Preliminary Design Report
Inflatable Lumbar Cushion for Passive Motion

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Client:

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Problem Statement

This device is designed to provide support and passive motion to the lumbar region of the lower back through the inflation of two cushions located between the individual's back and the car seat. A small pump powered via the cigarette lighter or via a rechargeable battery will inflate the cushions to the desired pressure (30mmHg – 240mmHg) based on an individual's weight not exceeding 250 lbs.

Background Information

Individuals driving for extended periods of time commonly suffer from lower back pain. This is due to strain placed upon the bones, muscles, and ligaments of the back. An article provided by Julie described the mechanism that results in lower back pain called "the vicious circle of pain". The circle consists of a muscular spasm or twitch, leading to decreased blood flow to the tissue, leading to tissue breakdown, and leading eventually to pain. Effective continuous passive motion to the lumber region would gently arch the back and roll the hips forward, flexing the surrounding ligaments and tissues. This flexing process increases the blood flow to the tissue area, and based on "the vicious circle of pain", would effectively reduce tissue breakdown and lower back pain (Arizona CPM and Medical Supply).

Another study found that lower back strain can be prevented with the use of a lumbar support cushion (Stevanovic, 2000). An inflating/deflating cushion could provide the continuous passive motion and support to the lower back. Primarily, individuals driving for extended periods of time develop lower back pain. This is because their bodies are in an unfavorable position for good posture. This unfavorable position placed great strains and stresses to the lower back. This paper focuses on various designs of inflatable lumbar cushions that would effectively provide continuous passive motion and support to the lower back. This device would then be used by driving individuals to reduce the risk of lower back pain.

Client Requirements

Our client, Julie Sherry, had only a few requirements for our design. One of the cushions needed to be roughly cylinder shaped. The cushion should then be able to effectively roll the pelvis forward and arch the back. The arching of the back should obviously not interfere with the individual's ability to drive a vehicle. The device would ideally be able to control a slow and steady inflation/deflation of the cushion on a variable time cycle. Finally, one additional option would be to incorporate heat to the device, aiding in its effectiveness. Appendix A includes the PDS that further describes the requirements for the design.

Alternative Solutions

Our first design solution involves four separated air chambers that inflate at a predetermined rate. This design is shown in Figure 1 and is intended for an individual sitting in a comfortable upright position while driving. The make-up of this design includes three cylinder shaped cushions at the lower and middle back positions. These three cushions gently arch the back away from the seat and toward the steering wheel. Additionally, a fourth "U-shaped" cushion is located behind the pelvis. This cushion is designed to effectively roll the hips forward, aiding in the back arching process. These cushions will be able to be turned off and on individually depending on the needs of the driver.

The inflation of the cushions is controlled by a small air pump located beneath the seat. The pump is powered by a rechargeable battery that has the capability to plug into the cigarette lighter. This air pump is capable of inflating/deflating the cushions between 30mmHg and 240 mmHg at a variable and steady rate of 5 to 20 seconds. The deflation is slow and steady during use, but a quick release valve is present in case of an emergency. A small remote control directly attached to the pump will conveniently control the pump's rate of airflow and the safety off/on switch. This remote will indicate functions through pictures making it easy to understand. The air from the pump is directed to the cushions via removable tubes that can be cleaned or replaced if necessary.

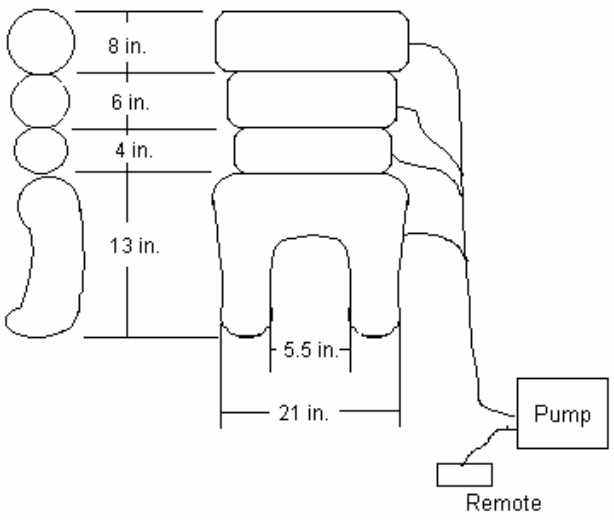

Figure 1 Design Alternative 1, Four-Cushion Design

Our second design includes two inflatable chambers. This design is included in Figure 2. An upright individual would place the top triangular cushion against his/her lower back. This cushion's purpose is to comfortably arch the lower back away from the seat. The second cushion closely resembles a "comma" in is placed behind the individual's pelvis. This cushion is thicker and circular at the top in order to effectively roll the pelvis forward.

The cushions again will be inflated by a small air pump, which is capable of maintaining 30mmHg to 240 mmHg pressures. This pump will be located underneath the car seat and will be powered by a rechargeable battery that can be plugged into the cigarette lighter. The pump can inflate/deflate on a variable 5 to 20 second interval. A quick release valve is also included for safety if rapid deflation is necessary. Additionally, a remote controls the pump's variable inflation rate and the safety on/off switch. Removable tubes were chosen for this design so damaged tubes can be replaced or clogged tubes can be cleaned.

The cushions are enclosed in a fabric shell that keeps them in place, protects them, and also adds to the comfort of the device. There is also a bottom extension of the fabric shell. This extension gives a rough seat surface keeping the driver in place.

