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Full Length Article

Changes in gait and posture as factors of dynamic stability during walking in pregnancy

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ABSTRACT

Changes in gait and postural control during pregnancy may lead to increased fall rates during walking relative to non-pregnant women. Due to lack of empirical evidence on balance and postural control in dynamic conditions, the primary aim of this study was investigate the changes in gait and postural control as factors of stability during walking. Gait and posture of thirty-five (35) pregnant women (27 ± 6.1 years) were analysed at self-selected walking speed, and at different stage of pregnancy. The results indicate that although the gait kinematics did not differ between the trimesters, significant associations were noted between the step width, the lateral trunk lean, and the medio-lateral deviations in centre of gravity and centre of pressure. In contrast to the static conditions, anterior-posterior postural sway is not present during walking, whereas the lateral trunk lean is the primary factor women use in pregnancy to keep the centre of gravity closer to the base of support. Postural changes and those in gait kinematics were largely affected by the relative mass gain, rather than the absolute mass. Considering the importance of relative mass gain, more attention during healthy pregnancy should be given to monitoring the timing of onset of musculoskeletal changes, and design of antenatal exercise programs targeting core strength and pelvic stability.

1. Introduction

Due to changes in gait and posture, women during pregnancy are more predisposed to falling relative to nulligravidae (Butler, Colón, Druzin, & Rose, 2006; Dunning et al., 2003; Inanir, Cakmak, Hisim, & Demirturk, 2014; Jang, Hsiao, & Hsiao-Wecksler, 2008; McCrory, Chambers, Daftary, & Redfern, 2011). Studies on balance during quiet standing demonstrate an increase in postural sway, especially later in pregnancy, which leads to decrease in balance and stability (Butler et al., 2006; Inanir et al., 2014). However, ***static*** measures of balance may not predict postural responses in *dynamic* conditions (McCrory, Chambers, Daftary, & Redfern, 2010) and therefore do not explain changes in spatio-temporal parameters used to maintain gait stability. Considering most falls occur during walking, the understanding of the interaction between gait and postural adaptations during pregnancy may provide useful information on the mechanisms of locomotor stability.

Preserving balance and postural control during walking requires the maintenance of the centre of mass (COM) within the base of support (BOS) (Hof, Gazendam, & Sinke, 2005; Winter, 1995). Recent studies demonstrate that when gait stability is challenged, as in patients with gait abnormalities or due to external factors such as a change in surface or avoiding an obstacle, common gait adaptations associated with maintaining stability are an increase in step width, decrease in step length, or even a change in step

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frequency (Dingwell & Marin, 2006; Hak et al., 2012, 2013; Peebles, Reinholdt, Bruetsch, Lynch, & Huisinga, 2016). However, during pregnancy changes in step length and width may be a mechanical consequence of increased pelvic width and an anterior pelvic tilt (Foti, Davids, & Bagley, 2000), hence whether locomotor stability may be attained via gait changes is uncertain.

Gait stability also relies on the spatiotemporal pattern of coordination between upper and lower body segments (Earhart, 2013). However, during pregnancy, asymmetric weight gain and subsequent postural adaptations alter the location of the COM which results in diminished intra-segmental coordination (Wu et al., 2004), a decrease in neuromuscular control and coordination (Wu et al., 2002, 2004), and altered (gait) biomechanics (Foti et al., 2000; Krkeljas & Moss, 2015; Lymbery & Gilleard, 2005). Considering the continuous weight gain during pregnancy, trunk moment of inertia will also continually alter leading to changes in trunk dynamics (Gilleard, 2013; Wu et al., 2004).

Interestingly, there is a paucity of data on postural and trunk kinematics during gait in pregnancy. Wu et al. (2004) demonstrated altered intra-segmental coordination between the trunk and pelvis as a result of pregnancy, but they also reported large intra-subject variability and limited gait parameters. More recently, Gilleard (2013) demonstrated a linear trend in step width, step length, and transverse motion of the trunk and pelvis with progression of pregnancy, however, the study was limited in sample size ($n = 9$). Therefore, the primary aim of this study was to investigate the changes in postural dynamics during walking, and determine its effect on gait stability during pregnancy. The results of this study are highly relevant for development and application of interventions for the prevention of falls in populations with locomotor instability.

