Dynamic postural stability in pregnant fallers and non-fallers

JL McCrory,[a,b] **AJ Chambers,**[c] **A Daftary,**[d] **MS Redfern**[c]

[a] Division of Exercise Physiology, Department of Human Performance and Applied Exercise Science, West Virginia University, Morgantown, WV, USA [b] Department of Health and Physical Activity [c] Department of Bioengineering and [d] Department of Maternal–Fetal Medicine, University of Pittsburgh, Pittsburgh, PA, USA
Correspondence: Dr JL McCrory, Division of Exercise Physiology, Department of Human Performance and Applied Exercise Science, West Virginia University, Health Sciences Center South, Morgantown, WV, USA. Email jmccrory@hsc.wvu.edu

Objective To compare dynamic postural stability in pregnant women who have fallen during their pregnancies with those who have not, and with a group of non-pregnant women.

Design The study was both longitudinal and cross-sectional. A cohort of pregnant women were followed through their second and third trimesters. A non-pregnant control group was used for comparison.

Setting University-based laboratory.

Population A total of 81 women (41 pregnant and 40 controls) participated. Twenty-nine pregnant women completed the protocol.

Methods Data were collected on the pregnant women in the middle of their second and third trimesters. Pregnant women were surveyed about their daily activities, exercise participation, and fall history. Postural reaction time and centre of pressure (COP) movement data, in response to translational perturbations, were collected using a force plate. A mixed-model analysis of

variants (ANOVA) was performed on each of the dependent variables ($\alpha = 0.05$). Chi-square analysis was performed to determine if exercise participation altered the likelihood of a subject experiencing a fall ($\alpha = 0.05$).

Main outcome measures Reaction time, initial sway, total sway, and sway velocity.

Results Fifty-two percent of our pregnant subjects experienced a fall. Initial sway response, total sway, and sway velocity were smaller in the pregnant fallers than in the non-fallers and control participants ($P < 0.05$). Thirty-one of the pregnant subjects participated in regular exercise. Sedentary pregnant women were more likely to experience a fall than those who exercised.

Conclusions Dynamic balance is altered in pregnant women who have fallen compared with non-fallers and controls. Exercise may play a role in fall prevention in pregnant women.

Keywords Balance, centre of pressure, exercise, falls, perturbation.

Introduction

Pregnancy-related falls are commonplace. In general, pregnant women fall at a similar rate (27%) to women over the age of 70 years (28%).[1] Falls are the leading cause of emergency department hospital admissions in pregnancy.[1] As many as 40% of all trauma-related visits to the emergency room or hospital admissions of pregnant women were attributed to accidental falls.[2–8] These falls may result in fractures, joint sprains, muscle strains, head injury, rupture of internal organs, placental separation, uterine rupture, and occasionally maternal or fetal death.[3,9–14] Little research has been performed on dynamic stability in pregnancy.[15]

Pregnant women undergo numerous anatomical, physiological, and hormonal changes that may be related to an increased risk of falling. They experience a substantial

weight gain, memory problems and difficulty in concentrating, an anterior shift in the location of the centre of mass, increased ligamentous laxity, decreased neuromuscular control and coordination, swelling of the arms and legs, altered biomechanics, decreased abdominal muscle strength, increased spinal lordosis, and changes in mechanical loading and joint kinetics.[1,16–24]

Several investigators have examined other aspects of postural stability during pregnancy.[25–27] Butler *et al.*[25] reported increased postural sway throughout pregnancy, as evidenced by the increased length of the centre of pressure (COP) path during quiet stance in pregnant women, when compared with non-pregnant women. They also reported a 25% incidence of fall in their pregnant study participants (two of eight). Similarly, Jang and colleagues[27] found increased anterior–posterior and radial sway, no change in

medial–lateral sway, and a wider preferred stance width in pregnant women during quiet stance when compared with non-pregnant women. Jang et al. also reported that 13% of the pregnant women in their study experienced a fall during their pregnancies. Davies et al.[26] reported differences in global measures of balance between pregnant women during labour and non-pregnant women. When dynamic postural stability in response to a fore–aft translation was investigated, women in their third trimester demonstrated less initial sway, total sway, and sway velocity during the third trimester than during the second trimester, and compared with non-pregnant women.[15]

Exercise participation in pregnancy is encouraged, as long as the woman is generally healthy and the pregnancy is free of complications.[28] A wide range of moderate intensity, non-contact activities are recommended. The American College of Sports Medicine reports that the benefits of chronic exercise reside with the mother; however, the risks of over-exercise and inappropriate exercise predominantly affect the fetus.[29] No studies have examined the effect of exercise on fall risk in pregnant women.

