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Pregnant women exaggerate cautious gait patterns during the transition between level and hill surfaces

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ABSTRACT

Falls are the leading cause of nonfatal injury across all age groups and a common incident for pregnant women. Thus, there is a critical demand for research to evaluate if walking strategies in pregnant women change throughout pregnancy in order to effectively intervene and minimize the incidence rate. The aim of the present study was to analyze modifications in temporal–spatial parameters as well as muscle activity during hill walking transitions in pregnant women between gestational week 20 and 32. Based upon previous literature, we hypothesized that in comparison to level walking, the transition strides of pregnant women would be distinct between trimesters in order to accommodate the physical changes within twelve weeks. Thirteen pregnant women completed a series of randomly assigned walking conditions on level and hill surfaces during gestational week 20 and 32. Our results demonstrated that pregnant women modulated their gait patterns throughout pregnancy with additional joint flexion as well as muscle activity at the ankle, knee and hip. In summary, pregnant women exaggerate cautious gait patterns by walking slower and wider with greater joint flexion and muscle activity in order to safely transition between level and hill surfaces.

1. Introduction

Falls are the leading cause of nonfatal injury across all age groups in the United States with over 9 million incidences reported in 2010 (Centers for Disease Control and Prevention, 2011). Recently, Dunning et al. (2003) evaluated falls in pregnant women and of the almost 4000 participants, 27% fell during their pregnancy. Changes in elevation are the primary source of falling accidents as a variation in walking surface of 6 mm is sufficient to cause a fall (Bell et al., 2010). Therefore, sidewalk cracks, street curbs, natural hills, and indoor stairs are all examples of high-risk areas. Taken together, these findings illustrate the critical demand for research to evaluate if walking strategies in pregnant women change throughout pregnancy in order to effectively intervene and minimize the incidence rate.

Despite the numerous physical and hormonal changes that occur during pregnancy such as weight gain, center of mass shift, joint laxity, and postural sway, there are few published accounts of biomechanical factors leading to an increased number of falls. Foti et al. (2000) completed a rigorous series of tests and concluded there were no significant differences between pregnant and non-pregnant women in walking velocity, stride length, or stride frequency during level walking. However, they did report significant differences in anterior pelvic tilt as well as joint moments and powers. Wu et al. (2004) reported similar reductions in pelvic and thoracic rotations but also stated that comfortable walking velocity was reduced in pregnant women. Last, Bird et al. (1999) found that step width increased throughout pregnancy while walking on level surfaces. Based upon these studies, pregnant women may demonstrate a greater recruitment of the hip abductors and ankle extensors in order to compensate for the anatomical modifications.

These previous evaluations of pregnant women walking were all performed on level ground. Since the majority of falls occur on non-level surfaces, it is possible that pregnant women adapt a unique gait pattern while transitioning between level and hill surfaces. We recently performed a study in non-pregnant adults on the biomechanics of the transition stride between level and hill surfaces in order to assess fall risk (Gottschall et al., 2011). Our results illustrated that adults adopt unique gait strategies depending upon the type of transition by modifying temporal–spatial variables. Thus, since non-pregnant adults modulate their walking mechanics during hill transitions, it is likely that pregnant women also make adjustments during these scenarios.

To date, there are no published data on the kinematics or muscle activity of pregnant women walking on hill surfaces or transitioning between hill surfaces. However, Lay and colleagues reported how these biomechanical variables are modulated in

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non-pregnant adults (Lay et al., 2007, 2006). In short, they demonstrated that walking adults adjust their posture during hill walking as well as increase knee and ankle flexion for clearance during toe off and heel strike (Lay et al., 2006). These kinematic modifications parallel those of muscle activity. Compared to level walking, during uphill walking, muscle activity was typically greater to aid in propulsion and stability. Likewise, during downhill walking extensor muscle activity was greater for power absorption (Lay et al., 2006).

Hence, the purpose of the present study was to analyze modifications in temporal–spatial parameters as well as muscle activity during hill walking transitions in pregnant women between gestational week 20 and 32. Our primary research question was, in comparison to level walking, are the transition strides of pregnant women distinct between trimesters? Specifically, we hypothesized that compared to gestational week 20, the transition stride speed would be slower, stance time would be greater, step width would be wider, rectus femoris activity would be greater, and lateral gastrocnemius activity would be greater at gestational week 32.

2. Methods

2.1. Participants

Thirteen pregnant women [age = 31.31 (4.53) yr, height = 1.67(0.05) m, mass 20 weeks = 70.88(13.94) kg, mass 32 weeks 79.46(14.22) kg (*standard deviation*)] completed the protocol (Table 1). All of the participants gave written informed consent following the guidelines of The Pennsylvania State University Human Participants Institutional Review Board Committee.

2.2. Protocol

Each participant completed a standing trial and a series of randomly assigned walking conditions on the level and hill surfaces between gestational week 20 and 32. All of the walking trials were completed at a self-selected velocity along a 25 m walkway. We utilized a custom-built portable apparatus composed of a 2.4 m ramp inclined at 15° continuous with a 4.8 m plateau (Fig. 1). The minimum total walking distance was 14.2 m.

