Effect of Backpack Position on Foot and Ankle Kinetics and Kinematics

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Introduction

Students carry backpacks in varying positions, which can impact the demands on their bodies in different ways. The purpose of this study was to assess if carrying a backpack in different positions impacts the kinetics and kinematics at the foot and ankle. Based on biomechanics and a literature review, it was hypothesized that stance phase time and vertical ground reaction force (VGRF) would increase in all backpack conditions, center of pressure (COP) would shift toward the backpack (posterior or lateral), and plantarflexion range of motion (ROM) would increase during toe off in stance phase.

Methods

Two female college students from the research team acted as subjects (P1 and P2). They ambulated on a Noraxon Myopressure treadmill at a self-selected speed for one minute per trial. Trials included a control (no backpack) and carrying the backpack with 2 straps, 1 strap on preferred shoulder, and in preferred hand. The Noraxon Myopressure Bilateral Gait Report provided data including: stance phase percentage difference between sides, COP parameters, and average GRF force curves. Trials were recorded on an iPad and the Hudl app was used to approximate dynamic ankle plantarflexion ROM. The 7.8 kg backpack was one of the participant's backpacks on the day of data collection, ensuring that it represented a typical backpack weight.

Results

For both participants, stance phase percentage difference was approximately the same between baseline and the 2 straps condition, though which side they favored and the magnitude of this difference varied between participants (Table 1). Stance phase symmetry for the remaining conditions was opposite between the 2 participants, so no definitive conclusion can be drawn.

VGRF increased under all conditions and with both participants. However, the side that had increased forces varied based on condition (Table 2 & 3). With 2 straps, VGRF increased symmetrically. With one strap, VGRF increased more on the contralateral side of the backpack. With handheld, VGRF increased more on the ipsilateral side of the backpack.

There were no significant COP differences observed in either participant in anterior/posterior excursion throughout all conditions (Table 4). There were no consistent changes noted in lateral symmetry between the conditions and therefore no patterns could be identified (Table 5).

For P1, there was decreased plantarflexion ROM at push off when carrying the backpack in hand. For P2, there was increased plantarflexion ROM at push off when carrying the backpack in one hand and with one strap (Table 6).

Discussion/Clinical Implications

The varying effects of backpack position on the foot and ankle is likely to impact physical therapy treatment. With a client who carries a backpack with 2 straps, stance phase symmetry is not necessary to measure clinically, as it does not result in kinematic changes. For unilateral carrying (1 strap and handheld), each client should be assessed individually for changes in stance phase symmetry. The increased VGRF demonstrates larger external moments, which leads to larger internal moments, thereby changing how the body produces the necessary force for ambulation. The typical backpack weight selected for this study may not be enough to see clinically significant changes in gait kinematics. Lastly, increased plantarflexion ROM may be necessary with backpack carriage.

This study attempts to fill a gap in the literature. Most research on injuries related to backpack carriage focuses on back injuries, spatiotemporal gait changes, or school-aged children. Measuring changes in kinetics and kinematics at the foot and ankle can help illuminate how to reduce injuries when combined with results from other studies. Future studies with larger randomized sample sizes are needed to make definitive recommendations about the best way to carry backpack to decrease kinematic changes and injury risk.

Conclusions

In this study, kinematic changes at the ankle while carrying a backpack in various positions were measured. Carrying a backpack alters stance phase symmetry, increases VGRF, does not change COP and can change plantarflexion ROM.

It is, however, unknown if and how kinematic changes at the ankle increase injury risk. Most individuals self-select to use the 2-strap carrying method, which was most similar to baseline, indicating that this may be the safest way to carry a backpack. Due to the limitations in this study, a definitive recommendation cannot be made at this time and further research is necessary.

References

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Table 1: Stance Phase

	Baseline	2 Straps	1 Strap	Handheld
P1	-1	-0.8	-0.07	-3.1
P2	0.4	0.4	-1.3	0
+ value = more time spent in right stance phase than left stance phase - value = more time spent in left stance phase than right stance phase				

Table 2: VGRF P1

	Baseline	2 Straps	1 Strap	Handheld
Left	544 N	624 N	620 N	612 N
Right	549 N	619 N	603 N	635 N

Table 3: VGRF P2

	Baseline	2 Straps	1 Strap	Handheld
Left	721 N	790 N	791 N	776 N
Right	749 N	809 N	805 N	805 N

Table 4: Center of Pressure, Anterior & Posterior Position

	Baseline	2 Straps	1 Strap	Handheld
P1	135 mm	143 mm	139 mm	137 mm
P2	142 mm	148 mm	148 mm	150 mm

Table 5: Center of Pressure, Lateral Symmetry

	Baseline	2 Straps	1 Strap	Handheld
P1	2 mm	4 mm	0 mm	1 mm
P2	1 mm	2 mm	-2 mm	3 mm

Table 6: Plantarflexion ROM

	Baseline	2 Straps	1 Strap	Handheld
P1 Push Off	46°	46°	45°	**33°**
P2 Push Off	31°	29°	**45°**	**46°**
P1 Midstance	10°	11°	14°	13°
P2 Midstance	8°	9°	10°	8°