The purpose of this study was two-fold. Our primary aim was to compare the dynamic stability of pregnant women who reported a fall against that of pregnant women who did not report a fall, as well as a non-pregnant control group. We defined dynamic stability as the response to anterior and posterior translation perturbations of different magnitudes. We hypothesised that the pregnant fallers would have a longer reaction time to the perturbations, and a greater COP movement and sway velocity. The second purpose of this paper was to examine if participation in regular exercise during pregnancy was related to the incidence of falls reported by the participants in our pregnant group.

Methods

Subjects

Eighty-one women (41 pregnant and 40 non-pregnant controls) between the ages of 18 and 45 years participated in this study. Subject demographics are shown in Table 1. Pregnant participants were recruited through the University of Pittsburgh Medical Centre (UPMC) Womancare Research Registry in the beginning of their second trimester. The registry can be briefly described as follows: women who receive medical care at the UPMC Magee-Womens Hospital are asked if they wish to be included in the database. If the woman agrees, certain details of her medical file (e.g. name, phone number, age, diagnosis, results of medical tests, etc.) are included in the database. Researchers granted access to this subject registry are then able to search specific diagnoses and demographic information. For this study, we searched for the keywords of: pregnancy, age 18–45, single gestation, and low-risk pregnancy. We searched this database approximately once a week so that we could find women newly enrolled in the registry as a result of their pregnancies. The registry provided us with the names and contact information of women meeting the criteria. We then called the potential subjects to determine their interest in participating in the study. If a woman expressed interest in the study during the telephone conversation, she was then asked a series of questions to determine if she met our eligibility criteria.
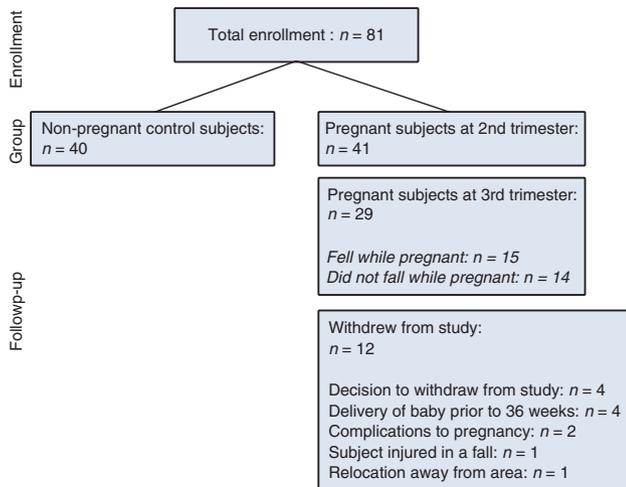
Non-pregnant controls were recruited via flyers placed around the university community, as well as through advertisements placed on the University of Pittsburgh Institutional Review Board website. Each control participant was body mass index (BMI)-matched to a woman in the pregnant group, based on the pregnant woman's self-reported pre-pregnancy mass. Control and pregnant participants were matched to within 2 kg/m^2 BMI.

Potential participants who were pregnant were excluded from the study if they were beyond their 20th week of pregnancy, were carrying more than one fetus, or if they had a history of any of the following: gestational diabetes, pre-eclampsia, toxemia, gestational hypertension, delivery of an older child prior to 36 weeks of gestation, or if they were considered by their obstetrician to have a high-risk pregnancy. Potential control or pregnant participants were excluded from enrollment if they were not between the ages of 18 and 45 years, had a history of type-I or -II diabetes, or any other condition that could affect sensation, a

Table 1. Subject demographics*

	Control group (n = 40)	Pregnant non-fallers (n = 14)	Pregnant fallers (n = 15)
Age (years)	26.5 ± 6.4	30 6 ± 3.8	29.4 ± 4.7
Height (cm)	165.8 ± 5.6	167.5 ± 7.4	165.8 ± 6.6
Mass	66.0 ± 8.9		
Second trimester mass (kg)		73.4 ± 11.2	74.7 ± 8.7
Third trimester mass (kg)		82.1 ± 12.4	81.0 ± 9.5

*The demographics for the pregnant subjects include data from the 29 pregnant subjects who completed the protocol. Demographics of the 12 pregnant subjects who withdrew from the study are not included in this table.

