Body mass as a factor in stature change

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Abstract

Background. Back pain is a common condition which has been described as a serious public health problem. Spinal shrinkage has been used as an index of spinal loading in a range of tasks. Epidemiological evidence shows that body mass index (BMI: 30 kg/m 2) is related to the development of low back pain however, no studies have described the stature change patterns of obese individuals. This study aimed to compare changes in stature after an exercise task in obese and non-obese individuals.

Methods. Twenty volunteers were divided into two equal groups; obese: BMI > 30 kg/m 2, non-obese: BMI < 25 kg/m 2. Stature was measured at 3 min intervals during a 30 min walking task and a 30 min standing recovery period. Tests were performed on two occasions, once with participants loaded during the walking task (10% body mass) and once unloaded. The influence of obesity and load condition on the magnitude and rate of stature change were compared by a two-way ANOVA.

Findings. In both groups the stature loss was greater in the loaded than unloaded condition (mean (SD)) (6.52 (1.45) mm and 3.55 (0.93) mm non-obese; 8.49 (1.75) mm and 7.02 (1.32) mm obese: P = 0.016). The obese presented a greater reduction in stature in both task conditions. The obese group were unable to recover stature regardless of the task condition during the recovery period (loaded: 0.06 (0.3) mm; unloaded: 0.32 (0.6) mm; P = 0.013).

Interpretation. It was concluded that the acute response of the spine to loading may represent a risk factor for low back pain in the obese, in addition to the chronic adaptations previously reported. A greater period of recovery may be necessary for obese individuals to re-establish intervertebral disc height. These findings may help to explain the high incidence of back disorders in obese individuals.

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Keywords: Obesity; Spinal shrinkage; Intervertebral disc; Back pain

1. Introduction

Back pain is a common condition which has been described as a serious public health problem in many industrialised countries (Panjani, 2003). Low back pain causes severe disruption for the sufferer’s quality of life by limiting his/her professional, quotidian and laboural tasks (Takeyachi et al., 2003), and for industry due to the costs involved in replacing and qualifying staff (Webster and Snook, 1994). It is also a concern for National Health Services because of the costs involved in treating and medicating low back pain and premature retirement (Deyo et al., 1991). Despite this, the mechanisms of low back pain remain unclear (Norcross et al., 2003), although mechanical stress has been pointed out as one of the main causes (Adams et al., 2000).

Loading the spinal column causes the intervertebral discs to lose height by the radial bulging of the annulus fibrosus and by expelling fluid from the nucleus pulposus and annulus fibrosus (Adams and Hutton, 1983; Adams and Dolan, 1995). These two mechanisms result...
in the decrease of the discs’ height and in a shortening of the spinal column (also called spinal shrinkage). Spinal shrinkage can be quantified by measuring variations in the whole body length and has been used as an index of spinal loading in a range of tasks (McGill et al., 1996). Reducing the intervertebral disc height decreases its ability to absorb/transmit forces and causes increased or abnormal loading on other structures of the spine e.g. facet joints, spinal ligaments etc. (Dunlop et al., 1984; Pollintine et al., 2004). Therefore, continuous spinal loading such as that sustained during certain occupational tasks (e.g., postal carriers, workers) may be a contributory factor to the development of low back pain (Rodacki et al., 2003; Kostova and Koleva, 2001).

Another continuous loading condition is that experienced by obese individuals. Obesity, described by a significant gain in corporal fat mass, may constitute a risk factor for the development of low back pain (Kostova and Koleva, 2001; Kaila-Kangas et al., 2003) due to the “chronic” loading of the spinal column. Although some studies (Webb et al., 2003) have provided some epidemiological evidence that body mass index (BMI: 30 kg/m²) is closely related to the development of low back pain, no studies have been performed to describe the mechanical behaviour of the intervertebral discs of obese individuals.

In a study performed with pregnant women (which represents a similar mechanism of chronic loading through increased body mass) (Rodacki et al., 2003) the relationship between low back pain and stature loss and recovery was analysed. It was reported that low back pain was more closely related to the inability of the intervertebral discs to regain height rather than to the magnitude of the height loss. It is not known if the continuous loading of spine affects the ability of the obese individuals to loose and recover their stature.

This study aimed to compare changes in stature (loss and regain) during and after a simple exercise task (walking with and without a standard deviation (SD) of less than 0.5 mm for 10 consecutive measurements was obtained (Rodacki et al., 2001)). The second and third visits were designed to assess stature changes during and after the physical activity task.

