EFFECTS OF SPEED AND CADENCE ON THE LOWER EXTREMITY JOINT REACTION FORCES AND TORQUES DURING WALKING

T. W. Kernozek1,2, Jessica Woodworth1, Kimberly Harbst1
1Physical Therapy Department, University of Wisconsin-La Crosse, La Crosse, WI, 2Gundersen Lutheran Sports Medicine, La Crosse, WI
E-mail: kernozek.thom@uwlax.edu

INTRODUCTION
Lower extremity modeling may yield useful information for injury prevention (Novacheck 1999; Winter 1992). A relationship between gait velocity and joint forces has been suggested by previous research. The speed of walking affects the ground reaction forces that may affect joint kinetics. Devita and Hortobagyi (2000) reported that the lower extremity joint torques were reduced with aging. Furthermore, Devita (2000) stated that elderly adults select a slower gait velocity with a shorter step length. However, the relationship between cadence and gait velocity and the resultant effect on joint forces has not been examined previously. The terms “Gait velocity” and “cadence” have often been used interchangeably in the literature. Thus, the effect of isolated alteration of cadence or gait velocity on resultant joint kinematics and kinetics are unknown. The purpose of this study was to examine these effects.

METHOD
Fifteen healthy, 20-25 year-old female subjects were studied. Fifteen reflective markers placed on the subjects on the pelvis and lower extremities prior to testing using the Helen Hayes marker set (Kadaba et al.1990). Markers were tracked by a 3-D motion analysis system (Motion Analysis Corporation, Santa Rosa, CA) at 60 Hz. Static data were collected to establish hip, knee and ankle joint centers. Subjects walked along a 15-meter walkway using photocells to monitor walking speed. A digital metronome provided auditory feedback on the specified walking cadence. During each walking trial, subjects contacted a force platform (Bertec, Columbus, OH) located flush with the walkway surface to capture ground reaction force data at 1200 Hz. OrthoTrak software (Motion Analysis Corporation, Santa Rosa, CA) was used to create the link segment model and calculate the joint reaction forces and torques at the right hip, knee and ankle.

Standing height, weight and bilateral foot lengths were recorded. The subject’s normal walking speed was measured using photocells and averaged over ten trials. The subject’s normal walking cadence was matched to a digital metronome. Five combinations of gait speed and cadence were measured: normal speed-cadence, normal cadence-speed 15% above (+15% speed), normal cadence-speed 15% below (-15% speed), normal speed-cadence 15% above (+15% cadence), and normal speed-cadence 15% below (-15% cadence). Each subject was instructed to walk along a 15-meter walkway at a specified speed while matching her cadence to the auditory cues of the metronome. The subject was required to contact a force platform with her right foot.

Kinematic and kinetic data were time-normalized and average data were presented for each condition. A 2-way ANOVA with repeated measures (alpha = 0.05) was used to analyze the data.
RESULTS AND DISCUSSION

Range of Motion during Gait Cycle
Subjects demonstrated the least ankle and hip joint excursion in the preferred cadence condition with walking speed reduced by 15% (-15% speed). Conversely, knee range of motion was maximized at a walking speed of 15% below normal (-15% speed) and minimized at a walking speed of 15% above normal (+15% speed). There were no changes with cadence either 15% above or below (±15% cadence).

Joint Compression Forces during Stance
Ankle joint and knee joint compression forces were minimized at a walking speed of 15% below preferred with preferred cadence (-15% speed). Increased cadence at preferred gait speed reduced ankle, knee and hip joint compression forces (+15% cadence) (see Figure 1).

Anterior Shear Joint Forces during Stance
Anterior ankle, knee and hip joint forces were minimized at a speed 15% below preferred walking speed (-15% speed).

Posterior Joint Forces during Stance
Reducing either walking speed or cadence by 15% (-15% speed or -15% cadence) resulted in a reduction in the posterior ankle joint forces.

Figure 1: Compression at the Knee during Stance

Moments during Stance
Peak flexor and extensor moments at the ankle, knee, and hip were minimized when the subject walked at a speed 15% below preferred (see Figure 2).

SUMMARY
The greatest reduction in lower extremity joint reaction forces and torques occurred when subjects walked reduced speed (-15% speed) rather than cadence (-15% cadence). Lower extremity compressive forces were minimized when the subject walked at a cadence that was faster than preferred (+15% cadence). The combined effects of reducing walking speed and increasing cadence results in a shorter stride length. Overall, reducing walking speed has a slightly greater effect on reducing joint compression and peak muscle moments during walking than altering cadence.

REFERENCES

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