.00	71.40
	N	5	5
	SD	6.44	22.47
1	*M*	176.00	67.80
	N	5	5
	SD	2.23	7.92
2	*M*	175.60	72.20
	N	5	5
	SD	5.90	17.17
3	*M*	176.40	77.40
	N	5	5
	SD	4.51	17.13
4	*M*	176.40	77.40
	N	5	5
	SD	4.51	17.13
5	*M*	177.40	84.40
	N	5	5
	SD	3.05	12.10
Total	*M*	175.97	75.10
	N	30	30
	SD	4.38	15.80

massage followed by no massage for the remainder of the session, (2) 1 min of massage every 5 min repeated for the duration of the session, (3) 1 min of massage followed by 1 min of no massage repeated for the duration of the session, (4) 2 min of massage followed by 2 min of no massage repeated for the duration of the session, and (5) 4 min of massage followed by 4 min of no massage repeated for the duration session. The conditions were selected to represent a broad range of massage system capabilities.

Six groups of 5 male participants participated in this study. Each group was arbitrarily assigned to a different experimental treatment. As a result, there were a total of 30 experimental sessions. All participants were healthy (i.e., no reported back problems). They ranged from 25 to 35 years of age. With respect to standing height and body mass, descriptive statistics for each group are summarized in Table 1.

The 5 participants participating in condition No. 5 were the tallest (177.4 cm) and heaviest (84.4 kg). The shortest participants were found in condition No. 0 (174.0 cm), whereas the lightest participants were found in condition No. 1 (67.8 kg).

Each experimental treatment lasted for 1 hr. The experimental condition drove the time intervals for data collection. In other words, the time intervals were selected to ensure that data were only collected when the lumbar mechanism was not performing its massaging function. This was, basically, a precautionary measure implemented to avoid the possibility of "noisy" data. Table 2 summarizes the time intervals in which data were collected for the different experimental treatments.

TABLE 2. Time Intervals for Data Collection in the Different Experimental Conditions

Experimental Condition	Time Intervals for Data Collection
0—no massage	15, 30, 45, and 60 min
1—5 min of initial massage	5, 7.5, 10, 16, 32, and 48 min
2—1 min on, 4 min off (repeated)	15, 16, 30, 32, and 48 min
3—1 min on, 1 min off (repeated)	16, 32, and 48 min
4—2 min on, 2 min off (repeated)	16, 32, and 48 min
5—4 min on, 4 min off (repeated)	16, 32, and 48 min

The Root Mean Square (RMS) activity of the EMG was averaged across all six channels at each data-capturing interval. The response variable was the difference between the average RMS value occurring during the first

30 min of data collection and the average RMS value occurring during the last 30 min of data collection. From this point on the dependent variable will be referred to as ΔRMS.

2.4. Procedure

Informed consent was obtained from each volunteer, approximately one week before the study. At this time, participants were also asked to refrain from any strenuous physical activity for the time frame leading up to their participation in a particular experimental condition.

The EMG activity of the sacrospinalis was measured using electrodes fixed, using medical tape, to both sides of the vertebral column. As mentioned, a total of 6 electrodes, were placed, in pairs, 3 cm from the center of the spine at the L3, L4, and L5 level. Two additional electrodes were taped to a chosen bony area (usually the elbow) to serve as neutral.

After attaching the electrodes, the participant was asked to sit on the experimental automobile seat. The participants were always seated on the automobile seat so that the sacrum, lumbar, and thoracic spine contacted the seatback. During their respective sessions, participants were asked to remain attentive and forward facing (with their heads up). As, in an actual vehicle, the pedals dictate the heel point, participants were required to maintain a designated heel point (i.e., they were not permitted to move their legs closer, or farther away, or to cross their legs). These stipulations forced participants into a reasonable driving position.

To ensure a pure EMG signal (i.e., one that is free from noise) the surface of the lower back was cleaned. For the same reason, when hair was found to cover the attachment sites, it was shaved. To achieve better conductivity, the electrodes were filled with an electrolyte paste. At the end of each experimental session, the electrodes were rinsed and dried.