At the beginning of each session participants were asked to lie in a supine position with their hip and knees flexed and ankles supported on a comfortable surface (Fowler’s position) for 30 min to allow for a period of controlled spinal unloading. This posture aimed to eliminate the effects of physical actives that may have occurred prior to arrival in the laboratory (Fowler et al., 1997). After the resting period, participants remained in a standing position for 1.5 min to minimise the effect of soft tissue creep deformation of the lower limbs (Foreman and Linge, 1989). Following this the first measurement on the stadiometer was conducted and used as a baseline (PRE). The complete description of the procedures in the stadiometer is provided by Rodacki et al. (2001).

After determining the baseline measurement participants performed the simulated daily physical task. This consisted of walking with and without a 10% body weight hand-load (5% each hand) at a self-selected pace for 30 min. The task was performed on an indoor course.

Table 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Body mass (kg)</th>
<th>Stature (cm)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBG</td>
<td>23.0 (3.7)</td>
<td>113.62 (12.52)</td>
<td>177.6 (5.9)</td>
<td>36.56 (4.69)</td>
</tr>
<tr>
<td>(n = 10)</td>
<td>[102.00–140.31]</td>
<td>[165.1–187.0]</td>
<td>[30.79–41.14]</td>
<td></td>
</tr>
<tr>
<td>NOG</td>
<td>22.4 (3.9)</td>
<td>72.13 (8.21)</td>
<td>176.8 (5.8)</td>
<td>23.1 (1.1)</td>
</tr>
<tr>
<td>(n = 10)</td>
<td>[55.00–83.10]</td>
<td>[167.2–187.3]</td>
<td>[18.81–24.78]</td>
<td></td>
</tr>
</tbody>
</table>

Note: values are mean ± standard deviation (SD in parentheses); values between square brackets are the minimum and maximum values, respectively.

2.2. Experimental procedures

Each participant attended the laboratory on three separate occasions. All sessions were performed in the morning (8:00–11:00 AM) to reduce the effects of circadian variation (Reilly et al., 1984). On the first visit, participants were familiarised and trained with procedures in the stadiometer (Fig. 1) to obtain repeatable measurements of changes in stature. They were deemed trained when a standard deviation (SD) of less than 0.5 mm for 10 consecutives measurements was obtained (Rodacki et al., 2001). The second and third visits were designed to assess stature changes during and after the physical activity task.

2. Methods

2.1. Participants

Twenty healthy males volunteered to participate in this study. Participants were recruited according to their body mass index (BMI) to produce two groups. The first group was formed by individuals with BMI greater than 30 kg/m² to represent the obese group (OBG: n = 10), while the second group was formed by those with BMI smaller than 25 kg/m² (18.5–25 kg/m²) to represent a non-obese group (NOG: n = 10) (Table 1). Volunteers were screened and those with current back pain or injury, a history of back pain or injury within the past 12 months, smokers, diabetes or any circulatory disease were excluded from the study. Before participating in the study written informed consent was obtained.
of 12.5 m. Velocity of the task was monitored, but no interference was made on the volitional pace of the participants. The order of the loaded and unloaded trials was randomised.

Stature variations were assessed during the task at intervals of 3 min to provide a set of 10 repeated measures (LOS3, LOS6, LOS9, LOS12, LOS15, LOS18, LOS21, LOS24, LOS27 and LOS30). After the task, participants remained in a standing position for 30 min to allow stature recovery. Again, a series of 10 measurements were taken to describe the rate of stature recovery (REC3, REC6, REC9, REC12, REC15, REC18, REC21, REC24, REC27 and REC30).

2.3. Statistical approach

Normalisation of changes in stature (loss and gain) with respect to stature was not performed due to body height similarities between groups \((P > 0.05)\). Initially, all data were described using standard descriptive statistics. The Kolmogorov–Smirnov test was applied and confirmed data normality. Absolute stature loss was determined by subtracting the loss found at the end of the task (LOS30) from the baseline height at the start of the task (PRE), while absolute stature gain was determined by subtracting the height after the task (LOS30) from the stature after 30 min of standing recovery (REC30). A student \(t\)-test was applied to analyse the absolute loss (LOS30–PRE) and recovery (REC30–LOS30) between groups. To analyse the rate of stature variation during the task and recovery, a strategy described by Dezan et al. (2003) was applied. This strategy consists of a piecewise-breakpoint statistical analysis in which a breakpoint (a deflection point) is estimated using the minimum square method. The estimation of this breakpoint allows the determination of a deflection point, from which the curve is divided into two straight lines: one anterior or equal and other posterior to the breakpoint. The coefficient of each segment represents the rate of stature variation. The first segment (anterior or equal to the breakpoint) is likely to be related to the elastic deformation that takes place in the annulus fibrosus of the intervertebral disc, while the second segment (posterior to the breakpoint) is likely to be related to the viscous response that occurs predominantly in the nucleus pulposus by fluid loss. The influence of obesity on the mechanical behaviour of the intervertebral disc during the loss and recovery periods were compared by a two-way ANOVA for repeated measures, in which segment coefficients were used as independent variables. A Scheffe test was used to determine where such differences occurred. All tests were analysed with a significance level of \(P < 0.05\) using the Statistica Software package, version 5.5.