Enrollment

Group

Follow-up

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                    │ Total enrollment : n = 81 │
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| Non-pregnant control subjects: n = 40 | Pregnant subjects at 2nd trimester: n = 41 |

Pregnant subjects at 3rd trimester: n = 29

Fell while pregnant: n = 15
Did not fall while pregnant: n = 14

Withdrew from study: n = 12

Decision to withdraw from study: n = 4
Delivery of baby prior to 36 weeks: n = 4
Complications to pregnancy: n = 2
Subject injured in a fall: n = 1
Relocation away from area: n = 1

Figure 1. A diagram illustrating the number of subjects in each group participating in the study.

leg or foot fracture within the last 5 years, ankle or knee sprain within the last year, current back or knee pain, or a history of ligament rupture at the ankle or knee. Subjects were also excluded if they were a current smoker or if they currently took any medication that would affect their ability to balance. Subjects were excluded if they typically consumed more than one alcoholic drink per day.

Pregnant subjects made two visits to the university to participate in this study. Their first visit occurred in the middle of their second trimester. The average gestational age during the subjects' first data collection session was 20.9 ± 1.2 weeks. Their second visit occurred during the middle their third trimester at 35.8 ± 1.5 weeks. Twelve subjects did not complete the second visit because of: a decision to withdraw from the study ($n = 4$), delivery of the baby prior to 35 weeks ($n = 4$), pre-eclampsia or other complications to their pregnancy ($n = 2$), injuries sustained from a fall required the subject to be placed on bed rest ($n = 1$), and relocation to another part of the country ($n = 1$). Their data are excluded from further analysis in this study. Figure 1 provides a diagram of subject enrollment and follow-up.

Control subjects participated in a single study visit. Because estrogen and progesterone are believed to influence movement patterns, flexibility, and dexterity,[30–32] data from the women in the control group were collected in the week following menses. During this week, concentrations of both estrogen and progesterone are low.[33] Additionally, by collecting data from the control group immediately following menses, we were certain that control women were not pregnant.

Procedures

Subjects reported to the Human Movement and Balance Laboratory on the campus of the University of Pittsburgh for testing. The study took 3 years to complete (2006–2009). Experimental procedures were explained to the subject, who was encouraged to ask questions. Following this, written informed consent approved by the University of Pittsburgh Institutional Review Board was obtained. Each subject's height and mass were obtained using a standard medical balance-beam scale and stadiometer.

Pregnant subjects completed a survey about the number of previous pregnancies they had had, and whether these pregnancies resulted in a live baby or a miscarriage or stillbirth. The survey also asked the subjects about any exercises in which they currently participated. Pregnant subjects were surveyed about their history of falls while pregnant, as well as an assessment of their exposure to common risk factors for falling. If the subject reported that she had fallen, she was given a questionnaire that asked her to provide specific details related to each fall, such as the date, time, and location of the fall, the month of gestation at the time of the fall, what the subject was doing when she fell, the type of shoes (if any) worn during the fall, whether or not she was carrying anything, hurrying, turning, pushing something, and if she required medical treatment after the fall.

Translational perturbations were performed using an Equitest posture platform under the Motor Control Test (MCT) protocol (NeuroCom International, Inc., Clackamas, OR, USA). The MCT test has been used to test other populations at risk for falling.[34–37] Postural responses were recorded via COP from underfoot force plates. Subjects stood on the platform and were fitted with a chest and hip harness. The harness was designed such that no straps were placed around the abdomen, only around the shoulders and upper thighs, thereby protecting the fetus should a loss of balance occur. Over the course of the study, no subject lost her balance such that she needed the harness during the dynamic stability testing. Subjects were instructed to stare straight ahead.

The platform on which the subjects stood was moved in the anterior and posterior directions. Data were collected at three magnitudes of perturbation: small, medium, and large. Three trials of each condition were collected (100 Hz). In each condition, the velocity of translation was 0.1524 m/seconds (i.e. six inches/second), which has been shown to elicit a physical response to the perturbation.[38] The time to maximum velocity was 0.05 seconds. Perturbation magnitude was scaled to the subject's height, while maintaining the duration of platform movement across all subjects. The formula used to calculate how much the platform was moved was:

$$\text{Translation magnitude}(m) = X\,[\text{subject's height (in m)}/1.83],$$

where $X = 0.013$ in the small perturbation trials, 0.032 in the medium perturbation trials, and 0.057 in the large perturbation trials. The durations of the translation of the small, medium, and large perturbations were 0.25, 0.3, and

0.4 seconds, respectively. The '1.83' was used to scale the translation to the subject's height, such that a 1.83-m (6-foot) tall person would have a translation of 0.013 m (0.5 inches) in the small perturbations, 0.032 m (1.25 inches) in the medium perturbations, and 0.057 m (2.25 inches) in the large perturbations. The Intraclass Correlation Coefficient (ICC) of this protocol is 0.79.[38] COP recordings were made during each perturbation response.

