

The effect of simulated gestational weight gain on balance, gait, and fear of falling

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ABSTRACT

The effects of pregnancy on balance with the eyes closed and maximum walking speed remain unclarified. The present study aimed to examine the effect of simulated gestational weight gain on balance, gait, and fear of falling in nulligravid women to enhance understanding of the impact of gestational weight gain. We prospectively evaluated the following outcomes in 24 healthy nulligravid women with and without a maternity-simulation jacket that simulated third-trimester pregnancy. To measure balance, we used the single-leg-stance test with eyes open and closed, and the functional reach test. We evaluated gait function by measuring walking speed, step length, and cadence at self-selected and maximum speeds. We used the timed-up-and-go test as a comprehensive measure of gait and balance, and the modified falls efficacy scale to evaluate fear of falling. Differences in these parameters between a simulated gestational weight gain condition and a “nonpregnant” condition were assessed. Simulated gestational weight gain caused significantly worse performances in the single-leg-stance test with eyes open and closed, functional reach test, walking speed, step length at self-selected and maximum speeds, and timed-up-and-go test. The effect size was larger for the single-leg-stance test with eyes closed than with eyes open. The average score for each modified falls efficacy scale item ranged from 4.7–8.5. In conclusion, balance decreased with simulated gestational weight gain, and balance may be more affected without visual feedback. Simulated gestational weight gain resulted in worse gait function at both self-selected and maximum speeds.

Keywords: gait, gestational weight gain, postural balance, pregnant women, walking speed

Abbreviations:

BMI: body mass index

FRT: functional reach test

MFES: modified falls efficacy scale

SLST: single-leg-stance test

TUG: timed-up-and-go test

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INTRODUCTION

Falling during pregnancy is a common problem. Dunning et al¹ reported that 27% of working women fell during pregnancy, and this fall rate is similar to that of community-dwelling older people aged ≥ 65 years (29%).² Weiss³ showed that pregnant women were hospitalized because of falls 2.3 times more than nonpregnant women. Additionally, Connolly et al⁴ found that 22% of trauma cases during pregnancy were associated with falls. Therefore, it is important to prevent falls during pregnancy.

Several anatomical and biomechanical changes occur gradually during pregnancy. These include significantly increased abdominal weight and circumference, center-of-gravity shift, increased body sway, and perceived degradation in balance.⁵⁻⁷ A review by Cakmak et al⁸ reported that postural stability is impaired during pregnancy and this increases the risk of falling. Takeda et al⁹ found that forward-reach distance decreased during pregnancy, and Inanir et al¹⁰ reported that dynamic postural stability decreased during pregnancy, particularly in the third trimester. However, few studies have evaluated dynamic balance, or static balance with eyes closed, during pregnancy in relation to the risk of falling.

Several changes in gait biomechanics occur during pregnancy. Previous studies have shown that step length decreases significantly during pregnancy.¹¹⁻¹³ Gill et al¹⁴ reported that additional anterior body mass using a custom-built artificial pregnancy belly decreased stride length. However, changes in walking speed and cadence during pregnancy remain controversial.^{11-13,15-16} These previous studies used a walking test with a self-selected walking speed only; to our knowledge, no studies have evaluated walking at a maximum speed during pregnancy. A previous study showed that 39% of work-related falls occurred when working pregnant women moved at a hurried pace.¹ Thus, it is important to assess walking competence at maximum walking speed during pregnancy.

Most research to date has focused on static balance and spatiotemporal or kinematic gait parameters; few studies have investigated the impact of pregnancy on fear of falling. Atay and Bařalan¹⁷ confirmed that half of the pregnant women in their study had a fear of falling; however, the authors did not clarify which activities of daily living affected the fear of falling.

A maternity-simulation jacket has been developed to simulate the life and activities of pregnant women, and the jacket has been used to educate midwives and expectant parents. The maternity-simulation jacket permits a better understanding of the effects of gestational weight gain on movements with a high risk of falling using evaluations such as static balancing with eyes closed, dynamic balance, and the walking test at maximum speed.

The study objective was to examine the effect of simulated gestational weight gain (using a maternity-simulation jacket) on static and dynamic balance, gait function, and fear of falling in nulligravid women, and to enhance understanding of the impact of gestational weight gain. We hypothesized that simulated gestational weight gain would have a large influence on balance under the 'eyes closed' condition and walking function at maximum walking speed.

MATERIALS AND METHODS

Participants

Twenty-four healthy nulligravid women participated in the study. The inclusion criteria were healthy female students aged 20–29 years. The exclusion criteria were a significant medical history affecting posture, neurological disorders, and musculoskeletal disorders. The research ethics committee of Nagoya University School of Health Science approved the study, and all

subjects provided written informed consent prior to participation. This study met the guidelines of the Declaration of Helsinki.