A complete data set was comprised of the successful completion of 5 level walking trials and 30 hill walking trials. Due to the limited collection volume of the motion analysis system, we shifted the apparatus to collect the appropriate stride. We collected 5 walking trials during the 2 hill only strides; downhill ramp (DN), and uphill ramp (UP), as well as, each of the following 4 transition strides; level plateau to downhill ramp (L-DN), downhill ramp to level floor (DN-L), level floor to uphill ramp (L-UP), and uphill ramp to level plateau (UP-L). A trial was defined as successful if a full stride of the left leg from toe-off to toe-off was captured in the collection volume. A stride was defined in this way in order to evaluate the step length and step width during the first double support after the transition.

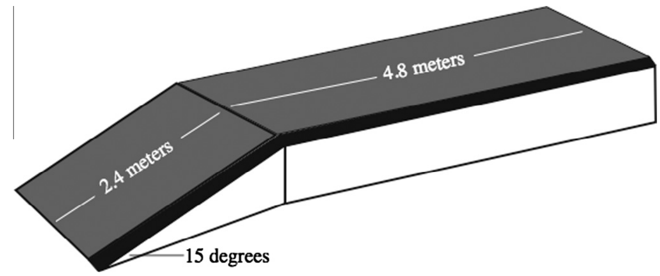

Fig. 1. Custom-built portable apparatus composed of a: (A) 2.4 m ramp inclined at 15° with a 4.8 m plateau.

2.3. Kinematics

We used a six-camera, passive marker 3D photogrammetry system (Motion Analysis Corporation, Santa Rosa, CA) with a calibration residual of less than 0.5 mm in a capture volume of approximately 2 m × 2 m × 2 m. We collected motion data with EVaRT software (Version 3.21, Motion Analysis Corporation) at 100 Hz for markers placed bilaterally on the first metatarsal (toe), calcaneus (heel), lateral malleolus (ankle), lateral epicondyle (knee), anterior superior iliac spine (hips), and the sacral crest (back). The data was processed with a Matlab program (Version R206b, The Mathworks, Natick, MA), which included a lowpass filter for the marker trajectories at 7 Hz (fourth-order, dual-pass, Butterworth).

2.4. Electromyography

We measured electromyography (EMG) using a wired amplifier system (Bortec Octopus AMT-8, Calgary, AB, Canada) at 1000 Hz with a bandpass filter setting of 5–500 Hz. The EMG data was also collected through the EVaRT program and synchronized with the kinematic data. We placed 1 cm × 1.5 cm bipolar, silver–silver chloride, surface electrodes (Vermed, A10041, Bellows Falls, VT) with an inter-electrode distance of 2 cm over the tibialis anterior (TA), lateral gastrocnemius (LG), biceps femoris (BF), and rectus femoris (RF) (Cram and Kasman, 1998). The proper placement of the electrodes was verified with a series of functional tests (Winter et al., 1994). We created linear envelopes from the EMG signals by high pass filtering the data at 20 Hz to remove the movement artifact, full wave rectifying, then low pass filtering at 5 Hz.

Table 1
Temporal–spatial parameters for each of the 7 walking conditions (downhill ramp (DN), uphill ramp (UP), level plateau to downhill ramp (L-DN), downhill ramp to level floor (DN-L), level floor to uphill ramp (L-UP), and uphill ramp to level plateau (UP-L)) within 20 and 32 weeks of gestation. All data are represented as the mean raw values of each trial averaged for all 13 participants, mean (standard deviation). Italicized values represent level walking. Bold values represent a statistically significant difference for the hill condition compared to level walking while shaded cells represent a statistically significant difference between 20 and 32 weeks gestation ($p < 0.05$).

Dependent variable		Transition stride						
	weeks	L-DN	DN	DN-L	*LEVEL*	L-UP	UP	UP-L
Speed (m/s)	20	**1.18** (0.30)	**1.18** (0.27)	**1.42** (0.22)	*1.37 (0.21)*	1.30 (0.22)	**1.18** (0.17)	**1.22** (0.21)
	32	**1.12** (0.26)	**1.18** (0.30)	**1.48** (0.29)	*1.37 (0.24)*	1.32 (0.24)	**1.15** (0.21)	**1.20** (0.18)
Step length (cm)	20	**68.79** (6.62)	**67.41**(7.31)	**80.22** (8.83)	*72.81 (9.16)*	79.19 (8.52)	**74.05** (9.76)	**78.67** (7.58)
	32	**64.77** (8.35)	**65.73** (8.22)	**81.02** (7.76)	*73.19 (10.62)*	79.24 (10.13)	**74.21** (10.82)	**79.02** (10.66)
Stance time (ms)	20	**611.02** (36.86)	621.75 (33.76)	**608.41** (33.76)	*630.94 (33.04)*	631.67 (32.46)	**647.12** (31.35)	629.63 (37.31)
	32	**621.22** (33.33)	625.57 (37.61)	**612.44** (27.73)	*632.47 (25.01)*	633.40 (25.37)	**658.79** (27.65)	633.45 (36.03)
Step width heel (cm)	20	**11.89** (2.71)	10.28 (2.76)	9.02 (3.68)	*9.00 (2.49)*	9.33 (2.47)	8.78 (1.78)	9.23 (3.03)
	32	**11.99** (3.76)	110.88 (2.10)	10.22 (3.33)	*10.21 (2.30)*	10.02 (1.62)	10.49 (1.50)	10.46 (2.76)