The COP time series were analysed to estimate reaction times and sway measures in response to the perturbations. Reaction time was defined as the time between the onset of the platform translation until the subject's COP was seen moving independently of the force plates.[39] Initial sway was defined as the maximum initial COP movement resulting from the translation of the platform. Sway velocity was defined as the initial sway divided by the time from the onset of COP movement to the time of the initial sway. Total sway was defined as the total anterior–posterior movement of the COP in response to the perturbation. The data from each of the three trials, at each magnitude, in each direction, for each subject, were averaged to yield a representative value for that subject.

Statistical analysis

A mixed-model analysis of variance (ANOVA) was performed on each of the four variables (reaction time, initial sway, sway velocity, and total sway). The subject was designated as a random factor, whereas fall group (pregnant non-faller, pregnant faller, or control), direction (forward or backward), and magnitude (small, medium, and large) were designated as fixed factors. Our hierarchical model for this analysis can be written as $Y_{ijklm} = \mu + \text{subject}_i + \text{fallgroup}_{(i)} + \text{direction}_{k(ij)} + \text{magnitude}_{l(ijk)} + \varepsilon_{ijklm}$, as well as first- and second-order interactions. The alpha level was set to 0.05 for each of the statistical analyses. For each of the statistical analyses, Tukey's *post-hoc* tests were performed to determine where the significant differences were between the non-pregnant controls, pregnant women who reported a fall, and those who did not fall, as well as between the three perturbation magnitudes ($\alpha = 0.05$).

Secondly, the effect of exercise on fall risk in pregnant women was examined. Pregnant subjects were categorised as participating in regular exercise at some point in their pregnancy or not. A chi-square analysis was performed to determine if non-fallers were more likely to be exercisers or, conversely, if pregnant women who fell were more likely to be non-exercisers ($\alpha = 0.05$). The type of exercise performed was not designated in the chi-square analysis.

Results

Fifteen of the pregnant subjects from whom we have complete data sets reported having at least one fall. A fall was defined as losing their balance such that another part of their body, other than a foot, touched the ground. A total of 24 falls were reported. These 15 women who reported falling represent 52% of the 29 pregnant women who completed the study.

Specifically, eight subjects reported falling once, five subjects fell twice, and two subjects fell three times. No subject reported falling more than three times. Three of the falls occurred during the first trimester, 13 during the second trimester, and eight during the third trimester. The locations of the falls included the home, on the stairs, on a public sidewalk or parking lot, at work, or in a public building. One fall involved falling more than 4 feet down, as the subject was on a staircase in her home and fell down five steps. Three total falls involved falling down the stairs or from a curb. Four falls involved slipping on ice or a slick surface. Four falls involved carrying an object or a small child. Two falls involved tripping over an object in front of the subject (both 'objects' were small children), whereas ten falls involved tripping when no other object was involved (i.e. poor toe clearance and hitting the toe of their swing leg on the ground). The shoes worn by the subjects at the time of the fall were as follows: barefoot ($n = 2$), socks ($n = 4$), slippers ($n = 1$), flat dress shoes ($n = 3$), flip-flops ($n = 4$), clogs ($n = 1$), athletic shoes ($n = 2$), and boots ($n = 2$).

None of the falls required hospitalisation, although two falls necessitated treatment in the hospital emergency room, and one fall required treatment at the doctor's office. No broken bones were reported to have been caused by the falls. The injuries sustained in the falls that required medical treatment were as follows: sprained ankle ($n = 2$), sprained knee ($n = 1$), and laceration on the knee ($n = 1$). One subject could not complete her second study visit because of a fall that had sprained one of her ankles. Additionally, she was placed on bed rest because of a suspicion of a tear in the amniotic membrane. No subject delivered prematurely because of a fall.