Maternity-simulation jacket

All participants were examined with and without the maternity-simulation jacket (Fig. 1, Maternity Simulation Jacket LM-054, Koken Co., Ltd, Tokyo, Japan). The maternity-simulation jacket is designed to simulate gestational weight gain and fits women 155–165 cm in height. Adjustable straps allow the jacket to be worn by people of different sizes. The weight can also be adjusted; we used approximately 7.3 kg to simulate the third trimester. Guidelines for obstetrical practice in Japan recommend gestational weight gain for women with normal body mass index (BMI) of 7–10 kg, to prevent gestational toxicosis.¹⁸ Therefore, the maternity-simulation jacket's weight (7.3 kg) was appropriate to simulate third-trimester pregnancy in Japanese women.

Outcome measures

The single-leg-stance test (SLST) with eyes opened and closed was performed to assess static balance. Participants were asked to stand on the leg of their choice, with the other leg raised so that the raised foot was near but not touching the ankle of their stance leg. Prior to raising their legs, participants were instructed to put their hands on their hips. The time began when a participant raised their foot off the floor and ended when (1) the participant touched the raised foot to the floor, (2) the participant moved the weight-bearing foot to maintain balance (i.e., rotated the foot on the floor), or (3) a maximum of 60 seconds had elapsed. The procedure was performed once for each leg, and the mean score for both sides was used for analysis. A rest



Fig. 1 Maternity-simulation jacket

period of at least 1 minute was allowed between each trial set to avoid fatigue.

The functional reach test (FRT) was performed to examine dynamic balance. The FRT is an easy-to-use clinical measure with predictive validity to identify recurrent falls.¹⁹ Functional reach was measured using a reach-measuring device (OG Wellness Technology Co., Ltd., Okayama, Japan). Participants were instructed to stand with their feet 10 cm apart and raise both arms horizontally. After taking the starting position, participants were instructed to reach as far forward as they could without losing their balance, and return to an upright position. To keep the arms level with the shoulders, participants reached forward while pushing a horizontal sliding bar with their fingers. We asked participants to perform the FRT with both arms to exclude any influence from trunk rotation on reach distance. Participants performed the FRT twice and the highest value was recorded.

Walking speed, step length, and cadence were investigated to determine gait function. These measurement data were collected using a 5-meter walk test under two conditions: (1) self-selected speed and (2) maximum speed. A 2-meter space was provided before and after the timed portion to allow for acceleration and deceleration and ensure that a steady walking speed was captured for analysis. Cadence was defined as the number of steps taken in 1 minute, and was calculated by measuring the number of steps and time taken to complete a 5-meter walk test. Two trials were performed under each condition and mean values were calculated.

The timed-up-and-go test (TUG) was performed to evaluate gait and balance. The TUG is frequently used to assess gait and balance and is reliable for quantifying functional mobility.²⁰ Participants were instructed to stand from an armless chair, walk straight for 3 meters, turn at a marker, walk straight back to the chair, and sit down as fast as possible without running. The total time was measured. Participants performed the test twice and the mean time was recorded.

The modified falls efficacy scale (MFES) was used to assess fear of falling. The falls efficacy scale is a psychometric instrument originally developed by Tinetti et al²¹ to measure fear of falling in the older population, based on a participant's perceived self-efficacy or self-confidence in their ability to avoid falls while performing simple activities of daily living. The original falls efficacy scale measures fear of falling during almost exclusively indoor activities; therefore, Hill et al²² adapted the original 10-item falls efficacy scale by adding four additional items incorporating tasks commonly reported by fallers as inducing a greater fear of falling, and demonstrated that the MFES is a reliable and valid measure of fall self-efficacy.²² Participants were asked, "How confident are you that you can ... without falling?" and rated their responses on a scale of 0 (no confidence) to 10 (full confidence). The total score ranges from 0–140; lower scores indicate worse self-efficacy or self-confidence in a participant's ability to avoid falls. The mean score was calculated by dividing the total score by the number of items; a lower mean score suggests more fear of falling, and a threshold of less than 8 has been used to denote the presence of fear of falling.²³ We used a Japanese language version of the MFES in this study.²⁴

Procedure

The participants first performed the SLST, FRT, 5-meter walk test, and TUG in random order without wearing the maternity-simulation jacket ("nonpregnant condition"). The participants then wore the maternity-simulation jacket for 5 minutes to get used to the "simulated gestational weight gain condition" before performing the SLST, FRT, 5-meter walk test, and TUG under the simulated gestational weight gain condition in the same order as in the nonpregnant condition. Participants were asked to complete the MFES to record their perceived ability to avoid falls while imagining they were performing simple activities of daily living under the simulated gestational weight gain condition.

