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Use of a backpack alters gait initiation of high school students

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ABSTRACT

We assessed how backpack carriage influences the gait initiation (GI) process in high school students, who extensively use backpacks. GI involves different dynamics from gait itself, while the excessive use of backpacks can result in adverse effects. 117 high school students were evaluated in three experimental conditions: no backpack (NB), bilateral backpack (BB), and unilateral backpack (UB). Two force plates were used to acquire ground reaction forces (GRFs) and moments for each foot separately. Center of pressure (COP) scalar variables were extracted, and statistical parametric mapping analysis was performed over the entire COP/GRFs time series. GI anticipatory postural adjustments (APAs) were reduced and were faster in backpack conditions; medial–lateral COP excursion was smaller in this phase. The uneven distribution of the extra load in the UB condition led to a larger medial–lateral COP shift in the support-foot unloading phase, with a corresponding vertical GRF change that suggests a more pronounced unloading swing foot/loading support foot mechanism. The anterior–posterior GRFs were altered, but the COP was not. A possible explanation for these results may be the forward trunk lean and the center of mass proximity of the base of support boundary, which induced smaller and faster APA, increased swing foot/support foot weight transfer, and increased load transfer to the first step.

1. Introduction

A large percentage of children and teenagers use a backpack to carry school items on a daily basis, because backpacks leave the upper limbs free for other activities and are more comfortable when carrying loads. In some cases, the backpack weight can be considered heavy in terms of body weight percentage, reaching values as high as 20% in this respect (Sheir-Neiss et al., 2003; Pau et al., 2011). There is a marked association between backpack use and back pain, muscle fatigue, and spinal deformity (Hong et al., 2008; Brackley et al., 2009), and concerns have been raised over the last decade regarding backpack use (Pau et al., 2011), particularly in schoolchildren and teenagers (Sheir-Neiss et al., 2003).

It is well established that backpack carriage increases muscle activity at the *rectus abdominus* and decreases muscle activity at the *erector spinae* (Motmans et al., 2006), induces muscle fatigue of the lower and upper *trapezius* (Hong et al., 2008), increases forward trunk lean (Singh and Koh, 2009; Mo et al., 2011), and alters kinematic (Connolly et al., 2008; Singh and Koh, 2009) and kinetic (LaFiandra et al., 2002; Pau et al., 2015) aspects of gait. However, few studies have assessed the effect of backpack carriage on transitory tasks, such as gait termination (Mo et al., 2011) and gait initiation (GI) (Caderby et al., 2013). Caderby et al. (2013) analyzed only anticipatory postural adjustments (APAs) in GI. They used an extra load that was symmetrically distributed, with regard to the anterior–posterior (AP) and medial–lateral (ML) directions around the body center of mass (COM), which is not the load distribution during a backpack use. On the basis of discrete values extracted from COM velocity and center of pressure (COP) excursion, these authors observed an increased APAs duration with no alteration in AP COM velocity and COP displacement in overload condition.

GI is the functional task of executing the transition from a standing posture to cyclic walking (Halliday et al., 1998; Couillandre et al., 2000). When beginning a new walking cycle, APAs are necessary for stabilizing the postural perturbation induced by the forthcoming voluntary movement (Aruin et al., 2001). Therefore, the role of GI is to generate the force and impulse necessary to move the COP toward the swing foot and then toward the support foot in order to enable a safe step. This task can be divided into three phases (Hass et al., 2008) (Fig. 1), as follows:

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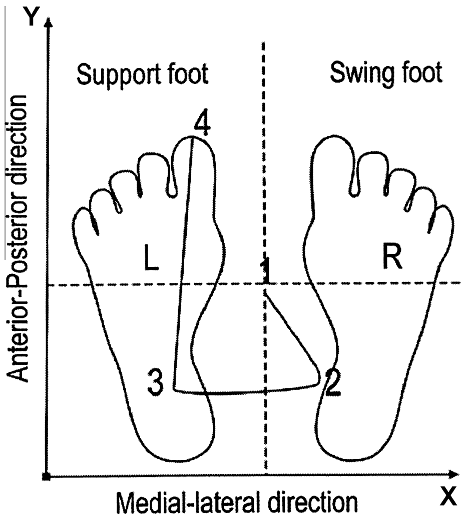

Fig. 1. Typical COP path during GI. R: right foot, L: left foot. 1–2: Phase 1 (APA phase); 2–3: Phase 2 (swing-foot unloading phase); 3–4: Phase 3 (support-foot unloading phase).

- The APAs, or swing-foot loading, phase (Phase 1; ~25% of the task) consists of a backward and lateral displacement of the COP toward the swing foot before any observable movement of the feet. This anticipatory adjustment protects the body from balance disturbances and simultaneously generates the forward impulse for the forthcoming progression (Ledebt et al., 1998).

