Biomechanical and physiological comparison of conventional webbing and the M83 assault vest

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Abstract

This study compared the effect of load distribution using two different webbing designs on oxygen consumption and running kinematics of soldiers. It was hypothesised that running with webbing that distributes the load closer to the body (M83 Assault Vest) would expend less energy compared to running with conventional webbing (CON). Seven soldiers randomly completed three treadmill trials; an unloaded VO$_2$max test, and two loaded (8 kg) efficiency tests using either the M83 or CON webbing. The VO$_2$max test and the loaded efficiency tests had 4-min stages at 5, 8, 10 and 12 km h$^{-1}$. Energy expenditure was measured via indirect calorimetry and video analysis was used to determine stride frequency (SF) and stride length (SL) during each trial. Participants using the M83 webbing expended significantly ($p<0.05$) less energy at all four running velocities compared to the CON trials. The M83 webbing resulted in smaller changes to SL and SF from the unloaded trial when compared to the CON trial. These results indicate that the M83 vest that is designed to distribute the load closer to the body may have an energy efficiency advantage over conventional webbing when soldiers are running.

Keywords: Webbing; Running efficiency; Running kinematics

1. Introduction

The Australian Army issues conventional (CON) webbing for the carriage of small loads of essential equipment (ammunition, water, food). The webbing comprises a belt, a harness, ammunition pouches, water bottle holders, and a rear pouch (Fig. 1). The load sits at hip level to the side and rear, which allows a large backpack to be worn over the top of the webbing. The M83 Assault Vest (M83) is an alternative piece of equipment designed to perform the same task. The load is carried on the chest in small pouches and at the side of the hips in larger pouches (Fig. 2). The M83 also allows for a backpack to be used.

CON webbing can be adjusted to suit the size of the individual: the harness length, the chest strap, and the belt can be lengthened or shortened. When tightened to fit the hips, the belt is loose at the waist which allows the webbing to rotate about the body, following the movement of the hips. The M83 has compression straps at the shoulders, the sternum, and at the sides for closer conformation with the torso. The webbing is designed to decrease the upward travel of the vest relative to the body.

Previous studies on the efficiency of webbing or backpack design have only used walking as the activity mode. Legg and Mahanty (1985) compared five modes of carrying loads close to the trunk. They found no significant differences between the systems in energy expenditure although there was a trend for the double pack (storage at the front and rear) to be associated with a lower physiological cost. Winsmann and Goldman...
compared a traditional military backpack with a system that allowed greater transference of load from the shoulders to the hips and also found no significant differences in energy expenditure associated with walking. Holewijn (1990) compared a military rucksack and a custom rucksack. The major difference between the two packs was that the custom pack supported the load on the hips rather than the shoulders. There was no significant difference in energy cost while carrying either 5.4 or 10.4 kg. Finally, Lloyd and Cooke (2000) compared a traditional rucksack with the AARN rucksack, which incorporates front balance pockets. They reported that oxygen consumption was significantly lower using the AARN pack compared to the traditional rucksack when walking uphill and downhill at various gradients.

Given the importance of running efficiency with soldiers in combat, and the popularity of the M83 vest, the aim of the present study was to compare energy expenditure, stride length and stride frequency using either the M83 or CON webbing during treadmill running. It was hypothesised that soldiers running with the M83 webbing would be more efficient compared to running with CON webbing.
2. Methods

2.1. Participants

Eight male infantry soldiers from the Australian Army volunteered to participate in the study. One soldier suffered a non-study related injury after completing one trial and his data was excluded from analyses. The physical characteristics of the seven participants were (mean ± SD): age 20.8 ± 0.7 yr; mass 73.6 ± 35.2 kg; height 178 ± 34.7 cm, VO₂max = 56.2 ± 5.8 ml/kg/min. All participants were able to complete a 2.4 km run within 10 min 40 s.

