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CLINICAL PROFILE, WALKING ACTIVITY, AND THE MOVEMENT AND MUSCULOSKELETAL DISCOMFORT OF THE LOWER LIMBS OF WOMEN WITH GESTATIONAL DIABETES DURING A PERIOD OF HOSPITALIZATION

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ABSTRACT

Aim: The purpose of this study was to verify and compare the clinical profile, walking activity, and joint angle and perimetry of the lower limbs of women with and without gestational diabetes mellitus (GDM)during a period of hospitalization and to determine the relationship between walking activity andlower limb joint angle. **Methods:** This study used a cross-sectional design and consisted of 20 pregnant women with hospitalized in the High-Risk Pregnant Women Home at the Hospital Municipal Maternity and a control group (CG)of 20 pregnant women without GDM, recruited from the same hospital during medical visits for prenatal care. Information about glycemic control, before and after hospital discharge, was collected from the daily medical records. The nursing team used a glucometer for insulin control in the following periods: 6 h fasting, 10 h post-coffee, 2 h post-lunch, and 8 h and 24 h post-dinner. The joint angles of their lower limbs were evaluated using a goniometer, their pain assessed using a visual analogue scale and the perimetry measured using a tape. The 6-minute walk test (6MWT) was used to determine walking distance. **Results:** The first admission and last hospital readmission days proved to be important and effective for the control and reduction of blood glucose levels during fasting, after 8 h and 24 h post-dinner, totaling an average hospitalization period of 16.0 ± 3.2 days. Insulin treatment was increased significantly in the morning of the first admission compared with the hospitalization period and the hospital discharge but was reduced in the evening period. The women with GDM presented significant reductions in the joint angles of the hip, knee, and ankle/foot and of the 6MWT compared with the CG, but without differences for perimetry. A multiple regression analysis showed that the reduction in knee joint movements was a predictorto the decrease in the walking distance of these women. **Conclusion:** Pregnant women with GDM require long periods of hospitalization and re-hospitalization for effective blood glucose control and reduction insulin treatmen t, especially in the evening. In addition, during the hospitalization period these women reduce the movements of the lower limbs and walking. The reduction in knee joint movements was a good predictor to the reduction in the walking distance inpregnant women with GDM.

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INTRODUCTION

Gestational diabetes mellitus (GDM), defined as any glucose intolerance first diagnosed during pregnancy, is one of the most frequent complications of gestation that can persist postpartum (Caughey, 2017; World Health Organization, 2013 and Metzger, 2007).

Studies have estimated that 7% of pregnancies were complicated by any type of diabetes and that approximately 86% of these cases represented women with GDM (Cho, 2018; Wilmot, 2014; Kim, 2002; Lehnen, 2013 and Werner, 2019). GDM is recognized as a significant public health problem reaching around 18.4 million live births worldwide (Cho,

2018), which increases the risk of macrosomia, hypoglycemia (Wilmot, 2014), and epigenetic changes in infants, which result in a new generation susceptible to obesity, a 70% chance of progressing to type 2 diabetes later in life (Kim, 2002 and Lehnen, 2013), and a high risk for late preterm birth (Werner, 2019). With a greater prevalence of obesity and sedentary lifestyles, the prevalence of GDM among reproductive-aged women is increasing globally (Committee, 2018), particularly in low- and middle-income countries among Hispanic, African American, Native American, and Asian or Pacific Islander women (Kolu, 2012; Xu, 2017; American Diabetes Association. 2008). These women with GDM are considered to be populations at high risk of death so, therefore, they require increased economic costs for health care, such as hospital treatment programs and primary health care for glycemic control (Caughey, 2017 and American Diabetes Association, 2008).