3. RESULTS

3.1. Participants

As different participants were used for the different conditions, it was useful to compare the samples with respect to standing height (cm) and body mass (kg). In the context of this study, standing height was important because the lumbar support was fixed (i.e., non-adjustable). More specifically, the apex of the lumbar prominence was not at the same lumbar level for all occupants. That is, the apex of the prominence was, probably, too low for taller individuals and too high for smaller individuals. An inappropriately located lumbar prominence can be speculated to increase muscle activity and thereby accelerate the onset of fatigue and pain.

Body mass is important for a different reason. As described, the lumbar massage mechanism is attached to the seatback frame, which is covered by the foam and trim. In order for the massage to be experienced, the occupant must penetrate the foam and trim. The more the penetration, the more significant the experience. From this perspective, heavier participants have the advantage.

A one-way ANOVA was used to determine if the anthropometric differences between groups (outlined in Table 1) were statistically significant at the .05 level. The results are included in Table 3.

TABLE 3. ANOVA Used to Compare the Standing Height and Body Mass of Different Groups of Participants

Source		*SS*	*df*	*MS*	*F*	Significance
Height	Between Groups	32.167	5	6.433	.294	.911
	Within Groups	524.800	24	21.867		
	Total	556.967	29			
Mass	Between Groups	862.300	5	172.460	.649	.665
	Within Groups	6380.400	24	265.850		
	Total	7242.700	29			

As the variation within the conditions is greater than the variation between the conditions, sample differences in anthropometry (i.e., standing height and body mass) can be ruled out as an explanation for any muscle activity effects found between experimental conditions. That is, the groups are, from an anthropometric standpoint, statistically identical.

3.2. Muscle Activity

Figure 2 depicts how the RMS activity changed from the first 30 min to the last 30 min. A negative slope or a positive ΔRMS value implied that the experimental condition had a beneficial effect on low back muscle activity.

That is, low back muscle activity decreased over time. Condition No. 2 and condition No. 4 (only marginally) were found to have a positive ΔRMS value.

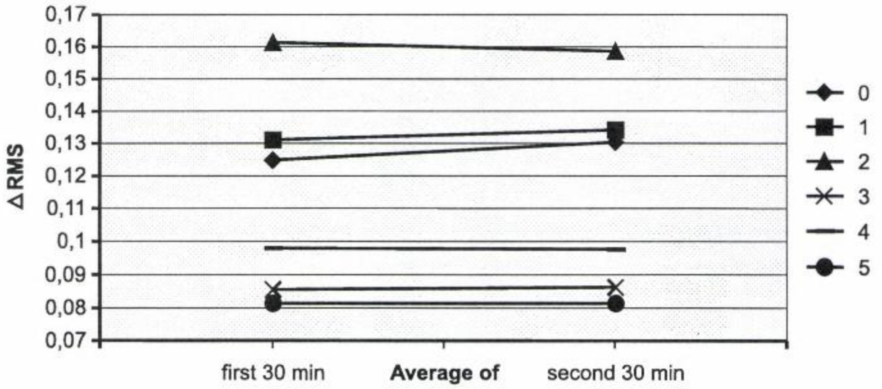

Figure 2. The average change in muscle activity over time (ΔRMS) for each experimental condition. Notes. 0–condition No. 0, 1–condition No. 1, 2–condition No. 2, 3–condition No. 3, 4–condition No. 4, 5–condition No. 5.

To determine if the differences between the conditions were statistically significant at the .05 level, a one-way ANOVA was, once again, performed. The results, outlined in Table 4, suggest that the experimental conditions had an effect on low back muscle activity.

TABLE 4. ANOVA Used to Compare ΔRMS Values Between Experimental Conditions

Source	*SS*	*df*	*MS*	*F*	Significance
Between Conditions	0.0002172	5	0.00004343	2.847	.037
Within Conditions	0.0003662	24	0.00001526		
Total	0.0005833	29			

Tukey's Honestly Significant Difference Test (Post Hoc) showed that condition No. 0 (no massage) was different than condition No. 2 (1 min massage every 5 min for the entire 1-hr session). More specifically, condition No. 0 resulted in an increase in muscle activity over time (detrimental effect), whereas condition No. 2 resulted in a decrease in muscle activity over time (beneficial effect). The mean difference was considered significant at the .05 level. These results are presented in Table 5.

