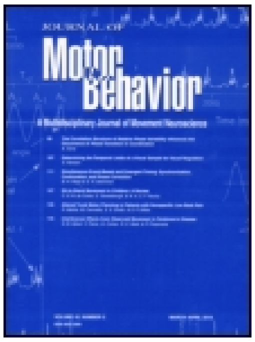

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RESEARCH ARTICLE

Head Posture Influences Low Back Muscle Endurance Tests in 11-Year-Old Children

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ABSTRACT. Poor low back muscle endurance has been shown to be a predictor of chronic low back pain. While posture is a modulator of low back muscle endurance, it is unclear whether the phenomenon is neural or mechanical. This study examined low back muscle endurance with changing head and neck posture in a sample of 117 children using the Biering-Sørensen test. Each subject performed the test in a neutral posture followed by randomly selected flexed and extended head and neck positions. Head posture was found to significantly influence low back muscle endurance within subjects ($p < .001$), with extension yielding the highest endurance scores (boys = 186.6 ± 66.2 s; girls = 192.1 ± 59 s), followed by a neutral posture (boys = 171.3 ± 56.5 s; girls = 181.7 ± 57.3 s), and flexion (boys = 146.2 ± 63.8 s; girls = 159.8 ± 49.3 s). Given the minimal influence of changing moment from head and neck posture, it appears other mechanisms influence endurance score.

Keywords: Biering-Sørensen test, cervical flexion and extension, neutral posture, neural tension, posture

Low back pain is a debilitating condition affecting a large portion of the population at some point in their lives (Hoy et al., 2012); further, it represents an enormous economic burden (Deyo, Cherkin, Conrad, & Volinn, 1991), with more than $50 billion of indirect cost per year in the United States alone (Frymoyer, 1993). While the etiology and classification of back pain is multifactorial and heterogeneous, there has been research that suggests that it is linked to poor low back muscle endurance (Alaranta, Luoto, Heliovaara, & Hurri, 1995; Biering-Sørensen, 1984; Hultman, Nordin, Saraste, & Ohlsen, 1993; McGill et al., 2003). Modulators of low back muscle endurance include age (Dejanovic, Harvey, & McGill, 2012; Johnson, Mbada, Akosile, & Agbeja, 2009), sex (Mannion & Dolan, 1994; McGill, Childs, & Liebenson, 1999), population, and pathology (Biering-Sørensen, 1984; Sjolie & Ljunggren, 2001). Within individuals, low back muscle endurance can be influenced by biceps femoris involvement (Moffroid, 1997), coactivity of the hip extensors (Kankaanpaa, Taimela, Laaksonen, Hanninen, & Airaksinen, 1998), and postural variance (Dejanovic, Cambridge, & McGill, 2014).

With change in posture comes change in the tension of the spinal cord and nerve roots along its entire length (Butler, 1989). While peripheral nerves are designed to cope with various body positions and movements by adapting to different forces (Ellis, 2011), diminished nerve mobility and increased nerve strain presents a potential risk factor for many peripheral neuropathic disorders (Coppieters & Butler, 2008). Excessive cervical flexion for example, provokes additional tension in neural structures, and cervical extension decreases the size of the foramen of the spinal canal (Shacklock, 2005). During passive cervical flexion, neural components in the lumbar region move toward the head, followed by significant tension in neural tissues (Shacklock, 2005), especially in the lumbosacral nerve roots (Breig, 1978). Changes in neural tension in one region of a neural tract impose changes in tension along the full length of the tract (Walsh, 2005).

There are two potential explanations for the influence of posture on low back extensor endurance: either neural tension modulates muscular endurance or a given posture change alters the mechanical burden placed on the extensors through the moment of force they must produce about the low back. The precise mechanism with which posture influences regional trunk muscle activation (Schuldt, Ekholm, Harms-Ringdahl, Nemeth, & Arborelius, 1986) and posture in another region of the spine (Black, McClure, & Polansky, 1996) remains unclear.

Among the many test for assessing low back muscle endurance, the Biering-Sørensen test (BST) has become the most widely used test to evaluate low back muscle fatigue and endurance capacity. Part of its wide use is that it is considered a safe, rapid, simple, and reproducible clinical tool for both healthy subjects and patient populations alike. In our previous study (Dejanovic et al., 2012) we noticed that changed neck and head postures may influence the endurance scores. The purpose of this study was to assess low back extensor endurance in children aged 11, as measured by the BST, under a flexed, extended, and neutral head and neck posture. It was hypothesized that the three head and neck postures would have different endurance scores.

Method

Boys and girls were tested for low back muscle endurance at an elementary school using the established original protocol of Biering-Sørensen (1984).

