CÓDIGO:04

MODULATION OF SHOCK WAVE TRANSMISSION DURING LOCOMOTION

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RESUMEN

Walking is a common form of physical activity that provides plenty of benefits for individual's health status. Also, lifting and carrying loads are daily tasks that may imply a certain level of injury risk for our body. As a consequence, using a backpack has become a well established manner of carrying load weight. Nevertheless, the shock wave produced by the impact forces when carrying a backpack can have detrimental effects on health status. Therefore, the aim of this study was to analyse the shock impact at the shank and head on males and females whilst carrying different loads when walking. Twenty nine sports science students (16 males and 13 females) participated in the study under 3 different conditions: no weight, 10% and 20% body weight (BW) added in a backpack. Results of measurements at the head for males and females were consistent throughout each backpack condition ($p>0.05$). Males showed a significant increase in shank accelerations at 20% BW compared to no weight ($p<0.05$). No other significant differences were found in shank accelerations. In conclusion, the body acts as a natural shock absorber, reducing the amount of force that transmits through the body between the foot (impact point) and head.

COMUNICACIÓN VIRTUAL

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Introduction

There is an increasing concern regarding the problems originated in the back related to physical exercise activities, from children carrying excessive load backpacks to school to adults dealing with too heavy working loads. Many researchers are carrying out studies to identify the potential harm that overweighting load activities can produce on the human body (Holt et al., 2005; Lafortune et al., 1996; Taaffe et al., 1997; Voloshin, 2000).

Not only labour tasks (i.e. construction or military manoeuvres) may lead to injury and body pain (Birrel et al., 2007), but also recreational and leisure activities such as hiking (Forjuoh et al., 2004; Voloshin, 2000) or students walking to school carrying heavy backpacks full of books, after-school activities supplies (music and sports equipment) and personal objects (Bauer & Freivalds, 2009; Chiang et al., 2006; Lockhart et al., 2004). Research looking into body pain as a consequence of carrying loads underlies factors such as the amount of load, time spent carrying and repeated loading, position and way of carrying the load, design of the backpack, physical condition as well as physiological characteristics such as age and gender of the individual (Chansirinukor et al., 2001; Grimmer & Williams, 2000; Keller et al., 1996; Knapik et al., 1996; Lockhart et al., 2004; Voloshin, 2000). Taking into account that a person may take over 6000 steps per day on average, making a cumulative of 2.5 million steps per year (Voloshin, 2000), it becomes highly recommended to control the conditions under which the load is carried and its subsequent consequences for the human body.

It is very well documented that a bone decreases in thickness and density as a direct response to a reduction in loading (Voloshin, 2000). However, impact produced during a long period of time (such as a marathon race) or under uncontrolled parameters (impairment of the musculoskeletal system, overweight backpack carriage) is considered an important factor in the development of spinal injuries and degenerative changes in joint and articular cartilage (Lafortune et al., 1996). Excess dynamic loading on the human musculoskeletal system may lead to the development of a variety of musculoskeletal disorders such as osteoarthritis or bone stress fractures, turning into muscular aches, back strain, bad posture and low back pain (Voloshin, 2000).

Methods

Participants

Twenty nine sports science students (16 males and 13 females) took part in the experiment (age: 24.66 ± 3.67 years; mass: 68.9 ± 10.27kg; height: 1.76 ± 6.81m). The University of Valencia ethics subcommittee approved the study and informed consent and a health history questionnaire was provided by participants.

Experimental Design

The participants warmed up "at libidum" and familiarized with the treadmill for ten minutes in order to become accustomed to walking on the treadmill at the given speed and to make sure they did not have any discomfort. Each participant was required to walk at 1.3m/s (4.68 Km/h) on a Technogym treadmill (Excite Run 700, TechnogymSpA, Gambettola, Italy).

Participants were required to carry a backpack during each of the conditions in which the weight was added. In order for the results to be normalised and compared between individuals, participants wore the same brand and type of Shoe. Two uniaxial accelerators (Signal Frame, SportMetrics, Valencia, Spain) were attached in the centre of the forehead and the tibia of the right shank. The accelerometers recorded samples at the rate of 100Hz and had a maximum range of ± 10G. Three levels of backpack load were tested: 0% BW, 10% BW and 20% BW. Weights were added into a backpack placed on the participants back (Crestone 60, The North Face, Lugano, Italy) and a grace period of 5 minutes was provided in order to get comfortable at the different weight conditions. So as to negate learning effects, variable test conditions (back pack mass) were conducted with randomised controlled trials. All the way through the experiment participants were given verbal encouragement and were monitored closely throughout the trials.

Data Analysis

All data was recorded using Signal Frame ©Software. Three steps were selected randomly from the total steps taken, disregarding the first 5 seconds of data as the participant was developing their gait to their normal walk after stepping on a moving treadmill.

For statistical analysis, data was exported into SPSS v.19 (SPSS Inc., Chicago, Illinois). A One way ANOVA was used to analyse the effect of back pack weight on shank and head accelerations, where males and females head and shank results were analysed independently. Post hoc tests (Bonferroni), with alpha level set at $p<0.05$, were used to provide detail as to the whereabouts of significant differences.