Glycemic control is performed after a diagnosis of GDM, with pregnant women receiving nutrition and exercise counseling, but if this fails to adequately control glucose levels, medication can be used for maternal and fetal benefit. Insulin is considered the first-line pharmacologic treatment for diabetes during pregnancy in a hospital environment for glycemic control (Caughey, 2017). Potential risk factors that may increase the clinical aspect of GDM include being overweight or obese (having a BMI greater than 25) (Chu, 2007), a high-risk race or ethnicity, hypertension, a high-density lipoprotein cholesterol level less than 35 mg/dL (Committee on Practice Bulletins—Obstetrics, 2018), physical inactivity (Zhang, 2006), and consuming a low-fiber and high glycemic-load diet (Zhang, 2006). Studies and meta-analyses suggest that physical activity during pregnancy provides a slight protective effect against the development of GDM (Mørkrid, 2014; Leng, 2016 and Russo, 2015). In general, the recommendation for pregnant women with GDM is to perform 30 min of moderate-intensity aerobic exercise at least five days a week or a minimum of 150 min per week (Caughey, 2017 and Committee on Practice Bulletins, 2018). In addition, exercise three times per week for 40–60 min at a maximum 65%–75% of age-predicted heart rate by cycling, walking, or circuit training, as a modality, was shown to improve glycemic control of GDM in pregnant women with obesity (Cremona, 2018). Simple physical activity, such as walking for 10–15 min after each meal, can lead to improved glycemic control and is commonly recommended (Hayashi, 2018), being the same activity recommended for healthy pregnant women without GDM (Warburton, 2017 and Ribeiro, 2015). However, the proportion of pregnant women who meet the recommended levels for physical activity range from 4%–60% (Juhl, 2012; Evenson, 2004; Evenson, 2011).

Daily walking is more popular during pregnancy because of its lower intensity and higher accessibility (Hayashi, 2018 and Pereira, 2017). However, the ability of women with GDM to adhere to a walking program necessary for glycemic control may be affected by a number of factors arising from the physiology of pregnancy itself. Recent review studies revealed discomfort associated with pregnancy from lower limb pain, hyperextension or valgus knee lower limb, decreased longitudinal arch with increased support bases, and distances between feet (Ribeiro, 2015). In addition, postural changes, such as increased lumbar and thoracic curvatures during pregnancy and up to two months after childbirth, pelvic ante version, and stretching of the abdominal musculature, result in the reduced functional stability of the hip (Ribeiro, 2015 and Ribeiro, 2013). Decreased postural stability during pregnancy and after childbirth can leadto an increased risk of falls (Ribeiro, 2015 and Ribeiro, 2013). From the first to the last trimester of pregnancy, gait patterns are characterized by greater hip flexion angles and greater extensor and abductor hip moments (Ribeiro, 2013) with increased plantar load over the forefoot and rear foot areas (Ribeiro, 2015). All these changes may limit the adherence to and practice of physical activity for pregnant women with GDM. Currently, for women with and without GDM, there is insufficient scientific evidence for clinical aspects (glucose and insulin), objectively performed walking distances, and the movement and perimetry of lower limbs during the pregnancy period, especially during hospitalization or while under prenatal care. Therefore, the purpose of the current study was to verify and compare the clinical profile, walking activity, and joint angle and perimetry of the lower limbs of women with and without GDM during a period of hospitalization, including the relationship between walking activity and joint angles. This information could help health professionals elaborate potential health promotion strategies; make possible the adherence of pregnant women with GDM to physical activity; and favor, directly or indirectly, the reduction of health care costs mainly due to uncontrolled clinical blood glucose.