Subjects

The experimental convenience sample consisted of 117 children from one Serb elementary school matched for age (11 years old, 69 boys and 50 girls). The experimental

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design and data collection methods were presented to, and approved by the Dean and Parents' Committee of the school. Both parents and Parents' Committee signed an informed consent form. The inclusion criteria for participants were (a) 11 years of age; (b) no neurological or orthopedic problems (as obtained from parents); (c) no back pain episodes; (d) no spinal, upper, or lower extremity disorders; and (e) no illness in the four weeks prior to testing.

A test jig (reported previously by Dejanovic et al., 2013) with dimensions 1500 × 600 × 300 mm (elevated 300 mm from floor) was employed for the BST, covered with a 45 mm thick soft pad to prevent discomfort over the pelvis or knees. A soft pad for arm support was placed on the floor in front of the jig. Straps secured the legs. Time was measured with a stopwatch (TAG Heuer electronic Microsplit MS200, La Chaux de Fonds, Switzerland). During each test, two assistants were present to ensure the subject's safety and proper test form (Figure 1).

Data Collection

Isometric back extensor muscle endurance was obtained with the BST in three different cervical positions: neutral, flexed, and extended. The original Biering-Sørensen position with a neutral cervical posture was performed first to obtain initial health and back muscle endurance status in addition to detecting and avoiding potential low back pain cases. The body was cantilevered out over the end of a test bench at the anterior superior iliac crest, arms were crossed over the chest, the pelvis, knees, and hips were secured with straps, and the ankles were held secure by an examiner. This was followed by the BST with either cervical flexion or cervical extension (these were randomized). The rest period between each test was a minimum of 48 and no longer than 96 hr, to allow full recovery and to reduce the risk of possible injury. Termination for each test was defined as a loss of horizontal torso position, or loss of form in the head, hands, arms or legs, or when a participant reached 400 s (Dejanovic et al., 2012). Participants were verbally corrected a maximum of twice to maintain the protocol position.

Data Analysis

To determine whether flexing and extending the neck influenced the load moment on endurance times, 20 participants were selected at random and the moment about the L4/L5 joint (a representative lumbar level) was calculated for each of the three postures (Figure 2). Anatomical lengths were measured from the ear canal, seventh cervical vertebra (C7), and the Iliac Crest (assumed to intersect with L4/L5 in the sagittal plane; McGill, Santaguida, & Stevens, 1993). The moment arms of the segments centre of mass for the head and neck and thorax were computed using the formulae of (Winter, 2009). Segment masses were computed based on a proportion of total body weight; the head and neck was 8.1% of total body weight, thorax and abdomen was 35.5% of total body weight, and total arm was 5% of total body weight (10% for both arms; Winter, 2009). Total arm mass was added to thorax and abdomen mass since they were crossed over the participant's chest, it was assumed to not affect the position of the thorax and abdomen center of mass. Moment about L4/L5 was computed by multiplying the distance from the iliac crest to the tragus by the head and neck mass, and multiplying 63% of the distance between the iliac crest and C7 by the total arm, thorax, and abdomen mass. These two moments were added together to obtain total joint reaction moment about L4/L5 for each of the cervical postures (flexed, extended, and neutral).

Statistical Analysis

A split-plot analysis of variance (ANOVA) was used to assess differences in endurance between boys and girls.

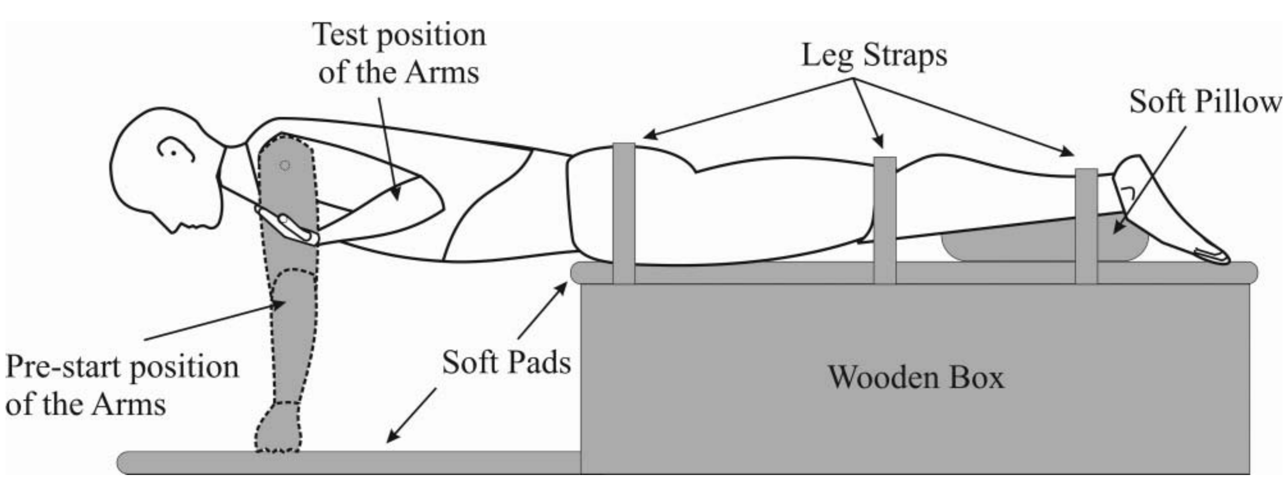

FIGURE 1. Test jig used to perform the Biering-Sørensen protocol and body positions of the subjects.

