Effect of Physical Activity during Pregnancy on Gestational Diabetes Mellitus

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Abstract

Aims: The present study evaluates association between physical activity and Gestational Diabetes Mellitus (GDM), for it can be an effective intervention for its management. Though physical activity helps maintain glucose homeostasis, evidences of GDM risk are less extensive. Therefore, this study also identifies its correlation with maternal blood glucose levels. **Materials and Methods:** A prospective case-control study was carried out among pregnant women attending regular antenatal clinic at two private hospitals. The study comprised of 100 cases and 273 matched controls. Data was collected by personal interviews using a standard questionnaire. Physical activity was assessed using long form of International Physical Activity Questionnaire (IPAQ) reported as Metabolic Equivalent-Minutes per week (MET-Minutes/Week). Statistical Package for Social Sciences (SPSS) was used for analysis. **Results:** Results shows high exposure rates for low-to-moderate physical activity among cases, across all domains and sub-activities. The odds of GDM engaged in domestic and gardening activities for <2999 MET-minutes per week are 10 times higher than involved for ≥3000 MET-minutes per week ($P < 0.001$). The study also shows poor or no correlation between physical activity during pregnancy and maternal blood glucose levels. **Conclusion:** Despite existence of poor or no relationship with maternal blood glucose levels, prolonged sedentary behavior and decreased physical activities, especially domestic, are potential risk factors for GDM, a major finding of the study.

Keywords: Exercise in pregnancy, gestational diabetes mellitus, International Physical Activity Questionnaire, maternal blood glucose level, oral glucose tolerance test, physical activity

INTRODUCTION

One of the most popular remedies to gestational diabetes mellitus (GDM) widely suggested is enhanced physical activity during pregnancy. It is of common experience that GDM is usually managed through glycemic control.[1,2] To provide adequate protection against adverse perinatal outcomes, it is prudent to achieve euglycemia in women with GDM until there is absolute evidence of normal fetal growth in ultrasonography.[3] Medical nutrition therapy propped up with physical activity, insulin therapy, self-care, and intensive blood glucose monitoring is the cornerstone of GDM management, which ultimately aims to attain and maintain euglycemia.[3]

So far, there has no guideline for GDM-specific exercise prescription until recently Padayachee and Coombes drafted the first guideline on exercise for GDM management, which states that a GDM-affected woman should perform exercise, both aerobic and resistance, at moderate intensity for a minimum period of 30–60 min at a frequency of three times/week.[2] Moderate activities are referred to those requiring normal physical effort that make pregnant women breathe slightly harder and their heart beat a little faster than normal.[4] Given the lack of large cohort studies implementing exercise as the management of GDM, these recommendations are drawn from "exercise in pregnancy" and "exercise in Type II diabetes mellitus" guidelines.[2] Meta-analysis has shown aerobic/resistance exercise to be an adjunct to standard care, significantly improved postprandial glycemic control (mean difference [MD]: −0.33 mmol/L, 95% confidence interval [CI]: −0.49 to −0.17) and lowered fasting blood glucose (MD: −0.31 mmol/L, 95% CI: −0.56 to − 0.05) compared to standard care alone.[5]

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It is well known that hyperglycemia in GDM mainly occurs due to maternal insulin resistance. Physical activity, on the other hand, helps in improving insulin sensitivity and secretion ensuring glucose homeostasis.[6-8] Despite this fact, evidences regarding benefits of physical activity on GDM prevention are less extensive and less convincing ,[9-35] largely due to non-uniformity in frequency, intensity, time/duration or intensity of physical activity.[36] Several studies,[14,17,19,21-25,27,32-35,37-39] but not all,[9-13,15,16,18,20,26,28] reported the existence of inverse association between higher physical activity and subsequent GDM risk with varying strength of association. There exists a wide disparity in the reduction of relative GDM risk due to physical activity ranging from 10–30%[22-24,35] to 50%–90%.[14,17,19,21,25,32-34,37] A meta-analysis of cohort and case–control study revealed an inverse relationship between physical activity and GDM.[40] This study however did not study the effect of dose on GDM. Other meta-analyses[41,42] of randomized trials showed two different kinds of results – one showing an inverse[41] and the other no association.[42] None of the published literature, however, reported the impact of the amount of physical activity on GDM.[36] Only few studies reported dose-dependent inverse relationship between physical activity and GDM risk.[21,22,29,33,35] However, studies found benefits of physical activity level from low to moderate.[23,25,32] A thorough investigation of the dose-dependent physical activity–GDM (linear or nonlinear) relationship is necessary to identify the threshold physical activity level for adequate recommendations on GDM risk reduction.[36] It will help health planners conduct large-scale randomized trials to prevent GDM in the future.[36]

Although health-care providers advise pregnant women to maintain or increase physical activity during pregnancy,[43] it hardly convinces them against their traditional belief/perception that pregnancy is a state that requires extra care/rest and recuperation.[44] Consequently, exercise during pregnancy remains at very low level of acceptability throughout the world.[45] One such study evidenced a nonlinear association between physical activity in early pregnancy and GDM with $p_{\text{nonlinearity}} = 0.008$ and no further decline in risk with physical activity >8 h/week.[36]

It is thus seen that the literature available in this area of research is too limited. Therefore, the present prospective case–control study was designed to identify the association between physical activity during pregnancy and GDM risk. In addition, the study also explores the existence of a correlation between physical activity during pregnancy and maternal blood glucose levels following oral glucose tolerance test (OGTT), a by-product of the study.

