Effect of Varying Loads on the Spine: An Ergonomic Approach

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Abstract: **This paper attempts to compare the effects of load on the spine when subjected to varying load conditions. Change in total body height was used as an indirect measure of disc compression with the help of the apparatus called stadiometer. Fifteen male subjects were measured under different load situations classified as light, medium and heavy loads. During the three conditions, measurements of changes in height were taken in the morning before work and in the evening before resting. Comparisons were made using a repeated measures Analysis of Variance (ANOVA) with a significant level set at (0.05). The result showed that duration of dynamic activities has significant effect on the disc compression for the light and heavy load (P<0.05) with no significant difference between the medium load and the mean shrinkage. Results also showed greater compression in younger people compared with older and greater compression is experienced during longer durations of dynamic activities. Finally, examples were given on how the findings of this research can be used in ergonomic evaluation, design, and intervention in a workplace.**

Index Terms: **Ergonomics, Stadiometer, Load, Spinal Compression**

I. INTRODUCTION

The prevalence and cost of occupational back injuries continues to increase despite the efforts of researchers to attempt to find new preventive methods of interventions to reduce the rate of injuries. Loads places repetitive stress on the lower limbs and lower back. Compressive load is inevitable as the body is supported with the feet which impact with the ground. This impact is transmitted directly to the leg and spine, resulting in an increased axial loading. Load is directly applied to the spine, the shoulder and many studies have been conducted to investigate its effect on the body including trunk position and spinal muscles [1,10]. In their research found out that the amount of spinal compression was associated with load carrying duration both in posterior and anterior positions [3]. Spinal shrinkage is recognised as an index of the compressive forces acting on the spine. This shrinkage is caused by visco-elastic creep from compression of motion segments. When the discs are unweighted (such as during sleep) this process is reserved [6]. Various methods for measuring load on the inter-vertebral disc has been developed. Direct methods include disc pressure and intra-abdominal measurements [11]. Indirect method includes electromyography, biomechanical calculations [6]. A recent study also showed that spinal compression in two groups of nurses was significantly less during 20 minutes seated versus 20 minutes standing break after completion of simulated nursing tasks [12]. The results are in agreements with disc pressure measurement reported in literature and changes in spinal length were used to evaluate a new concept for an office chair. This so called dynamic chair impacts passive force motion to the seated subject. Stadiometer has been adopted for spinal compression measurement as it could precisely control the participant’s head and body alignment [8]. Spinal compression measurement methodology, varies not only in terms of degree of invasiveness and type of equipment but also in the postural requirements of the participants. Some studies have measured spinal compression with subjects seated while in other studies participants were required to stand [4,11,13]. Considerable efforts had been made by ergonomist and work system designers to develop a better understanding of the effects of load on the spine yet the prevalence and cost of occupational back injuries continues to increase. It is against this background that this research was conducted with the view to finding new preventive methods of intervention to reduce the incidence of back injuries by comparing three different conditions classified as (light, medium, and heavy loads).

II. MATERIALS AND METHODS

Fifteen male subjects aged between 20 and 35 years were measured under different loading conditions with the help of stadiometer. Each participant body stature (spinal shrinkage) was measured using a stadiometer with the aid of a Linear Variable Differential Transformer LVDT. All participant were healthy males with no reported musculoskeletal disorder or back pain in the last 12 months. The loading conditions were classified as Light, Medium and Heavy Load, as applied to the spine. Under light load, five students were measured early in the morning before going for lecturers and equally in the evening after day’s activities. For medium load five sedentary workers preferably, tailors were measured in the morning and evening after work. Then for heavy load five subjects loading and off-loading blocks in block industry were measured equally in the same way. In all the three classifications, the same specific tasks were performed and the duration of the period was taken. To allow for the normal shrinkage the starting time was the same on each of the measurement days.

III. DATA ANALYSIS

The shrinkage measured under load application at different time points were normalised with respect to the baseline reference obtained at no loading condition (i.e. time = 0) to determine the amount of spinal compression. The effect of loads at varying conditions (light, medium and heavy load) were compared using two-way repeated measures Analysis of Variance (ANOVA). All the statistical analyses were conducted using statistical software (SPSS v. 10) with level of significant set at 0.05.

IV. RESULTS

The effects of load at different load conditions on spinal compression were investigated. Spinal compression was observed for both light, medium and heavy loads.