Results

Results were normalised to body weight. Accelerations were analysed both at the shank and head when carrying different backpack loads (Figure 1 and 2). Male accelerations in the shank were measured at 3.52 ± 0.58 G/BW, increasing to 3.69 ± 0.65 G/BW and reaching a maximum of 3.78 ± 0.76 G/BW for the 0W, 10%BW and 20%BW respectively (Figure 1). Although this increase was noted, the only significant difference measured was between the 0W and the 20%BW conditions (p=0.043). At the head a similar increase was seen between the 3 conditions, with a minor increase across the different backpack weights, increasing from 1.88 ± 0.28 G/BW in the 0W condition, to 1.91 ± 0.30 G/BW in the 10%BW condition and 1.93 ± 0.28 G/BW in the 20%BW condition. No significant differences were found between the accelerations in the 3 conditions measured at the head (p>0.05).

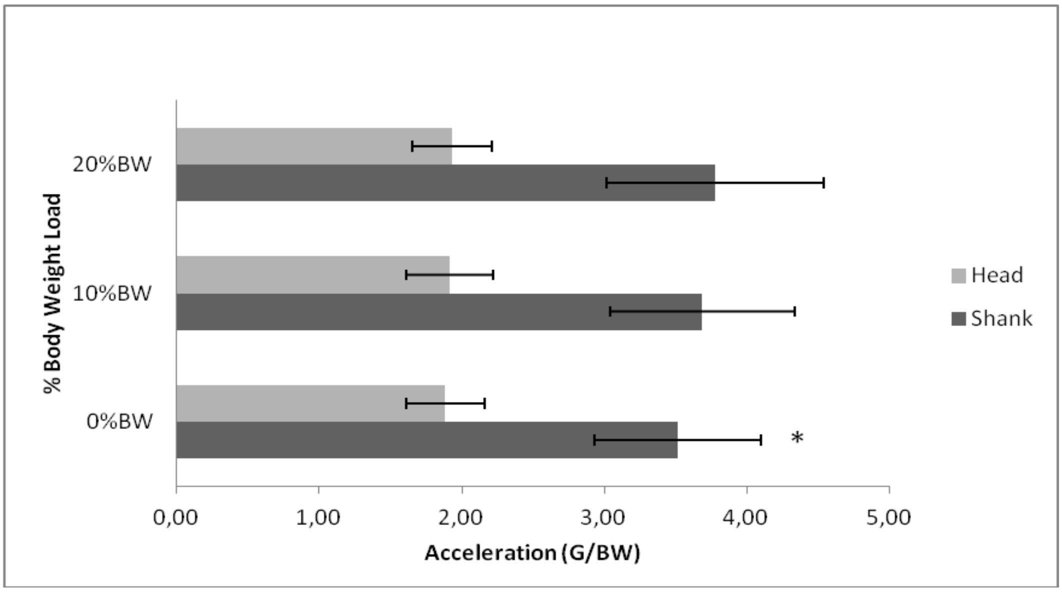

Figure 1: Male results for different backpack conditions. (*) $p<0.05$.

Although females were shown to have greater accelerations when compared to males, when analysing the changes in different backpack weights, the females showed a consistent pattern across the conditions. In the 0W condition accelerations at the shank were measured at 5.14 ± 1.45 G/BW, decreasing to 4.94 ± 1.23 G/BW in the 10%BW trial, but increased to 5.53 ± 1.77 G/BW in the 20%BW trial (Figure 2). At the head the accelerations were measured at 2.80 ± 0.68 G/BW (0W), 2.74 ± 0.62 G/BW (10%BW) and 2.76 ± 0.61 G/BW (20%BW), the accelerations at the head being highest in the 0W trial, although were fairly consistent across the 3 trials. No significant differences were found either at the head or the shank between the 3 trials ($p>0.05$). The results of the females show the higher accelerations at the head and shank compared to males, but also shows that the spread of data is less consistent than their male counterparts.

