Effect of Varying Loads on the Spine: An Ergonomic Approach

D.O. Isiohia
Department of Mechanical Engineering, Imo State University, Owerri, Nigeria

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 lectures 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

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

Table 2. Medium load: Measurement conducted for five tailors

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

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

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

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 lumbar 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\textsubscript{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.

REFERENCES


