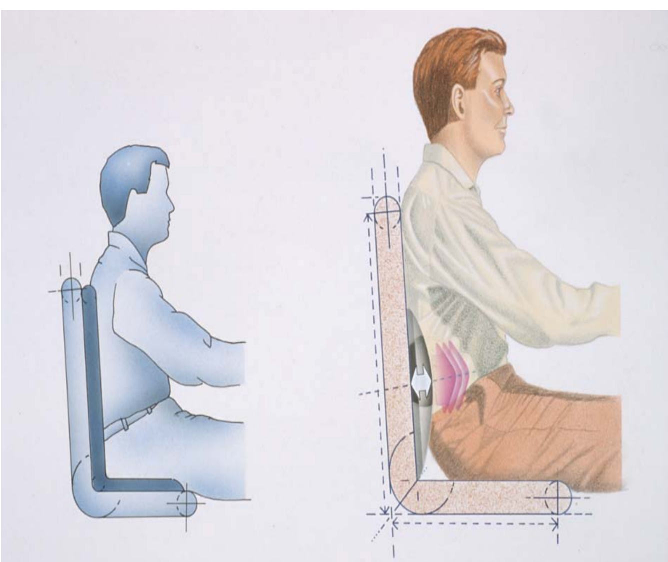
Continuous Passive Lumbar Spinal Motion: The BackCycler® System for Preventing Low Back Discomfort, Stiffness and Fatigue During Sitting

Rowland G. Hazard, MD
University of Vermont & Ergomedics, Inc. 15 Tigan Street, Winooski, VT 05404

ABSTRACT

Low back pain is the most common physical complaint of motor vehicle drivers and passengers. Various seat back contours have been developed to improve low back comfort, and lumbar support has some advantages. Recently, a series of experiments have demonstrated that a continuously inflating and deflating (BackCycler®) lumbar support bladder system can reduce low back discomfort, stiffness and fatigue in drivers with and without clinical back problems. As demonstrated by radiographic movies, this system works by gently keeping the user's lumbar spine moving through greater and lesser forward curves (lordosis). The purpose of this paper is to present the efficacy research and to review the proposed mechanisms of action for this emerging seating comfort technology.



The BackCycler®

INTRODUCTION

Low back pain is epidemic in industrialized countries. It is the second most common reason for people to consult a physician behind the common cold, affecting up to 70% of adults. Annual costs for low back pain in the United States exceed $50 billion. An ironic biomechanical feature of low back pain is that it is frequently made worse by prolonged sitting. Intervertebral disc herniation, perhaps the most notorious anatomic cause of back problems, has been statistically associated with motor vehicle operation in the course of or commuting to and from work. One of the major problems confounding back pain research in general is the lack of a clear anatomic explanation for the pain in most people with clinical problems, not to mention the vast majority of people who complain of discomfort, stiffness and fatigue while sitting.

SOURCES OF BACK PAIN – Muscles and ligaments that support the spine can be strained by the constant loading of the spine that occurs during sitting. The intervertebral discs are compressed by the upper body's weight more during sitting than in standing, because the center of gravity is thrown forward, requiring the muscles in back of the spine to counterbalance it through a very short lever arm. While the disc's interior has no blood or nerve supply, it can clearly cause pain when its central nucleus migrates backward causing distension of the posterior wall and pressure on the adjacent nerve roots.

Two seatback strategies reduce the effects of sitting on these structures: inclination (reclining) and lumbar support. Electromyographic studies have shown decreases in spinal muscle tension during inclination and with lumbar support, and reduced disc compression has been measured directly with probes inserted into the disc. X-ray studies have recorded forward migration of the central nucleus during the forward curving (lordosis) of the lower spine that occurs with lumbar support. A careful clinical study has shown that lumbar support can reduce low back and referred leg pain (sciatica) when compared to an unsupported backward slouching (kyphotic) posture.[1]

In spite of these arguments for lumbar support and seatback inclination, they are often not employed in the real world. Observing virtually any group of people sitting can easily prove this. Commonly half of them will be sitting in lordosis, while the rest are slouched in kyphosis. In a matter of minutes, many of them will switch to the opposite posture. This observation inspired the development of a lumbar support that could automatically provide continuous spinal motion back and forth between kyphosis and lordosis during tasks requiring steady head positioning such as deskwork and motor vehicle operating.

The purpose of this paper is to present the research background for continuous passive lumbar spinal motion (CPLSM) during seating including:

- Initial surveys to determine optimal bladder, pump and valve operating specifications.
- Efficacy testing of the CPLSM system during simulated and actual driving for people with and without clinical back problems.
- X-ray demonstration of spinal motion during CPLSM use.
- Studies of intervertebral disc effects and driver alertness during CPLSM use.