Materials and Methods

Study design and participants

This study was carried out at two private hospitals of Udupi district situated along the coastline in the southern part of Karnataka (India). It covers a population of 1.18 million spread over a geographical area of 3575 km^2. As per the report of District Level Household and Facility Survey-4 (2012–2013), 53.4% of the antenatal women residing in district availed complete antenatal care.[46] The district has been identified with better maternal and child health indicators than the national average. Most deliveries (98.8%) are institutional in the district, out of which 68.1% were in private health-care institutions.[46]

The study population included all those pregnant women who were coming to secondary care hospitals for routine antenatal checkup. Potential cases included incident cases of GDM reporting to antenatal outpatient department. All those pregnant women, who were beyond 20 weeks of gestation, were universally screened for GDM by subjecting them to 1-h 50 g glucose challenge test (GCT). Their GCT reports reviewed after a week time. All those women whose 1-h 50 g GCT exceeded the cutoff of 140 mg/dL were called for diagnostic 3-h 100 g OGTT the next day. A pregnant woman who was newly diagnosed with GDM in her present pregnancy by 3-h 100 g OGTT following 20 weeks of gestation using Carpenter and Coustan criteria[47] at the study setting was enrolled as an incident case. The next pregnant woman, frequency-matched with period of gestation (POG) (±2 weeks), whose 1-h 50 g GCT value fell below 140 mg/dL was identified as non-GDM (or control). Women who were diagnosed with DM before their pregnancy were excluded from the study. Physical inactivity as a risk factor for GDM was considered for sample size estimation. Expecting 57.7% of the cases to be not physically active[48] and anticipating a difference of at least 20% between the cases and controls to be clinically significant for a power of 80%, at 5% level of significance, and 10% nonresponse rate, a minimum of 73 cases and 219 controls, frequency matched with POG, were required to be recruited with a case-to-control ratio of 1:3. Data were collected over a period of 24 months during 2014–2016.

GDM was diagnosed using Carpenter and Coustan criteria[47] at the onset of the study. Subsequently, Diabetes in Pregnancy Study Group India (DIPSI) criteria[49] was adopted as the new diagnostic criterion since November 2015. It was uniformly adopted by the treating obstetricians at both the study settings by consensus following a departmental review. The data collection was continued to interview the predetermined number of cases and controls as per the sample size calculation. However, to ascertain the similarity between risk factors among cases and controls, additional number of cases and POG frequency-matched controls at a case-to-control ratio of 1:2 was required to be recruited as per the new criterion. This additional number was decided based on the time available to the investigator for data collection as per the stipulated study period until the last recruitment of a study subject.

Accordingly, operational definition of both the cases and controls was changed according to the new DIPSI guidelines.[49] An antenatal woman who was newly diagnosed with GDM in her present pregnancy by 2-h 75 g single venous plasma glucose following 20 weeks of gestation exceeding the cutoff of 140 mg/dL (irrespective of the last meal timings) at a health-care setting was included as a new case. The next pregnant woman, frequency matched with POG (±2 weeks), whose 2-h 75 g single venous plasma glucose value was <140 mg/dL was included as a new control in 1:2 ratio.

Data collection methodology

Institutional ethical committee (IEC: 623/2014*)* approval was obtained before the beginning of the study. Subsequent modification due to the change in the diagnostic criterion and sample size was duly notified to the ethics committee. Subject information sheet was distributed to, and written informed consent obtained from, all participants before data collection.

At the study setting, newly diagnosed GDM cases visiting hospitals for routine antenatal care were identified from the outpatient records. On the same day, POG frequency-matched controls were also identified and included in the study. Fulfilling the inclusion criteria, cases and controls were interviewed using a pretested questionnaire that included details on sociodemographic variables. Socioeconomic status (SES) was assessed using modified Udai Pareek Scale.[50] Accordingly, a score of <40 was identified as belonging to low, 40–70 middle, and ≥70 high SES.[50] Stress was assessed using Cohen Perceived Stress Scale: score of <20 was graded as low stress whereas ≥20 was considered as high stress.[51,52]

As a part of anthropometric measurements, weight at first antenatal registration visit in the first trimester was considered as prepregnancy weight. Height was measured using a measuring tape or stadiometer (cm) to the nearest 1 cm. Women were required to stand upright barefoot with their back against the wall, heels together, and looking forward.[53] Prepregnancy body mass index (BMI) was calculated as the ratio of prepregnancy weight (kg) to the square of height (m).[53] A woman was considered to be overweight if BMI ≥25 kg/m^2.