3. Results

The mean (SD) walking speed of the non-obese group (NOG) was 1.08 (0.06) m/s (unloaded) and 1.09 (0.09)
m/s (loaded). The obese group (OBG) presented a walking speed of 1.05 (0.15) m/s (unloaded) and 1.01 (0.1) m/s (loaded). These results showed no significant differences between groups and experimental conditions.

3.1. Stature changes after physical activity

The NOG showed a stature loss of 6.52 (1.45) mm and 3.55 (0.93) mm after a 30-min walking with and without load, respectively. The OBG presented a stature loss of 7.02 (1.32) mm without load and 8.49 (1.75) mm in the loaded condition. In both groups the stature loss in the loaded condition was greater than that observed in the unloaded condition ($P = 0.016$). It was observed that the OBG presented a greater reduction in stature in both task conditions when compared to NOG (Fig. 2). On average, the OBG showed a stature loss of 30.2% and 97.7% greater than NOG in both conditions (with and without load), respectively.

The correlation analysis between BMI and stature loss in the unloaded task demonstrated a correlation coefficient $r = 0.78$ ($P < 0.05$). These results are presented in Fig. 3.

Regardless of the task condition (loaded or unloaded), stature loss presented a negative exponential behaviour (Fig. 2). The statistical procedure used in this study fractionated the curve of the stature loss into two components (TX1 and TX2) (Table 2). Significant differences were found between the OBG and NOG for TX1 when performing the task in the unloaded condition ($P < 0.05$). In the unloaded condition, OBG presented a higher rate of stature loss in comparison to NOG.

3.2. Stature recovery

After performing the task the NOG were able to recover stature ($P = 0.010$) in both experimental conditions (loaded = 3.69 (1.02) mm; unloaded = 2.70 (0.80) mm). On the other hand, OBG was unable to recover stature regardless of the task condition (loaded: 0.06 (0.3) mm; unloaded: 0.32 (0.6) mm; $P = 0.013$) (Fig. 4).

![Fig. 2. Mean stature loss of obese (OBG) and non-obese (NOG) in loaded and unloaded conditions. The thin lines represent the standard deviations.](image)

![Fig. 3. Relationship between stature loss (top) and recovery (bottom) of obese (OBG) and non-obese (NOG) groups and BMI in the unloaded condition.](image)

![Fig. 4. Stature recovery of obese (OBG) and non-obese (NOG) participants.](image)

### Table 2

| Stature loss rate coefficients for obese (OBG) and non-obese (NOG) participants |
|-------------------------------|-------------------------------|-------------------------------|-------------------------------|
| Stature loss rate coefficients | Loaded  | | Unloaded  | |
| Fast component (≤ breakpoint—TX1) | NOG: −1.80 (0.54) | OBG: −2.62 (0.7) | NOG: −1.08 (0.75) | OBG: −2.10 (0.46)* |
| Slow component (> breakpoint—TX2) | NOG: −0.19 (0.16) | OBG: −0.22 (0.24) | NOG: −0.12 (0.1) | OBG: −0.16 (0.12) |

SDs are in parentheses.

* OBG TX1 ≠ NOG TX1 ($P < 0.01$).
Significant differences were found in absolute recovery between groups, where NOG presented a greater recovery than OBG ($P = 0.0012$). Such differences are shown in Fig. 5, which demonstrated a correlation between BMI and absolute recovery of stature ($P < 0.05$) after the loaded ($r = -0.86$) and unloaded conditions ($r = -0.78$), respectively.

4. Discussion

This study was conducted to compare stature changes in obese and non-obese individuals during the performance of a walking task. As the task was performed at the same speed in both groups and conditions, differences in the spinal response were assumed to be unrelated to task variations, but to be due to the characteristics of the groups.

