EFFECTS OF BACKPACK DESIGN AND FATIGUE ON POSTURE IN CHILDREN

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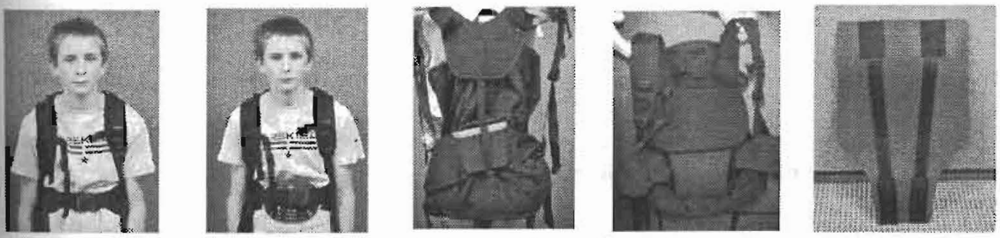
The purpose of this study was to determine which hip belt/frame sheet combination reduced postural changes associated with load carriage in children. Thirty-six 10-12 year olds walked 1000m around a track in 3 randomly assigned hip belt and frame sheet conditions. Two strides were digitized at 100 and 900m with mean head and trunk angles, as well as posture across the gait cycle recorded. Hip belt and frame sheet design did not alter head flexion separately, but interaction between the design features indicated less compromise in posture with the Back Balancer. The solid and padded frame sheet reduced counterbalance of the weight in the trunk.

KEY WORDS: load carriage, backpack design, children, posture.

INTRODUCTION: Load carriage increases head and trunk flexion, as well as body lean (Hong, 1999; Knapik, Harmon, & Reynolds, 1996; Goh, Thambyah, & Bose, 1998). Although extensive research has been conducted regarding the effect of load carriage on the adult spine (Orloff et al., 2001; Martin & Nelson, 1986; Bloom & Woodhull, 1987), until recently there has been little attention given to load carriage and its effect on a child's posture (Hong, 1999; Orloff & Warren, 2003; Grimmer et al., 2002).
At Loads exceeding 20% body weight (BW), studies show children increase forward trunk lean and head flexion (Goh et al., 1998; Pascoe et al., 1997; Li & Hong, 2001). These postural changes may place increased tensile and compressive forces on the intervertebral discs (White & Panjabi, 1990). In adult research, backpacks equipped with hip belts and frame sheets reduce the postural adjustments made by subjects (Orloff et al., 1999; Lafiandra et al., 2002). The purpose of this study was to determine which hip belt/frame sheet combination reduced postural changes associated with load carriage in children.

METHODS: This study was approved by the University of Puget Sound Institutional Review Board. Experimental procedures were explained to 36 apparently healthy, 10-12 year old children and their parents and written informed consent was obtained from both.
The three hip belt conditions included: no hip belt, padded hip belt, and the Back Balancer. The three frame sheet (FS) conditions included: no FS, padded FS, and a solid FS with aluminum stays (Figure 1). Each child was randomly assigned 3 of 9 backpack conditions. Each backpack was uniformly loaded with book bundles and lead shot equaling 15% of the subject's BW to ensure the center of mass remained constant for each condition.
Each subject walked 1000m around a track on three different testing days. A video camera (60 Hz) collected data in the saggital plane of motion at 100 and 900m. Two complete strides in both a rested and fatigued state were digitized. Head and trunk flexion means, as well as across six phases of gait were recorded (Figure 2). Absolute angles of the trunk and head were measured from the joint through the neck to the y-axis (Figure 3). A repeated measures multiple analysis of variance (3x3x2) was used to determine significance (? < .05).



Hip Belt | Back Balancer | No Frame Sheet | Padded Frame Sheet | Solid Frame Sheet

Figure 1: Hip belt and frame sheet designs.

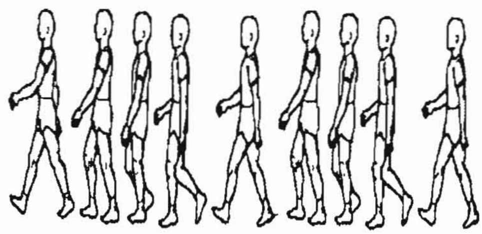


Figure 2: Phases of Gait flexion.

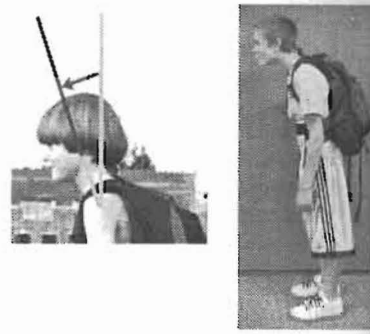


Figure 3: Measurement of trunk and head.

RESULTS: Mean head flexion was not significantly different between the hip belt or frame sheet conditions (Table 1). Although head flexion was significantly different between phases of gait, there were no differences across hip belts or frame sheets (Figures 4 & 5). Trunk flexion was not significantly altered under hip belt conditions, but was significant between frame sheets (Table 1). The padded and solid frame sheets lead to lower trunk flexion across the phases of gait (Figures 6 & 7). The interaction effect between hip belts and frame sheets were significant with conditions seven, eight, and nine producing the lowest combined mean head and trunk flexion (Figure 8). Fatigue was not a significant factor in either posture (head and trunk flexion) or with backpack design features (frame sheets/hip belts).