MATERIALS AND METHODS

Study design and participants: This study used a cross-sectional design and consisted of 20 pregnant women with GDM in a hospital setting and a control group (CG) of 20 pregnant women without GDM in prenatal care. The pregnant women with diabetes were hospitalized in the High-Risk Pregnant Woman's Home at the Hospital Municipal Maternity School Dr. Mário Altenfelder Silva, a public institution that serves women who depend on Unified Health System. Pregnant women without GDM were recruited from the same hospital during medical visits for prenatal care. The study's procedure was reviewed and approved by the Departmental Research Committee of the Department of Health Sciences, University Santo Amaro (approval by number:1.414.464) and was registered at the Hospital Municipal Maternity School Dr. Mário Altenfelder Silva, São Paulo, Brazil. All the participating women provided their informed written consent prior to their participation. The eligibility criteria were 28 weeks or more gestation and in prenatal care; a clinical diagnosis of GDM; hospitalization; no hemodynamic or obstetrical complications (e.g. premature labor or bleeding and/or hemorrhage), clinical intercurrences (e.g. hypertensive peak or acute respiratory pathology), or multiple gestations; and without cardiac and respiratory diseases or previous musculoskeletal dysfunctions, such as fractures, sprains, neuropathies, and tissue lesions. In addition, they could not have lower limb prostheses and/or orthoses or have received corticosteroid or intra-articular hyaluronic acid injections in the knee in the previous six months, respectively. A medical release for the proposed evaluations and normal fetal growth were also required.

Initial assessment and musculoskeletal discomfort of the lower limbs: For the initial evaluation, a questionnaire was applied in which the following information was recorded: age, height, body mass, BMI, clinical aspects of GDM, hospitalization data, referral data, clinical treatment, and social aspects. Pain symptoms for segments of the lower limbs (i.e.

hip, knee, and ankle/foot) were evaluated using a visual analogue scale (10 cm - 0 no pain and 10 maximum pain) (Ribeiro, 2010).

Clinical aspects of GDM during the hospitalization period

Information about glycemic control, before and after hospital discharge, was collected from the patient's daily medical records. Blood glucose control was always collected by the nursing team of the local hospital before and after hospital discharge. The nursing team used a glucometer for insulin control over the following periods: 6h of fasting, 10 h post-coffee, 2 h post-lunch, and 8 h and 24 h post-dinner. The "after-meal" times were always counted as two hours after they started. If any meal was delayed, the exam was also delayed. The women with GDM were instructed not to eat any food close to the time of the profile so as not to alter the result of the examination. Insulin control data for the pregnant women with GDM were also collected from medical records at admission and after hospital discharge. The orientation of the patients with insulin control was performed by the nursing team regarding the type of insulin, type and place of application, syringe and needle recognition, aspiration technique, and self-application. For patients who presented some difficulty with orientation on insulin control, this was carried out by a family member and/or the person responsible for the patient during the hospitalization period, who demonstrated enough cognitive and physical capability to insulin application.

Assessment of lower limb joint motion, perimetry, and walking tests: The measurement of the angles of movement of the lower limbs was performed using a goniometer with the pregnant woman in a supine position on the hospital bed after performing all ambulatory and medical procedures. An experienced physiotherapist verbally requested that the pregnant woman perform a maximum joint movement according to its limit. The goniometer was then used to evaluate the following articular angles: hip (flexion and extension, abduction and adduction, and internal and external rotation), knee segment (flexion and extension) and ankle/foot (flexion and extension and inversion and eversion). It is important to note that for the greater comfort of the pregnant woman, the rotation movements (internal and external) were evaluated in a seated position. To perform the perimetry of the lower limbs using a tape measure, the following anatomical points were considered: thigh (5 and 10 cm above the center of the patella) and leg (5 and 10 cm below the anterior tuberosity of the tibia). A6-minute walk test (6MWT) was undertaken in 30-m well-lit indoor hospital corridors where the patients, with and without GDM, were hospitalized or attending prenatal care. Each participant underwent the 6MWT according to the standardized guidelines used in clinical practice (Supplemental Digital Content, Document 1, http://links.lww.com/AA/C586). The testing commenced with a 5-min seated rest period during which standardized instructions were read to the participant (Dennis, 2018).

Resting heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), and respiratory rate (RR) were measured. Hemodynamic variables were measured using a calibrated automated blood pressure machine. Each woman underwent two 6MWTs separated by a rest period of at least 5 min. During each recovery period, vital signs were measured every minute (with the first measurement taken 1 min after the test was completed) for at least 5 min until the HR had returned to the resting value (or below) or within 4 bpm of the resting measurement. A maximum of 15 min of measurement was made after each test. The 6MWT and recovery period were then repeated (Dennis, 2018).

