The Effects of Small Changes in Cadence on Sagittal Plane Kinematics and Kinetics

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Introduction: Individuals normally show some degree of variability in walking patterns from stride to stride. Many studies have shown that walking speed influences stride dimensions as well as lower extremity kinematics and kinetics (1). Some researchers choose to tightly control walking velocity by using treadmills, however, treadmill walking has been shown to elicit different walking patterns than over ground walking (2). In uninjured individuals and those with minimal disability self-select a walking speed that remains consistent for that individual (3). Researchers are often satisfied using the self-selected or free walking speed because the lower extremity kinematic patterns are relatively consistent, particularly in the sagittal plane (4). However, the question remains, what amount of variability in the free walking speed of subjects is acceptable? The purpose of this study was to determine the effect of small changes in walking cadence on lower extremity kinematics and kinetics in an effort to provide guidelines as to a range variability that is acceptable in research on walking.

Statement of Clinical Significance: Treatments that effect walking ability are often assessed with automated motion analysis however some investigators fail to account for walking speed when interpreting results. Clinicians and researchers must appreciate the effect of variable walking cadence on joint kinematics and kinetics in order to evaluate gait literature.

Methodology: Eighteen subjects without injury, 7 male and 11 female, ages 18- 37 (mean 21.9; +/-4.42 years) were tested using a six camera, passive, three-dimensional motion analysis system (Vicon Workstation, Oxford Metrics, London, England). Video data were collected at 120 Hz (filtered with a low pass, 4th order, phase corrected Butterworth filter, with a cut off frequency of 6 Hz. Kinetic data were collected at 960 Hz using a force platform (Bertec Corporation, Worthington, OH). Force data were filtered with a 4th order, phase corrected Butterworth filter, with a cut off frequency of 50 Hz.

A digital metronome (DM-20, Seiko, Maidenhead, Berks) was set to the subject's self selected free walking cadence and subjects synchronized their steps with the metronome and 5 strides were collected at cadences including 5% slower, and 5% and 10% faster cadences. Joint motions and moments were calculated from markers (located on the pelvis, and bilaterally on the thigh, shank and foot) and force plate data using Move3d software (MOVE3D, NIH Biomotion Laboratory, Bethesda MD). Kinetic data were normalized to body mass and vertical ground reaction force was normalized to body weight. Differences in kinematics and kinetics were evaluated using repeated-measures ANOVA followed by Tukey's Honest Significant Difference post hoc tests (SPSS, SPSS Inc, Chicago, IL). Significance was determined by level of $p<0.05$.

Results: As one would expect, speed, cadence and stride length varied linearly. Relatively few differences were observed in the sagittal plane kinematics and when differences were observed they were generally between the slow and free cadences (see Table 1 for partial results). Differences were observed in the peak vertical ground reaction forces during loading response (Table 1) and terminal stance. Joint moments and power were much more influenced by walking cadence with differences observed between all conditions in hip, knee and ankle moments and power (see Table 1 for partial results).

Table 1. Representative Results of Kinematic & Kinetic Changes due to Walking Cadence

Point in Cycle	**5% Slower**	**Free Speed**	**5% Faster**	**10% Faster**	**Post-hoc comparison**
Hip Flexion IC	33.54 (5.8)	34.781 (6.1)	35.4 (6.1)	35.6 (5.9)	F ≠ S*
Peak Vertical Force (%BW) during LR	1.174 (0.119)	1.215 (0.124)	1.24 (0.126)	1.26 (0.12)	F ≠ S* F ≠ +5%* F ≠ +10%*
Peak Hip Extensor Moment (Nm/kg)	-1.145 (0.333)	-1.26 (0.33)	-1.44 (0.44)	-1.60 (0.49)	F ≠ S* F ≠ +5%* F ≠ +10%*
Ankle PF Power Generation (W/kg)	3.41 (0.72)	3.76 (0.72)	4.10 (0.96)	4.19 (0.93)	F ≠ S* F ≠ +5%* F ≠ +10%*

S=5% slower cadence
F= Free cadence
+5% = 5% faster than free cadence
+10% = 10% faster than free cadence

IC = Initial contact
LR = Loading response
MS = Midstance
TS = Terminal Stance

Discussion: The findings of this study indicate that changes in sagittal plane kinematics are minimally affected by small changes in walking cadence while greater affects are seen in the kinetic data underscoring the need for careful interpretation of data when differences in walking cadence exist. Consistent differences were observed in the ground reaction forces and joint kinetics. This is not surprising since joint kinetics are based on joint motions, gravitational forces and ground reaction forces. When the variability in walking cadence is held to within 5% of the free walking speed there are few changes in the hip, knee or ankle kinematics, however, when joint kinetics are in question, investigators may want to hold walking speeds from changing less than 5% to ensure that changes found in their studies are not simply due to changes in walking speed.

References:

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