Assessment of physical activity

Physical activity was assessed through the administration of a standardized questionnaire – the long form of International Physical Activity Questionnaire (IPAQ).[54] The long version of IPAQ, assessed physical activity in the last 7 days of the interview, has been validated for estimating physical activity among pregnant women,[55] showing poor correlation between the questionnaire and an accelerometer, 0.03 for moderate physical activity, 0.15 for total physical activity.

The questionnaire was undertaken across a comprehensive set of four domains: work-related, transport-related, domestic and garden (yard)-related, and leisure time-related physical activities. Work-related activities included all kinds of paid and unpaid jobs that the woman did outside her house. Details pertaining to both long- and short-distance travel were included under transport-related activities, for example, travel from one place to other including places of work, stores, and movies. Domestic and garden (yard)-related activities included those carried out in and around home such as housework, gardening, yard work, general maintenance work, and caring for own family. Activities solely carried out for recreation, sport, exercise, or leisure were covered under leisure time-related physical activities.[54]

Under each domain, details pertaining to specific type of physical activities were interviewed, viz., walking, moderate-intensity, and vigorous-intensity physical activities. The last referred to hard physical effort requiring the woman breathe much harder than normal. On the other hand, moderate activities required moderate physical effort making woman breathe somewhat harder than normal.[54]

Domain-specific scores were assigned pertaining to each type of physical activity. The total score was taken as the summation of the duration (in minutes) and frequency (days) for all types of activities in all domains. Data so collected were reported as metabolic equivalent-minutes per week (MET-minutes/week), which can be computed by weighing each type of activity by its energy requirements defined in METs. These METs are multiples of the resting metabolic rates. MET-minute/week is then computed for each activity as follows:[54]

MET-minutes/week = MET level × minutes of activity/day × days/week

Total score was calculated for each domain, and then, the overall grand total was estimated. Domain-specific scores or activity-specific subscores may also be computed as summation of the scores for walking, moderate-intensity, and vigorous-intensity activities within the specific domain, whereas activity-specific scores are summation of the scores for the specific type of activity across domains:[54]

Total physical activity (MET-minutes/week) = Total MET-minutes/week (at work + for transport + in domestic chores + in leisure).

MET-minute scores are equivalent to kilocalories for a 60-kg person = MET-min × (weight in kilograms/60 kg).

MET-minutes/day can also be presented as more popularly used MET-minutes/week. As there exist no established thresholds for presenting MET-minutes, the IPAQ Research Committee proposed to report as median values and interquartile range. However, the overall grand total scores so computed can be categorized into three levels of physical activity: high: total physical activity ≥3000 MET-minutes/week; moderate: 600 < total physical activity <3000 MET-minutes/week; low: total physical activity <600 MET-minutes/week.[54]

The above criteria were also used to subcategorize domain- and activity-specific scores. Details pertaining to time spent in sedentary activity were considered as an additional indicator but not included in the summary score of physical activity. It gives an estimate of sitting on typical weekdays and weekend days excluding the time spent in sitting during travel covered under transport domain. For the assessment of time spent in sitting, "minutes" was used as an indicator instead of MET-minutes which refers to energy expenditure. Data on sitting were reported as categorical variable although there exist no well-accepted thresholds till date.[54]

Statistical analysis

The above data were analyzed using Statistical Package for the Social Sciences (SPSS) version 15 for windows (SPSS South Asia, Bangalore, Karnataka, India) in four steps: (1) Results were expressed as percentages and proportions for categorical variables. Cases and controls were compared for exposure using univariate logistic regression. Odds ratio (OR) with 95% confidence interval (CI) was reported to study the association between different variables; $P < 0.05$ was considered statistically significant. (2) Stratification technique was employed to control confounding to assess the true association between exposure (physical activity during pregnancy) and outcome of interest (GDM risk) within the homogenous strata of each potential confounding variable. Pooled summary OR estimate adjusted for probable confounder was derived using Mantel and Haenszel test statistic assuming uniformity in stratum-specific estimates over the range of confounding variables. (3) The strength of relationship between IPAQ scores as independent variable (in MET-minutes/week) and maternal venous plasma glucose levels as dependent variable (in mg/dL) was determined using coefficient of determination (R^2). (4) The relationship was quantified and described using regression analysis.

RESULTS AND DISCUSSION

As above, a total of 100 GDM cases and 273 POG frequency-matched controls (1:2.7 ratio) were recruited, as shown in Figure 1. As seen, among the total, 52 cases and 156 controls were recruited based on Carpenter and Coustan criteria (1:3 ratio). After change in diagnostic criteria, remaining 21 cases and 63 controls were enrolled as per the DIPSI criteria to meet the sample size (1:3 ratio). An additional of 27 cases and 54 controls were recruited based on the time available to the investigator as per the stipulated study period. This enrollment was in accordance with new criteria (1:2 ratio), making a total of 48 cases and 117 controls (1:2.4 ratio). An interim analysis was carried out at the end of data collection to assess comparability of risk factors profile with respect to diagnostic criteria. The two criteria were found to be similar. Mean (±standard deviation [SD]) POG of diagnosis for cases and controls was 27 weeks 2 days (±5 weeks 2 days) and 26 weeks 2 days (±4 weeks 2 days), respectively.