Statistical analysis

The 40pregnant women sample-size calculation was based on the 6MWT variable using Bioinst at software (2015). A moderate effect size (F=0.25), an 80% power, and a 5% significance level were considered for the calculation. Data were analyzed using SPSS Statistics. The distribution of the data was assessed using the Shapiro–Wilk test. Comparisons between the GDM group and the CG were performed using paired (pre- and post-hospitalization) or unpaired t-tests. A forward stepwise multiple regression analysis was used to predict the relationship between the 6MWT walking distance and the joint angle change of the lower limb. The dependent variables were sequentially included in the model in three consecutive blocks: the variables of the hip angles, knee angles, and ankle/foot angles. After reducing the variables, only those with correlation coefficients higher than 0.20 were entered into the model. For all the analyses, we adopted $p<0.05$.

RESULTS

Initially, 50 pregnant women volunteered for this study; however, seven were excluded due to the preset criteria and three were excluded because they were not available to perform the evaluations in the hospital. Pregnant women with GDM presented with greater weight and BMI before and during pregnancy compared with the pregnant women without diabetes, as shown in Table 1.

Table 1. Mean, standard deviation and comparison of anthropometric characteristics between groups: women pregnancy with gestational diabetes mellitus - GDM and pregnancy women healthy– CG

Characteristics	GDM	CG	p
Age (years)	34.0±5.2	29.0±9.5	0.090
Gestacional age (week)	30.0±4.1	32.6±2.2	0.490
Weight in pregnancy(kg)	94.3±19.0	84.0±21.6	0,040*
Body Mass Index (kg/m^2)	37.6±6.9	29.2±6.7	0,017*
Height (m)	1.6±0.3	1,6±0.6	0,500
Weight before of pregnancy (kg)	82.1±21.2	74.6 ±19.7	0,002*

* Teste t Student independente, considerando diferenças estatísticas p<0,05.

The mean time for pregnant women with GDM presenting for a first hospitalization was7.3 ± 3.7 days, and the last hospitalization was 3.4 ± 2.5 days. The mean days in hospital for re-hospitalization was 5.8 ± 2.8, and the reason for hospitalization in 98% of the cases was glycemic control (blood glucose). The average total hospitalization period was 16.0 ± 3.2 days. The first admission and the last hospital readmission proved to be important and effective for the control and reduction of blood glucose levels (glycemia) post-fasting and 8 h and 24 h post-dinner when compared with hospital discharge. Another important observation was that the first hospital admission was also important for reducing blood glucose levels after lunch compared with the hospitalization period and hospital discharge (Table 2). Table 3 shows that insulin treatment was significantly increased in the morning of the first admission compared with the hospitalization period

and the hospital discharge. However, insulin treatment was significantly reduced in the evening for the first and last admission compared with the hospital discharge, indicating improved effectiveness of insulin treatment during this period. Table 4 shows that women in the GDM group presented significant reductions in joint angles for hip flexion and abduction; medial and lateral hip rotation; knee flexion and extension; and ankle/foot flexion, extension, and inversion compared with the CG.

These results have a great clinical impact because health professionals who recommend physical activity, such as walking, for women with GDM may be unaware of the greatly limited joint movement in the lower limbs that these women present in relation to pregnant women without GDM. No difference was found between the groups for the perimetry of the lower limbs. Table 5 shows that 6MWT (distance and turn) was reduced in the GDM group compared with the CG. It was also observed that the SBP was higher after walking in the

Table 2. Mean, standard deviation and comparison of the glycemia between period hospitalization and hospital discharge during admission and readmission of the women pregnancy with gestational diabetes mellitus