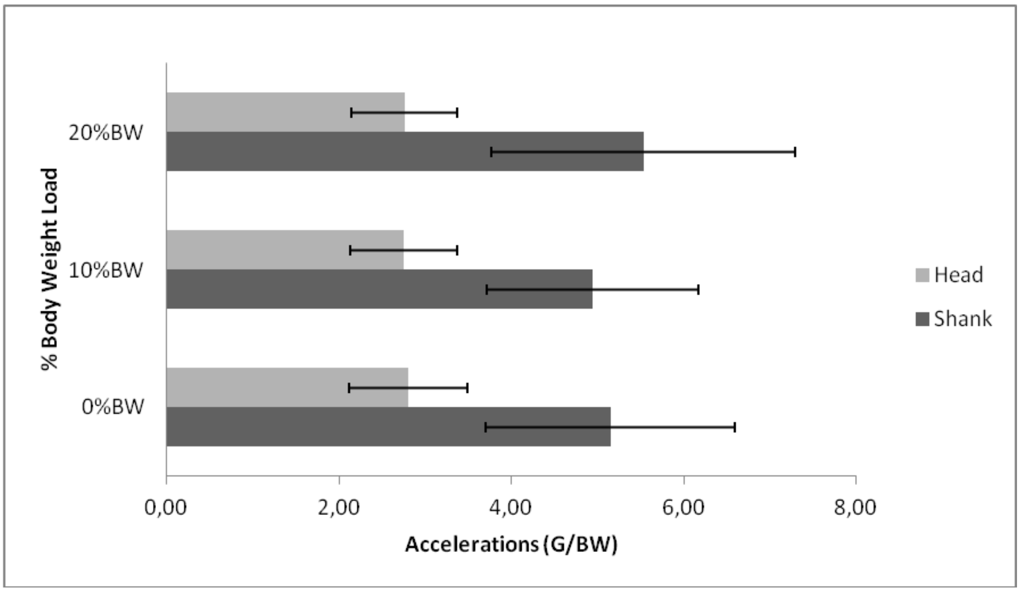

Figure 2: Female results for different backpack weights.

Discussion

The main aim of the study was to investigate the effects of different loads placed on the human body whilst walking, analysing the differences in the accelerations at the head and shank in both male and female individuals.

In this study we found that accelerations ranged between 3-7 G's in the shank and 2-3 G's at the head taking into account every condition tested. These findings are in agreement with other studies, where peak accelerations were found to be between 1-5 G's at the tibial tuberosity (Voloshin, 2000), 1,5-5m·s^{-2} at the knee and 1-3,5m·s^{-2} the head (Holt et al, 2005).

However, the results found by Holt et al. (2005) showed a decrease in the measured accelerations at the shank to 1,5-3,5m·s^{-2} when load was added, being these results in contrast to the present findings. Despite a small decrease in the accelerations measured in the female subjects when a 10% weight was added, all other conditions for males and females showed minor increases in the recorded accelerations. A possible explanation for these differences is that Holt et al. (2005) constructed a rigid frame where weights were attached at shoulder height, in comparison to this study where weights were added to a backpack placed on the subjects back, hence weights were in line to the lumbar area of the spine compared to the shoulder. Also, there is evidence that the forces are absorbed and dissipated through the body, being greatest at the ankle and lowest at the head, supporting the findings of this study (Mulavara & Bloomberg, 2003, Voloshin, 2000). This result supports the idea of other researchers who proposed high vibration at the skull is not advantageous as it leads to a greater risk of injury, such as low back pain, sciatic pain and degenerative changes in bones (Kiiski et al., 2008).

Relatively few studies have quantified the impacts on the human body. Those which have looked into forces and accelerations placed on the body typically used single sex designs (Birrell et al., 2007; Goh et al., 1998; LaFortune et al., 2002; Ren et al., 2005). Only a minor number of studies have used mixed-sex designs, analysing males and females in the same study (Henriksen et al., 2008; Holt et al., 2005; Keller et al., 1996; LaFiandra et al., 2002). These few studies combined results from the males and females, rather than analysing genders separately, therefore this study is one of the first which has analysed differences between males and females.

There may be many reasons why differences occurred in this study between the male and female participants. Physical variables between males and females need to be taken into account. Females mean height was 169cm compared to a mean height of 178cm in males. Therefore the backpack positioning would have been in different positions and thus the impact loading at different joints would have been different (Henriksen et al., 2008). As a consequence, the measurements recorded at the shank could vary due to the gait patterns associated with loading area and location. Continuing on the same theme of genetic makeup, males had a mean mass of 73 kg compared to females mean mass of 57 kg. As the human body acts as a natural shock absorber (bones and tissues), the greater bone/muscle masses and lengths could have influenced the transmission recorded as there is more body tissue to absorb forces before they reach the head.

Some official associations recommend a maximum of 15% body weight load when carrying a backpack for health reasons (American Chiropractic Association, American Occupational Therapy Association, American Academy of Orthopaedic Surgeons; Furjuoh et al., 2004; Hong & Li, 2005; Lindstrom-Hazel, 2009). Although only one significant difference was found in the males between 0% BW and 20% BW, there was an increase in the accelerations recorded on the body for the rest of the conditions both in males and females, suggesting that individuals maybe either approaching a recommended load for carriage and any greater loads may cause injury due to the forces placed on the body as well as kinematic changes in walking in order to accommodate such heavy loads (Goh et al., 1998; Harman et al., 2000; Holt et al., 2005).

Conclusion

The main outcome of this study shows that there may be significant differences in accelerations measured in males and females when walking on a treadmill, both shank and head accelerations were greater in the females participants compared to their male counterparts. To coincide with these findings the results also showed that accelerations at the shank increased when load was added, although no increases were seen at the head, suggesting the body attempts to absorb forces placed on the body, most likely as a protective mechanism for motor and sensory centres in the head. According to our findings, it is not clear whether 20% and 10% of body weight load implies a significant load compared to 0%BW. Therefore, further research involving more subjects and taking into account different velocities and loads is needed to provide a greater understanding to these findings.

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