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Blood lactate thresholds and walking/running economy are determinants of backpack-running performance in trained soldiers

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ABSTRACT

We developed a standardized laboratory treadmill protocol for assessing physiological responses to a simulated backpack load-carriage task in trained soldiers, and assessed the efficacy of blood lactate thresholds (LTs) and economy in predicting future backpack running success over an 8-mile course in field conditions. LTs and corresponding physiological responses were determined in 17 elite British soldiers who completed an incremental treadmill walk/run protocol to exhaustion carrying 20 kg backpack load. Treadmill velocity at the breakpoint ($r = -0.85$) and Δ 1 mmol l^{-1} ($r = -0.80$) LTs, and relative $\dot{V}O_2$ at 4 mmol l^{-1} ($r = 0.76$) and treadmill walk/run velocities of 6.4 ($r = 0.76$), 7.4 ($r = 0.80$), 11.4 ($r = 0.66$) and 12.4 ($r = 0.65$) km h^{-1} were significantly associated with field test completion time. We report for the first time that LTs and backpack walk/run economy are major determinants of backpack load-carriage performance in trained soldiers.

1. Introduction

Soldiers who aspire to serve in the elite units undergo rigorous selection procedures, with the ability to carry backpacks at speed over undulating and/or arduous terrain being key to their success (Allsopp and Shariff, 2004; Wilkinson et al., 2008). As attrition rates are typically high, identifying the physiological underpinnings of successful backpack load-carriage performance is important to generate valid discriminative entry-level physical assessments and to develop adequate training regimens for aspiring recruits (Rayson et al., 2000). The physiological determinants of backpack load-carriage performance are likely to include measures of strength, body composition and endurance (Haisman, 1988; Rayson et al., 2000). The maximal oxygen uptake ($\dot{V}O_{2max}$), regarded as the 'gold standard' measure of maximal aerobic capacity, is positively associated with non-load-carrying endurance performance (i.e. running), and has been correlated with successful load-carriage performance also (Rayson et al., 2000). Conversely, many studies have found $\dot{V}O_{2max}$ to be a weak determinant of successful load-carriage (Bilzon et al., 2001), even when peak oxygen uptake is measured during a prior load-carriage task (Simpson et al., 2006). The ambiguity surrounding $\dot{V}O_{2max}$ could be due to inconsistencies in experimental design, including backpack weight, the performance outcome measure (i.e. maximum weight carried or time taken to carry a fixed weight over a set distance), and whether $\dot{V}O_{2max}$ was measured during a load or non-load carrying task, and the training status of the participants (i.e. civilians, conventional soldiers, or elite soldiers).

For tasks that do not involve load-carriage, submaximal physiological parameters are often preferred over $\dot{V}O_{2max}$ to predict endurance performance. The blood lactate threshold (LT), although widely varied in concept and interpretation, is generally defined as the absolute workload above which blood lactate levels rise exponentially during incremental exercise (Faude et al., 2009; Weltman, 1995). This rise usually occurs concomitantly with a disproportionate increase in minute ventilation relative ($\dot{V}_E$) to oxygen uptake ($\dot{V}_E/\dot{V}O_2$) , a concept known as the ventilatory threshold

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(Vent^T) (Gaskill et al., 2001). The LT is believed to represent an increased involvement of the anaerobic energy pathways to provide ATP and has been shown to be superior to $\dot{V}O_{2max}$ when predicting endurance performance in homogenous groups of athletes (Faude et al., 2009). Moreover, the oxygen cost of running at a given submaximal speed (referred to as economy) and the ability to maintain high percentages of the $\dot{V}O_{2max}$ without substantial increases in blood lactate concentration, are also useful indicators of performance in endurance athletes (Saunders et al., 2004).

Despite the success and ubiquitous use of LTs, Vent^T and running economy as predictors of endurance performance in athletes (Faude et al., 2009; Saunders et al., 2004), no previous studies have attempted to identify the efficacy of these variables as determinants of backpack load-carriage performance, or their effectiveness for predicting future success in field based load-carriage tasks. Moreover, while there is a large body of normative data available on the physiological responses to simulated backpack load-carriage tasks in conventional military troops (Beekley et al., 2007; Christie and Scott, 2005; Rayson et al., 2000) and recreationally active males (Faghy and Brown, 2014), comprehensive physiological data on elite soldiers are lacking (Simpson et al., 2006, 2010; Wilkinson et al., 2008).

Our aim in this study was to determine the physiological values associated with a simulated backpack load carriage task in a controlled laboratory setting, using an incremental treadmill protocol for a homogenous group of elite soldiers, and to establish the efficacy of the measured physiological variables for predicting future performance of a backpack load carriage task conducted in a field setting. We hypothesised that LTs and backpack walking/running economy would be associated with the time taken to complete an 8-mile backpack running test in this group of trained soldiers.

