



Effect of load mass on posture, heart rate and subjective responses of recreational female hikers to prolonged load carriage

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ABSTRACT

Load carriage has been associated with a risk of upper and lower limb musculoskeletal disorders with women suffering significantly higher injury rates than their male counterparts. Despite this injury risk, there are limited evidence-based guidelines for recreational hikers, particularly female recreational hikers, regarding safe backpack loads. The purpose of the present study was to determine how variations in load mass affected the heart rate, posture and subjective responses of women during prolonged walking to provide evidence for a load mass limit for female recreational hikers. Heart rate (HR), posture and ratings of perceived exertion (RPE) and discomfort were collected for 15 female experienced recreational hikers (22.3 ± 3.9 years) while they hiked for 8 km at a self-selected pace under four different load conditions (0%, 20%, 30% and 40% of body weight (BW)). Although HR was not significantly affected by load mass or walking distance, increasing load mass and distance significantly affected posture, RPE and discomfort of the upper body. Carrying a 20% BW load induced significant changes in trunk posture, RPE and reported shoulder discomfort compared to the unloaded condition. The 20% BW load also resulted in a mean RPE rating of 'fairly light', which increased to 'hard' when carrying a 40% BW load. As load carriage distance increased participants reported significantly increased shoulder, neck and upper back discomfort. Based on the changes to posture, self-reported exertion and discomfort when carrying loads of 20%, 30% and 40% BW over 8 km, it was concluded that a backpack load limit of 30% BW should be recommended for female recreational hikers during prolonged walking.

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1. Introduction

Hiking is an increasingly popular outdoor recreational pursuit (Gretchen, 2004) with large participant numbers who vary widely in terms of age, gender and hiking experience (Lobb, 2004). Hikes can range from simple day hikes to multi-day expeditions and the loads carried by recreational hikers vary with factors such as terrain, hike duration and the season of travel. Although recreational hiking has been associated with positive health benefits (Ainslie et al., 2005), these benefits can be negated by the occurrence of injury or discomfort (Blake and Ferguson, 1993). Load carriage has been associated with an increased risk of musculoskeletal disorders in both the upper and lower limbs in recreational and working populations (Twombly and Schussman, 1995; Miranda et al., 2001; Bentley et al., 2004) relative to walking without

carrying a load. Furthermore, research has found that women suffer significantly higher injury rates than males participating in the same hiking activities in outdoor education (Twombly and Schussman, 1995; Leemon and Schimelpfenig, 2003). Despite this injury risk, there are limited evidence-based guidelines, particularly for female recreational hikers, regarding safe backpack loads.

Determining safe and efficient methods of carrying load have been the subject of investigation for many years (Haisman, 1988; Knapik et al., 2004), with researchers examining the physiological (Patton et al., 1991; Sagiv et al., 1994; Beekley et al., 2007), postural (Kinoshita, 1985; Attwells et al., 2006), gait (Harman et al., 2000) and subjective responses (Legg et al., 2003; Birrell and Haslam, 2009) to load carriage. Postural measures have been used to examine responses to load carriage (Harman et al., 2000; Attwells et al., 2006) based on the rationale that postures which deviate from normal alignment may be associated with increased energy cost of walking, as well as back, shoulder and neck pain and discomfort (Grimmer and Williams, 2000). The results of these studies have consistently observed increased forward flexion of the trunk (Kinoshita, 1985; Goh et al., 1998) with loads as low as 15% of body weight (BW) in adults (Devroey et al., 2007). Although it is

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assumed that this forward trunk flexion results from a need to move the mass of the backpack closer to the body's centre of gravity to ensure walking stability (Attwells et al., 2006), this posture may lead to increased loading and consequent discomfort in the shoulder and back regions (Goh et al., 1998). Increased trunk flexion may also contribute to back pain by stressing ligaments and/or muscles in the back or by increasing the lumbosacral forces on the spine (Goh et al., 1998; Vacheron et al., 1999). Trunk flexion as low as 5° has been suggested as being a significant indicator of spinal stress (Watson and Trott, 1993). Therefore, determining postural changes as load increases may assist in determining recommendations for safe load carriage mass.

Subjective measures, such as ratings of perceived exertion (RPE) and measurement of pain and discomfort, maybe also be helpful in developing backpack load mass guidelines (Birrell and Hooper, 2007; Fergenbaum, 2007). Previous studies have reported that RPE is significantly higher as load mass increases (Gordon et al., 1983; Goslin and Rorke, 1986), although the perceived level of exertion varies between subject populations, with civilians rating loads as being more difficult to carry than military subjects. For example, Beekley et al. (2007) found that male soldiers rated a load mass of 26% BW as "light", 43% BW between "light" and "somewhat hard" and 60% BW between "somewhat hard" and "hard" and Sagiv et al. (1994) found that male soldiers rated load masses of both 53% BW and 66% BW as between "light" and "somewhat hard". In comparison, Goslin and Rorke (1986) and Gordon et al. (1983) found that civilian males rated a 20% BW load mass as "light" and 30% and 40% BW as "somewhat hard" on a RPE scale. Although it is unknown how female military personnel or recreational hikers perceive increased load mass during prolonged load carriage, it has been suggested that local discomfort may dominate perceptions of exertion resulting in increased RPE (Gordon et al., 1983).

