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Backpack carriage effect on joint torques computed from a range of models: a preliminary study.

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1. Introduction

In a military framework, it could be interesting to predict biomechanical quantities such as joint torques and ground reaction forces while walking and carrying heavy loads. Indeed, these quantities could help to study injuries mechanism of low back pain or stress fractures related to the mass of the soldier's equipment carried on the field, which has nearly doubled since World War I (Knapik et al. 2004). The aim of this study is thus to determine to what extent it is possible to predict the influence of different load carriage conditions, on joint moments, with a baseline kinematic acquisition combined with predicted ground reaction forces and moments (GRF&Ms) as inputs.

2. Methods

2.1 Experimental data

Data have been collected from French army soldiers who participated to a previous study (Puchaud 2020) (CPP n° 2018-A00484-51). Motion for 5 walking tasks without backpack and with 10, 20 and 30kg was recorded for 9 soldiers. We thus chose to focus this study on a single soldier (height = 174cm, weight = 75,4kg) who performed ten gait trials: 1 without backpack, 3 carrying 10kg, 4 carrying 20kg and 2 carrying 30kg with the selected gait cycle (first left heel strike on the force platform to the next) (Fig.1). The marker set used was a full body marker set based on ISB recommendations. Three markers were hidden by the backpack (T10 and 2 PSIP) and removed from the marker set. Technical markers placed on the pelvis and thorax were used to reconstruct the trajectories of the markers in these areas.

2.2 Modelling

A generic osteoarticular model of the entire body with 18 segments linked by ball joints was designed in CusToM (Muller et al. 2019a), then scaled to the subject (Puchaud et al. 2020). The inertial parameters (mass, center of mass, inertia matrix) of the thoracic body segment have been modified to virtually represent the mass of the backpack as a point mass. Firstly, the ground reaction forces and moments (GRF&Ms) from experience and kinematics

associated to the loading condition were conserved but

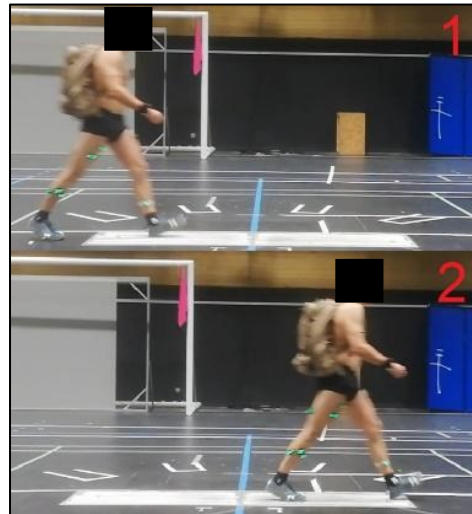


Figure 1: Heel to heel gait cycle description

GRF&Ms were predicted thanks to a motion-based prediction method (PRE1) (Muller et al. 2019b). Thirdly, only no-load gait motion and predicted GRF&Ms (PRE2) were used to compute joint moments for each loading condition.

2.3 Post-processing

A comparison between each method was made for flexion/extension joint torques at the L5/S1, left hip, knee, and ankle joints. All cycles were normalised according to cycle length. For repetitive sessions (10, 20, 30 kg), joint torques were averaged between trials. In addition, the RMSE of joint torques between the EXPE and PRE1 methods, and between the EXPE and PRE2 methods were computed over the gait cycles.

3. Results and discussion

Results from PRE2 displayed a lower RMSE for the left hip flexion/extension joint torque than PRE1. This was the opposite for L5/S1, and not entirely the case for left knee and ankle flexion/extension joint torques. Hence, in this case and for this subject, PRE2 led to a similar level of approximation as PRE1. Moreover, similar results in terms of shape and peak joint torque were obtained in the literature (Harman et al. 2000) where lower limbs joint torques for 20kg backpack carriage were computed for 16 subjects (height=181,2±7,5cm, weight=76,8±8,9kg) (Fig.2). However, the number of samples used for this study is not sufficient to assess the repeatability of the results. The model of the backpack used is limited. Indeed, the backpack tends to deform during walking, which was not considered in this first study. In addition, only the kinematics unaffected by wearing a backpack were used in the PRE2 method and the

results obtained could differ depending on the baseline kinematics chosen. Finally, walking speed was not controlled

Load (kg)	RMSE between EXP and PRE1 (N.m)			
	L5/S1	Hip	Knee	Ankle
0	19,4	19,4	11,3	9,5
10	13,1	23,9	19,3	16,9
20	12,5	32,1	23,0	23,6
30	10,7	42,5	36,0	28,5

Load (kg)	RMSE between EXP and PRE2 (N.m)			
	L5/S1	Hip	Knee	Ankle
10	15,9	22,9	20,1	19,0
20	24,3	20,0	25,9	20,3
30	43,4	19,6	35,7	25,3

Table 1: Comparison of the RMSE of PRE1 and PRE2 with respect to EXPE (in bold: lowest RMSE).

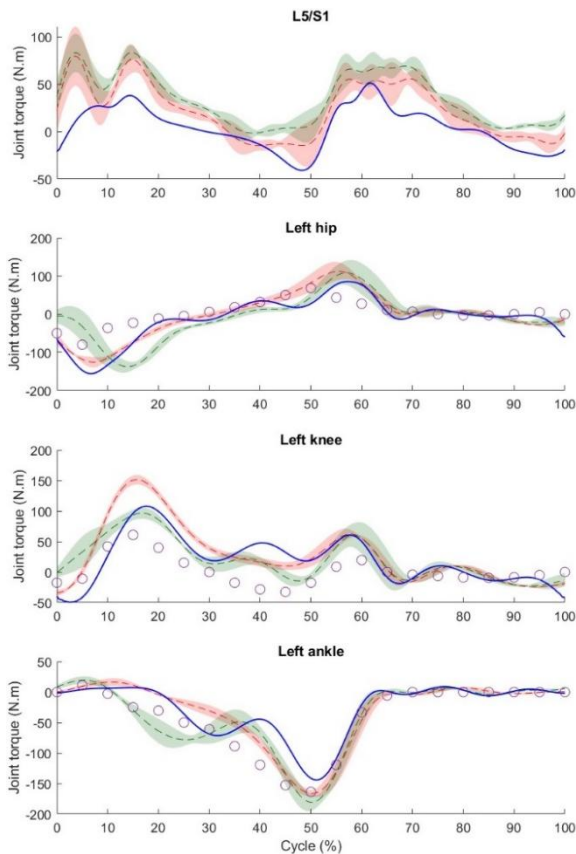


Figure 2: Joint torques for a loading of 20kg. (in red: EXPE, in green: PRE1, in blue: PRE2. Circles: Joint torques from Harman et al. 2000.

which led to a temporal shift. This could be compensated by a dynamic time warping method.

4. Conclusions

The purpose of this study was to assess if it is possible to predict the influence of load carriage on joint torques with a baseline gait (here carrying-free) and a virtually heavier model. Altering a generic

biomechanical model and keeping baseline kinematics offers the possibility of inverse dynamics computation for multiple configurations of load carriage. Results emphasized that such a prediction (PRE2) is possible for specific loading conditions. A future parametric study could investigate the choice of baseline kinematics, for an inverse dynamics method based on GRF&Ms prediction, on joint torques with respect to experimental results.

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