Open Journal of Obstetrics and Gynecology, 2023, 13, 566-588
https://www.scirp.org/journal/ojog
ISSN Online: 2160-8806
ISSN Print: 2160-8792

Association between Anthropometry and Gestational Diabetes Mellitus

Thusitha Nandana Bodhinarayana*, Madhava Karunarathne

Department of Obstetrics and Gynaecology, Sri Jayawardenepura General Hospital, Kotte, Sri Lanka
Email: *thusitha84@gmail.com

How to cite this paper: Bodhinarayana, T.N. and Karunarathne, M. (2023) Association between Anthropometry and Gestational Diabetes Mellitus. *Open Journal of Obstetrics and Gynecology*, **13**, 566-588.
https://doi.org/10.4236/ojog.2023.133050

Received: February 14, 2023
Accepted: March 26, 2023
Published: March 29, 2023

Abstract

Introduction: The predictive value of various anthropometric indicators for identifying benefits or risks for maternal health outcomes of pregnancy is discussed around the globe. Anthropometric measurements can be a cost effective, efficient method of screening for gestational diabetes mellitus (GDM) especially, in developing countries with low-cost health care settings. **Objectives:** To determine a relationship between anthropometric measurements and GDM and to assess the importance/suitability of an anthropometric measurement in predicting GDM. **Methods:** A correlational study with the evaluation of diagnostic test accuracy was conducted among 48 pregnant women at period of amenorrhoea (POA) of 26 - 34 weeks of gestation. The obstetrics ward and the antenatal clinic of Peradeniya teaching hospital was the study setting. Systematic random sampling technique was used for participant selection. Singleton pregnancies with Body Mass Index (BMI) less than 30.0 kg/m^2 were included. Women with pre-existing diabetes and medical disorders were excluded. Mid arm circumference (MAC), tricipital skin fold thickness (TSFT), bicipital skin fold thickness (BSFT) were measured according to the National Health and Nutrition Examination Survey (NHANES) anthropometry manual. An interviewer-administered questionnaire was applied to collect the data. Data was evaluated in accordance with the objectives by using SPSS version 25. **Results:** Mean age of the participants was 29.67 years (SD = 4.76 years). Mean height and weight of the study participants were 154.93 cm and 67.45 kg respectively. Mean BMI value was recorded as 28.13 kgm^2. Mean mid arm circumference was 9.43 cm. According to the multivariate analysis done by using logistic regression, calculated TSFT and BSFT values were independently associated with GDM in the population. Successful prediction can be achieved by using the BMI and the body weight (AUC < 0.5). 24.8 kg/m^2 is taken as the best cut off value to predict GDM (Sn = 79.2; Sp = 29.2). Best cut off value for body weight appears as 60 kg (Sn = 79.2; Sp = 32.3) and the best cut off value for height is 150 cm (Sn = 80.0; Sp = 25.0). When the predictive variables are compared with each other, highest predictive ability was recorded by the body mass index (AUC = 0.632). Predictability of TFT and BSFT appeared significant. 27.0 cm can be considered as the most accurate cut off value of MAC (Sn = 80; Sp = 30). Best cut off values for BSFT and TSFT were 22 mm (Sn = 80; Sp = 60) and 10.5 mm (Sn = 83.3; Sp = 41.7) respectively. The best predictive is provided by TFST values (AUC = 0.721; P = 0.009). **Conclusions and Recommendations:** Regional anthropometric measurements showed a positive correlation with each other. TSFT and BSFT showed a significant contributory association with gestational diabetes mellitus. Predicting gestational diabetes mellitus is significantly higher in tricipital skinfold thickness and bicipital skinfold thickness. Predicting gestational diabetes mellitus by regional anthropometric measurements should be used at antenatal care practices. Conducting a broad study regarding the ability of obtaining early gestational diabetes mellitus predictions by combining several anthropometric measurements should be initiated. Then strategies based on these findings should be included into the maternal care guidelines. It is possible to obtained successful obstetric outcomes by conducting target oriented gestational diabetes mellitus prevention on mothers identified by predictions of anthropometric measurements.

Keywords

Anthropometry, Gestational Diabetes, Predictions

1. Introduction

1.1. Background and Justification

Gestational diabetes is a common endocrinological disorder in pregnancy [1]. It is defined as glucose intolerance of any degree with first recognition or onset during pregnancy [2] [3]. This condition presents usually in the latter half of the pregnancy [4].