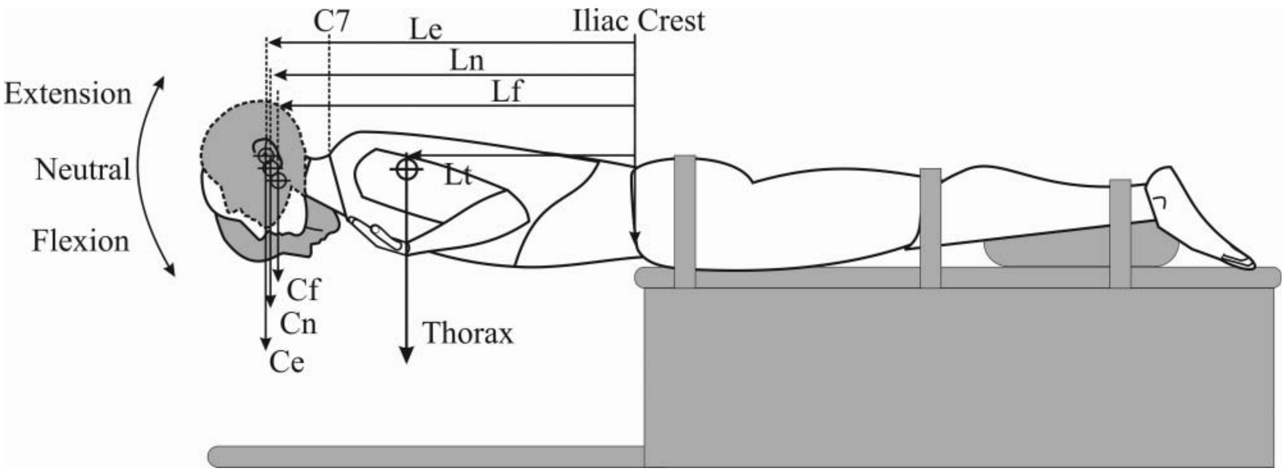

FIGURE 2. Low back extensor endurance test with flexed, neutral, and extended postures. Le, Ln, and Lf are the lengths of the head and neck moment arms for the extended, neutral, and flexed postures, respectively. Lt represents the length of the thorax moment arm. Cf, Cn, and Ce are the positions of the ear canal in the flexed, neutral, and extended postures, respectively, as well as the centers of mass of the head and neck. Thorax denotes the location of the center of mass of the thorax.

Then, pairwise comparisons in endurance between head postures (flexed, extended, and neutral) were performed followed with a Bonferroni adjustment to correct for multiple comparisons. A repeated measures ANOVA was used on the moment data about L4/L5 to assess the effect of posture within subjects. Subsequently, pairwise comparisons determined statistical differences between the three postures using a Bonferroni adjustment to correct for multiple comparisons. All statistical tests were performed using SPSS software (IBM, Somers, NY).

Results

Mean anthropometric data for the two groups (boys and girls) are presented in Table 1. Significant differences within subjects were found for low back endurance scores across the three head postures tested ($p < .001$; Table 2). Pairwise comparisons found significant differences between all head postures (flexion-neutral: $p < .001$, flexion-extension $p < .001$, neutral-extension: $p < .01$). Low back muscle endurance was greatest in the extended posture, with the neutral posture following, and the flexed posture yielding the lowest endurance times. While girls consistently scored higher endurance times compared to boys, no statistically significant differences were observed between the two groups.

Mean values for the moment computed about L4/L5 for the 20 randomly selected participants are shown in Table 3. While repeated measures ANOVA revealed statistically significant differences within subjects for the computed moment across the three postures assessed ($p < .01$), the differences were considered to be biologically insignificant (0.6 Nm). The ANOVA was influenced by every subject having a smaller moment arm in flexion. While this is a function of posture, the magnitude change simply was too small to have any moment effect on endurance time.