Table 1
Duration and ML and AP COP displacements (Path) and mean velocities (Vel) of GI Phase 1.

		NB	BB	UB
Phase 1	Duration (s)	0.31 ± 0.05[a,b]	0.28 ± 0.04[a,c]	0.29 ± 0.05[b,c]
	Path ML (cm)	5.88 ± 1.33[d]	5.65 ± 1.31[d]	5.83 ± 1.57
	Path AP (cm)	−5.16 ± 1.58	−5.27 ± 1.66	−5.27 ± 1.97
	Vel ML (cm/s)	19.44 ± 5.53[e]	21.10 ± 6.34[e]	20.63 ± 6.26
	Vel AP (cm/s)	−17.08 ± 6.11[f,g]	−19.82 ± 7.34[f]	−18.93 ± 7.55[g]

Values expressed as mean ± standard deviation. Repeated measures ANOVA – pairwise comparisons:
[a] $p < 0.001$.
[b] $p < 0.001$.
[c] $p = 0.004$.
[d] $p = 0.039$.
[e] $p = 0.001$.
[f] $p < 0.001$.
[g] $p = 0.008$.

- The swing-foot unloading phase (Phase 2; between ~25 and ~55% of the task) consists of the COP movement toward the support foot, beginning with the swing-foot heel-off and ending with the ipsilateral toe-off.
- The support-foot unloading phase (Phase 3; between ~55% and 100% of the task) consists of the forward COP movement under the support foot. This phase corresponds to the initial single-support phase, followed by the double support phase of the first step, and ending with toe-off of the support foot.

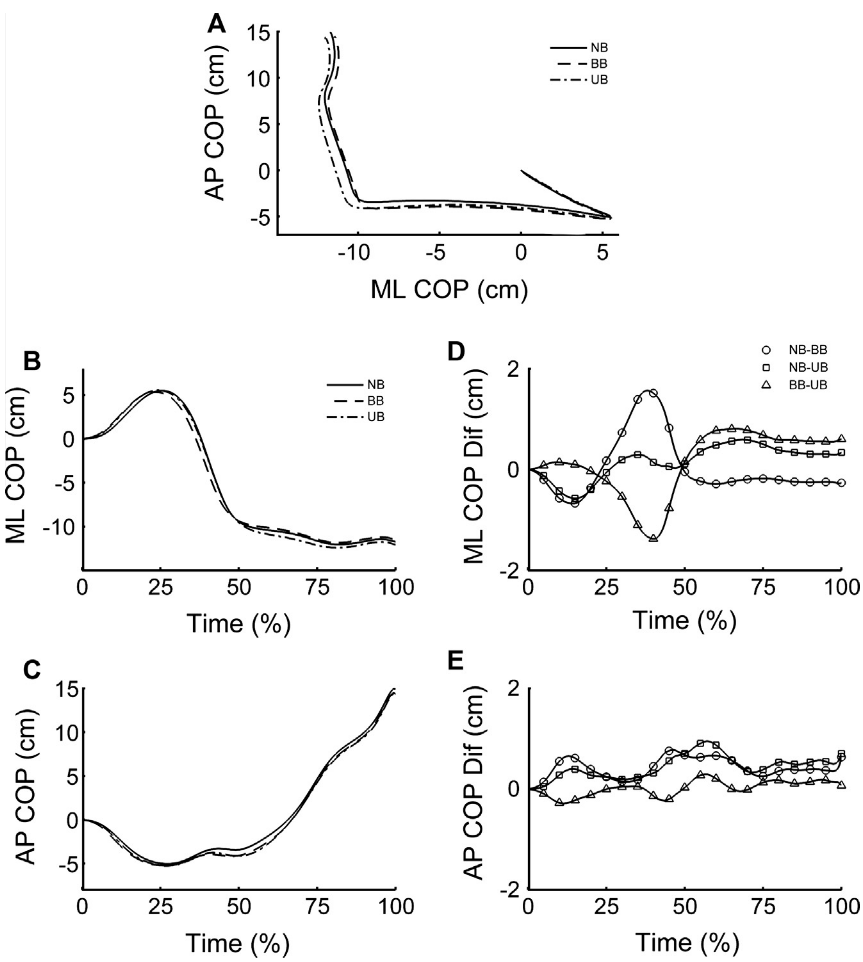

Fig. 2. Mean COP path time series in NB, BB, and UB conditions. (A) resultant COP path, (B) ML COP path, (C) AP COP path, (D) ML COP differences, (E) AP COP differences.