4.1. Absolute stature reduction

The task chosen resulted in a reduction in the stature of all participants, with a greater stature loss in the loaded condition, indicating that a greater stress was applied. It is interesting to observe that the stature reduction experienced by the non-obese individuals in the loaded condition was similar to that experienced by the obese group in the unloaded condition. This further supports the notion that the difference in stature loss was associated with the total mass being transported. It is suggestive that obese participants sustain a “chronic” loading condition and are more prone to the negative effects of this loading than their non-obese counterparts. The effects of continuous loading of the intervertebral discs have been described as a cause for the overloading of other spinal structures, which may lead to back disorders e.g., nerve root impingement (Adams and Dolan, 1995), increased vertebral arch stress (Pollintine et al., 2004), stenosis of the intervertebral foramen (Hayshi et al., 1987) and reduced disc nutrition (Adams and Dolan, 1995). This acute loading response may be considered as additive to the chronic effects previously described in the literature as contributing to the high prevalence of low back disorders among obese individuals (Deyo and Bass, 1989; Webb et al., 2003).

4.2. Stature loss rate

The present study confirmed a negative exponential behaviour of the intervertebral disc height loss (Dezan et al., 2003), in which a rapid loss rate at the beginning of the load application (Koeller et al., 1986) is followed by a slow loss rate that occurs after the first third of the task. The first component of the curve (TX$_1$) is likely to be related to the elastic deformation of the annulus fibrosus. It has been suggested that a decrease in disc height produces overstress upon other spinal structures (e.g., facet joints, vertebral body) (Adams and Dolan, 1995). After the rapid elastic deformation imposed at the beginning of the task, fluid is expelled in a gradual and slow way through the walls of the annulus fibrosus. This phenomenon has been demonstrated in vitro and is commonly referred to as creep deformation. This second component of the curve (TX$_2$) is likely to be related to the slow fluid content expulsion.

An alternative approach to interpreting the data would be to use the approach advocated by Althoff et al. (1992) in which the exponential function to represent the rate of stature loss in normal standing and walking is used to predict the change that would have occurred had no additional load been applied. This in effect is represented by the unloaded task in this study. Interestingly had the Althoff approach been used in this study it would suggest that the additional stature loss due to the loaded condition was less in the obese than in the non-obese group. Clearly such an approach is unsuitable for an investigation where the basic response characteristics of the two groups differ. Although the
method is a useful means to compare the effects of different types of intervention.

Two arguments may explain the greater stature loss rate (fast component) found at the beginning of the task during the unloaded condition in the obese group. The first argument is related to the magnitude of the compounded load (external load and body weight) applied on to the spine (Althoff et al., 1992). The second argument is related to the probable existence of a certain degree of disc degeneration in these participants which could have been caused by the chronic loading condition experienced by the obese group. The ability of the intervertebral disc to dissipate mechanical loading is closely related to the integrity of the disc components. The disruption of the annulus fibrosus has been shown to cause faster rates of intervertebral disc height loss in degenerated discs (Van Dieen et al., 1994). On the other hand, Koeller et al. (1986) have reported that, after a short period of loading, degenerated discs show greater and faster creep deformation than normal discs. However, the age matching of the two groups and the exclusion of any history of back disorders in the inclusion criteria for participants are arguments against the idea that any important disc degeneration level was present.

4.3. Stature recovery

In the present study the non-obese individuals were able to regain approximately 76% of their initial stature during the standing recovery in contrast to the obese group who did not recover from loading. Interestingly, some of the obese individuals continued to loose stature during the standing recovery period (−0.7% loaded; −4.55% unloaded). These further height reductions may be related to the effect of their body mass excess or elevated muscle activity associated with the more anterior displacement of the body mass.

Rodacki et al. (2003) showed comparable effects in pregnant women who performed a task similar to the present study. It was demonstrated that the body mass gain is an important factor that influenced their reduced ability to regain stature. It was also demonstrated that low back pain was related to their inability to regain stature rather than to the magnitude of the spinal shrinkage. In a similar study, Fowler et al. (2005) reinforced a strong association between low back pain and the inability to regain stature.

The findings of the present study demonstrate that the magnitude of the stature variation depends on the magnitude of the load, which is closely influenced by the participant’s body mass. Therefore, future studies using small stature variations must take into account not only the influence of body stature, but also the effect of the body mass when comparisons between participants are to be performed.

5. Conclusion

The findings of the present study provided a better insight into responses of the spinal column to loading and unloading conditions in obese individuals. It is concluded that the acute response of the spine to loading may represent a risk factor for low back pain in the obese in addition to the chronic adaptations previously reported. A greater period of recovery (unloading) may be necessary for obese individuals to re-establish the intervertebral disc height after loading. These findings may help to explain the high incidence of back disorders in obese individuals and to provide further evidence of the adverse problems caused by obesity.

References