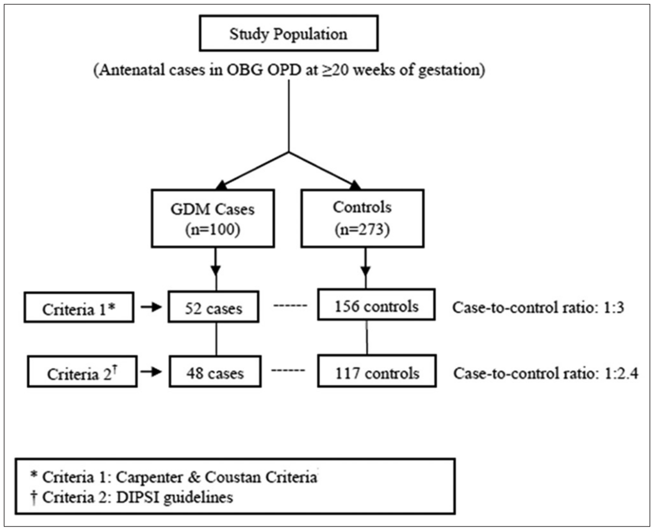

Figure 1: Recruitment of Study Subjects

Table 1 shows the baseline sociodemographic characteristics of the studied women. Visibly, the odds of GDM aged ≥30 years are 17 times higher than those aged ≤25 years ($P < 0.001$). All study participants were literate, except one who was an illiterate ($P = 0.392$). Over 90% of the women were homemakers ($P = 0.05$) whereas most belonged to middle- and high-socioeconomic class. Higher odds of GDM were identified among high-socioeconomic class ($P = 0.021$), those being overweight and obese (BMI ≥25 kg/m2), weighing ≥60 kg during their pre-pregnancy period ($P = 0.001$), and those with high stress were also higher ($P < 0.001$) than controls.

It can be further inferred from the results of Table 1 that GDM risk among ≥30 years of age was similar to that observed in prospective cohort studies carried out in Uttar Pradesh (India)[56] and Tianjin (China),[57] when employed the World Health Organization (WHO) criteria and International Association of the Diabetes and Pregnancy Study Group-WHO criteria, respectively. On the other hand, when used the DIPSI criteria, other prospective cohort studies carried out in Rohtak (Haryana),[58] Hyderabad (Andhra Pradesh),[59] and Jodhpur (Western Rajasthan)[60] in India revealed high GDM prevalence among those ≥25 years of age. Two hospital-based studies carried out in Wardha (Maharashtra)[61] and Rohtak (Haryana)[62] showed GDM prevalence significantly associated with higher education when identified using the WHO and American Diabetes Association (ADA) criteria, respectively. However, other community-based cross-sectional studies carried out in Punjab,[63] Gujarat,[64] and Kashmir[65] invariably showed positive association between GDM and illiteracy, irrespective of the criteria used. In another community-based study,[64] the authors found the prevalence of GDM positively associated with nonworking group when diagnosed using ADA criteria, though the association was statistically nonsignificant (OR = 1.14; 95% CI: 0.20–6.35; $P = 0.28$). However, in another retrospective matched case–control study carried out in Malaysia, the authors found a significant association between GDM and occupation ($\chi^2 = 4.01$; $P = 0.045$).[66]

Similar to above, high odds of GDM in high-socioeconomic class were consistent with the works of Kalyani *et al*.[61] and Rajput *et al*.[62] when scored using Kuppuswamy classification. These studies, however, diagnosed GDM using the WHO and ADA criteria, respectively. In contrast, Raja *et al*.[65] found high GDM prevalence in lower socioeconomic class

Table 1: Demographic characteristics of cases (*n*=100) and controls (*n*=273)

Variables	Cases (*n*=100) *n* (%)	Controls (*n*=273) *n* (%)	Crude odds ratio (95% CI)	*P*
Age (years)				
≤25	16 (16.0)	117 (42.9)	1.0	
26-29	25 (25.0)	131 (48.0)	1.4 (0.7-2.7)	0.333
≥30	59 (59.0)	25 (9.1)	17.3 (8.6-34.8)	<0.001
Literacy				
Primary (≤Class 7th)†	8 (8.0)	18 (6.6)	1.0	
Middle &PUC (Class 8th-12th)	67 (67.0)	221 (81.0)	0.7 (0.3-1.6)	0.4
Graduation & above	25 (25.0)	34 (12.4)	1.7 (0.6-4.4)	0.392
Occupation				
Homemakers	89 (89.0)	259 (94.9)	1.0	0.05
Working	11 (11.0)	14 (5.1)	2.3 (1.0-5.2)	
SES Class				
Low	8 (8.0)	49 (17.9)	1.0	0.021
Middle & High	92 (92.0)	224 (82.1)	2.5 (1.1-5.5)	
Pre-pregnancy weight (kgs)¥				
<50	29 (29.0)	106 (44.0)	1.0	
50-60	31 (31.0)	79 (32.8)	1.4 (0.8-2.6)	0.226
≥60	40 (40.0)	56 (23.2)	2.6 (1.5-4.7)	0.001
Pre-pregnancy BMI (kg/m^2)¥				
<25	67 (67.0)	200 (83.0)	1.0	0.001
≥25	33 (33.0)	41 (17.0)	2.4 (1.4-4.1)	
Cohen Perceived Stress Scale Score				
Low Stress	47 (47.0)	251 (91.9)	1.0	<0.001
High Stress	53 (53.0)	22 (8.1)	12.9 (7.2-23.1)	

