

Spinal disc hydration status during simulated stooped posture

Kenneth Johannaber^a and Fadi A. Fathallah^{a*}

^a Occupational Biomechanics Laboratory, Department of Biological and Agricultural Engineering, University of California, Davis, USA

Abstract. Stooped work has been shown to be associated with the development of low back disorders, particularly those that affect the spinal intervertebral discs. Although several studies have been conducted to evaluate the effects of physical factors on disc health, little research has focused on the effect of prolonged stooped work on disc hydration- a critical component of disc health. The purpose of this study is to explore the connection between stooped work and low back pain through controlled mechanical loading and quantitative analysis of disc hydration during *in vitro* simulated stooped and erect loading conditions of porcine discs. The results showed that stooped postures exhibit significantly decreased overall water content relative to erect postures. Since as disc hydration forms the foundation for overall disc health and proper function, these results have implications for the injury mechanisms associated with stooped work.

Keywords: Low back disorders; biomechanics; back pain

1. Introduction

Stooped postures remain prevalent in the agricultural, mining and construction industries [2]. Stooped work requires a specific duration of spinal loading with forward flexion, which evidence has suggested may lead to increased risk of developing low back disorders (LBDs). Hydration is a critical indicator of spinal disc health. The load-bearing capability of the disc depends on the ability of the disc to attract and retain water. In normal physiological conditions, the disc utilizes an aggregated core of proteoglycans and the structural encapsulation of the annulus to retain 80-90% water content and generate an osmotic swelling pressure that can support compressive loading [1]. It is logical, then, that the cumulative injury mechanism in disc degradation typically occurs via some adaptation of these normal hydration mechanisms. Despite the apparent link between stooped postures, disc hydration and LBDs, studies in spinal biomechanics have done little to elucidate the direct effect of stooped loading on disc hydration. *In vivo* analyses of stooped work are not

able to provide quantitative analysis of the individual discs, while most *in vitro* disc models have not specifically focused on stooped loading conditions. The purpose of this study is to evaluate disc hydration under simulated stooped posture conditions.

2. Methods

The entire cervical spine was harvested from four male pigs (average age 5 months, average weight 80lbs) and placed in storage at -20° C in sealed polyethylene bags within 3 hours of slaughter. Immediately prior to testing, all discs were equilibrated by placing them in 0.9% physiologic saline at 4°C for 30 hours. This process is shown to effectively thaw the discs and allow them to swell in a consistent manner [4].

* Corresponding author. E-mail: Fathallah@ucdavis.edu. Biological and Ag Engineering, One Shields Ave, Davis, CA 95616, USA. Phone: +1-530-752-1612. Fax: +1-530-752-2640

The discs were then immediately transferred to the testing apparatus, a device designed to transfer an accurate, consistent force and moment from the loading platform to the disc [3,5]. For consistency and optimal fluid perfusion at the endplates, the discs were placed between two wafers of 40 μ m porous metal, each set in a ported aluminum cylinder. The entire disc assembly was housed in an acrylic container filled with circulating .9% saline at 27°C.

A series of loading conditions in simulated erect and stooped postures ranging from 300N to 2200N were conducted. Following testing, the discs were quickly sealed in polyethylene pouches and frozen at -80°C to immediately retain post-testing hydration distribution. Each disc was then removed from the freezer and cut into standardized segments using a custom fabricated template. The template ensured consistent cut location and segment size, separating the disc into 3 sections in the transverse plane and 6 sections in the sagittal plane (sections 1-6 center portion of the disc; sections 7-12 left lateral portion of the disc). These disc segments were then placed in pre-weighed cryogenic vials and the mass of each combined segment/vial was measured and recorded. The vials were returned to -80°C for storage/transport and then lyophilized for 72 hours at 117mBarr and -53°C in a bench-top freeze dryer (Labconco Freeze-Zone 4.5L, Fort Scott, KS). Each vial was then weighed a final time to determine dry tissue weight.

All hydration data based on percentages were transformed prior to analysis. The differences between stooped and erect hydration percentage for each disc section were compared using matched pair t-tests and one-way ANOVA.

3. Results

Stooped postures loaded the disc to a greater extent than erect postures. As a result, the disc sections from the stooped group contained less water than their erect or pre-load counterparts. This difference was significant in the internal disc sections (Figure 1). Hydration values varied largely in the anterior and posterior sections; however, as a result, stooped and erect hydration data for these sections did not display significant differences.

The hydration profile for the center sections showed that the outer annulus sections contained more water than the inner annulus and that water content increased from the inner annulus to the nucleus pulposus sections. The lateral disc hydration

profile was less consistent between groups. Water content was relatively constant from anterior to posterior, although greater hydration was still noted in the outer annulus and inner nucleus, with a slight decrease near the inner annulus.

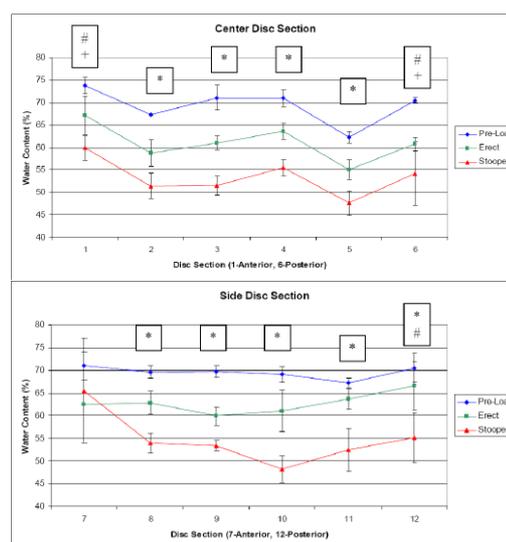


Fig 1. The water content (mass %) of disc sections 1-6 (center) and 7-12 (lateral) for all three loading conditions.

* stooped significantly different from erect and pre-load ($p < .05$)

stooped only significantly different from pre-load ($p < .05$)

+ erect was only significantly different from pre-load ($p < .05$)

4. Discussion

There existed an approximately 10% loss of hydration in each disc section with stooped posture (relative to erect posture). This is logical, as the discs were exposed to greater loading and therefore expelled a greater amount fluid. Additionally, this relationship was very consistent in most of the disc sections. The only exceptions to this were in the most anterior and posterior samples (sections 1, 2, 6, 7, and 12; Figure 1), which had averages that followed the trend but were not statistically significant due to large standard deviations within each group. This may have occurred for a number of reasons. Although consistency was maintained in post-processing (and no differences were observed), water content in outer sections could have varied due to insufficient drying following removal from the aqueous environment. The fibrous layers of the outer

annulus could have also retained environmental water, thereby influencing the data. Finally, the tissue in these sections was much less consistent; some samples exhibited a tight laminated structure while others were more sinuous. These compositional differences may have played a role in water content variation. Sample 7 was also found to be anomalous, experiencing an increase in water content above the erect samples. This may have resulted from the flexion angle experienced during testing, where simulated stooped postures focused the applied forces on the anterior disc. That this force resulted in radial expansion of the disc, which could have contributed to the increased volume of section 7 in the stooped condition, and, coupled with increased fluid retention observed in the outer annulus samples, could have contributed to the observed higher hydration.

In conclusion, the results of this study further our basic biomechanical understanding of the link between stooped work and LBDs, and provide further insights on ways to contain the effects of stooped work.

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