Materials and Methods

Participants and protocol

Three male participants (age: 28 0y; height: 185 6.56 cm; mass: 94.33kg 9.71kg) were recruited in the study. participants were given unlimited time to warm-up. Each participant performed of 5 steps walking with body weight, and 3 trials of 5 steps walking with wearing a backpack of 10% their body weight.

Trial conditon

Motion data was captured using a commercially available markerless [mocap system](https://www.sciencedirect.com/topics/nursing-and-health-professions/motion-analysis-system) (Theia 3D, Theia Markerless Inc., Kingston, ON) operating at 100 Hz setting up with the vertical direction was represented by the y-axis, anterior to the y-axis and in the direction of movement was the positive x-axis, and orthogonal and to the right of the x- and y-axes was the positive z-axis. Group reaction data was captured using via two force plates embedded underneath a batter’s box at 1,000 Hz (Bertec Corp.; Columbus, OH, USA).

Data Analysis

The position data from selected trials were low-pass filtered at 6Hz. Secondary points were derived from the filtered coordinates, including the hip, knee, trunk, and foot center of mass in the X and Y axes. The body was modeled as a 2D structure with multiple lines to calculate joint angles. Ankle dorsiflexion/plantarflexion: Knee-ankle line relative to foot-ankle line. Knee flexion/extension: Trunk-hip line relative to hip-knee line. Hip flexion/extension: Trunk-hip line relative to knee-hip line. Trunk flexion/extension: Global Y-axis relative to trunk-hip line. Angular velocities were computed using the first derivative (positive = flexion, negative = extension). Steps on the force plate were analyzed with the preceding toe-off. Stride length was the foot distance between consecutive toe-offs, and stride time was the time between them. Data was time-normalized to 100% of the gait cycle (toe-off to toe-off) for angular velocity analysis. This analysis was performed using Python 12.7.3.

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**Figure 1.** The function of related angle

The following variables were extracted from each step for statistical analysis:

* Peak extension angular velocity of each joint ( in cm/s)
* Time of peak extension angular velocity of each joint (time in % of gait cycle)
* Peak flexion angular velocity of each joint (in cm/s)
* Time of peak flexion angular velocity of each joint ( time in % of gait cycle)
* Angular velocity of heel down of each joint (in cm/s)
* Angular velocity of toe of each joint (in cm/s)
* Stride length (in cm)
* Stride time (in ms)

Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics 28. An independent t-test was performed to compare the differences between the two conditions: body weight gait and gait with a 10% body weight backpack. The analyzed variables included the angular velocity of the ankle, knee, hip, and trunk at maximum extension and flexion, as well as the timing of these events. Additionally, angular velocity at heel contact and toe-off during the gait cycle was examined. Statistical significance was set at p < .05.

Results

Significant differences were observed between the two conditions in the timing of maximum trunk extension angular velocity (96 2 VS 83 16ms), the angular velocity of the ankle (15.4 44.8 VS 16.1 11.1 cm/s), and hip (-12.1 23.9 VS 6.0 40.5 cm/s),at heel contact, and stride length (155.9 31.1 VS 167.1 24.7 cm) (Table 1, Figure 2). However, no significant differences were found in the other analyzed variables.

Table 1. the variables show significant differences between two conditions

|  |  |  |
| --- | --- | --- |
|  | T-value | p-value |
| Time of max extension trunk angular velocity | 2.568 | < .001 |
| the angular velocity of ankle at heel contact | -.038 | .008 |
| the angular velocity of hip at heel contact | -1.120 | .044 |
| Stride length | -.422 | .007 |

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**Figure 2.** the ankle, knee, hip, and trunk angular velocities of the gait cycle in two conditions

Discussion

The present study investigated the effects of carrying a 10% body weight backpack on gait parameters, specifically focusing on angular velocity changes in the ankle, knee, hip, and trunk during the gait cycle. The findings revealed significant differences in the timing of maximum trunk extension angular velocity, the angular velocity of the ankle and hip at heel contact, and stride length between the two conditions.

The observed delay in the timing of peak trunk extension angular velocity when carrying a backpack suggests an adaptive response to additional load. The earlier occurrence of peak trunk extension angular velocity in the loaded condition may indicate that carrying backpack might affect postural control and movement coordination, potentially leading to compensatory trunk motion to maintain stability and forward propulsion.

The significant differences in ankle and hip angular velocities at heel contact suggest load-induced modifications in lower limb mechanics. Constantly, previous study indicated that carrying 10% body weight backpack will change the hip and ankle angular motion [4]. Decrease in hip and ankle angular velocity at heel contact in the loaded condition may be attributed to altered neuromuscular control strategies aimed at reducing impact forces and maintaining balance. The increase in stride length when carrying a backpack may be a compensatory mechanism to counteract the additional weight and maintain a normal gait pattern [1, 5, 9].

Conclusion

In summary, carrying a 10% body weight backpack leads to notable changes in specific gait parameters, particularly in trunk extension angular velocity timing, ankle and hip angular velocities at heel contact, and stride length. These findings highlight the body's adaptive responses to external load, emphasizing the importance of considering load effects in gait biomechanics. Future studies should explore the long-term impact of load carriage on gait mechanics and investigate potential strategies to mitigate load-induced gait alterations.

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