Original Article

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Daily walking decreases casual glucose level among pregnant women in the second trimester

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Summary **The objective of this study was to explore the relationship between carbohydrate metabolism and the number of steps walked daily, as evaluated by accelerometer, among Japanese women in the second trimester of pregnancy. This longitudinal study was conducted at a university hospital in Tokyo, Japan, from August 2012 to January 2013. Healthy pregnant women at 14 to 18 gestational weeks were recruited. Participants wore accelerometers on the waist for 4 weeks. Casual glucose and hemoglobin A1c (HbA1c) levels were compared between two groups based on whether participants habitually walked ≥ 6,000 steps/day or < 6,000 steps/day. Fifty-one pregnant women were included in the present study; data from 35 were analyzed. There were 22 women in the group that habitually walked ≥ 6,000 steps/day and 13 in the group habitually walking < 6,000 steps/day. Although the median serum casual glucose level at the end of the investigation was 90.0 mg/dL in the group walking < 6,000 steps/day, the level in the group walking ≥ 6000 steps/day was 83.5 mg/dL (p = 0.01). HbA1c levels were not significantly different between the two groups. Our results suggest that walking as a daily habitual physical activity is effective for controlling casual glucose levels in the second trimester of pregnancy.**

Keywords: Walking, glucose, pregnancy trimester, second

1. Introduction

Gestational diabetes mellitus (GDM) is one of the perinatal complications. This disorder of carbohydrate metabolism during the gestational period not only affects women during pregnancy, but also affects them after delivery. Previous studies have reported that women who experienced GDM developed type 2 diabetes in the future at a high rate (*1,2*). Since complete recovery is difficult once a woman develops type 2 diabetes, preventing its occurrence is of primary importance. In order to maintain a woman's health over her lifetime, it is useful to determine how GDM can be prevented.

Pregnancy itself easily induces abnormalities of carbohydrate metabolism because the placenta, which completes development in the second trimester, makes proteolytic enzymes and decomposes insulin in the mother's body. Furthermore, because Asians show the least insulin secretion of all ethnic groups (*3-5*) due to genetic factors, it is possible for them to develop disorders of carbohydrate metabolism without concomitant obesity. An unhealthy lifestyle, including poor nutrition and low physical activity, influences the expression of genes that participate in the energy metabolism process via oxidative phosphorylation of cell mitochondria and induces insulin resistance (*6*). Thus, it is necessary for pregnant Asian women to be cognizant not only of their diet but also of their physical activity. Similar to the way that many management protocols are available for preventing type 2 diabetes based on diet and physical activity, management protocols for preventing GDM must be prepared. Although many previous studies have focused on the effects of diet, physical activity has only recently become a focus. Thus, scientific findings concerning physical activity are still lacking (*7*).

Appropriate physical activity can be effective in improving carbohydrate metabolism, including glucose

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level, in the general population (*8*). However, there is currently no evidence regarding the effects of physical activity on glucose level among pregnant women. Physical activity consists of daily habitual physical activity and leisure sports. Leisure sports are defined as body movements that induce a heart rate > 140 beats/minute with a duration of over 60 minutes; that is to say, high-intensity activity. Daily habitual physical activity is defined as any form of body movement that induces energy expenditure above resting levels in daily life. Therefore, daily habitual physical activity is assessed as a low-intensity activity. Previous research indicates that daily habitual physical activity improves insulin resistance in middle-aged women (*9*). Because GDM seems to be caused by increased insulin resistance, it is likely that insulin resistance in pregnant women would improve with adequate daily habitual physical activity. The purpose of this study was to explore the relationship between daily habitual physical activity, defined as the number of steps walked, as assessed by accelerometer, and carbohydrate metabolism among pregnant Japanese women.

2. Materials and Methods

2.1. *Subjects*

This longitudinal study was conducted at a university hospital in Tokyo, Japan, from August 2012 to January 2013. One hundred and sixty-four pregnant women visited the hospital for a routine prenatal examination between 14 and 18 gestational weeks from August through December 2012, the recruiting period. Inclusion criteria were that participants should be healthy pregnant women. The exclusion criteria included pregnant women who were less than 20 years old, who could not respond to a questionnaire, who had a history of recurrent or habitual abortion, who experienced intrauterine fetal death, who had a threatened miscarriage or premature delivery, who had type 1 or type 2 diabetes, who were using steroids, who required hospitalization, and who had a pregnancy complicated by fetal disorders. Additionally, women with a casual glucose level > 100 mg/dL at ~12 gestational weeks were excluded from analyses, since they had to receive nutritional guidance due to having a high risk of developing GDM (*10*).