In studies of male soldiers, the shoulder has been reported to be the most painful and uncomfortable body region when carrying loads between 15% BW and 70% BW (Birrell and Hooper, 2007; Fergenbaum, 2007). The neck, upper back and hips are other body regions reported to incur pain or discomfort during prolonged load carriage (Fergenbaum, 2007; Birrell and Haslam, 2009). As 70% of the backpack mass is supported by the upper back and shoulders (LaFiandra and Harman, 2004), women may be more affected by shoulder discomfort and cease hiking activities at a lower relative load mass than males due to less upper body strength (Freedson, 1994). In support of this notion, backpack strap-related discomfort in the shoulders has been reported as a factor for women stopping load carriage activities in the military (Davies et al., 1994). In addition, higher shoulder strap-skin pressures have been reported for women compared to men (Harman et al., 1999). However, recent research on pressure mapping technology using a human shoulder-shaped model has found high error rates under dynamic conditions (Fergenbaum, 2007). Therefore, using female hikers' own perceptions of the effects of variations in load mass during backpack carriage may be a useful approach in attempting to develop safe backpack load mass guidelines, especially if the results are used in conjunction with objective measures such as heart rate and posture.

Physiological studies have consistently shown that heart rate and oxygen consumption increase as load mass increases during short term load carriage (<1 h) (Quesada et al., 2000; Beekley et al., 2007). During prolonged load carriage, that is, walking with a load for longer than 1 h, the effects on physiological parameters are not as clear. Although some investigators have reported no significant differences in oxygen consumption or heart rate for male soldiers walking on a treadmill at constant pace with loads ranging from 33%–66% BW for durations of 1–4 h (Soule and Goldman, 1972; Kirk and Schneider, 1992; Sagiv et al., 1994), others have reported

increased oxygen consumption and heart rate (Gordon et al., 1983; Patton et al., 1991; Roberts et al., 1996) after male soldiers walked for 40 min to 4 h with 30%–64% BW loads. It has been suggested that the between-study differences in results are related to a subject's level of work intensity. That is, a work intensity greater than 50% of VO_2max is required before an increase in VO_2 has been found (Epstein et al., 1988). However, most of these previous studies were conducted with male subjects walking at a constant controlled speed on a treadmill. As recreational hikers walk over-ground at a self-selected speed, they may modify their gait to maintain a steady pace, matched to their preferred level of work intensity as load mass or distance increase. Few studies have considered the effect of increases in load mass on subjects, particularly women, walking over-ground at a self-selected speed for an extended time. It is therefore unknown what load recreational hikers are capable of carrying for longer durations without undue physiological stress.

Although a general recommendation for an "optimal" backpack load mass of 30% BW exists, other research has suggested that 40%–60% BW can be safely carried (Haisman, 1988; Fergenbaum, 2007; Pal et al., 2009). These recommended limits are based on research on healthy young adult males, mostly soldiers (Haisman, 1988). The literature also recommends load mass guidelines for school backpack load carriage in school children of between 10% and 15% BW (Hong and Brueggemann, 2000; Steele et al., 2003; Brackley and Stevenson, 2004; Mackie et al., 2005). However, these school backpack load mass guidelines are likely to be impractical for adult recreational hikers who often need to carry food, clothing and camping equipment and are exposed to load carriage for longer periods than they would be during daily schoolbag load carriage (Mackie et al., 2004). Of all the studies on load carriage located, only three investigated female subjects exclusively (Kirk and Schneider, 1992; Davies et al., 1994; Harman et al., 1999). These studies assessed female soldiers carrying backpacks of different design while walking on treadmills at constant speeds. None of the studies, however, assessed female recreational hikers carrying a load over prolonged distances. Despite the positive association between injury and female gender in outdoor education participants (Gentile et al., 1992; Twombly and Schussman, 1995), there is a lack of research on the heart rate, postural or subjective responses of women to prolonged load carriage upon which to develop safe load carriage mass guidelines for women. Therefore, the purpose of the present study was to determine how variations in load mass affected the heart rate, postural and subjective responses of women during a prolonged hike. The results will be used as evidence upon which to develop recommendations for a load mass limit for female recreational hikers.

2. Methods

2.1. Participants

Fifteen healthy, active female recreational hikers (mean age = 22.3 ± 3.9 years; height 1.69 ± 0.1 m; mass 61.2 ± 5.3 kg) volunteered to participate in the study. Participants were screened to ensure they had no musculoskeletal or neurological disorders that would be aggravated by load carriage. Information relating to the participant's health status and physical activity were obtained through a screening questionnaire that comprised questions from the American College of Sports Medicine pre-exercise screening guidelines (American College of Sports Medicine, 1997) and the Physical Activity Rating (PA-R) Scale (Jackson et al., 1990). The experimental protocol was approved by the University of Wollongong Human

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