Glycemia	Hospitalization	Period Hospitalization	Hospital Discharge	p-value
Fasting	Fist Admission	117.8 ± 20.7	102.8 ± 16.2	0.017*
	Last Readmission	86.2 ± 11.1	81.2 ± 12.0	0.012*
After coffee	Admission	153.2 ± 39.5	136.8 ± 20.5	0.147
	Readmission	109.1 ± 31.0	115.2 ± 22.6	0.156
After lunch	Admission	170.1 ± 37.8	130.6 ± 19.0	0.002*
	Readmission	126.7 ± 23.1	124.7 ± 21.0	0.293
After dinner	Admission	160.3 ± 39.6	133.9 ± 22.8	0.015*
	Readmission	126.7 ± 25.5	115.9 ± 23.0	0.044*
After 24 h	Admission	147.0 ± 36.7	128.3 ± 19.7	0.005*
	Readmission	118.7 ± 19.6	105.9 ± 20.6	0.041*

*Test t Student independent, considering significant differences p<0,05.

Table 3. Mean, standard deviation and comparison of the insulin between period hospitalization and hospital discharge during admission and readmission of the women pregnancy with gestational diabetes mellitus.

Insulin	Hospitalization	Period Hospitalization	Hospital Discharge	p-value
Morning	Fist Admission	17.5 ± 6.3	22.7 ± 9.9	0.006*
	Last Readmission	27.3 ± 9.2	24.6 ± 12.7	0.100
Evening	Admission	8.0 ± 2.9	3.0 ± 4.1	0.022*
	Readmission	8.2 ± 5.0	5.5 ± 3.0	0.031*
Night	Admission	8.0 ± 5.2	10.5 ± 6.2	0.104
	Readmission	16.6 ± 7.8	16.0 ± 7.7	0.446

*Test t Student independent, considering significant differences p<0,05.

Table 4. Mean, standard deviation and comparison of the joint angle and perimetry of the lower limb between groups: women pregnancy with gestational diabetes mellitus - GDM and pregnancy women healthy– CG

Joint Angle(degrees)	Side	GDM	CG	p
Hip flexion	Right	95.2±14.0	121.2±3.5	0.001*
	Left	95.7±13.7	121.6±2.6	0.001*
Hip extension	Right	28.0±4,7	28.9±2.6	0.230
	Left	27.7±4,9	29.8±3.5	0.066
Hip abduction	Right	34.4±7.3	40.5±3.5	0.012*
	Left	35.2±7.3	40.5±3.6	0.003*
Hip adduction	Right	16.7±4.9	15.3±0.1	0.107
	Left	16.5±4.6	15.1±0.2	0.060
Hip medial rotation	Right	32.8±6.1	40.1±3.8	0.001*
	Left	33.2±6.2	40.2±3.7	0.002*
Hip lateral rotation	Right	31.6±9.6	42.5±3.0	0.001*
	Left	33.5±6.8	42.6±3.1	0.001*
Kneeflexion	Right	100.4±17.3	134.2±5.6	0.001*
	Left	99.7±17.5	135.0±5.6	0.002*
Kneeextension	Right	11.0±2.6	39.5±7.9	0.001*
	Left	11.5±2.8	40.5±6.9	0.001*
Ankleflexion	Right	31.5±8.0	42.8±2.4	0.001*
	Left	32.3±6.7	43.0±2.5	0.003*
Ankleextension	Right	1±6.1	19.7±1.1	0.335
	Left	19.5±6.0	19.6±1.8	0.457
Ankleinversion	Right	28.1±7.3	37.1±4.0	0.001*
	Left	28.2±6.9	37.4±3.7	0.001*
Ankleeversion	Right	18.0±6.1	19.1±2.0	0.260
	Left	18.1±4.4	19.2±1.8	0.183
Perimetry lower limbs	Side	GDM	CG	P
Thigh (10 cm)	Right	51.8±7.6	48.4±8.5	0.093
	Left	51.7±7.9	47.9±8.1	0.100
Leg (10 cm)	Right	40.0±4.8	41.2±5.4	0.237
	Left	38.8±9.0	41.0±5.2	0.177
Thigh (5 cm)	Right	46.4±6.4	45.6±7.8	0.359
	Left	46.3±6.6	44.7±6.7	0.216
Leg (5 cm)	Right	39.4±5.7	39.9±5.4	0.494
	Left	39.6±5.0	38.9±5.3	0.396

*Test t Student independent, considering significant differences p<0,05.