Analysis

Data distribution was evaluated using Shapiro-Wilk's test for continuous variables. When data were normally distributed, we used the paired *t*-test for comparisons between the simulated gestational weight gain and nonpregnant conditions. When data were not normally distributed, we used Wilcoxon's signed rank test to compare differences between the conditions. All data were statistically analyzed using SPSS 19.0 (IBM Inc., Armonk, NY, USA). P-values < 0.05 were considered statistically significant.

To assess the clinical implications, we calculated an effect size (*r*). The effect size lies between 0 (no effect) and 1 (perfect effect). An *r* value of 0–0.1 indicates no effect, *r* of 0.1–0.3 indicates a small effect, *r* of 0.3–0.5 indicates a moderate effect, and *r* ≥ 0.5 indicates a large effect.²⁵

RESULTS

A total of 24 healthy nulligravid women participated in the study. Mean age, height, weight, and BMI were 21.7 ± 0.9 years, 159.2 ± 5.5 cm, 52.2 ± 5.3 kg, and 20.7 ± 1.7 kg/m², respectively. All women were of reproductive age, none had a BMI > 25 kg/m², and one had a BMI < 18.5 kg/m².

Shapiro-Wilk's test showed that the FRT and TUG data were normally distributed, while the other outcome data were not normally distributed.

A comparison of static and dynamic balance between the simulated gestational weight gain and nonpregnant conditions is shown in Table 1. The SLST time with eyes open and closed and FRT scores were significantly lower in the simulated gestational weight gain condition than in the nonpregnant condition. The effect size for SLST with eyes open and closed was large (*r* = 0.52 and *r* = 0.68, respectively), and the effect was greater with eyes closed than open. Additionally, the effect size was the largest for the FRT, which reflected dynamic balance (*r* = 0.89).

A comparison of the gait parameters between the simulated gestational weight gain and nonpregnant conditions is shown in Table 1. Self-selected and maximum walking speeds were significantly lower in the simulated gestational weight gain condition than in the nonpregnant condition. Step length was significantly lower with simulated gestational weight gain than without, whereas there were no statistical differences in cadence between the simulated gestational weight gain and nonpregnant conditions regardless of walking speed. The effect sizes of walking speed and step length at both self-selected and maximum speeds were large (*r* = 0.57–0.78). However, the effect size of cadence at maximum speed was small (*r* = 0.29) and that at self-selected speed was negligible (*r* = 0.03). Additionally, the TUG performance was significantly slower in the simulated gestational weight gain condition than the nonpregnant condition.

The fear of falling during simulated gestational weight gain is shown in Table 2. Participants had the highest fear of falling during simulated gestational weight gain when considering performing light gardening or hanging out laundry. The average score for each MFES item ranged from 4.7–8.5; the average total score was 95.5 ± 22.2 . In total, 18 (75%) of the participants had a mean score lower than 8, which is the threshold denoting 'fear of falling'. Twelve of the 14 items had a mean score of less than 8, of which the lowest was for confidence when performing light gardening or hanging out laundry.

Table 1 Comparison of balance and gait parameters between simulated gestational weight gain and nonpregnant conditions

	Simulated gestational weight gain (n = 24)	Nonpregnant (n = 24)	<i>P</i>	Effect size (r)
SLST time with eyes opened (sec)	53.8 ± 9.6	58.5 ± 4.6	< 0.05	0.52
SLST time with eyes closed (sec)	27.8 ± 18.8	42.1 ± 19.5	< 0.001	0.68
FRT (cm)	27.3 ± 4.5	32.5 ± 3.8	< 0.001	0.89
5-meter walk test with self-selected speed				
Walking speed (m/sec)	1.43 ± 0.16	1.55 ± 0.17	< 0.01	0.57
Step length (m) †	0.69 ± 0.05	0.76 ± 0.07	< 0.01	0.70
Cadence (steps/min) †	124.7 ± 9.1	124.4 ± 11.8	0.88	0.03
5-meter walk test with maximum speed				
Walking speed (m/sec)	2.01 ± 0.18	2.32 ± 0.42	< 0.001	0.73
Step length (m) †	0.78 ± 0.07	0.89 ± 0.08	< 0.001	0.78
Cadence (steps/min) †	154.8 ± 11.3	156.1 ± 26.6	0.18	0.29
TUG (sec)	6.67 ± 0.75	5.88 ± 0.66	< 0.001	0.90