RESEARCH METHODS AND RESULTS

CPLSM OPERATING SPECIFICATIONS – Initial CPLSM prototypes included air bladders inserted between the user's lower back and the seatback. Various pump and valve combinations were applied to the bladder to create cycles of inflation and deflation such that the user's spine could be gently mobilized for maximum comfort. Survey testing showed that users were more comfortable if they could control maximum inflation pressure to accommodate variations in body size, spinal compliance, and seating positions. Pressure control was provided first with a regulator and eventually by a pressure sensor in the air conduit giving constant output to a microprocessor that compared the pressure to the user's preset maximum and activated the pump or valve accordingly. A series of tests in office settings showed that slow cycles averaging 60 second inflations and 45 second deflations were preferred over faster cycles and static support, suggesting that the observed comfort benefits were due to spinal motion rather than to any superficial massage effect. Optimal flow rates were 6-8 liters per minute and preferred maximal bladder pressures approximated 1.5 psi.[2]

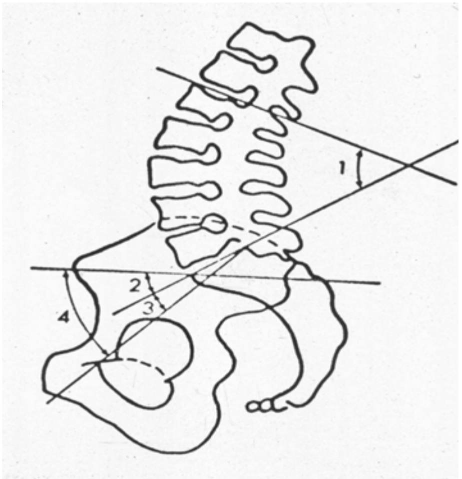
EFFICACY TESTING DURING SIMULATED DRIVING - Twelve people without complaints of back pain sat for two-hour sessions on consecutive days with and without the CPLSM in random order. The automobile seat was vibrated 3mm vertically at 4.5Hz, while the person watched a video at windshield position. Lumbar lordosis was sampled at 2Hz by output from a flexible ruler with integrated strain gauges applied to the lower back. Testees completed discomfort, stiffness and fatigue visual analogue scores (VAS) before, midway through and at the end of each test session. Spinal flexibility was measured before and after each session with a skin distraction technique.

Results – While measured spinal flexibility improved only slightly with CPLSM, lordotic motion was greater by an average 9.3 degrees ($p<0.005$) during CPLSM sessions. Most important, improvements in all three VAS self-assessments of discomfort, stiffness, and fatigue were at least twice as great with the CPLSM than without it, all other variables held constant ($p<0.005$).[3]

EFFICACY TESTING: MOTOR VEHICLE DRIVERS WITH BACK PAIN – Twenty-eight people with at least 3 months of ongoing back pain and constant severity for at least two weeks were tested with and without CPLSM in their usual motor vehicles during customary driving. After familiarization with the CPLSM, two days were assigned randomly for driving with or without CPLSM in operation. Cycle rates were 75 seconds for inflation and for deflation. Driving times and VAS scores for discomfort, stiffness and fatigue were recorded at the end of each driving day. On the final day, testees were allowed to drive with or without the CPLSM in operation.

Results – The average drive time was 5.2 hours per day, with no statistically significant difference between test days. Mean self-assessment scores were at least 3 points better on a 10-point VAS scale for each comfort variable on the CPLSM days ($p<0.005$).[3]

X-RAY MEASUREMENT OF SPINAL MOTION DURING CPLSM USE – After the efficacy testing reported above, there was considerable interest in testing the hypothesis that there was true spinal motion occurring with the CPLSM as opposed to a superficial soft tissue compression effect. The external flexible ruler approach to spinal measurement had been indirect, and studies had shown some discrepancies between external measurements and direct observations of spinal movement using x-rays. Therefore, two veteran CPLSM users underwent lateral spinal fluoroscopic x-ray analysis while using the CPLSM device at customary, maximally comfortable inflation pressures. Lateral x-rays were taken of the testees' spines at end inflation and again at end deflation. The cyclic change in forward curvature of the lumbar spine (angle of lordosis) was recorded using the Cobb technique common to orthopaedic analysis of spinal curvature. These measurements were then compared with known lordosis angle changes previously reported for common postures.