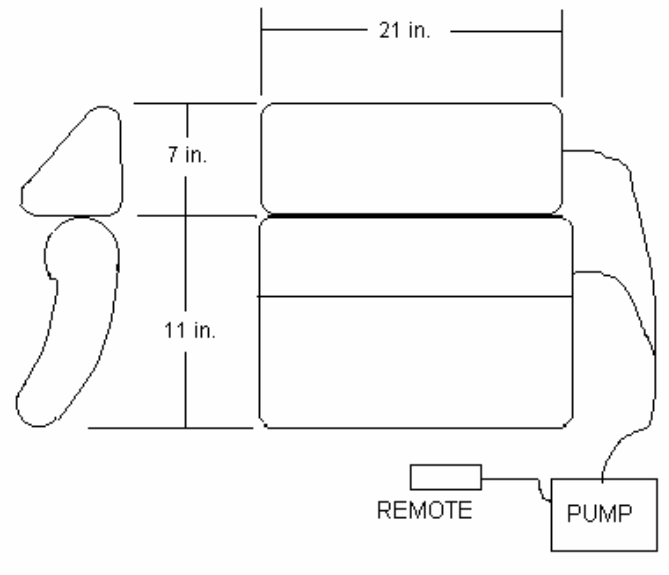

Figure 2 Design Alternative 2, Two Cushion Design Without "U-shaped" lower Cushion

Our final design again includes two inflatable chambers. This design is included in Figure 3. The upper chamber is teardrop shaped in order to fit the contours of the back properly. This cushion pushes the lower back out, causing it to arch. The bottom cushion is "U-shaped" so undesired pressure is not placed on the tailbone. This design effectively rolls the hips forward complementing the arch of the back. The top portion of the "U-shaped" cushion is cylinder shaped and slowly narrows as it reaches the seat.

The two cushions are inflated via a small air pump located beneath the car seat. This pump will have a steady inflation/ deflation rate with variable cycle times ranging from 5 to 20 seconds. The introduction of a quick release valve allows for rapid deflation in case of an emergency. The pump will be able to withstand pressures of 30mmHg to 240mmHg. A small remote with an easily understandable graphical user interface will control this pump.

This design also includes a fabric cover surrounding the cushions. This fabric cover protects the cushions from damage and provides a surface with a high coefficient of friction. This surface ensures that the individual is not simply pushed away from the seat during inflation/deflation of the cushions.

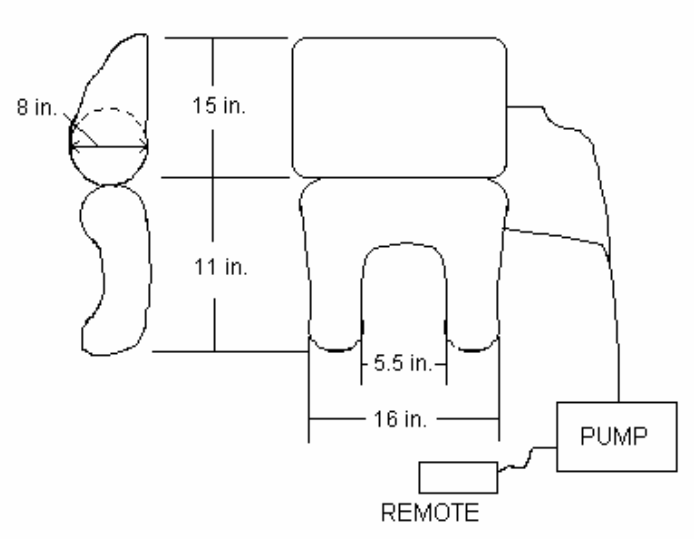

Figure 3 Design Alternative 3, Two Cushion Design With Tear Drop Cushion

Proposed Solution

Through our analysis of the three designs, we determined that design three is the best alternative. The main advantages of design three are its simplicity, its convenience, and its effectiveness. Option three is simple because there are only two cushions to inflate/deflate while supporting the lower back and pelvis. Its convenience is in the device's compact size and ability to quickly deflate for storage. This option is also very universal for many different body types and weights (up to 250 lbs). This design effectively produces the passive motion to the lumber region by slowly rolling the hips forward and arching the back.

The other two designs had flaws that design three did not. Alternative one was very complicated with its four-cushion design. It would have been very difficult to regulate each cushion's inflation/deflation rate independently. Secondly, this design did not effectively fit to the contours of the back. This design is also less universal because the placement of the four cushions may not be as suitable for different body sizes and weights. The four cushions would also have been harder to store because it would be considerable more bulky.

The main concern with design two was the shape of the cushions. The upper cushion's triangular shape may have put unwanted pressure in some area of the lower back. The lower cushion was not in a "U-shape" form. This may have put an uncomfortable amount of pressure on the tailbone

while attempting to roll the hips forward. Additionally, the “comma” shape would not effectively fit individuals with different hip sizes.

Potential Problems

There are a few potential problems with our design. The first problem may arise with the “U-shape” of the lower cushion. While this shape would be the most comfortable, it may not be able to withstand the pressures of 30mmHg – 240mmHg that it would endure. Secondly, the fabric bottom is a start to making sure the individual does not slide away from the seat, but it may not be effective. This design may also need an upper restraint portion guaranteeing that the entire device does not slide down the seat.

References

Arizona CPM and Medical Supply. <http://azcpm.adpebs.com/>.

Article from Julie Sherry. "Engineering Approaches to Standing, Sitting, and Lying". Chapter 17, pp. 431.

Stevanovic, S. and Jovelic, S. "Usefulness of the Lumbar Support Cushion for Pilots of Military Helicopters". *Vojnosanitetski Pregled.* Volume 57, pp. 657-663, Nov-Dec 2000.