Table 1. Light load: Human height shrinkage measurement conducted for five students for light load

S/No.	Age (yrs.)	Height in The Morning (Before Work)	Height In The Evening After Work (mm)	Spinal Shrinkage Difference in Height (mm)
1.	20	1531	1533.10	2.10
2.	25	1603	1604.90	1.90
3.	21	1654	1656.00	2.00
4.	30	1719	1720.90	1.90
5.	33	1586	1587.80	1.80
			Mean shrinkage = 1.94	

Table 2. Medium load: Measurement conducted for five tailors

S/No.	Age (yrs.)	Height in the Morning (before work)	Height in the Evening after work (mm)	Spinal shrinkage Difference in Height (mm)
1.	28	1701	1703.10	2.10
2.	30	1596	1597.70	1.70
3.	23	1672	1674.20	2.20
4.	27	1663	1665.10	2.10
5.	35	1585	1587.00	2.00
			Mean shrinkage = 2.02	

Table 3. Heavy load: Measurement conducted for five block packers in the block industry

S/No.	Age (yrs.)	Height in the Morning (before work)	Height in the Evening after work (mm)	Spinal shrinkage Difference in Height (mm)
1.	26	1649	1651.20	2.20
2.	24	1568	1570.30	2.30
3.	31	1714	1716.10	2.10
4.	29	1601	1603.20	2.20
5.	34	1547	1548.90	1.90
			Mean shrinkage = 2.14mm	

V. DISCUSSION

Table 1,2, and 3 gives the magnitude of spinal shrinkage during three sets of conditions classified as light, medium and heavy loads. Mean scores collected were compared using repeated measures Analysis of Variance (ANOVA). Comparison of results were made between three sets of repeated measurements carried out in the morning and evening before resting. A small but consistent pattern of variation was found between the three sets of repeated measures for both the morning and evening sessions. The highest mean value was found in the last measurement (2.14mm). For heavy load see Table 3. The spinal comparison under light load were found to be consistently lower than the medium load. The results showed that duration of dynamic activities has significant effect on the shrinkage for the light and heavy, ($P<0.05$). Although loss of stature for medium load conditions were not significantly greater for medium load. It is assumed that the sedentary nature of the job which requires the upper body to maintain balance, may have contributed to the greater amount of shrinkage in the condition and the needs to be investigated further, possibly by measuring muscle forces acting on the spine. Dolan and Adams, (1995) reported that compressive loading due to body weight is about 380N (55% of body weight) when standing still. As total compressive forces acting on the lumber discs during standing and about 500N. The remainder must come from stabilization of the upper body by the action of the back and abdominal muscles. The loss of stature (spinal shrinkage) that occurs during heavy load condition may be attributed to muscles tension in maintaining an upright posture during block packing. In this study, mean values of successive measurements (mean spinal shrinkage) taken both during the morning and afternoon increased from measure one to measure three. During variation (as measured by difference in scores) also decreased across subsequent measures. It is likely that most if not all of these differences are due to simple regression to the mean. Some of the change, may be due to either measurement error as is inherent in all measurement processes, or small changes in spinal length occurring between measures. While it is impossible to identify the principal cause of these changes, I believe using the mean score across the three measures provided the most stable estimate of the true value. It is important however to remember that comparisons between measures taken at the same time in a day were also found to be consistent.

VI. CONCLUSION

In this paper, a reliable fact was established which captured the effect of load on the spine in a varied sample of subjects under varying load conditions. The rate of shrinkage increased progressively showing it is a function of the load on the spine, which supports other results in the literature. Thus, according to Reilly *et al.*, (1984), when the compressive load exceeds osmotic pressure of the fiscal tissues, fluid is expelled from the inter-vertebral discs. The resultant loss in disc height is reflected in a loss of stature, which has been referred to as spinal shrinkage. However, it is not conclusive whether spinal shrinkage values were totally dependent on the nature of the load or were influenced in part by the absolute VO_2 level. Further research is needed to determine whether metabolic responses per se affect the load on the spine.

Finally, the association between back pain, heavy workload, and spinal compression has been well established in literature. The changes in total height as an indirect measure of disc compression under varying daily activities can be a useful predictor of back pain when the spine is loaded. This finding has implications for ergonomic designs and evaluation in the workplace.

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