Table 5. Mean, standard deviation and comparison of the 6-minute walk test (6MWT) between groups: women pregnancy with gestational diabetes mellitus - GDM and pregnancy women without diabetes mellitus – CG

6MWT	GDM	CG	p
Numberturns	8.4±1.5	9.5±0.5	0.004*
Distance walked test(m)	251.4±47.8	290.5±12.3	0.002*
Resting heart rate (bpm)	95.1±10.8	99.3±2.7	0.067
Heart rate after walk (bpm)	100.7±13.3	103.2±3.2	0.232
Oxygen saturation (%)	98.0±1.1	98.0±1.0	0.782
Systolic blood pressure (mm Hg)	120.0±19.8	118.2±4.3	0.407
Systolic blood pressure after walk (mm Hg)	128.4±13.3	119.0±4.4	0.007*
Diastolic blood pressure (mm Hg)	68.2±10.6	78.5±3.6	0.005*
Diastolic blood pressure after walk (mm Hg)	69.8±9.8	78.5±3.5	0.001*

*Test t Student independent, considering significant differences p<0,05.

Table 6. Mean, standard deviation and multiple regression analyses between distance walked by the 6MWT and joint angle change of lower limb in womens pregnancy with gestational diabetes mellitus – GDM

Joint Segment	Joint Angle	6MWT	R	R^2	F	P
Hip flexion	121.4±3.1	251.4±47.8	0.19	3,9%	0.2	0.964
Hip extension	29.3±3.1	251.4±47.8	0.19	3.9%	0.2	0.922
Hip abduction	40.5±3.5	251.4±47.8	0.19	3.9%	0.3	0.839
Hip adduction	15.0±3.8	251.4±47.8	0.18	3.6%	0.4	0.724
Hip medial rotation	40.1±3.7	251.4±47.8	0.16	2.7%	0.5	0.608
Hip lateral rotation	42.5±3.0	251.4±47.8	0.10	1.2%	0.4	0.512
Kneeflexion	134.6±5.5	251.4±47.8	0.58	33.7%	9.4	0.001*
Kneeextension	7.5±5.0	251.4±47.8	0.32	10.5%	4.4	0.038*
Ankleflexion	19.7±1.1	251.4±47.8	0.22	-2.2%	2.0	0.156
Ankleextension	42.9±2.4	251.4±47.8	0.27	7.3%	1.4	0.243
Ankleinversion	37.2±3.8	251.4±47.8	0.26	6.8%	2.8	0.095
Ankleeversion	19.0±1.9	251.4±47.8	0.26	6.9%	1.3	0.261

*Multiple regression analyses (step-wise), considering significant differences p<0,05.

GDM group and the reduced DBP pre and post the 6MWT was higher compared with the CG. The multiple regression analysis found that the knee flexion and extension movement angles in the GDM group were good predictor to reduction walking distance verified by of the 6MWT.

DISCUSSION

In accordance with our resulted, pregnant women with GDM presented higher BMIs compared with pregnant women without GDM. The period of hospitalization was an effective intervention for the control and reduction of glycemia levels after fasting and 8h and 24h post-dinner for pregnant women with GDM compared with hospital discharge, totaling an average period of hospitalization of 16.0 ± 3.2 days (between hospitalization and re-hospitalization). The insulin treatment was significantly reduced in the evening for the first and last admissions compared with the hospital discharge, indicating the improved effectiveness of insulin treatment during this period. The women in the GDM group presented significant reductions in the joint angles of the hip, knee, and ankle/foot compared with the CG, but showed no difference for the perimetry of the lower limbs. The 6MWTwas reduced in the GDM group compared with the CG. In addition, the SBP after walking was higher in the GDM. The multiple regression analysis showed that the reduction in knee joint movement was a good predictor to decreased walking distance for these women. In the literature, maternal obesity is a risk factor for obstetric complications, and its association with GDM strongly affectspregnancy outcomes[13,30,31].According to Huert *et al.,* (2018)[30], when GDM is associated with obesity, patients have an increased risk of caesarean section, preeclampsia, and maternal morbidity compared with non-obese patients with GDM and obese patients without GDM. Another recent study observed that GDM and maternal obesity are linked to weight gain in childhood and an increased risk of cardiovascular disease later in life[31]. In agreement with the literature, the current study also observed higher BMIs in women with GDM compared with pregnant women without GDM (control) and increased vulnerability to maternal and fetal complications, which has a greater economic impact on hospitals due to possible complications and re-hospitalization needs. The period of hospitalization was shown to be an effective intervention and way to control and reduce blood glucose levels in pregnant women with GDM compared with hospital discharge. However, this has a high economic impact for hospitals because of the length of the hospitalization period (16.0±3.2 days in the current study), but it is necessary and important for insulin treatment compared with hospital discharge.