2.2. *Research protocol*

Daily physical activity was estimated from the number of steps taken and amount of exercise performed daily, as measured using an accelerometer (Lifecorder EX; Suzuken Co Ltd, Nagoya, Japan) (*11*), and carbohydrate metabolism was measured with casual glucose and hemoglobin A1c (HbA1c) levels.

Healthy pregnant women were recruited at 14-18 gestational weeks while they were awaiting their routine prenatal examination in the outpatient hospital room. Background information of the participants, including maternal age, gestational week, pre-pregnancy body mass index (BMI), pregnancy history, fetus number, any pregnancy complications, and laboratory biochemical data in the first trimester were obtained from patients' medical charts. Participants attached the accelerometers to the waistbands of their skirts or pants, as instructed at the time of recruitment by investigators. If participants experienced any discomfort from wearing the accelerometer on their waistbands, they wore belts that were accessories to the accelerometers and fixed the accelerometers to the belts. The accelerometers assessed their daily activity based on the number of steps taken and amount of exercise performed every day for 4 weeks; the accelerometers were removed for sleeping and bathing. They were asked not to participate in any leisure sports unless they were part of their normal habits.

After 4 weeks, the participants removed the accelerometers and completed questionnaires, which assessed dietary intake and habitual physical activities. We also collected 11 mL of blood during the second trimester for use in the present study, in addition to the blood collected during routine prenatal visits.

Because it has been reported that middle-aged women could prevent metabolic syndrome by walking at least 6,000 steps per day (*9*) and that the average number of steps taken in the second trimester by pregnant Japanese women who do not play sports was about 6,000 steps/day (*12*), participants were classified into two groups based on whether they walked ≥ 6,000 steps/day or < 6,000 steps/day.

Each participant was given detailed information on the study protocol, and all provided their written informed consent. This study procedure was reviewed and approved by the Ethics Committee of the Graduate School of Medicine, The University of Tokyo (No.3812) and was registered in the University Hospital Medical Information Network (UMIN) Center (ID: 000008607).

2.3. *Measurements*

All participants completed a questionnaire regarding their habitual physical activities about 1 year before pregnancy and after becoming pregnant. Daily habitual physical activity was assessed using the accelerometer (*10*), which measured steps, exercise intensity, and energy expenditure. Because pregnant women avoid high-intensity exercise to prevent premature delivery, energy expenditure is proportional to the number of steps taken. Thus, steps were taken for normal life activity. The frequency of the accelerometer was 32 Hz, and its time base range was 0.06-1.94 g. As accelerometers have two axes, the detectable range is limited. No reports from previous research have indicated adverse events related to accelerometer use for pregnant women.

Casual glucose and HbA1c levels were measured to assess participants' carbohydrate metabolism. Casual glucose level was measured by the fully automatic glucose analysis apparatus GA08 (A&T Corporation, Tokyo, Japan) in the University Hospital. The blood samples for HbA1c analysis were immediately stored at 4ºC and assessed with the ADAMSA1cHA-8160 (ARKRAY, Inc., Kyoto, Japan) at FALCO Biosystems Ltd., Kyoto, Japan. The values were expressed as percentage to Hb. Oral glucose tolerance test and insulin release test were not performed in this study because the subjects were healthy pregnant women and it was difficult to ask them to fast for our study due to ethical considerations.

Dietary intake during the most recent month were assessed with a brief self-administered diet history questionnaire (BDHQ), from which we calculated the amount of daily intake for 50 foods and selected nutrients (*13,14*).

2.4. *Statistical analysis*

We consulted the previous randomized controlled trial reported by Barakat *et al*. (*15*). The influence of an exercise program performed by healthy pregnant women on maternal glucose tolerance was studied. Significant differences were found between study groups on the 50 g maternal glucose screen. Values corresponding to an exercise group (103.8 ± 20.4 mg/dL) were better than those of a control group (126.9 ± 29.5 mg/dL), $p < 0.01$. On the basis of this study, sample size was calculated with 40 pregnant women by using G*power (*16*) ($p < 0.05$ and 80% power).