Discussion

The hypothesis that low back endurance between the three postures assessed would differ from each other was supported. The extended posture yielded the highest

TABLE 1. Mean Anthropometric Data for Study Subjects

	Boys ($n = 69$)		Girls ($n = 50$)	
Parameter	*M*	*SD*	*M*	*SD*
Age (years)	11.5	0.5	11.5	0.7
Mass (kg)	46.4	10.4	46.2	8.2
Height (cm)	153.0	8.1	155.4	7.0
Body mass index (kg/m^2)	19.7	3.5	19.0	2.4

TABLE 2. Low Back Muscle Endurance Data

	Head extended time (s)		Head neutral time (s)		Head flexed time (s)	
Gender	*M*	*SD*	*M*	*SD*	*M*	*SD*
Male	186.6	66.2***	171.3	56.5***	146.2	63.8***
Female	192.1	59.0***	181.7	57.3***	160.0	49.3***
Combined	189.0	63.0**	175.7	56.8**	152.0	58.3

**$p < .01$ (pairwise difference). ***$p < .001$ (within-subjects difference for endurance score).

endurance times, followed by the neutral posture, while the flexed posture yielded the lowest endurance times. Given the lack of effect of load moment with posture change, the observed differences were not due to the influence of moment. Specifically, the endurance times changed 24% while the load moment changed less than a third of 1% between flexed and extended postures. To our knowledge, this is the first report that documents a link between different head positions in the sagittal plane and low back muscle endurance.

The results of this study have potential implications with respect to risk for future back pain episodes. Data presented here shows significantly compromised low back extensor endurance when the head is placed in a flexed posture. The average value was well below the 176 s cutoff found by Biering-Sørensen (1984) for risk of future low back pain episodes. This may have implications for chronic neck flexion postures, such as adopting a flexed cervical posture while doing prolonged seated work, or with handheld communication devices, reducing the endurance capabilities of the low back extensors and placing individuals at risk for future low back pain.

Mechanically, neck flexion provokes elongation of the cervical semispinalis muscles group, while in extension these muscles work oppositely and have special physiological and mechanical characteristics (Kapandji, 1974; Vasavada, Li, & Delp, 1998). Moreover, full neck flexion involves myoelectric silencing and a flexion-relaxation phenomenon of this cervical muscle section (Diesbourg, 2011), which alter muscle activity, transferring the load-supporting role on the passive components of both muscle and the spine (McGill, 1991). This observation coupled with flexion having the lowest endurance suggests that mechanical factors are unlikely the dominant mechanism. It seems that the muscle length tension and myoelectric properties are different between postures and may have influence on the endurance times as well.

It is possible that the link between endurance time and cervical posture has neural origins. Work from Hultman et al. (1993) indicated that back extensor muscle torque does not influence the back extensor capacity in the BST; nor do the cross-sectional area of psoas and back extensor muscles (Peltonen et al., 1998), body weight (Moffroid, Reid, Henry, Haugh, & Ricamato, 1994; Umezu, Kawazu, Tajima, & Ogata, 1998), and mass of the trunk (Holmstrom, Moritz, & Andersson, 1992). These results would seem to agree with the findings of this study, in that moment about L4/L5 could not explain the differences in back extensor endurance seen across the three postures tested. Mechanoreceptors positioned in the thoracolumbar spinal cord (Beith, Robins, & Richards, 1995), mechanoreceptive nerve endings in the facets (McLain & Raiszadeh, 1995), and mechanically sensitive ganglion cells (Devor & Rappaport, 1990) can respond due to changed head positions, which are hypersensitive for mechanical, biochemical (Bove & Light, 1995), or pathophysiologic changes due to sliding and convergence mechanisms of neural tissues (Adams & Logue, 1971). These structures have potential to influence, and to be influenced by, changes in head position, muscle activity, and the associated tensions.

Limitations of this study include that the data were collected over healthy 11-year-old Serbian elementary school children. Thus, direct generalizations to low back pain patients cannot be made, although given the strong links

TABLE 3. Computed Moment About L4/L5 for 20 Randomly Selected Subjects

Head extended moment (nm)		Head neutral moment (nm)		Head flexed moment (nm)	
M	*SD*	*M*	*SD*	*M*	*SD*
80.8	21.6***	81.1	21.6***	80.5	21.5***

Note. The authors submit that the difference in moment across the three postures tested has no practical significance.
***$p < .001$ (within-subjects difference for endurance score).

between low back muscle endurance and changed head position, these results could be potentially applicable to identifying those at risk for future low back pain. Motivation in participants could be an influential factor on measured endurance scores, but all participants were highly encouraged during testing over the three neck postures.

The results of this study indicate that back extensor endurance capacity is influenced by head and neck position in the sagittal plane. Cervical flexion produces the lowest back endurance scores while cervical extension produces the highest. The mechanism appears to be of a neural origin rather than mechanical, but the results of the present study cannot clearly discriminate which mechanism is dominant. More research is required to determine whether the results from this study are applicable to other postures, however, it is possible that when a flexed cervical posture is adopted, individuals may be exposing themselves to a higher risk for future low back pain episodes by reducing the endurance capacity of the low back extensors below threshold levels for low back pain risk.

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