Gestational diabetes mellitus is known to be closely associated more often with various fetal, neonatal and maternal complications [5]. Miscarriage, pre-eclampsia, diabetic nephropathy, neuropathy, diabetic ketoacidosis, infections & preterm labour are more common in women, with diabetes [4] [6]. In addition, diabetic retinopathy and nephropathy can be aggravated during pregnancy [7]. Numerous gynaecological and maternal morbidities could be associated with gestational diabetes mellitus [8]. It is a significant burden for the Sri Lankan health care system [9]. In addition to that multiple perinatal morbidities could be raised due to maternal diabetes mellitus [10] [11].

Gestational diabetes mellitus is a well-known obstetric morbidity which can be managed in antenatal health care delivery system [12]. It is easy to apply primary and primordial preventive strategies to reduce the incidence of diabetes mellitus during pregnancy [13] [14].

Development of gestational diabetes mellitus is due to alterations of maternal endocrinological pathophysiology during pregnancy period [8]. There are several identified contributory factors to occurrence of gestational diabetes mellitus [15]. A strong family history with first degree relative with diabetes mellitus and high Body Mass Index of the pregnant woman are major contributors [16] [17] [18]. Mothers who have a history of previous child birth with birth weight more than 4.5 kg are vulnerable candidates for gestational diabetes mellitus [15].

According to the information published by World Health Organization certain ethnicities are more prone to diabetes mellitus as well as gestational diabetes mellitus [19]. South Asian countries were identified with high-risk ethnic population with increased incidence of diabetes mellitus [20]. So, there are considerable efforts to reduce the burden of diabetes as well as gestational diabetes among countries located in south East Asian Region [21]. With age less than 25 years at the time of pregnancy, having optimum body weight and body mass index before pregnancy and no past history of glucose intolerance were identified as considerable protective factors for gestational diabetes mellitus [22]. There are multiple threshold values for the diagnosis of GDM published by various organizations [23]. International Association of Diabetes and Pregnancy Study (IADPS) recommends screening for gestational diabetes with one step 75 g Oral Glucose Tolerance Test (OGTT) for all women not already known to be diabetic, at 24 - 28 weeks of gestational age. Diagnosis of the diabetes is made when 1 or more threshold value is exceeded (fasting ≥ 5.1 mmol/l, 1-hour ≥ 10.0 mmol/l, 2-hour ≥ 7.8 mmol/l). These values were set considering the key outcomes of pregnancy [24]. Prevalence of gestational diabetes mellitus varies with the region of living and time; therefore, different values can be found in literature. Considering the statistics of western countries, in United States (USA) gestational diabetes occur in about 14% [25]. In China the prevalence of GDM is 7.3% [26]. In India the situation, was 14.5% [16]. The prevalence of GDM ranged between 9% - 26% in the 15 centers that participated in the Hyperglycemia and Adverse Pregnancy Outcome (HAPO) study conducted in 2016 [13]. When considering the situation in Sri Lanka, the prevalence of GDM is 5.7% [23]. There are well known and acceptable association between diabetes mellitus and anthropometric measurements [27] [28] [29]. Those who with a high body fat content are more likely to get gestational diabetes mellitus in later stages of pregnancy, anthropometric measurements can be used as indicators of the dimensions of body content of adipose tissue, bone and skeletal musculature [22].

There are several identified anthropometric parameters available to measure. Weight, height and skin fold thicknesses are the parameters which are used commonly in routine clinical practice [30]. The feasibility of application of anthropometric measurement in routine antenatal clinic in view of screening for gestational diabetes has not been tested before and such a measurement will be cost effective, especially in low resource countries like Sri Lanka. This is a timely need to find out the scientific association of anthropometric measurements and gestational diabetes mellitus. The fundamental aim of this study is to find out the relationship between body mass dimensions and gestational diabetes mellitus. The second aim is to find out capability of using anthropometric measurements for predicting gestational diabetes mellitus in early stages of pregnancy.

1.2. Literature Review

Anthropometric parameters are identified as reliable indicators for predicting the incidence of diabetes in several studies published in electronic and printed data bases. During pregnancy high BMI has been associated with adverse feto-maternal and neonatal outcomes. High BMI is a known risk factor for GDM and insulin resistance [31] [32]. A study done in 2010 has demonstrated tricipital, bicipital, subscapular, subscapular, costal, supra-iliac, and knee skin folds were associated with occurrence of gestational diabetes mellitus [29]. Subscapular skin fold is a known important and independent factor which could be used to detect pregnant mothers who are at risk and for implementing preventive policies [29]. But it is a relatively difficult measure to obtain in routing clinic settings and it is high tendency of having errors during the process of measurements. In 2015, Australian study has found that BMI and waist to hip ratio are good predictors of gestational diabetes in their native aboriginal mothers [16]. But this study was targeted only for well demarcated ethnic community, so the external validity of the study findings is not sufficient to apply other communities in the world.