2.2. Procedures

All experimental procedures were approved by the University of Tasmania’s Human Ethics Committee. Subjects reported to the Human Performance Laboratory in the Centre for Human Movement at the University of Tasmania wearing army fatigues and running shoes. The laboratory was climate controlled to 22°C and 60% relative humidity. They randomly completed three running trials, separated by at least two and no more than 5 days apart, on a treadmill (Quinton, Q65, Bothwell, WA, USA). One of the trials was an incremental unloaded VO₂max test the other two required participants to run either with the M83 vest or CON webbing, both loaded with 8 kg. The treadmill protocols for the trials are shown in Table 1 and a pilot study found the repeatability of the VO₂ measures during the treadmill protocol to be <5%. Expired air was collected during each trial using open circuit spirometry with a Quinton metabolic cart (Quinton, QMC, Bothwell, WA, USA). Prior to each testing session, the analysers were calibrated using standard gas mixtures and the flow volume was calibrated using a 3l calibration syringe (Hans Rudolph, Kansas City, MO, USA).

2.3. Video analysis

During each trial the right sagittal plane of the subject was recorded using a digital video camera (Palmcorder, Panasonic, Secaucus, NJ, USA). Video was analysed at 25 frames per second using HM Analyse (WAIS, WA, Australia) to determine mean stride frequency (SF). The stride length (SL) was calculated by dividing the velocity by SF.

2.4. Data analysis

The additional energy expenditure for the M83 and the CON webbing were calculated by subtracting the oxygen consumption (VO₂) measured during the unloaded trial from the respective loaded trial. Statistical analysis of the data was performed using analysis of variance (ANOVA) with a Scheffe post hoc test. Significance was established a priori at p < 0.05.

3. Results

Table 2 compares the oxygen consumption (VO₂), SF and SL between the three trials when running at 12.0 km h⁻¹. Not surprisingly, the addition of 8 kg of weight in both the M83 vest and the CON webbing significantly (p < 0.05) increased VO₂ compared to unloaded running. Furthermore, the VO₂ when running with the CON webbing was significantly greater (p < 0.05) than when running with M83 vest. SL and SF were not significantly different in any of the trials. In addition, Fig. 3 shows that at all four speeds tested (5, 8, 10 and 12 km h⁻¹), the additional VO₂ above the unloaded trial was significantly greater (p < 0.05) when participants were wearing the CON webbing compared to the M83 vest. Indeed, all seven subjects had a higher VO₂ with CON webbing at all trial speeds indicating that a greater energy expenditure is required to run wearing the CON webbing.

To determine the change in running kinematics due to the two webbing designs we correlated SL and SF

<table>
<thead>
<tr>
<th>Time</th>
<th>Unloaded VO₂ max protocol (km h⁻¹)</th>
<th>Loaded protocols (M83 and CON webbing) (km h⁻¹)</th>
<th>VO₂ (ml/kg/min)</th>
<th>Stride frequency (strides/min)</th>
<th>Stride length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00–4:00</td>
<td>5</td>
<td>5</td>
<td>41.7 ± 0.6 *</td>
<td>80.6 ± 1.0</td>
<td>2.48 ± 0.03</td>
</tr>
<tr>
<td>4:01–8:00</td>
<td>8</td>
<td>8</td>
<td>47.7 ± 0.9</td>
<td>82.0 ± 0.9</td>
<td>2.44 ± 0.03</td>
</tr>
<tr>
<td>8:01–12:00</td>
<td>10</td>
<td>10</td>
<td>49.6 ± 1.1 **</td>
<td>84.0 ± 3.1</td>
<td>2.40 ± 0.08</td>
</tr>
</tbody>
</table>

*Significantly less than both the M83 and CON trials (p < 0.05). **Significantly greater than M83 trial (p < 0.05).
between the unloaded trial and each webbing trial at 12 km h\(^{-1}\). Fig. 4 shows that SL with the M83 was significantly correlated \((r = 0.77, P < 0.05)\) to unloaded SL, however there was no significant relationship between the CON webbing SL and the unloaded SL \((r = 0.19, P > 0.05)\). SF in the M83 trial was also significantly correlated \((r = 0.89, P < 0.05)\) to unloaded SF values however there was no association between the CON webbing SF and the unloaded SF \((r = 0.17, P > 0.05)\). Combined these data indicate that soldiers running kinematics were more similar to the unloaded trial when wearing the M83 vest compared to the CON webbing.