SLST: single-leg-stance test

FRT: functional reach test

TUG: timed-up-and-go test

Data are presented as mean ± standard deviation

† Data are only presented for 21 women, as data for three women were missing

Table 2 Fear of falling during simulated gestational weight gain assessed using the MFES

	Simulated gestational weight gain (n = 24)
Get dressed and undressed	6.2 ± 2.4
Prepare a simple meal	7.3 ± 1.6
Take a bath or a shower	5.7 ± 2.2
Get in/out of a chair	7.8 ± 1.9
Get in/out of bed	6.6 ± 2.1
Answer the door or telephone	8.5 ± 1.8
Walk around the inside of your house	7.8 ± 1.8
Reach into cabinets or closet	8.0 ± 1.8
Light housekeeping	7.5 ± 1.8
Simple shopping	6.5 ± 2.1
Using public transport	5.7 ± 2.0
Crossing roads	7.2 ± 1.7
Light gardening or hanging out the washing	4.7 ± 2.4
Using front or rear steps at home	5.7 ± 2.1
Total score	95.5 ± 22.2
Mean score	6.8 ± 2.0

MFES: modified falls efficacy scale

Data are presented as mean ± standard deviation

DISCUSSION

Our study showed that simulated gestational weight gain resulted in worse performances in the SLST with eyes open and closed, FRT, walking speed, step length at both self-selected and maximum speeds, and the TUG. We also evaluated the fear of falling with simulated gestational weight gain. To our knowledge, ours is the first study to investigate the effect of simulated gestational weight gain on balance, gait, and fear of falling using validated outcomes to assess the risk of falls.

In the present study, the effect size of the SLST time with eyes open and closed was large, and the effect size was larger with eyes closed than open. These results suggest that static balance may be worse with gestational weight gain regardless of visual feedback, and that balance may be more affected without visual feedback than with visual feedback. Regarding dynamic balance, the effect size of the FRT was large, consistent with the results of a previous study.⁹ Duncan et al¹⁹ showed that if a participant's reach was less than 10 inches (25.4 cm), the adjusted odds ratio of having two or more falls was 2.00 (95% confidence interval: 1.35–2.98) compared with those with a reach of more than 10 inches. In the present study, nine of 24 women (38%) were unable to reach 25.4 cm during simulated gestational weight gain, whereas only one of 24 women (4%) was unable to do so during testing under the nonpregnant condition. These results suggest that the risk of falling during pregnancy may increase because of gestational weight gain.

Regarding gait function, our results are consistent with previous studies demonstrating that pregnancy decreased the walking speed^{11,13,15} and step length¹¹⁻¹³ at a self-selected speed. However, we found no significant change in cadence at both self-selected and maximum speeds. Thus, reduced walking speed might be associated with decreased step length. These results suggest that pregnant women should be educated that their gait ability at both self-selected and maximum speeds may decrease due to decreased step length with gestational weight gain.

In terms of comprehensive gait and balance parameters, we found that the TUG performance was significantly slower with simulated gestational weight gain compared with the nonpregnant condition. The TUG requires participants to rise to a standing position from a chair, walk in a straight line, turn around at a marker, walk straight back to the chair, and sit down. These actions may be easily affected by gestational weight gain.

Regarding fear of falling, we found that the average total score for the first 10 MFES items was 72.2, which is consistent with the performance of 20-week pregnant women in a previous study using the Tinetti falls efficacy scale.¹⁷ The present participants had the greatest fear of falling with simulated gestational weight gain when doing light gardening or hanging out laundry, which require the ability to reach forward.

Our study has two limitations. First, we did not test pregnant women, and instead used nonpregnant women wearing a maternity-simulation jacket to elucidate the risk of falls in pregnant women. However, the use of nulliparous women eliminates hormonal factors such as ligament elasticity during pregnancy, which allowed us to focus on the impact of gestational weight gain. Aoyama et al²⁶ analyzed gait in pregnant women and nonpregnant women with a load on the belly (pseudo-pregnant condition). They concluded that the pseudo-pregnant condition was useful for the comparison of gait analysis between the pregnant and nonpregnant conditions. Second, gestational weight gain varies among pregnant women, whereas the increased weight was fixed in our study. Therefore, our conclusions may not be applicable to different levels of weight gain.

In conclusion, the present study showed that simulated gestational weight gain resulted in worse performances in the SLST with eyes open and closed, FRT, walking speed, step length at both self-selected and maximum speeds, and the TUG. Our results suggest that static and dynamic balance was lower with gestational weight gain, and that static balance may be more

affected in the absence of visual feedback. Gait ability at both self-selected and maximum speeds may be worse with gestational weight gain.

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CONFLICT OF INTEREST

We have no conflict of interest to declare.

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