TABLE 5. Tukey's Honestly Significant Difference Test Results

					95% Confidence Interval	
(I) COND	(J) COND	Mean Difference (I-J)	*SE*	Sig.	Lower Bound	Upper Bound
0	1	−2.51475842E-03	.002	.907	−1.01529242E-02	5.1234074E-03
	2	−8.51100017E-03	.002	.023*	−1.61491659E-02	−8.72834385E-04
	3	−4.97531677E-03	.002	.364	−1.26134825E-02	2.6628490E-03
	4	−5.94914677E-03	.002	.193	−1.35873125E-02	1.6890190E-03
	5	−5.42206677E-03	.002	.276	−1.30602325E-02	2.2160990E-03
1	0	2.5147584E-03	.002	.907	−5.12340737E-03	1.0152924E-02
	2	−5.99624175E-03	.002	.187	−1.36344075E-02	1.6419240E-03
	3	−2.46055835E-03	.002	.915	−1.00987241E-02	5.1776074E-03
	4	−3.43438835E-03	.002	.732	−1.10725541E-02	4.2037774E-03
	5	−2.90730835E-03	.002	.843	−1.05454741E-02	4.7308574E-03
2	0	8.5110002E-03	.002	.023*	8.7283438E-04	1.6149166E-02
	1	5.9962417E-03	.002	.187	−1.64192403E-03	1.3634408E-02
	3	3.5356834E-03	.002	.708	−4.10248238E-03	1.1173849E-02
	4	2.5618534E-03	.002	.901	−5.07631238E-03	1.0200019E-02
	5	3.0889334E-03	.002	.808	−4.54923238E-03	1.0727099E-02
3	0	4.9753168E-03	.002	.364	−2.66284902E-03	1.2613483E-02
	1	2.4605583E-03	.002	.915	−5.17760743E-03	1.0098724E-02
	2	−3.53568340E-03	.002	.708	−1.11738492E-02	4.1024824E-03
	4	−9.73830000E-04	.002	.999	−8.61199578E-03	6.6643358E-03
	5	−4.46750000E-04	.002	1.000	−8.08491578E-03	7.1914158E-03
4	0	5.9491468E-03	.002	.193	−1.68901902E-03	1.3587313E-02
	1	3.4343883E-03	.002	.732	−4.20377743E-03	1.1072554E-02
	2	−2.56185340E-03	.002	.901	−1.02000192E-02	5.0763124E-03
	3	9.7383000E-04	.002	.999	−6.66433578E-03	8.6119958E-03
	5	5.2708000E-04	.002	1.000	−7.11108578E-03	8.1652458E-03
5	0	5.4220668E-03	.002	.276	−2.21609902E-03	1.3060233E-02
	1	2.9073083E-03	.002	.843	−4.73085743E-03	1.0545474E-02
	2	−3.08893340E-03	.002	.808	−1.07270992E-02	4.5492324E-03
	3	4.4675000E-04	.002	1.000	−7.19141578E-03	8.0849158E-03
	4	−5.27080000E-04	.002	1.000	−8.16524578E-03	7.1110858E-03

Notes. *—denotes statistically significant difference, sig.—significance.

4. DISCUSSION

In automobile seating, posture is a primary determinant of muscle tension. Thus, the anthropometric characteristics of people and their geometric interactions with seats are directly related to physiological factors. This study showed that lumbar massage, if properly set, acts to decrease low back muscle activity. This effect may reduce the risk of low back pain.

From a seat design perspective, the results suggest that there is an optimal massage-to-no-massage ratio. Based on the ΔRMS values, it is apparent that condition No. 1 is the worst of the massage conditions (although it is not statistically different than the no massage condition). This can, probably, be attributed to the fact that the initial massage action in condition No. 1 stimulated the sacrospinalis and then, for the remainder of the experimental session (i.e., 55 min), did nothing to reduce the activated state of the musculature. The three conditions with a 1:1 massage-to-no-massage ratio (i.e., condition No. 3, 4, and 5) did not produce an effect that was statistically different than that observed in condition No. 1. It can be argued that a one-to-one massage-to-no-massage ratio results in an over-stimulation of the sacrospinalis. Only condition No. 2 had a beneficial effect on sacrospinalis muscle activity. This condition had a massage-to-no-massage ratio of 1:4. The implication is that blood flow is optimized by a regular period of massage applied to the lower back, followed by an extended period of no activation. The finding should become a standard setting for all lumbar massage systems built into automobile seats.