The four measures of dynamic stability of pregnant women who reported falling were compared with those who did not fall, and with the non-pregnant control group. The reaction time was not significantly different between the three groups of subjects ($P = 0.093$). Across groups, the reaction times were significantly different between small, medium, and large perturbations ($P = 0.001$), but not between the forward and backward perturbations ($P = 0.430$). No interaction effects were significant. The reaction times for each group of subjects for each magnitude and direction are shown in Table 2.
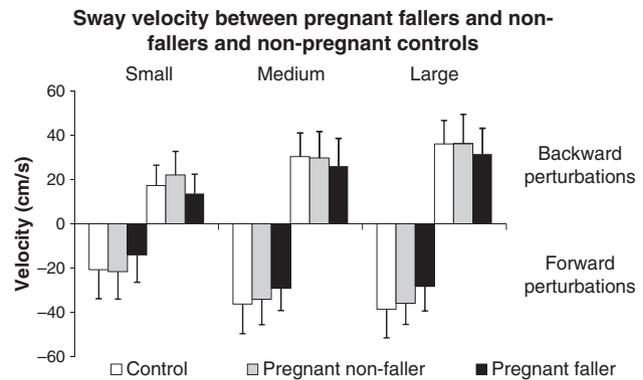
The initial sway measure was significantly less in the pregnant fallers when compared with the pregnant non-fallers and controls ($P < 0.001$) (Figure 2). No differences were noted between the latter two groups. The magnitude

Table 2. Reaction times (ms) for the non-pregnant controls and the pregnant fallers and non-fallers to forward and backward perturbations at each of the three perturbation magnitudes. The data shown are means ± SD

Group (*P* = 0.093)	Direction (*P* = 0.430)	Magnitude (*P* = 0.001)	Reaction time (ms)
Non-pregnant controls 124.1 ± 18.6 ms	Forward 125.6 ± 21.4	Small	128.3 ± 13.8
		Medium	123.6 ± 12.4
		Large	124.9 ± 32.0
	Backward 122.5 ± 15.2	Small	125.4 ± 16.9
		Medium	122.6 ± 13.8
		Large	119.4 ± 14.3
Pregnant non-fallers 126.8 ± 25.9 ms	Forward 127.2 ± 22.6	Small	129.4 ± 13.5
		Medium	130.4 ± 34.2
		Large	121.6 ± 11.8
	Backward 126.4 ± 29.0	Small	127.5 ± 16.7
		Medium	124.2 ± 13.0
		Large	127.5 ± 45.5
Pregnant fallers 124.8 ± 17.7 ms	Forward 124.6 ± 17.6	Small	125.9 ± 23.6
		Medium	127.1 ± 13.7
		Large	120.9 ± 13.1
	Backward 124.8 ± 17.7	Small	125.6 ± 23.4
		Medium	128.5 ± 14.8
		Large	120.7 ± 13.0
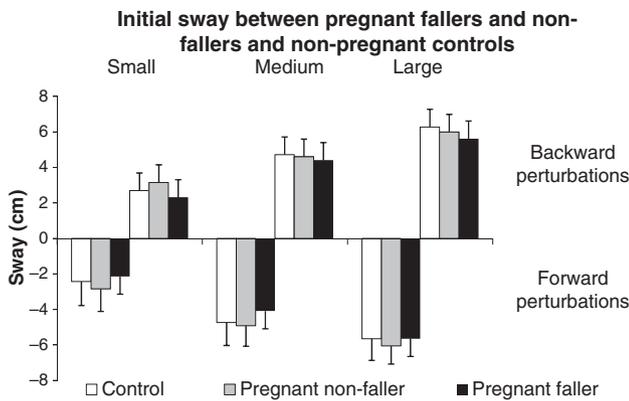
Figure 2. Initial sway between the pregnant fallers, pregnant non-fallers, and non-pregnant controls. The initial sway was significantly different between groups (control, pregnant fallers, and pregnant non-fallers; $P < 0.001$) and the small, medium, and large perturbations ($P < 0.001$). It was not significantly different between forward and backward perturbations ($P = 0.125$).
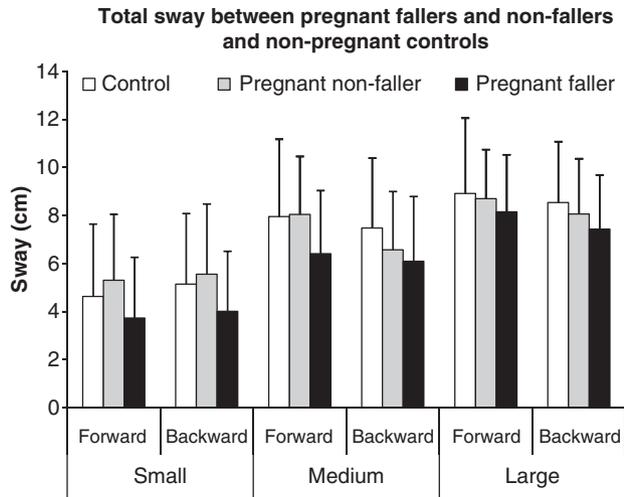