The lordosis angle (1)

Results – Lumbar spinal lordosis excursions were similar in this study and in the flexible ruler efficacy study described above. Cobb angle changes through the lumbar spine (between the first lumbar vertebra and the superior table of the sacrum) were 21 and 41 degrees during CPLSM operation. These angle changes are similar to the movement that occurs when a person rises from an unsupported seating position to standing. Therefore, the angle changes and spinal excursions were felt to be safe, and certainly of sufficient magnitude to attribute the comfort benefits of the CPLSM to spinal motion rather than to any soft tissue compression effect such as might occur with massage or vibration.[4]

CPLSM EFFECT ON DISC FLUID MECHANICS – Spinal disc fluid mechanics can be studied indirectly by measuring overall height. The discs have no blood supply, and their nutrient influx and metabolic waste removal depend on fluid flow into and out of adjacent bone. When hydrostatic pressures exceed osmotic pressures in the disc during sitting and standing, fluid flows out of the disc and into adjacent bone. The opposite flow occurs when the disc is unloaded by lying down. Static loading of the disc during prolonged sitting has been postulated as a possible cause of back pain over time. To test the effect of CPLSM on fluid dynamics in the disc, Whiteside and McGill compared subjects' heights before and after sessions of five sitting conditions: unsupported kyphosis, unsupported lordosis, unsupported alternating postures, static lumbar support, and CPLSM.

Results - The cyclical sitting conditions produced less spinal shrinkage and perceived discomfort than the static postures.[5]

CPLSM EFFECTS ON DRIVER ALERTNESS – Driver alertness is a well-known and serious safety issue. Up to 10% of the most serious traffic accidents may be due to driver somnolence. Considering prior evidence that monotonous body movement could reduce alertness, and variable motion could have the opposite effect, Bystrom, et al. investigated the effect of the BackCycler® CPLSM system on the alertness of ten people in a sleep lab. Electroencephalographic (EEG) monitoring and periodic subjective reports of alertness were recorded during a series of 30-minute sitting sessions with and without the CPLSM BackCycler®. To control for noise, the CPLSM BackCylcer® was turned on but not inflating and deflating the bladder for one of the sessions.

Results – EEG and subjective ratings showed driver alertness was significantly ($p<0.05$) greater during CPLSM use compared to sessions in which the CPLSM was inactive and all other variables were held constant. Oral reports clearly confirmed that the BackCycler® was comfortable.[6]

CONCLUSION

While the debate over optimal seat-back contours continues, it is clear that static loading of the spine during prolonged sitting is uncomfortable, if not painful for many motor vehicle drivers and passengers. A new strategy has been developed to keep the lumbar spine gradually moving through cycles of increasing and decreasing lordosis without disturbing upper body, head and eye stability during task seating. The CPLSM BackCycler® consists of a lumbar support bladder that is inflated by a pump and valve system. The system is controlled by a pressure feedback system so the user can set the maximum filling pressure for optimal personal comfort. Through a combination of carefully controlled laboratory and actual drive tests, the BackCycler® has proven effective in reducing low back discomfort, stiffness and fatigue. These benefits have been attributed to true lumbar spinal motion, as opposed to the soft tissue effects of massage or vibration, through x-ray documentation and users' preference for cycle times that are too long for such potentially distracting effects.

Lumbar spinal motion during sitting could improve comfort and reduce stiffness and fatigue in a variety of anatomic ways. The forward motion of the inflating bladder would reduce compression of the intervertebral discs and encourage forward migration of the nucleus pulposus, away from pain-sensitive structures. The motion could affect disc nutrient and metabolite exchange through a pumping mechanism as the rocking vertebrae create cycles of regional pressure differentials. Gradual mobilization of the facet joints in back of the spine may also decrease arthrogenic pain. By changing the vectors of spinal loading due to upper body mass, the CPLSM may have its greatest effect through shifting loads back and forth between muscle and ligament groups. Both muscle and ligament are painful when under static loads. By load sharing over time with cyclic spinal motion, the muscles and ligaments can experience periodic rest much as one experiences when shifting a weight from outstretched hand to hand. Such load sharing may also help to prevent injury due to creep and subsequent microscopic fatigue fracture in the ligaments and in the outer wall of the disc leading to disc herniation and nerve compression. Finally, CPLSM may reduce pain and discomfort through the gate mechanism first described by Melzack and Wall. Sensory input from the spinal motion is processed in the spinal cord such that the gate for pain signal transfer to the brain is closed. Since the exact anatomic source of low back pain is usually not known, and may be due to a combination of the potential sources described, it is reasonable to conclude that the CPLSM may work through several mechanisms simultaneously.

The CPLSM BackCycler® technology has emerged from the laboratory to the real world most dramatically in aircraft. United Airlines has 10,000 seats equipped with BackCyclers®, and passenger survey ratings have been in the 90% better or best category. With major home furniture and heavy truck seating manufacturing programs underway, this technology is now ready for introduction to the automotive markets.

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CONTACT

Rowland G. Hazard, MD is Professor of Orthopaedics and Rehabilitation at the University of Vermont and CEO of Ergomedics, Inc. Education: BA, Harvard College; MD, U of Vermont; Internal Medicine, U of Rochester; Orthopaedic Fellowship, U of Texas. E-mail: rhazardmd@aol,com. Website: www.backcycler.com