†One subject in the control was illiterate. ¥BMI could not be computed for 32 subjects as they did not remember their pre-pregnancy weight

following modified BG Prasad classification and DIPSI guidelines ($P < 0.05$).

A retrospective ADA-based study of Varghese *et al*.[67] revealed increased GDM prevalence in subjects weighing >60 kg consistent with the results of the present study. Another study carried out in Canada also revealed a positive association between National Diabetes Data Group-defined GDM and pregravid obesity (weight >91 kg).[68] Similarly, various prospective cohort Indian studies also found high GDM prevalence in subjects with prepregnancy BMI ≥25 kg/m^2, irrespective of the criteria used,[56,60,69,70] whereas Kalyani *et al*.[61] and Nanda *et al*.[71] found high GDM prevalence among BMI ≥30 kg/m^2 based on the WHO criteria. Increased stress from early to mid-pregnancy, as identified by Cohen Perceived Stress Scale-14, found positively associated with increased GDM risk.[72]

Physical activity during pregnancy and gestational diabetes mellitus risk

Table 2 shows that more than half of the cases (57.0%) were low-to-moderately active physically while 81.7% of the controls were highly active during pregnancy. High odds of GDM were among those involved in low-to-moderate physical activities ($P < 0.001$). These results are consistent with the findings of several other studies carried out elsewhere but with varying strengths of association,[14,17,19,21-25,27,32-35,37-39] except for a few[9-13,15,16,18,20,26,28] describing no association.

Similar to the above, it can be seen from Table 2 that the odds of GDM in those spending ≥3000 min/week of their time in sitting are 11 times higher than those spending <2900 min/week ($P < 0.001$), consistent with the works of Anjana *et al*.[73] and Oken *et al*.,[23] who found increased sedentary behavior during pregnancy associated with abnormal glucose tolerance.

Based on subgroup analysis, Table 2 exhibits high-exposure rates in cases exhibiting low-to-moderate physical activity across all domains and subactivities. For example, 88% of the reported cases were engaged in domestic and gardening activities for <2999 MET-minutes/week while 57.5% of the controls were involved for ≥3000 MET-minutes/week (OR = 9.9; 95% CI: 5.2–19.0; $P < 0.001$). Odds of GDM cases being less-moderately active (<2999 MET-minutes/week) during their pregnancy period are seven times higher than controls ($P < 0.001$), consistent with the study of Tobias *et al*.[40] dealing with physical activity associated with GDM. However, the case–control study of Nasiri-Amiri *et al*.[74] revealed significantly high risk but in transportation domain.

Stratified analysis

As seen from Table 3, the stratum-specific estimates adjusted for age and stress levels identified decreased physical activity levels as a risk factor for GDM uniformly across all defined age and stress subcategories. However, when controlled for maternal education, occupation, and socioeconomic class, these behaved as effect modifier. Notably, no confounding

Table 2: Association between physical activity during pregnancy and risk of gestational diabetes mellitus

Physical activity	Cases (*n*=100) *n* (%)	Controls (*n*=273) *n* (%)	Crude odds ratio (95% CI)	*P*
Total IPAQ Score (MET-minutes/week)				
Low-to-moderate (<2999)	57 (57.0)	50 (18.3)	5.9 (3.6-9.8)	<0.001
High (≥3000)	43 (43.0)	223 (81.7)	1.0	
Average Sitting (Total Minutes/week)				
≥3000	66 (66.0)	44 (16.1)	10.6 (6.2-17.9)	<0.001
<2999	33 (33.0)	229 (83.9)	1.0	
Domain-specific Physical Activity (MET-minutes/week)				
Work				
Low-to-moderate (<2999)	92 (92.0)	262 (96.0)	0.5 (0.2-1.2)	0.129
High (≥3000)	8 (8.0)	11 (4.0)	1.0	
Active Transportation				
Low-to-moderate (<2999)	100 (100.0)	271 (99.3)	-	-
High (≥3000)	0 (0.0)	2 (0.7)		
Domestic & Garden (Yard Work)				
Low-to-moderate (<2999)	88 (88.0)	116 (42.5)	9.9 (5.2-19.0)	<0.001
High (≥3000)	12 (12.0)	157 (57.5)	1.0	
Leisure-time				
Low-to-moderate (<2999)	100 (100.0)	270 (98.9)	-	-
High (≥3000)	0 (0.0)	3 (1.1)		
Activity-related Physical Activity (MET-minutes/week)				
Walking				
Low-to-moderate (<2999)	94 (94.0)	261 (95.6)	0.7 (0.3-2.0)	0.524
High (≥3000)	6 (6.0)	12 (4.4)	1.0	
Moderate				
Low-to-moderate (<2999)	83 (83.0)	111 (40.7)	7.2 (4.0-12.7)	<0.001
High (≥3000)	17 (17.0)	162 (59.3)	1.0	
Vigorous				
Low-to-moderate (<2999)	100 (100.0)	271 (99.3)	-	-
High (≥3000)	0 (0.0)	2 (0.7)		

