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The effects of body armour and load carriage on respiratory function and physical performance during a simulated military task in male and female soldiers

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Introduction

It is well established that load carriage has a detrimental effect on soldier performance. Torso load carriage alters breathing mechanics and causes respiratory muscle fatigue (RMF)¹. RMF exacerbates limb fatigue which impairs performance during short term high intensity exercise². RMF will influence perceived exertion and may also have implications for injury, given the role of the respiratory muscles in the maintenance of posture.

In July 2016, the ban excluding women from ground close combat roles was lifted in the UK. Sex differences may make females more susceptible to the detrimental effects of load carriage. When matched for height, females have smaller lung volumes and airways, a decreased capacity for lung diffusion and weaker respiratory muscles³. Thus during tasks requiring high ventilation rates, females experience greater airway resistance and more turbulent airflow. The impact is lower peak expiratory flow rates and a higher resistive work of breathing. However, females demonstrate greater resistance to exercise-induced fatigue of the diaphragm and peripheral skeletal muscle which may counteract the aforementioned differences⁴.

Aim

To investigate the effect of wearing body armour and load on respiratory function and physical performance during a pre-fatiguing loaded march followed by a best time test, in male and female soldiers.

Method

- Twelve male (stature: 1.81 (0.07) m; mass: 77.94 (8.4) kg) and ten female soldiers (stature: 1.68 (0.09) m; mass: 71.38 (9.11) kg);
- VO_{2max} and anthropometric assessments undertaken;
- Participants completed an exercise test (Figure 1) in four different load configurations: Body Armour (BA) 21 kg; Assault Order (AO) 26 kg; Patrol Order (PO) 33 kg and Marching Order (MO) 43 kg (Figure 2). The best time test was completed wearing assault order loads.

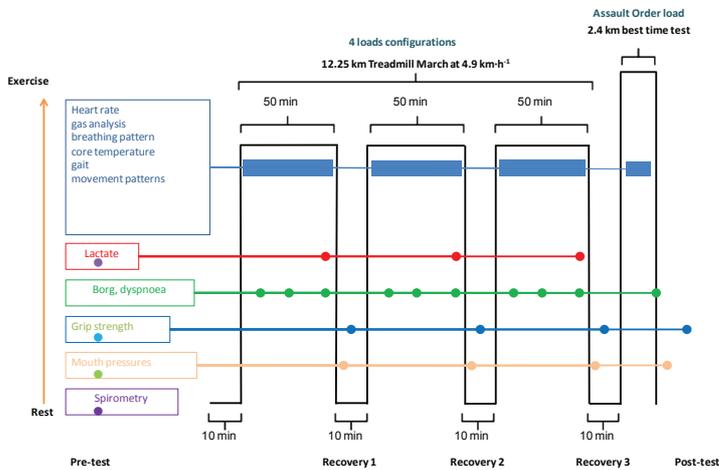


Figure 1: Exercise Test Overview

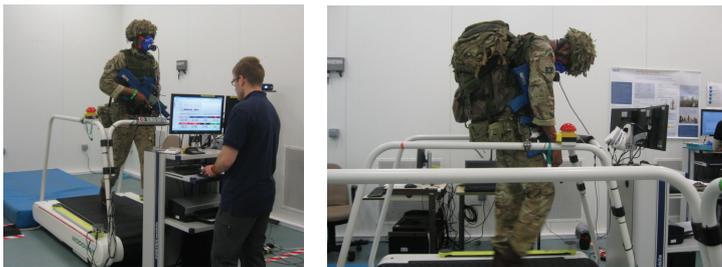


Figure 2: LEFT: Participant wearing Assault Order. RIGHT: Participant wearing Marching Order.

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Results

- Only 50 % of male and 10 % of female participants were able to complete all elements of the exercise test in all conditions. The main limiting factor for completing trials was self-reported discomfort.
- Load carriage caused a restrictive ventilatory impairment in both sexes indicated by a reduction in lung volumes at rest (women: up to 15 %; men: up to 17 %).
- Inspiratory and expiratory muscle fatigue was evident (7 % to 22 %) within the first 50 minutes of marching in all loads in both sexes. This increased with time but not load and fatigue was similar between sexes
- Time to complete the best time test in AO was unaffected by the load carried during the march.
- It was not always possible to achieve the desired equipment fit in the female group due to poor integration of the body armour with the webbing.

- Women carried a significantly greater percentage of their lean body mass (44 % to 93 %) than men (36 % to 74 %) (Figure 3).

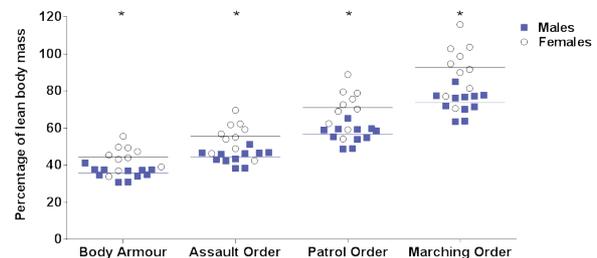


Figure 3: Load as a percentage of lean body mass.

- Women marched at an increased percentage of VO_{2max} compared to men (Figure 4). VO_{2max} did not exceed the gas exchange threshold at any point, indicating that the intensity remained as moderate throughout for all participants.
- VO_{2max} drift was first observed in loads of 33 kg (PO) within 50 minutes of marching in women, and 110 minutes in males.

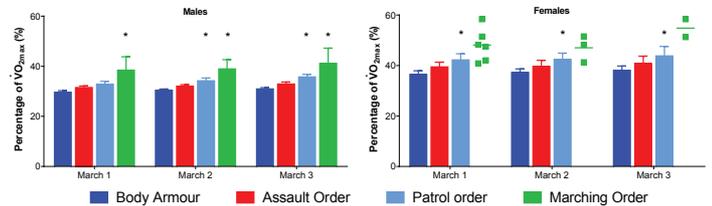


Figure 4: Percentage of VO_{2max} at the end of each march. * indicates a difference from the start of March 1. Individual data is provided for indication where statistical comparisons were not possible.

- Increases in ventilation observed with load and over time were similar in men and women (women: 7 % to 54 %; men: 8 % to 35 %) and were achieved by increased breathing frequency, but not tidal volume.
- Breathing frequency was significantly greater (11 % to 18 %) in women than men throughout the march (Figure 5).

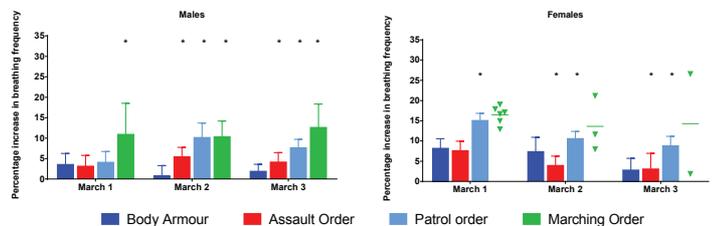


Figure 5: Breathing Frequency. * indicates a difference from pre-march values. Individual data is provided for indication where statistical comparisons were not possible.

Conclusions and Recommendations

- Physical performance decrements during prolonged loaded marching are evident in both sexes;
- These decrements occur with lighter loads and earlier during marching in women;
- These results may reflect differences in body size between sexes; however, further analyses are required to understand the independent mediators of these findings;
- These data highlight the need to investigate, and improve, the load carriage ability of women;
- Future work should consider the requirement for equipment designed specifically for the female form.