The Mann-Whitney *U*-test was performed using Statistical Package Social Sciences version 19.0 (SPSS Japan Inc.). Two-tailed *p*-values less than 0.05 were considered statistically significant.

3. Results

3.1. *Participant characteristics*

Among 94 pregnant women recruited, 51 (54.3%) agreed to participate in the present study. The women who refused participation primarily stated that they did not wish to wear accelerometers. Because five women dropped out, the remaining 46 women completed the study. With respect to parity, 32 women were primiparous, and the others were in their second pregnancy (Table 1). There were no women with a pre-pregnancy BMI <18 kg/m^2 or >25 kg/m^2 or who had anemia, type 1 or type 2 diabetes or GDM during the previous pregnancy. Among them, casual glucose levels were not checked for two women in the first trimester and for one woman in the first and second trimesters, and walking data were not obtained from two women. For this reason, six women were excluded for further analyses. Thus, final data obtained from 35 pregnant women were analyzed. The average number of steps for all participants were classified into two groups; 22 women walked ≥ 6,000 steps/day, and 13 walked < 6,000 steps/day. Thus, 65.7% of the subjects walked ≥ 6,000 steps/day in the present study.

As shown in Table 1, there was no statistically significant difference in the median age, pre-pregnancy BMI, gestational week, hemoglobin level, or casual glucose level between the two groups at recruitment, around 16 gestational weeks.

3.2. *Physical activities and dietary intake*

As shown in Table 2, seven women regularly walked during the study. Women in the group walking ≥ 6,000 steps/day showed significantly higher calorie consumption (189 kcal/day) compared to those in the group that walked less (115 kcal/day). There was no statistically significant difference between the two groups with respect to energy, protein, fat, and carbohydrate intake.

3.3. *The relationship between physical activity and carbohydrate metabolism*

The relationship between the number of steps walked and casual glucose level was analyzed (Table 3). The median casual glucose level for the group walking ≥ 6,000 steps/day (83.5 mg/dL) was significantly lower than that for the group walking < 6,000 steps/day

Table 1. Characteristics at recruitment

Items	Total (n = 35) Median (IQR[a])	< 6000 steps/day (n = 13) Median (IQR[a])	≥ 6000 steps/day (n = 22) Median (IQR[a])	p value
Age (years)	36.0 (31.5, 39.0)	36.0 (26.0, 39.0)	35.5 (33.0, 37.8)	0.73[d]
pre-pregnancy BMI[b] (kg/m^2)	20.8 (19.0, 21.9)	21.5 (19.1, 22.3)	20.8 (18.7, 21.3)	0.18[d]
Primipara (n)	32	13	19	0.28[e]
Single pregnancy (n)	33	12	21	1.0[e]
Gestational weeks	16.0 (14.5, 17.0)	17.0 (14.0, 17.0)	16.0 (15.0, 17.0)	0.99[d]
Weight (kg)	52.3 (49.6, 56.6)	52.3 (49.4, 56.6)	53.3 (49.9, 56.6)	0.69[d]
Casual glucose (mg/dL)	87 .0 (81.0, 89.0)	82.0 (80.0, 87.0)	87.0 (82.5, 89.0)	0.06[d]
Hb[c] (mg/dL)	12.8 (11.5, 13.3)	12.9 (12.7, 13.4)	12.3 (11.3, 13.3)	0.33[d]

[a]IQR: interquartile range; [b]BMI: Body Mass Index; [c]Hb: hemoglobin; [d]Mann-Whitney-*U* test; [e]Fisher's exact test.

Table 2. Physical activity and dietary intakes among the investigation

Items	Total (n = 35) Median (IQR[a])	< 6000 steps/day (n = 13) Median (IQR[a])	≥ 6000 steps/day (n = 22) Median (IQR[a])	p value
Life activity				
Exercise habits (n)	5	0	5	0.13[c]
Exercise habits (days/week)	–	–	7.0 (5.9, 7.0)	–
Exercise habits (min/day)	–	–	40.0 (32.5, 40.0)	–
Step (steps/day)	6862 (5349, 8341)	5031 (4331, 5386)	8044 (6950, 8666)	< 0.001[b]
Calorie consumption (kcal/day)	161 (122, 194)	115 (98, 127)	189 (164, 207)	< 0.001[b]
Dietary intakes				
Energy (kcal/day)	1400 (1201, 1689)	1316 (1187, 1396)	1525 (1226, 1715)	0.30[b]
Protein (%E)	14.5 (13.7, 15.8)	15.2 (14.3, 15.6)	14.1 (13.3, 15.9)	0.46[b]
Fat (%E)	26.4 (24.4, 28.2)	26.3 (24.6, 29.1)	26.4 (24.3, 27.4)	0.6[b]
Carbohydrate (%E)	57.9 (56.1, 60.8)	57.6 (55.7, 60.2)	57.9 (56.4, 61.2)	0.73[b]

[a]IQR: interquartile range; [b]Mann-Whitney-U test; [c]Fisher's exact test.