Figure 3. Sway velocity between the pregnant fallers, pregnant non-fallers, and non-pregnant controls. The initial sway was significantly different between groups (control, pregnant fallers, and pregnant non-fallers; $P < 0.001$), as well as between forward and backward perturbations ($P < 0.001$), and the small, medium, and large perturbations ($P < 0.001$).

of initial sway was significantly different between the small, medium, and large perturbations, with each magnitude being significantly different than the other two magnitudes ($P < 0.001$). Initial sway was not different between the forward and backward perturbations ($P = 0.125$). The sway velocity (Figure 3) and the total sway (Figure 4) were significantly less in the pregnant fallers when compared with their non-faller counterparts, as well as with the control participants (both *P* values < 0.001). No differences were

noted between the pregnant non-fallers and the controls. Similarly, both the sway velocity and total sway were significantly different between the forward and backward perturbations, as well as between the small, medium, and large perturbations ($P < 0.05$). No interaction terms were significant.

The pregnant women reported participation in a variety of exercise modalities. Thirty-one of the 41 pregnant participants reported regular exercise at some point during

Total sway between pregnant fallers and non-fallers and non-pregnant controls

Figure 4. Total sway between the pregnant fallers, pregnant non-fallers, and non-pregnant controls. The sway velocity was significantly different between groups (control, pregnant fallers, and pregnant non-fallers; $P < 0.001$), as well as between forward and backward perturbations ($P = 0.017$), and the small, medium, and large perturbations ($P < 0.001$).

their pregnancies, whereas ten reported no exercise at all while pregnant. Several subjects reported participation in more than one exercise modality. Walking was by far the most common exercise modality, with 29 of the 41 pregnant women stating that they walked at least three times a week for at least 30 minutes per session at some point during their pregnancy. Prenatal yoga or Pilates was the second most preferred exercise, with 29.2% of the women reporting that they participated in these activities at some point during their pregnancy. Other forms of exercise included jogging ($n = 4$), swimming ($n = 8$), cycling ($n = 3$), aerobics ($n = 4$), dancing ($n = 2$), strength training ($n = 6$), and martial arts ($n = 1$). No subject reported participation in organised sports while pregnant.

A chi-square analysis was performed on the falls and exercise categorisation data. Of the 29 women for whom we have complete data sets, 15 were categorised as fallers and 22 were categorised as exercisers. Specifically, the distribution was as follows: exercisers who did not fall, $n = 14$; exercisers who fell, $n = 8$; non-exercisers who did not fall, $n = 0$; non-exercisers who fell, $n = 7$.

It is noteworthy that all seven of the sedentary pregnant women fell, whereas only eight of the 22 pregnant women who exercised reported that they fell. Therefore, the faller/exercise categorisations are not independent of one another. The chi-square test for the fall categorisation was 0.31 ($P = 0.577$), meaning that fallers were statistically not more likely to be non-exercisers than exercisers. However, the chi-square test for the exercise categorisation was 7.759 ($P = 0.005$), meaning that non-exercisers were more likely to fall than those who participated in regular exercise.

Discussion

The primary purpose of this study was to compare the dynamic stability of pregnant women who have experienced a fall while pregnant against that of pregnant women who did not report a fall, as well as against non-pregnant women. No differences were found between the non-pregnant control women and pregnant women who did not report a fall in any of the four dynamic stability variables. Reaction time was not significantly different among the groups. However, the pregnant fallers demonstrated significantly less movement responses (i.e. initial sway, sway velocity, and total sway) than the pregnant non-fallers and the control group.

We hypothesised that the magnitude of the movement responses to the perturbation would be greater in the pregnant fallers compared with the non-fallers and the non-pregnant control group; however, the opposite was seen such that the pregnant fallers demonstrated less sway and slower sway velocity. We suggest that the fallers may have altered motor control systems that may not be as responsive as those of the non-fallers.

The measures of COP used in this study reflect the muscle responses used to maintain stability in response to a perturbation. The centre of mass (COM), which is the net location of the subject's mass in three-dimensional space,[40] can be thought of as the position of the body that is being controlled by the COP. The COM is typically located in the lower torso region in women.[40] A person's COM must remain within their base of support (i.e. the length of the feet) to remain upright during stance. The plantar flexor and dorsiflexor muscles create the movement of the COP.[40] This COP movement regulates the fore–aft movement of the COM.[40] In a stable system, the ankle musculature would effectively control the movement of the COP so that the COM remains within the base of support. However, the pregnant women in our study who reported falling demonstrated decreased movement of the COP. This could be reflective of an altered control system, such that the ankle plantar flexors and dorsiflexors do not have an appropriate response to control the ankle joint torques. This would result in greater COM movement, and could potentially result in a fall.