According to Bottalico (2007) and Mulla*et al.,* (2010), with the rising prevalence of GDM, it is likely that more women will require pharmacotherapy to maintain glycemic control during pregnancy. In the current study, we confirmed this need in a hospital environment. In a recent review, Brown *et al.,* (2017) suggested that minimal harms are associated with the effects of oral insulin and oral anti-diabetic pharmacological therapies for GDM. The choice to use one or the other may be down to the medical or maternal preference, availability, or severity of the GDM. In the current study, we observed that the choice of insulin treatment was effective for GDM, especially when given in the evening, compared with hospital discharge for better glycemic control (Brown, 2017). Another way to maintain glycemic control in GDM is to practice regular and adequate physical activity (5 days a week or a minimum of 150 min per week) (Caughey, 2017; Cremona, 2018). Simple physical activity such as walking for 10–15 min (Hayashi, 2018; Warburton, 2017; Ribeiro, 2015) is recommended for healthy pregnant women because of its lower intensity and higher accessibility (Hayashi, 2018; Pereira, 2007). However, the ability of women with GDM to adhere to a walking

program may be affected by various body changes during pregnancy, such as lower limb pain, valgus knee, decreased postural stability, greater hip flexion angles, and overloading of the rearfoot and forefoot (Ribeiro, 2010; Ribeiro, 2013; Ribeiro, 2015). In the current study, women with GDM presented significant reductions in the joint angles of the hip, knee, and ankle/foot compared with a CG of pregnant women without GDM, but without any difference for the perimetry of the lower limbs. However, in agreement with Ribeiro *et al.,* (2015, 2013), when evaluating pregnant women with GDM, it was also observed in the current study that reductions in the articular angles of the lower limbs can be explained by the presence of obesity in relation to the CG, which may increase hip joint overload and make hip and knee joint movements difficult. The differential of this study was showed that the reduction of the knee joint angle was predictor to the decrease in the 6MWT walking distance of the GDM group and that this was reduced compared with the CG. Walking is a physical activity that has a protective agonist effect in the control and development of GDM (Mørkrid, 2014; Russo, 2015; Leng, 2016). Hayashi *et al.,* (2018) recommended that pregnant women with GDM should walk a minimum of 6,000 steps/day for efficient glycemic control. Dennis *et al.,* (2018) reference the distance walked in the 6MWT for pregnant women as 302–674 m. A differential of this study showed a significant reduction in the distance walked during the 6MWT for the GDM group compared with the CG. Pregnant women should be encouraged to walk and informed that it might prevent adverse pregnancy outcomes such as GDM. Therefore, future investigations of physical activity among pregnant women with GDM should employ longitudinal designs to examine physical activity levels during pregnancy in relation to glycemic control. Such approaches will enhance the accuracy of public health policy for the elaboration of effective strategies and interventions to increase physical activity among pregnant women.

Conclusion

Pregnant women with GDM require long periods of hospitalization and re-hospitalization for effective blood glucose control and reduction insulin treatment, especially in the evening. In addition, during the hospitalization period these women reduce the movements of the lower limbs and walking. The reduction in knee joint movements was a good predictor to the reduction in the walking distance in pregnant women with GDM.

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