LOWER EXTREMITY JOINT MOMENTS DURING CARRYING TASKS IN CHILDREN

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INTRODUCTION

Farm youth perform tasks that are often designed for adults, resulting in children carrying asymmetric loads that are proportionally large and/or heavy. Field measurements indicate lifting and carrying tasks performed by farm children are equivalent to industrial manual materials handling tasks that pose high injury risks [1]. Differences in gait mechanics between children and adults would be expected to contribute to age-related differences during carrying tasks. Adult-like kinetic gait patterns have been observed by 5 years of age, except that ankle plantarflexion moments are reduced in children below 9 years of age [2]. Changes in characteristics of the carrying task such as load amount, symmetry, and size would be expected to contribute to task-related differences. For example, maximum normalized hip abduction, hip internal/external rotation, knee extension, and ankle plantarflexion moments have been shown to increase when adolescent girls carried loaded backpacks [3].

Upper body joint moments are dependent upon load amount and symmetry for bucket carrying tasks. Increasing unilaterally carried loads from 10% to 20% body weight (BW) or carrying the same load amount unilaterally as compared to split bilaterally increases shoulder flexion/abduction/external rotation and L5/S1 lateral bending/axial rotation moments [4]. It is unknown whether the increases in upper body joint moments are also reflected in lower body joint moments. Bucket carrying requires balancing external loads in the frontal plane, so it was hypothesized that hip abduction and adduction moments would increase when increasing carried loads from 0% to 20% BW. Increases in normalized upper/lower body joint moments for children may indicate increased risk of injury. When considering frontal plane challenges combined with potentially reduced ankle moment generating capacity in children, it was also hypothesized that 8-10 year olds would have increased ankle inversion and eversion moments as compared to adults.

METHODS

Thirty-five participants in three age groups (8-10 years, 12-14 years, adult) participated in the study (gender distribution, average age, height, mass):

- 6/3 M/F, 8.8±1.0 year, 1.37±0.08 m, 33±7 kg,
- 9/5 M/F, 12.4±0.9 year, 1.56±0.06 m, 51±11 kg,
- 7/5 M/F, 24.0±1.7 year, 1.76±0.07 m, 72±13 kg.

Two sizes of buckets were carried: large (18.9 L, 36.8 cm high, 30 cm diameter) and small (3.8 L, 19.5 cm high, 16.7 cm diameter). The buckets were filled using sealed bags of lead shot amounting to three levels of load based on body weight: 0%, 10%, and 20% BW. Unilateral carrying tasks were performed with both large and small buckets, while bilateral carrying tasks were only performed with small buckets. Buckets were carried unilaterally with the self-selected dominant hand, and the load was evenly split between the buckets during the bilateral conditions. In total, three repetitions of the nine conditions (3 loads x 3 bucket/symmetry combinations) were completed.

Participants carried buckets 6 m while reflective markers placed on the lower extremities and pelvis were tracked by an eight optical camera system. Ground reaction forces were measured by a force platform at the halfway point of the walking path. Using inverse dynamics, lower extremity joint moments were calculated during the stance phase on the side of the body where unilateral loads were carried. Maximum ankle plantarflexion/dorsiflexion, ankle inversion/eversion, knee flexion/extension, hip flexion/extension, hip abduction/adduction, and hip internal/external rotation moments were calculated for each carrying trial, normalized by BW·height, and averaged across trials. Multivariate ANOVA was used to test for main effects of age group, carrying condition, and their interactions (significance $p<0.05/6=0.0083$ with Bonferroni correction). When significant main effects were found, post-hoc Scheffe comparisons were determined at a significance level of $p<0.05$.

Table 1. Maximum normalized joint moments as a function of age (* children significantly greater than adults, # adults significantly greater than children).