Additionally, the pregnant fallers demonstrated a slower sway velocity compared with the pregnant non-fallers and the non-pregnant controls. The ability to adapt quickly in response to a perturbation may be an important factor in remaining upright. Thus, the slower sway velocity may be an indication of slower response generation capabilities to respond to threatening situations, leading to an increased risk of falls.

We have no data on whether or not a subject feared falling. However, for the purpose of this discussion, we

performed a *post-hoc* test to determine if pregnant fallers became rigid following the first perturbation. Three trials per condition per magnitude were performed in each direction. We examined the data from each of the three trials in each magnitude in each direction to determine if the pregnant fallers became significantly more rigid following the first perturbation, whereas perhaps the non-pregnant controls and pregnant non-fallers did not demonstrate significant differences between trials. Indeed, the initial sway in the first trial was significantly greater than in trials 2 and 3 ($P < 0.001$). Trials 2 and 3 were not significantly different ($P = 0.108$). However, this was seen in all groups of subjects, not just the pregnant fallers. The interaction between the group (control, pregnant faller and pregnant non-faller) and trial number did not near significance ($P = 0.405$). Therefore, the reason why the pregnant fallers experience less initial sway is not that they experience the first trial and then get very rigid in response to the latter two trials, because all three groups had greater sway on trial 1 than on trials 2 and 3.

The dynamic postural stability between the second and third trimesters in these same subjects has been investigated previously.[15] The initial sway, total sway, and sway velocity was significantly less during the third trimester than during the second trimester, or when compared with the control subjects. Whether or not the subject fell in her pregnancy was not considered in that analysis. As in the current study, no differences in reaction time were noted between any of the groups.[15]

Anthropometric factors are not likely to have played a role in whether or not the subject fell. There were no differences in pregnant mass, weight gain during pregnancy, or waist circumference between the fallers and the non-fallers ($P > 0.10$), nor was there a significant interaction between the trimester and fall incidence for any of the above variables ($P > 0.80$).

The altered response to the perturbation in pregnant fallers may result from factors not assessed in this study, such as muscle strength. The official position of the American College of Obstetricians and Gynecologists is that maximal strength testing, maximal weight lifting, and any activity that could elicit a dramatic pressor response are contraindicated in pregnant women.[28] It is plausible that the pregnant women who fell were weaker than those who did not. Researchers who study older individuals report that decreased lower extremity extensor and hip abductor strength is a risk factor for falls in the elderly.[41–43] Chambers and Cham asserted that older adults with a higher incidence of falls may not be able to react with the power required to recover balance in response to a hazardous slip.[44,45]

The rate of falls in the pregnant women of our sample was 52%, approximately twice that reported by Dunning *et al.* and Butler *et al.*[1,25] In the study by Dunning and colleagues[1], 6217 women in the greater Cincinnati area were identified as potential study participants through medical records at the hospital in which they delivered. All of the women, who were no more than 8 weeks postpartum and at least 20 years of age, were asked to complete a survey either via the mail, the internet, or over the telephone, about whether or not they had fallen while they were pregnant, as well providing any details about the fall. The women were also queried about whether or not they were currently employed. A total of 3997 women responded to the survey. Overall, 26.8% of the women reported falling during their pregnancy.[1] The robustness of the large sample size in the Dunning *et al.* study gives that investigation strong validity.

The study by Dunning *et al.* was performed entirely postpartum. The large number of falls reported in our current study may result from the fact that we questioned the subjects about falls during their pregnancies, not afterwards. At their study visit when the participants were at approximately 5 months of gestation, they were given our falls survey. They were given the survey again at approximately 8 months of gestation. Many of the women who fell anecdotally mentioned to us that their fall was so minor that they did not think that they would have remembered it had they not been participating in the study. Additionally, several of the women who reported falling in their first trimester told us that they were interested in participating in our study because they had fallen. This may have biased our study to include a greater number of fallers in our sample.