4. Discussion

Although a number of studies have reported an improvement in energy efficiency during walking when using a pack that distributes the weight closer to the body, this is the first study to investigate this question during running. Furthermore, we evaluated a popular new pack (M83 Assault Vest) against CON webbing used by the Australian Army. In summary, at all running speeds tested participants had a lower oxygen consumption when using the M83 vest. Running kinematics (stride length and frequency) were more similar to an unloaded run when using the M83 vest compared to the CON webbing. Combined this indicates that soldiers will run more efficiently when using the M83 vest as there is less change to normal running kinematics.

The mean decreases in energy expenditure (ml kg\(^{-1}\) min\(^{-1}\)) when comparing running with the M83 vest compared to the CON webbing were 3.6, 2.2, 3.7 and 2.9 at 5, 8, 10 and 12 km h\(^{-1}\) respectively. This would translate into savings of approximately 35 kCal during a 30 min run at any of these speeds. As well as conserving energy, this should also mean that the soldiers would be able to maintain these speeds for longer.

Studies looking at the change in energy expenditure with changes in the position of the centre of mass of the carried load have consistently found that the closer the centre of mass of the carried load is to the body the greater the reduction in energy expenditure during walking. Maloiy et al. (1986) reported that 20% body weight could be carried on the head without an increase in oxygen consumption. Furthermore, Obusek et al. (1997) found a significant linear relationship between the sagittal plane location of the centre of mass of a loaded backpack and metabolic cost of an individual walking.

The mean percentage improvements in energy expenditure in the M83 trial were 5.4, 4.0, 5.5 and 4.7 greater than CON webbing for the four speeds. These are similar to other studies that have reported the percentage improvement in energy expenditure when the load is moved closer to the body during walking; Lloyd and Cooke (2000) = 6%, Legg and Mahanty (1985) = 6.4% and Datta and Ramanathan (1971) = 9.5%.

The correlations between unloaded running and running using either the M83 assault vest or CON webbing showed that participants had greater changes to both SL and SF when running with the CON
webbing compared to the M83 assault vest. The SL correlations between unloaded running and running with the M83 was \( r = 0.77 \) compared to \( r = 0.19 \) with the CON webbing. SF correlations were M83, \( r = 0.89 \) and CON, \( r = 0.17 \). Large gait alterations are well recognised as a sign of inefficiency during running (Williams, 1985) and the similar running kinematics between the unloaded trial and the M83 trial may explain the decrease in oxygen consumption in the M83 compared to the CON trial.

It is proposed that two main factors may be responsible for these findings. Firstly, the close conformation of the M83 webbing to the body during movement may maintain preferred kinematics. Any design modifications that fix the pouches to the body and reduce their movement vertically or rotationally will improve the maintenance of the preferred kinematics by creating smaller alterations in the body’s centre of gravity (Williams, 1985). Secondly, the M83 vest allows for a more even carriage weight distribution. Smaller pouches produce a smaller change in the body’s centre of gravity while running. These factors would result in the present findings that the loaded running gait using the M83 is more similar to the unloaded running gait. These factors would also explain the increased oxygen consumption while running using the CON webbing compared to the M83 assault vest.

4.1. Extrapolation to the field

Wank et al. (1998) found that overground running involved greater vertical displacement than treadmill running. This would lead to a greater vertical movement of the webbing relative to the body, and a greater change in the soldier’s centre of gravity. In this situation it is expected that the differences in energy cost between the two webbing designs would be greater, further supporting the use of a webbing system similar to the M83 assault vest in the field. Further investigation of a larger sample, with more realistic field conditions (operational load, boots, and a weapon) at a faster speed is required to confirm these initial results and trends. Furthermore, although the M83 webbing may have advantages in regards to energy expenditure, the greater conformation with the soldier’s body may increase thermal insulation and reduce cooling in heat load conditions. These are interesting research questions for further investigation.

5. Conclusions

This study compared CON webbing used by the Australian Army and the M83 assault vest. The results showed a significant improvement in the energy cost of running when using the M83 assault vest at 5, 8, 10 and 12 km h\(^{-1}\). This gain in energy efficiency was associated with less variation in running kinematics when using the M83. Therefore the M83 assault vest appears to be superior to CON webbing during treadmill running.

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References