The obtained effect would have, most likely, been more pronounced if the driving task was better simulated. Although measures were taken to ensure that participants sat in a representative driving posture, the passive nature of the experimental protocol precluded assessment of the dynamic effects typically encountered when sitting in an actual automobile seat. Consider, for example, the fact that all driving activities involve the muscles of the trunk. Steering involves the muscles of the upper limb and the extensors and rotators of the spine. Pulling on the hand brake has a similar effect. The psoas muscle, which originates from the spine and is the principle hip flexor, is active every time the foot is lifted onto the pedal. Accelerating, braking, and cornering, as well as vibration, tend to move the body in relation to the seat. These events impact the muscular effort required to maintain a stable sitting posture.

The vehicle package is another related and important factor in the amount of muscle activity and, consequently, the risk of low back pain. To clarify, Andersson et al. (1974) showed that it is beneficial to angle the seatback to the rear. However, if the increased seatback angle is coupled with a reduction in legroom (which is, very often, a vehicle-imposed packaging restriction), the occupant will be forced to extend his knees. This action causes a pull on the hamstring muscles that will tend to cause the pelvis to rotate posteriorly (Floyd & Roberts, 1958). The net result is a flattening of the lumbar lordosis, which could contribute to low back pain.

Individual factors, as described earlier in this paper, were not the focus of this paper; other than to say that the selected population was younger than the highest risk group (as identified by Delin et al. [1976] and Hosea et al. [1986]). It should be stated that, while the experiment was being designed, an older sample with comparatively more back problems was considered. However, in the end, it was decided that an understanding of the effect of lumbar massage on young, relatively healthy participants was a prerequisite to an understanding of the effect of lumbar massage on older, less healthy participants. Two deciding factors were (a) the ethics of exposing a low back pain sufferer to a new, unproven device and (b) the fact that more intense massage would, probably, be required to relieve stress in an individual with a history of low back pain than in a healthy individual. The present system was not engineered to provide rigorous massage.

The favourable findings using a young and healthy population (i.e., those without back problems) encourage the claim that the massaging lumbar mechanism is a potentially proactive way to reduce the onset of low back pain in higher risk populations. This claim, obviously, needs to be substantiated through a future research study. The goal of this type of investigation would be to determine if the massaging lumbar has a therapeutic effect on those with permanent lower back muscle tension.

Lumbar massage will, probably, be marketed as a comfort-enhancing feature. For this reason, a limitation of the present experimental protocol is that subjective perceptions of comfort were not assessed. This requires a reliable and valid subjective instrument. A review of the published literature in automotive seating did not yield such an instrument. Once this deficiency is addressed, future research should attempt to quantify the subjective experience of individuals exposed to lumbar massage. This type of study would help to refine engineering parameters (like massage time) and determine whether or not the product will sell.

The dilemma of the automobile seat designer, which Reed et al. (1991) described as the need for a balance between “prescribing” a lumbar posture and “accommodating” a driver in a preferred lumbar posture, can be simplified by providing an infinitely adjustable lumbar mechanism. That is, a four-way lumbar (in-out and up-down) may be the key. Adjustability has been advocated, even with basic seat designs, for some time. It has been 20 years since Andersson, Murphy, Ortengren, and Nachemson (1979) recommended a lumbar support that is variable both perpendicularly to the seatback and in height above the seat. The automotive seating industry has, obviously, balked at this recommendation, except in some of the more luxury-level seats. The associated costs make this understandable. However, until the problem of low back pain due to driving is adequately addressed, there is really no other recourse.

The recommendations can be summarized as follows:

1. Standardize base setting for lumbar massage at a ratio of 1 min on and 4 min off.
2. Improve simulation of driving environment in future studies.
3. Investigate the purported benefits of lumbar massage with populations at higher risk for low back pain (individuals aged 35 to 55).
4. Assess the impact of lumbar massage on subjective perceptions of comfort.
5. Advocate adjustability to further improve the performance of lumbar massage systems.

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