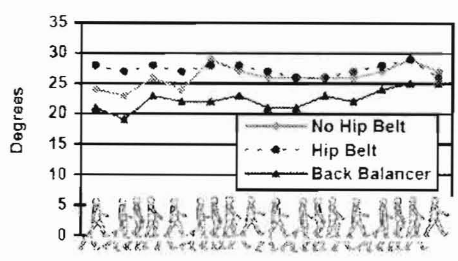


Figure 4: Head flexion during hip belt conditions.

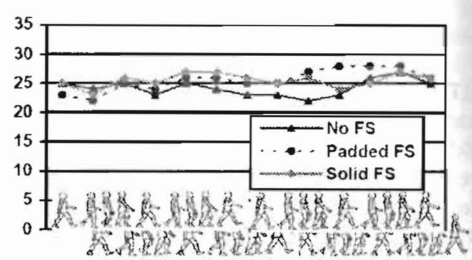


Figure 5: Head flexion during FS conditions.

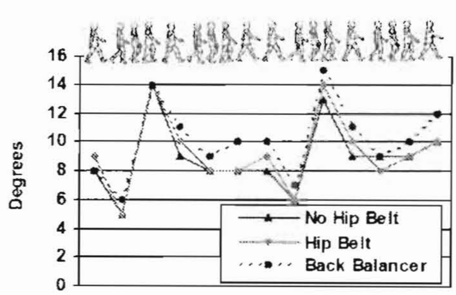


Figure 6: Trunk flexion during hip belt conditions.

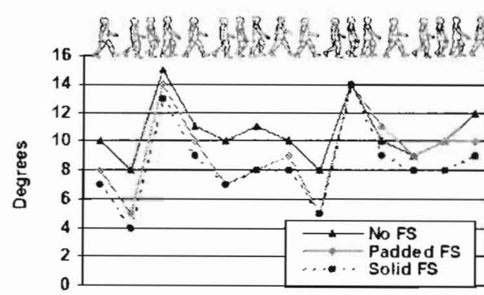
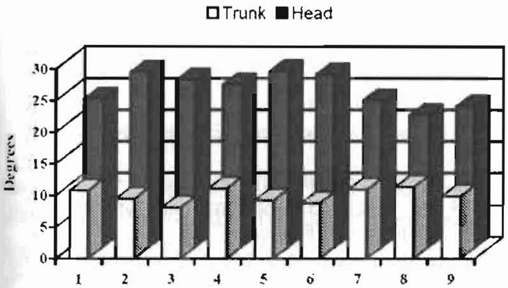


Figure 7: Trunk Flexion during FS conditions.

Table 1 Mean, SD and cell sizes for head and trunk flexion in all backpack conditions.

		Head			Trunk		
		No FS	Padded FS	Solid FS	No FS	Padded FS	Solid FS
No Hip Belt	Mean	24°	28°	27°	11°	9°	8°
	SD	11.3	16.4	11.1	5.6	3.1	4.7
	n	22	24	21	21	24	22
Hip Belt	Mean	26°	28°	27°	11°	9°	9°
	SD	11.0	9.9	11.2	4.3	4.3	4.7
	n	22	26	26	22	26	26
Back Balancer	Mean	23°	21°	22°	11°	11°	10°
	SD	10.1	12.7	10.1	5.4	4.9	4.2
	n	22	24	22	22	24	22



	No FS	Padded FS	Solid FS
No Hip Belt	1	2	3
Hip Belt	4	5	6
Back Balancer	7	8	9

Figure 8: Mean head and trunk flexion across backpack conditions.

DISCUSSION: Separately, hip belts and frame sheets did not indicate differences in head flexion, however trunk flexion was affected by frame sheet design. In adult women, stiffer framed backpacks produced significantly less head and trunk flexion (Orloff et al., 1999). The results in this study support the notion that trunk flexion is reduced in backpacks with internal suspension, but head flexion in children was not altered by backpack design features. Other authors have found differences in posture with children, but most of these studies involved weights greater than 15% of body weight (Li & Hong, 2001; Grimmer et al., 1999). Fatigue was not found to alter posture in the children used in this study. In an earlier study Orloff & Warren (2003) found fatigue affected younger children as early as 500 m. The children in the 2003 study carried lower weights in comparison to this study.

Interestingly the interaction effect between trunk and head flexion and backpack design features were significant. Although separately none of the hip belts reduced postural adjustments, when combined with frame sheet design the Back Balancer by Kelty © seemed to limit head and trunk flexion. LaFiandra et al. (2002) found that in adult men approximately 30% of the weight of a loaded backpack is carried on the hips. It may be that the Back Balancer increased intra-abdominal pressure, thus acting like a weight belt. This increased pressure would hold the lumbar spine erect (Ivancic, Cholewicki, & Radebold, 2002), as well as support more weight on the hips versus the shoulders (Poumarat et al., 1998). It should be noted that although the more ideal postures were produced in conjunction with the Back Balancer, not one of the children said they would wear the safety feature on a daily basis.

Future studies may want to investigate the effects of sternum straps on posture during load carriage, as they seem to be a popular design features in backpacks.

CONCLUSION: The Back Balancer with a stiff frame sheet produced more upright posture in children wearing backpacks. The solid frame sheet, as well as the padded frame sheet, helped reduce counterbalancing of weight in the trunk.

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Acknowledgments

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