was indicated for a reason that overall crude and adjusted risk estimates were similar.

Physical activity versus maternal blood glucose levels

Figures 2-6 generally show poor or no relationship between physical activity during pregnancy and maternal blood glucose levels, when OGTT is followed. Figure 2 exhibits weak-positive association between IPAQ scores and fasting venous plasma glucose levels, with increasing physical activity during pregnancy. There exists a concurrent rise in fasting glucose levels ($R^2 = 0.036$). Expressed mathematically,

$$y = 0.002x + 99.78 + \varepsilon$$

where ε represents an error between observed and expected values of the dependent variable. Assuming this error to follow a normal distribution (mean = 3.96 and SD = 33.52 mg/dl), the dependent variable can be predicted with 95% confidence level as below:

$$y = 0.002x + 103.74 \pm 33.52$$

The corresponding mathematical relations between IPAQ scores and maternal glucose levels at varying timings post-OGTT [Figures 2-6] can be described as shown in Table 4.

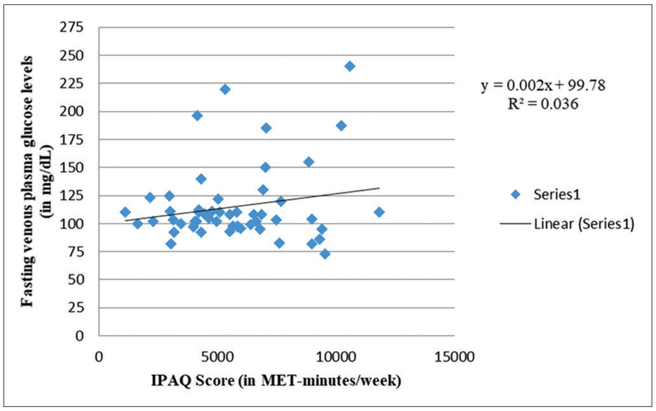

Figure 2: Correlation between fasting glucose levels and IPAQ score

In contrast to the above [Figure 2], Anjana *et al*.[73] reported low levels of fasting blood glucose among physically active pregnant women. However, Idowu *et al*.[75] and Oostdam *et al*.[11] exhibited no correlation between physical activity levels and maternal fasting plasma glucose levels. The latter study findings might be due to low compliance as explained earlier.

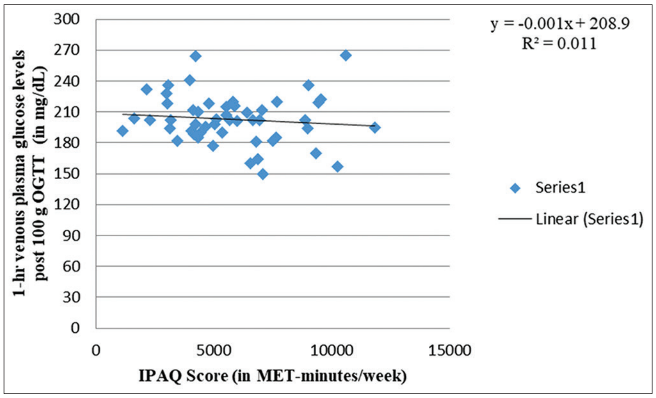

Figure 3: Correlation between 1-hr venous plasma glucose levels post 100g OGTT and IPAQ score

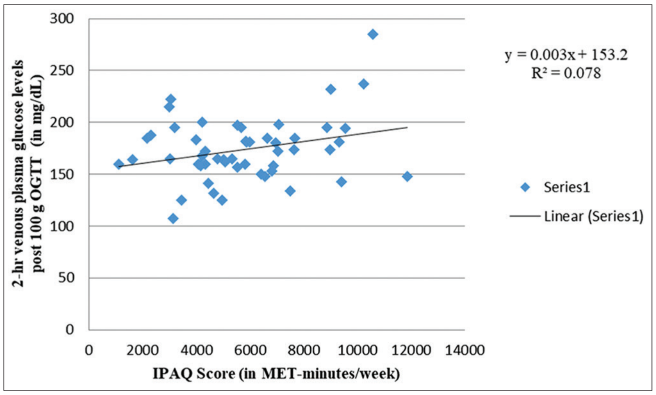

Figure 4: Correlation between 2-hr venous plasma glucose levels post 100g OGTT and IPAQ score