Moment (%BW·ht)	**8-10 years**	**12-14 years**	**Adults**
Ankle			
Plantarflex	0.82±0.11	0.87±0.12*	0.81±0.12
Dorsiflexion	0.20±0.07*	0.14±0.06	0.11±0.04
Inversion	0.17±0.07*	0.14±0.06*	0.12±0.03
Eversion	0.08±0.06*	0.07±0.08*	0.05±0.04
Knee			
Flexion	0.21±0.09	0.24±0.08*	0.19±0.05
Extension	0.39±0.13	0.39±0.11	0.48±0.17#
Hip			
Flexion	0.73±0.16	0.71±0.17	1.01±0.16#
Extension	0.58±0.12*	0.68±0.18*	0.43±0.10
Abduction	0.34±0.15	0.42±0.15	0.43±0.15
Adduction	0.25±0.11*	0.19±0.08	0.19±0.08
Int. rotation	0.41±0.11	0.42±0.08	0.41±0.09
Ext. rotation	0.27±0.07	0.33±0.09*	0.25±0.06

Table 2. Maximum normalized joint moments as a function of carrying task (* weight effect: 20% BW > 0% BW, # weight reverse effect: 0% BW > 20% BW, ** symmetry effect: unilateral > bilateral, ## symmetry reverse effect: bilateral > unilateral).

Moment (%BW·ht)	**Unilateral Large 0% BW**	**Unilateral Large 10% BW**	**Unilateral Large 20% BW**
Ankle			
Plantarflex	0.77±0.10	0.83±0.11	0.89±0.13*
Hip			
Abduction	0.42±0.13#	0.34±0.14	0.25±0.12
Adduction	0.18±0.08	0.23±0.09	0.29±0.11*
	Unilateral Small 0% BW	**Unilateral Small 10% BW**	**Unilateral Small 20% BW**
Ankle			
Plantarflex	0.76±0.11	0.83±0.11	0.90±0.10*
Hip			
Abduction	0.44±0.12#	0.40±0.13	0.32±0.14
	Bilateral Small 0% BW	**Bilateral Small 10% BW**	**Bilateral Small 20% BW**
Ankle			
Plantarflex	0.77±0.11	0.84±0.10	0.90±0.11*
	Bilateral Small 20% BW	**Unilateral Small 20% BW**	
Hip			
Abduction	0.54±0.13##	0.32±0.14	
Int. rotation	0.38±0.09	0.48±0.09**	

RESULTS AND DISCUSSION

Maximum joint moments were dependent upon age (Table 1) and carrying task (Table 2), but not their interaction. For age effects, ankle inversion, ankle eversion, and hip extension moments were greater for children age groups than for adults. In contrast, knee extension and hip flexion moments were greater for adults than for both children age groups. For load amount, ankle plantarflexion moments were greater when carrying unilateral large, unilateral small, and bilateral small buckets at 20% as compared to 0% BW. Hip adduction moments were greater when carrying a unilateral large bucket at 20% BW than at 0% BW, while the opposite effect was seen for hip abduction moments. For symmetry effects, internal hip rotation moments were greater when carrying a unilateral small bucket than for bilateral small buckets at 20% BW, while hip abduction moments showed the opposite effect. There were no significant differences for bucket size effects.

The first hypothesis was not supported because while hip adduction moments increased with load amount, hip abduction moments actually decreased. In general, hip abduction moments decreased in tasks involving higher load amounts and unilateral carrying. Hip abduction moments may be less effective during these challenging tasks, with individuals instead utilizing upper body postural adjustments such as generating L5/S1 lateral bending moments [4]. The second hypothesis was supported since ankle inversion and eversion moments were greater for 8-10 years olds than for adults. This is of practical concern for ankle sprains, especially in rough and/or muddy terrain beyond idealized lab conditions. Children also appear to rely more on hip extension moments, while adults rely more on knee extension and hip flexion moments. Overall, carrying 20% BW loads that increase moments in the low back and shoulders also increase moments in the ankles, particularly in children.

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