EFFECTS OF LOAD CARRIAGE ON CURVATURE OF THE SPINE

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The purpose of this study was to measure the curvature of the spine during load carriage in a rested and mildly fatigued condition. Twelve female subjects walked around an indoor track wearing a 9 kg backpack, in which fifteen spring loaded rods protruded from the back of the pack. The rods were separated by 1.9 cm and were designed to measure the curvature of the spine. The subjects walked for 21 minutes at a rate of 1.79 m/s. Fifteen samples were recorded over 2.5 s at 3 minutes and again at 18 minutes. The means of the two curves were derived from the data to achieve the mean rested and fatigued curves. With fatigue, the cervical to thoracic cavity was thrust forward, causing a significant increase in lordosis of the thoracic to lumbar region. With load carriage, increased lordosis was present to counter balance the weight of the backpack.

KEY WORDS: load carriage, backpack, spine curvature, fatigue

INTRODUCTION: Many studies have reported increased trunk flexion when carrying a backpack (Hong, 1999; Knapik, Harman, & Reynolds, 1996; Orloff, White, & Tanaka, 1999; Pascoe et al., 1997). These postural adjustments have been reported in both static and dynamic situations (Bloom & Woodhull, 1987; Kinoshita, 1985; Martin & Nelson, 1986). Although it has been established that low back trouble is higher in groups with low static endurance of the trunk extensors, such as hikers and students, it is unknown how changes in the curvature of the spine occur with fatigue (Jorgensen & Nicolaisen, 1987).
Not only does increased trunk flexion occur, but head-on-neck posture is also compromised when wearing a backpack (Grimmer, Williams, & Gill, 1999; Vacheron et al., 1999). Flexion as great as 30° has been reported with fatigue (Orloff et al., 1999). The flexion of the head is tied to a flattening of the cervical spine, but this has not been measured directly. The data collection of curvature of the spine has been elusive, due to the fact that the backpack limits the ability to precisely mark and clearly see the back and neck area. The purpose of this study was to measure curvature of the spine during load carriage in a rested and mildly fatigued condition.

METHODS: Subjects signed a consent form approved by the internal review board at the University of Puget Sound prior to participating in this study. Twelve apparently healthy college age women, with no history of back pain, mean (SD) age of 20.9 (1.6) years and weight of 63.3 (4.8) kg volunteered for this study. The subjects routinely wore backpacks weighing 5-12 kg for 30 minutes or more per day.
The subjects were asked to wear a data-logger backpack developed specifically for this study. The 9 kg pack had 15 spring-loaded rods protruding from the middle of the posterior wall of the backpack. The rods were separated by 1.9 cm, covering 30. 5 cm, and were designed to measure the curvature of the spine as displacement values (See Figure 1 & 3). Fifteen samples were recorded over 2.5 s (6 samples per second) at 3 minutes and again at 18 minutes into the trial. Subjects were asked to wear a light weight t-shirt so that thickness of the shirt would not influence displacement values. Subjects were fitted with non-stick tape along their spines to reduce friction and to avoid having the rods catch on t-shirt material. The subjects were asked to walk at a constant 1.79 m/s pace around an indoor 200 m circuit for 21 minutes. After each subject completed the trial the data was downloaded using a Basic X© program. The data was then copied into an excel file to obtain mean resting and fatigued values for the 15 rods.
Initial calibration adjustments were made to the rods to establish a zero point. The distance the rod protruded from the backpack was measured 10 times and a constant value was assigned to all but the longest rod. Each rod had a constant correction value that was then added to the value downloaded from the Basic X© program. Validity was established by holding a metal

goniometer with 8 angles between 86-100° during a data collection phase of the backpack (See Figure 2). The fifteen data points for each rod were graphed and 95% confidence intervals for the lines were established at each of the angles.

Figure 1 - Rods protruding from backpack.

Figure 2 - Goniometer measurement.

The 95% confidence interval measurement ranged between .5-1.0 mm. Reliability was conducted as three separate measurements at each angle. The reliability coefficients ranged from .95-.99. It was concluded that the rods were a valid and reliable measure of 2-dimensional displacement.

For this study the 15 rod displacements were graphed 15 times over 2.5 s at 3 minutes and again at 18 minutes. Mean resting plots established the curvature of the spine for each subject in a relatively rested state and again with mild fatigue. The data was then graphed as mean resting and fatigued curves of the spine. Repeated measures analysis of variance (ANOVA) was used to establish significance ($\alpha < .05$).