2. Methods

2.1. Subjects

Thirty-five (35) healthy pregnant women (mean age 27 ± 6.1 years) volunteered for the study at different stages of pregnancy distributed as follows: first trimester 9–12 weeks ($n = 14$), second trimester 20–22 weeks ($n = 20$) and third trimester 28–32 weeks ($n = 10$). Subjects were recruited by advertisements in the local press, the consulting rooms of local gynaecologists and a local health clinic. Participants were excluded from the study if they were considered a high-risk according to ACSM guidelines (Artal & O'Toole, 2003), were unable to complete the test procedures and presented with physical limitations or musculoskeletal pathologies that may prevent movement. Prior to data collection all participants gave written consent for participation in the study. The study was approved by the University's Human Research Ethics committee.

2.2. Procedures

Prior to any data collection participants were asked to change in appropriate clothing, cycling shorts and a tank top which would allow marker placement on the skin and minimize any artefacts from clothing movement. Before gait analysis, height and body mass were measured and recorded. Body mass measured was used to determine the (relative) mass gain by subtracting the pre-pregnancy body mass obtained from participants' medical records where available, or as self-reported by participants.

Gait kinematic data were recorded with a 3D motion analysis system (Qualisys, Sweden) consisting of eight Oqus 300+ cameras at 220 Hz. Reflective markers (12 mm) were applied to anatomical landmarks according to the full-body CAST/IK/HH gait model (Cappozzo, Catani, Della Croce, & Leardini, 1995), and as previously described in Krkeljas and Moss (2015): heel at the insertion of the Achilles tendon, heads of the first, second and fifth metatarsal, medial and lateral malleoli, 4-marker cluster on the lower leg (shank), lateral and medial knee epicondyles, 4-marjer thigh cluster, greater trochanter, anterior and posterior superior iliac spine, inferior angle of scapula, thoracic vertebrae (T10), cervical vertebrae (C7), radial and ulnar styloid processes, humeral lateral epicondyle, humerus, acromion. Prior to each test, 90-s wand calibration was completed.

Firstly, participants were asked to stand still in the centre of the calibrated space in order to create a reference measure for a dynamic model used for walking trials. Secondly, subjects were instructed to walk in a straight line, at a self-selected pace along the 15-m walkway. Video data were collected simultaneously for five seconds in the middle portion of the runway. The average of three trials were used for data analysis. The participants were instructed to rest between trials as long as necessary should they feel tired at any stage, but none of the participants exercised this option.

2.3. Data analysis

All data were processed via Visual 3D (C-Motion, Germantown, MD, USA) motion analysis software, using bidirectional Butterworth with a 10-Hz cut-off frequency. From the standing reference model, anterior-posterior (AP) and medio-lateral (ML) inclination angle (i.e. trunk lean), as well as AP and ML pelvic tilt were measured. Inclination angle of the trunk in the sagittal plane was calculated as a front to back deviation of the line connecting the acromion to the greater trochanter. Lateral trunk tilt was calculated as an intersection of the line connecting the left and right acromion process, with an absolute horizontal line. Pelvis lateral angle was calculated as an intersection of the line connecting the left and right ASIS and a horizontal line.

For the analysis of stability during walking, the following gait and postural parameters were measured: walking speed, stride length and width, bilateral one-leg stance time and foot clearance height, maximum medio-lateral deviation of centre of pressure (COP_{ML}) and centre of gravity (COG_{ML}) during single-leg stance. Similarly to the static measure of inclination angle, the horizontal distance between COP and COG (COP/COG trunk inclination angle) in the coronal plane was also measured (Lee & Chou, 2006). Lastly, margin of stability is a stability index proposed by Hof et al. (2005) and is derived from the x and y projections of the COM and