Most of the falls in the present study were in the second trimester. Dunning and colleagues[1] reported that 61.4% of the falls in their study occurred between 5 and 7 months of gestation. Similarly, Connolly *et al.*[2] stated that most of the falls in their study occurred between 25 and 30 weeks of gestation. We do not believe that the increased rate of falls in the second trimester is solely the result of physiological and biomechanic reasons: we have previously reported that statistically significant alterations in balance in these subjects were not apparent until the third trimester.[15] However, others have purported that women begin to curtail their activities in their third trimesters so that they do not place themselves in as many fall-risk situations.[2]

Jang *et al.*[27] also assessed the incidence of falls of their pregnant study participants over the course of their pregnancies. Only two of their 15 pregnant subjects (13%) reported falling, and one additional subject reported slipping several times. No injuries were sustained during the falls. We cannot explain why the incidence of falls in our study is so much greater than the 13% reported by Jang *et al.*[27] The study by Jang *et al.* took place at the University of Illinois at Champaign-Urbana, whereas our study took

place in Pittsburgh. Both locations experience diverse seasons throughout the year, so we do not believe that the difference in the fall rate is related to the weather. Pittsburgh is quite hilly and central Illinois is very flat, but because none of our subjects reported falling down a hill, we do not believe that the difference is caused by the terrain. Rather, the difference in the fall rate may simply be attributable to the relatively small sample size in both studies.

All of the pregnant subjects in our study completed a survey about their typical daily activities. Qualitative assessment of the activity surveys revealed no apparent differences between the fallers and non-fallers. Therefore, we believe that all of the subjects encountered the same risk factors. A plausible explanation for why some women fell and why some did not would be that the fallers had slower reactions to the factors that precipitated the fall. However, reaction time to the sliding perturbation in this study was not significantly different between the fallers and non-fallers. If we extrapolate this result to the actual fall incident, we do not believe that the fallers would have had a slower reaction time than the non-fallers in response to the event that instigated the fall.

We found that participation in regular exercise at some point during the pregnancy was associated with a reduced number of falls. This finding further supports the hypothesis that increased muscle strength may reduce fall risk. Remarkably, all of the sedentary pregnant women in our study reported a fall. Our sample size of 29 women is relatively small, and we certainly cannot extrapolate our findings to assume that all sedentary pregnant women fall. Unfortunately, exercise participation was not addressed in Dunning et al.'s[1] large study of 3997 pregnant women. Further research on the relationship between exercise participation, exercise modality, muscle strength, and fall risk is warranted.

Obstetricians should make their patients aware of the increased risk of falls during pregnancy. This knowledge may help patients decide if certain activities/scenarios may be best avoided while pregnant. The reasons for the increased fall rate are elusive. When comparing women who fell with women who did not fall, differences in the ability to react to a perturbation were apparent. Future studies should include the development of simple balance tests that can be performed in the clinic that may help physicians determine which of their patients are at a greater risk of falling. Moreover, exercise may have a protective role in fall prevention.

Conclusion

Pregnant women who experienced a fall exhibited altered dynamic postural stability compared with those who did not fall, as well as with non-pregnant women. Namely, although there were no differences in reaction time to a translational perturbation, the movement of the COP was markedly different. The pregnant women who have not fallen demonstrated similar COP movement patterns to non-pregnant women. The biomechanical reasons behind this finding need to be further investigated.

Exercise participation may play a role in reducing fall risk. All of the sedentary pregnant women in this study fell during their pregnancies. Although some of the pregnant women who reported exercise participation experienced a fall, the majority did not. Further investigation of the efficacy of exercise in fall prevention in this population is warranted.

Disclosure of interests

No author has any financial, personal, political, intellectual, or religious conflict of interest with this work.

Contribution to authorship

JLM was the principal investigator of the K01 award, which funded this research. She participated in all aspects of the study, including planning, subject recruitment, data collection, data processing, statistical analysis, and manuscript preparation. AC is the manager of the Human Movement and Balance Laboratory where the data collection took place. She participated in planning the study, data collection and processing, and manuscript preparation. AD was the medical director of the study, as well as a co-investigator on JLM's K01 award. He cleared all of the subjects for participation, as well as being on-call during the data collection sessions, should a subject require medical attention. Additionally, he participated in data interpretation and manuscript preparation by contributing his clinical expertise to our discussions. MSR is the director of the Human Performance Lab as well as being JLM's sponsor for her K01 award. He consulted with JLM on all aspects of the study, including subject recruitment, data collection, data processing, and interpretation and manuscript preparation.

Details of ethics approval

This study was approved by the University of Pittsburgh Institutional Review Board, Committee B: approval 0505095. Original approval date: 12 August 2005.

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