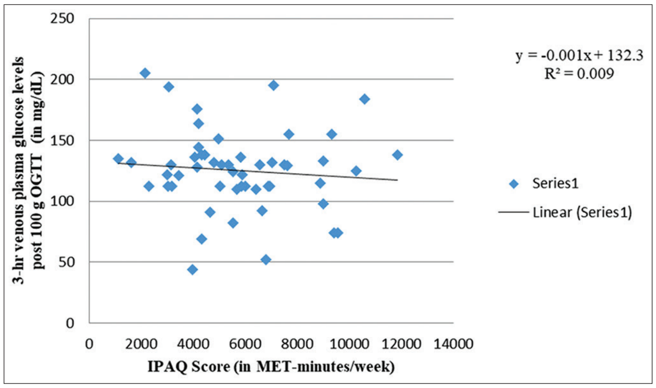

Figure 5: Correlation between 3-hr venous plasma glucose levels post 100g OGTT and IPAQ score

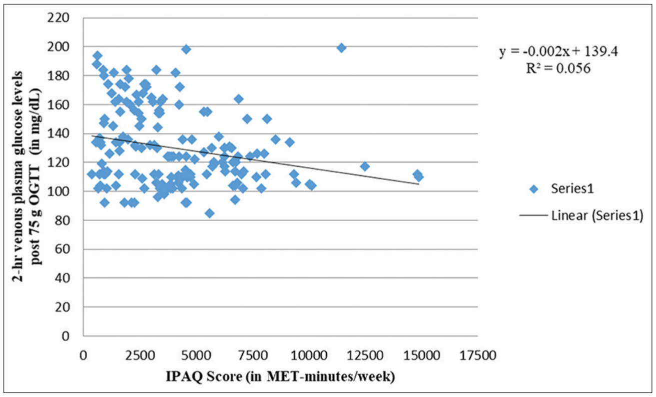

Figure 6: Correlation between 2-hr venous plasma glucose levels post 75g OGTT and IPAQ score

Figure 3 shows a negative association between physical activity and 1-h venous plasma glucose levels after 100 g OGTT (R^2 = 0.011), thus implying protective impact of physical activity on 1-h venous plasma glucose levels. This is consistent with the work of Anjana *et al*.[73] revealing lower 1-h postprandial glucose levels among physically active women. Nonetheless, similar to Figure 2, Figure 4 shows a comparable weak-positive trend for 2-h venous plasma glucose levels after 100 g OGTT (R^2 = 0.078) with increasing physical activity levels. Therefore, similar to fasting venous plasma glucose levels, exposure to physical activity also increases 2-h venous plasma glucose levels after 100 g OGTT. In contrast, Anjana *et al*.[73] observed low 2-h postprandial glucose levels among physically active women. In an observational cohort study, Idowu *et al*.[75] documented no correlation between physical activity levels and 2-h plasma glucose levels during late pregnancy. On the other hand, 2-h postprandial glucose in late pregnancy was found associated and predictive of 2-h glucose in early pregnancy (Spearman's correlation coefficient [rho] $\rho = 0.468$; $P \leq 0.001$).

Similar to Figures 3, 5 and 6 also exhibit weak-negative trends of physical activity scores with 3-h and 2-h venous plasma glucose levels after 100 g and 75 g OGTT, respectively. Halse *et al*.[76] showed low mean daily postprandial glucose concentrations in bicycling intervention group compared to controls. They, however, found no difference in postprandial glucose among both the groups when assessed after 6 weeks of intervention. Similarly, Ong *et al*.[77] observed at 2-h postintervention OGGT and found blood glucose to remain elevated from baseline among controls compared to intervention group following 10-week supervised exercise program among 12 obese pregnant women. It may largely be attributed to small sample size. A total of seven trials that included five randomized trials, revealed that physical activity for a mean duration of six weeks during last trimester of pregnancy led to significant fall in glycemic parameters.[78]

The prospective enrolment of GDM cases in 1:3 case-to-control ratio, in a hospital setting, is the main highlight of the study. Change of diagnostic criteria during the study, a possible limitation in any prospective design, indirectly helped compare the two criteria with respect to physical activity. Although the study was not powered enough to detect subgroup differences, overall power of the study might not be compromised as the primary objective was to ascertain association between physical activity and GDM. Identifying similarity between exposure variables among cases and controls was a by-product of the study. In addition, the sample size was calculated based on a risk factor of physical inactivity. Furthermore, nonuniformity

Table 3: Stratified analysis of confounding variables between physical activity during pregnancy and risk of gestational diabetes mellitus