Figure 3 - Inside of the data logger backpack

RESULTS AND DISCUSSION: The mean curvature of the spine in both the rested and fatigued states can be found in Figure 4. A repeated measures ANOVA indicated that significant cubic curves were present at rest and with mild fatigue. While the means between the two curves were not different, the magnitude of the curves were significantly different. With fatigue, the cervical to thoracic cavity was thrust forward, causing a significant increase in lordosis of the thoracic to lumbar region. With the head forward it seemed the subjects counterbalanced the weight with hyperlordosis starting at the bottom of the rib cage area. Orloff et al. (1999) found that head flexion was extreme with fatigue, yet trunk flexion only differed slightly. Trunk flexion was measured from the hip to the shoulder to the y-axis. Thus it could be that trunk flexion can remain the same while the curvature of the spine differs. Martin and Nelson indicated that to counterbalance the weight of the backpack some trunk flexion is needed in order for the subject to maintain balance (1986). This study found that the curvature of the spine was compromised during load carriage. Others have also found that head-on-neck posture changes with load carriage in both dynamic and static conditions (Grimmer et al., 1999; Vacheron et al., 1999). It is evident from this study that not only is the head thrust forward, but that the changes in the curvature of the upper thoracic cavity cause a counter movement of the lower thoracic area (See Figure 5). With these changes the intervertebral discs may be under torsional forces: as the posterior area is being compressed the anterior area is under tensile forces (White & Panjabi, 1990) (See Figure 6). This would imply that not only do the posture muscles have to work harder with fatigue in load carriage (Neuman & Cook, 1985; Potvin & Norman, 1993), but that the passive tissues are stressed with

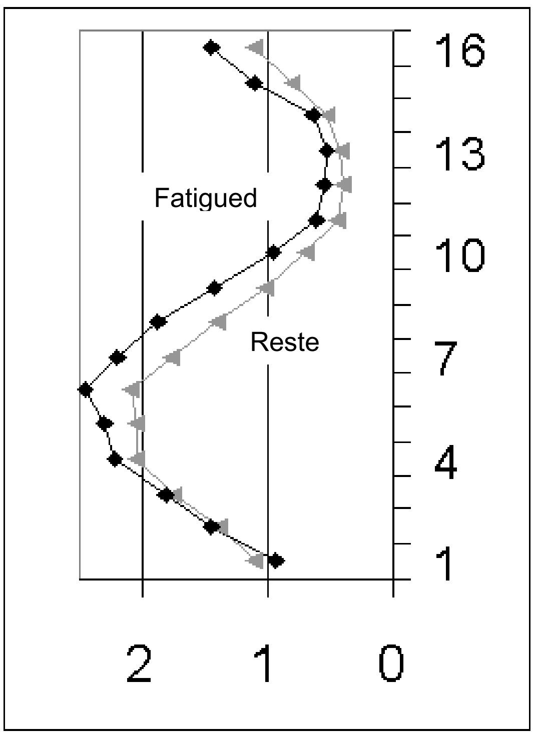

Figure 4 - Curvature of the spine with 16 representing T2 and 1 representing the lumbar region.

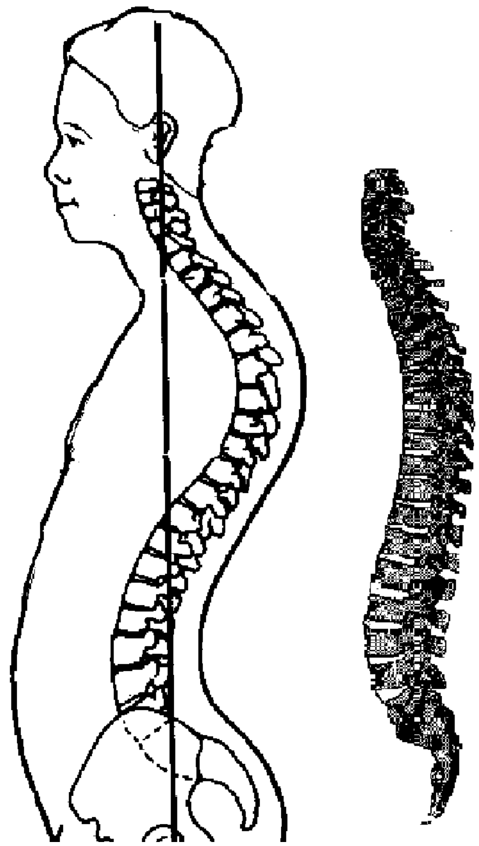

Figure 5. Exaggerated and normal curvature of the spine.

the compromises in posture. While compressive forces can be relatively great without detrimental consequences, shear and torsional forces have been noted to cause damage to the intervertebral discs in heavy lifting (Potvin et al., 1991; White & Panjabi, 1990). More relevant to low constant weight baring activities, Potvin & Norman (1993) found that fatigue can be significant as early as 20 minutes into a low load lifting condition, leaving the intervertebral discs unprotected from increasing torsional forces due to increased lordosis of the spine. The current study would seem to support this theory, as 18 minutes of carrying a backpack caused changes in the curvature of the spine with a relatively light load. Although the changes seemed small they were consistent across subjects. All subjects had exaggerated curves, as noticed in rods 4-8 (See Figure 4).

CONCLUSION: This study found that the curvature of the spine does change in a relatively short period of time when load carrying with a backpack. The flattening of the upper thoracic region caused a more pronounced lordosis in the lower back region.

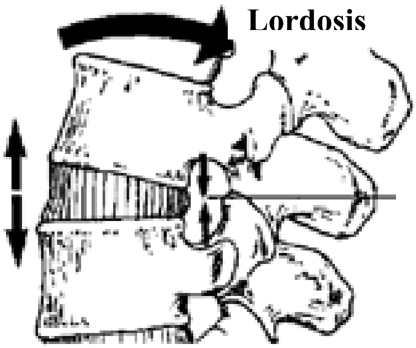

Figure 6 - Forces applied to intervertebral discs with lordosis.

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