Table 3. Laboratory data at the end of the investigation

Items	Total (n = 35) Median (IQR[a])	< 6000 steps/day (n = 13) Median (IQR[a])	≥ 6000 steps/day (n = 22) Median (IQR[a])	p value[d]
Gestational weeks	20.0 (19.0, 21.5)	21.0 (20.0, 22.0)	20.0 (19.0, 21.0)	0.31
Weight (kg)	54.5 (51.4, 59.0)	54.5 (51.2, 57.4)	55.4 (51.9, 58.4)	0.66
Casual glucose (mg/dL)	85.0 (80.5, 90.0)	90.0 (85.0, 96.0)	83.5 (79.3, 86.8)	0.03
HbA_{1c}[b] (%)	5.0 (4.9, 5.1)	5.0 (4.8, 5.2)	5.0 (4.9, 5.0)	0.90
Hb[c] (mg/dL)	11.6 (11.0, 11.9)	11.6 (11.0, 11.8)	11.6 (10.8, 12.0)	0.58

[a]IQR: interquartile range; [b]HbA_{1c}: hemoglobin A_{1c}. [c]Hb: hemoglobin; [d]Mann Whitney-U test.

(90.0 mg/dL; p = 0.012). After the 4-week observation period, casual glucose level in the women walking ≥ 6,000 steps/day decreased by 3.5 mg/dL, from 87.0 to 83.5 mg/dL. In contrast, that in the group walking less increased by 8.0 mg/dL, from 82.0 to 90.0 mg/dL. Thus, a large difference in the alteration of the casual glucose level (11.5 mg/dL) was observed between the two groups. On the other hand, HbA1c levels were not significantly different between the two groups.

4. Discussion

Although previous studies suggested that physical activities could be effective for management of pregnant women with GDM (*15-19*), to our knowledge, this is the first report that simple walking as a habitual daily physical activity is effective for controlling casual glucose levels in pregnant women during the second trimester. Our results suggest that daily habitual physical activity is associated with carbohydrate metabolism among pregnant women, as it is for middle-aged women (*9*).

It is known that casual glucose levels decrease easily when high-intensity exercise is performed. In a previous study, an exercise program for healthy pregnant women consisting of three sessions of aerobics and swimming per week resulted in a decrease in the casual glucose level in the intervention group (*20*). However, it can be difficult for pregnant women to begin participating in leisure sports because they usually receive a recommendation from their obstetricians to avoid high-intensity exercise in order to prevent miscarriage and premature delivery. Thus, the present study focused on daily walking as a moderate-intensity activity for healthy pregnant women. The observation that a significant difference occurred in casual glucose level based only on the number of steps walked daily is a very interesting one. We believe that walking as a habitual daily physical activity will be very attractive for pregnant women.

In a previous study, improvement in HbA1c level was directly proportional to exercise intensity, and there was no significant HbA1c improvement based on the amount of exercise (*21*). That study suggested that the casual glucose level improved in proportion to exercise intensity, not to its amount. In our research, the exercise intensity was low, as we measured walking, which may be why we did not observe an improvement in HbA1c level.

There are several limitations of this study. First, because it was conducted in one hospital with a small number of participants, our results may not be generalizable. Second, participants could not be blinded to the data from the accelerometers. The way of wearing was guided individually at the time of study, but walking steps may have been underestimated by poor wearing. Third, the influence of a meal could not be ruled out, because casual glucose levels were evaluated. However, it took at least 1 hour from check-in at the reception desk to blood collection, so this influence may have been small. Moreover, further

studies should be performed to confirm that not only blood glucose level but also insulin resistance improves by walking.

In conclusion, we found that a relationship exists between the number of steps walked per day and casual glucose level, whereas walking may prevent GDM from occurring in pregnant Japanese women.

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