Variables	Total IPAQ Score	Cases (n=100) n (%)	Controls (n=273) n (%)	Total	Stratum-specific OR (95% CI); P	Adjusted OR (95% CI); P
Age (years)						
<25	<2999	7 (43.8)	14 (12.0)	21 (15.8)	5.7 (1.8-17.8); 0.003	5.3 (2.9-9.6); <0.001
	≥3000	9 (56.2)	103 (88.0)	112 (84.2)	1	
	Total	16	117	133		
26-29	<2999	16 (64.0)	30 (22.9)	46 (29.5)	6.0 (2.4-14.9); <0.001	
	≥3000	9 (36.0)	101 (77.1)	110 (70.5)	1	
	Total	25	131	156		
≥30	<2999	34 (57.6)	6 (24.0)	40 (47.6)	4.3 (1.5-12.3); 0.007	
	≥3000	25 (42.4)	19 (76.0)	44 (52.4)	1	
	Total	59	25	84		
Literacy						
Primary (≤Class 7th)[†]	<2999	3 (37.5)	3 (16.7)	6 (23.1)	3.0 (0.5-19.9); 0.255	5.6 (3.4-9.3); <0.001
	≥3000	5 (62.5)	15 (83.3)	20 (76.9)	1	
	Total	8	18	26		
Middle & PUC (Class 8th - 12th)	<2999	40 (59.7)	37 (16.7)	77 (26.7)	7.4 (4.0-13.5); <0.001	
	≥3000	27 (40.3)	184 (83.3)	211 (73.3)	1	
	Total	67	221	288		
Graduation & above	<2999	14 (56.0)	10 (29.4)	24 (40.7)	3.1 (1.0-9.0);0.043	
	≥3000	11 (44.0)	24 (70.6)	35 (59.3)	1	
	Total	25	34	59		
Occupation						
Homemakers	<2999	54 (60.7)	49 (18.9)	103 (29.6)	6.6 (3.9-11.2); <0.001	6.5 (3.9-10.9); <0.001
	≥3000	35 (39.3)	210 (81.1)	245 (70.4)	1	
	Total	89	259	348		
Working	<2999	3 (27.3)	1 (7.1)	4 (16.0)	4.9 (0.4-55.3);0.201	
	≥3000	8 (72.7)	13 (92.9)	21 (84.0)	1	
	Total	11	14	25		
SES Class						
Low	<2999	3 (37.5)	8 (16.3)	11 (19.3)	3.1 (0.6-15.5);0.174	5.8 (3.5-9.6); <0.001
	≥3000	5 (62.5)	41 (83.7)	46 (80.7)	1	
	Total	8	49	57		
Middle & High	<2999	54 (58.7)	42 (18.8)	96 (30.4)	6.2 (3.6-10.5);<0.001	
	≥3000	38 (41.3)	182 (81.2)	220 (69.6)	1	
	Total	92	224	316		
Cohen Perceived Stress Score						
Low Stress	<2999	26 (55.3)	47 (18.7)	73 (24.5)	5.4 (2.8-10.4);<0.001	6.2 (3.4-11.0); <0.001
	≥3000	21 (44.7)	204 (81.3)	225 (75.5)	1	
	Total	47	251	298		
High Stress	<2999	31 (58.5)	3 (13.6)	34 (45.3)	8.9 (2.3-33.9);0.001	
	≥3000	22 (41.5)	19 (86.4)	41 (54.7)	1	
	Total	53	22	75		

Table 4: Regression analysis for maternal venous plasma glucose levels versus physical activity (IPAQ) scores

IPAQ Score (in MET-minutes/ week) $(\varkappa)$	Maternal Venous Plasma Glucose levels (in mg/dL) (y)	Mathematical equation	Coefficient of determination (R^2)
IPAQ Score	Fasting	$y = 0.002\varkappa + 103.74 \pm 33.52$	0.036
IPAQ Score	1-h post 100 g OGTT	$y = -0.001\varkappa + 208.77 \pm 23.41$	0.011
IPAQ Score	2-h post 100 g OGTT	$y = 0.003\varkappa + 156.2 \pm 29.32$	0.078
IPAQ Score	3-h post 100 g OGTT	$y = -0.001\varkappa + 131.04 \pm 32.61$	0.009
IPAQ Score	2-h post 75 g OGTT	$y = -0.002\varkappa + 138.13 \pm 25.97$	0.056

in the diagnostic GDM criteria across centers and geographical areas makes comparisons difficult. Hospital-based data collection limits the generalization of the study findings, but community-based identification of GDM cases was a difficult task, due to varying time periods of diagnosis, multitude of tests, and varying modifications of diagnostic criteria in practice. Thus, this approach was most feasible. Moreover, in a region where institutional antenatal care is universal, the findings would reflect the true population scenario.

CONCLUSION

The present study showed higher exposure rates for low-to-moderate levels of physical activities among cases across all domains, especially among those involved in domestic and gardening activities during pregnancy. Risk of GDM was higher among those less moderately active in their pregnancy. Prolonged sitting was also a significant risk factor. There was no or poor relationship existing between physical activity and blood glucose levels. It is thus advisable that pregnant women should perform moderate-intensity domestic chores that can help reduce GDM risk.

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Conflicts of interest

There are no conflicts of interest.

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