Biomechanical changes associated with heavy load carriage using differing rucksack designs

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INTRODUCTION

Military personal carry operational heavy loads, often consisting of a rucksack and body armour [1]. Heavy load carriage has been shown to change biomechanical variables during walking, standing and running e.g. [2]. There is limited understanding of the effects of rucksack design on these changes despite numerous commercial designs issued to service personnel worldwide. The effects of wearing a rucksack over armour as opposed to integrated armour are also unknown. The aim of this study was to quantify the effects of common rucksack features such as hip and chest strapping on the biomechanical changes associated with loaded running. The interaction of body armour and rucksack was also investigated.

METHODS

15 males who participated in regular resistance and cardiovascular training were recruited. Participants undertook four 1 km runs consisting of 50 x 20 m shuttles. Four loaded conditions were investigated: PC (5 kg plate carrier); LF (plate carrier + litefighter rucksack); BFMout (plate carrier + Camelbak BFM rucksack); BFMin (plate carrier + Camelbak BFM rucksack, rear plate moved from plate carrier to rucksack). The litefighter rucksack did not have any hip or chest strapping whilst the BFM had both; the litefighter had fixed shoulder straps whilst the BFM had back length adjustment. Rucksack loads were set at 20 kg such that total load was always 25 kg when wearing a rucksack and plate carrier. Retroreflective markers were used to identify the segments of the right lower limb, torso and head. Kinematic data was collected for one stace phase during each shuttle run using 15 Raptor cameras and Cortex software (version 7.02 Motion Analysis Corporation, CA). Peak knee flexion, peak forward torso lean and peak lateral torso lean timing were calculated for analysis, timings of peaks were also calculated. Variables were compared using a one-way repeated measures ANOVA. Bonferroni adjusted post-hoc t-tests were used where significant effects were identified.

RESULTS AND DISCUSSION

Discrete statistics and p values for all analysies can be seen in Table 1. Peak knee flexion timing was found to be different between conditions. Post hoc tests showed that peak knee flexion occurred significantly later in stance in the BFM_{out} condition compared to PC ($p = 0.024$). Peak forward torso lean during stance was found to be different between conditions. Post hoc tests showed that all three rucksack conditions had greater forward lean than PC (LF $p \leq 0.001$; BFM_{out} $p \leq 0.001$; BFM_{in} $p \leq 0.001$). Additionally, the BFM_{in} condition had significantly greater lean than the LF condition ($P = 0.004$). Peak forward torso lean timing occurred significantly later in stance for PC compared with the three rucksack conditions (LF $p = 0.009$; BFM_{out} $p \leq 0.001$; BFM_{in} $p \leq 0.001$). All three rucksack conditions had earlier peak lateral lean than PC (LF $p = 0.002$; BFM_{out} $p \leq 0.001$; BFM_{in} $p \leq 0.001$).

CONCLUSIONS

Results demonstrate that rucksack design has a significant effect on the biomechanics of heavy loaded carriage. Integration of body armour and rucksack can have significant effects on torso lean during stance and should be considered when combining these two pieces of equipment.

REFERENCES

[1] Andersen et al. *S Medicine* **22**, 2016.
[2] Birrell et al. *Ergonomics* **52**: 1298-1304, 2009.

Table 1: Mean, standard deviations and p values for all discrete variables analysed

Variable	Mean ± SD				p	F
	PC	LF	BFMin	BFMout		
Peak knee flexion (deg)	45.80 ± 5.10	44.00 ± 4.47	44.95 ± 3.36	45.22 ± 5.26	0.329	1.17
Peak knee flexion timing (% stance)	29.79 ± 3.35	39.05 ± 16.07	40.20 ± 20.59	45.99 ± 19.45	0.023	3.824
Peak forward torso lean (deg)	6.32 ± 4.60	13.16 ± 4.12	15.76 ± 4.05	14.88 ± 3.97	≤0.001	50.216
Peak forward torso lean timing (% stance)	63.12 ± 13.72	45.46 ± 13.40	45.26 ± 11.72	42.99 ± 8.79	≤0.001	14.957
Peak lateral torso lean (deg)	2.45 ± 1.15	4.67 ± 6.68	2.86 ± 1.40	3.09 ± 1.22	0.335	1.165
Peak lateral torso lean timing (% stance)	63.27 ± 20.36	33.83 ± 20.00	30.59 ± 11.69	30.59 ± 10.11	≤0.001	17.211