2. Methods

2.1. Participants

Seventeen male soldiers of the British Army volunteered to participate in this study. All participants were serving with the Parachute Regiment or the Special Air Service (SAS) Regiment and had previously passed pre-parachute selection (P-Company) and/or United Kingdom Special Forces (UKSF) selection prior to their participation in this study. We previously compared selected physiological variables and performance markers between soldiers of these two regiments and found no discernable differences (Simpson et al., 2006). All participants completed and passed their unit specific annual physical fitness tests within the preceding 12-months of the study and refrained from strenuous physical activity for 48 h before participating in the exercise trials. All participants provided written informed consent and institutional ethical approval was granted. The physical characteristics of the participants are presented in Table 1.

Table 1
Physical and performance characteristics of the participants ($n = 17$).

	Mean ± SD	Range
Age (yrs)	25.9 ± 4.3	21–35
Height (cm)	180.1 ± 6.3	168.5–189.5
Mass (kg)	79.3 ± 6.5	67–87.4
Backpack load (% body mass)	25.9 ± 4.3	22.9–29.9
$\dot{V}O_{2peak}$ (l min^{-1})	4.34 ± 0.38	3.60–4.87
$\dot{V}O_{2peak}$ (ml kg^{-1} min^{-1})	55.0 ± 5.2	46.0–62.3
HR peak (beats min^{-1})	196 ± 10	174–207
Maximal blood lactate (mmol l^{-1})	9.8 ± 1.7	6.4–12.9
Maximal treadmill time (min:sec)[a]	23:30 ± 0:52	21:00–24:24
8-mile backpack run time (h:min:sec)[b]	1:28:38 ± 0:04:27	1:21:50–1:34:25

[a] Does not include the 60-s intervals after each incremental stage of the protocol.
[b] Data obtained from ten participants only.

2.2. Pre-exercise measures

On arrival to the laboratory, height and body mass (nude) of each participant was recorded. Participants wore standard issue combat trousers, military style boots (according to individual preference) and a T-shirt, were fitted with a heart rate monitor (S610, Polar Electro, Kempele, Finland), and asked to rest on a plinth in the supine position for 10 min. After the rest period, ratings of perceived exertion (RPE), using the Borg 6–20 scale (Borg, 1998), and heart rate were recorded, and a capillary blood sample was collected from the earlobe to determine blood lactate concentration [assayed in duplicate using an automated analyser (P-GL5, Analox Instruments, London, UK)]. Each participant was then fitted with a face-mask, which was connected to the online gas analysis apparatus (CPX Medgraphics, Oldham, UK), and asked to rest in a seated position for 5 min. During this period, mean minute ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}O_2$), expired carbon dioxide ($\dot{V}CO_2$), the respiratory exchange ratio (RER) and the ventilatory equivalent of oxygen ($\dot{V}_E/\dot{V}O_2$) and carbon dioxide ($\dot{V}_E/\dot{V}CO_2$) were recorded.

2.3. Backpack treadmill-running protocol

The Backpack-Treadmill Running Protocol is depicted in Fig. 1. After obtaining the resting measures, each participant put on a standard British Army Bergen (backpack), which weighed 20 kg and was previously packed prior to testing and checked for individual comfort. A discontinuous backpack running protocol was then completed on a motorised treadmill (Woodway Ergo ELG 55, Weil am Rhein, Germany). The protocol began with the subject walking on a +1% incline at a velocity of 6.4 km h^{-1}. The treadmill was set at a 1% gradient to best mimic outdoor running conditions (Jones and Doust, 1996). The velocity of the treadmill was increased by 1.0 km h^{-1} every 3 min until a maximal running velocity of 12.4 km h^{-1} was attained. After each 3 min stage of exercise, the participant straddled the treadmill for a 1 min period to allow a capillary blood sample to be taken for subsequent blood lactate analysis and provided their RPE score. After obtaining RPE and the capillary blood sample following the period of maximal running velocity (12.4 km h^{-1}), the participants stepped back on the treadmill with the velocity maintained at 12.4 km h^{-1} and the inclination set at +3.5% and ran continuously, with the inclination of the treadmill increasing by 2.5% after every subsequent minute until volitional exhaustion. All participants were encouraged to progress as far into the protocol as possible until volitional exhaustion. A final capillary blood sample was taken immediately at the end of the test to determine maximal blood lactate concentration. The RPE was also recorded immediately at the end of the test. Heart rate was recorded continuously during the exercise protocol and averaged over 5sec intervals. Similarly, breath-by-breath analysis was used to collect respiratory data ($\dot{V}O_2$, $\dot{V}_E$, $\dot{V}_E/\dot{V}O_2$, $\dot{V}_E/\dot{V}CO_2$), which was also averaged over 5 sec intervals. To reduce the influence of a respiratory lag phase at the beginning of each incremental stage of the discontinuous protocol, only the heart rate and respiratory data obtained during the final 2-min of each stage of the protocol was processed for analysis.

2.4. Identification of blood lactate and ventilatory thresholds

Five blood lactate thresholds (LTs) were determined from the backpack treadmill running protocol using the methods described by Weltman (Weltman, 1995). These included: (i) the lactate