There was a systematic review conducted by Susan *et al.* in 2008 targeting maternal obesity and the assessment of risk associated with gestational diabetes mellitus [33].

They have taken studies published mainly in the journals published in USA and elsewhere in the world as well. They have reported that considerable number of studies had found that there is a clear association with the status of obesity and overweight within incidence of gestational diabetes mellitus. There is a high risk in women with obesity compared to women with lean body mass. Overall consistency of findings was identified. But the magnitude and the association between obesity and gestational diabetes mellitus were uncertain. They used Bayesian model to perform the meta-analysis but only cohort study designs were included for the review. Pregnancies with normal body mass indexes were quantitatively reviewed. Meta regression models were applied, and measurements of risks were calculated.

According to the comprehensive results of reviewed twenty studies the unadjusted Odds Ratios of developing gestational diabetes mellitus in third trimester of pregnancy were 3.56 (95% CI = 3.05 - 4.21) for obese people, 2.14 (95% CI 1.82 - 2.53) for people with overweight, and 8.56 (95% CI = 5.07 - 16.04) among severely obese participants when compared to pregnancies with women of normal body weight. They used meta regression analysis model, and no evidence were found to estimate prevalence of gestational diabetes mellitus among pregnant women with normal body weight. Usually in routing clinical practices risk factor modification strategies are applied during the pregnancy period. So, the retrospective study findings might be associated with considerable degree of systematic errors. In that meta-analysis, the investigators have taken studies have both retrospective and prospective studies. So, the applicability of the findings of the meta-analysis is less. On the other hand, gestational diabetes mellitus and other endocrinological disorders usually associated with some regional, ethnic and sociocultural variations. So those facts should be considered before the applications of the findings.

Another study was done by Torloni *et al.* in 2009 to address the pre pregnancy Body mass index and the risk of gestational diabetes mellitus [16]. That was also a systematic review associated with meta-analysis. The objective of that systematic review is to quantify and evaluate the risk of having gestational diabetes mellitus in later stages of pregnancy with the characteristics of general anthropometric measurements. They selected the studies which were conducted pre pregnancy body mass index is the only exposure variable to predict the gestational diabetes mellites. Four electronic data bases were used to select the relevant studies published during thirty years duration. Only observational studies were selected for the review. Studies which were designed to screen the gestational diabetes mellitus were excluded. Altogether 1745 citations were screened for the ultimate selection. Seventy studies consisting of eleven case control studies and 59 cohort studies. They calculated the unadjusted pooled odds ratio for developing gestational diabetes mellitus in women with low body weight was 0.75 (95% CI = 0.69 - 0.82) [16].

Another prospective cohort study was conducted with the aims of evaluate the effect of Body mass index and other anthropometric measurements with the adverse outcomes of pregnancy. 1030 women were recruited between 10 - 20 weeks of gestation. They used WHO criteria for diagnose gestational diabetes mellitus during the selection process. The investigator had found that the prevalence of Gestational diabetes mellitus was positively correlated with increasing Maternal Body Mass Index. But the tendency of delivering a baby having birth weight more than 4 kg was significantly less. In the conclusion section of the research paper mentioned that there is high risk associated with gestational Diabetes mellitus with increasing maternal Body mass index [34].

2. Objectives

2.1. General Objectives

- To determine a relationship between anthropometric measurements and GDM.
- To assess the importance/suitability of an anthropometric measurement in predicting GDM.

2.2. Specific Objectives

- Determine a relationship between circumference of midarm and GDM.
- Determine a relationship between thickness of tricipital skin fold and GDM.
- Determine a relationship between thickness of bicipital skin fold and GDM.

- Determine a relationship between mid-arm circumference and thickness of tricipital/bicipital skin folds.

3. Methodology

3.1. Study Design

Correlational study associated with evaluation of diagnostic test accuracy.

3.2. Study Setting

Obstetrics ward (ward 18) and antenatal clinic at teaching hospital Peradeniya, which is a tertiary care and post graduate training hospital with about 280 deliveries per month.

3.3. Study Population

Pregnant mothers at POA of 26 - 34 weeks and who had undergone OGTT test at 26 - 28 weeks were considered as study population.

3.4. Sampling Technique

Systematic random sampling technique was used for sample selection. First study participant was selected by simple random technique. Then every third eligible person was selected for the study. This procedure was continued until the expected sample size was completed.

3.5. Eligibility Criteria

Inclusion criteria

- Women who are 24 weeks to 28 weeks of gestation.
- Singleton pregnancies.
- Body Mass Index less than 30.0 kg/m^2.

Exclusion criteria

- Mothers with pre-existing diabetes (already diagnosed patients or patients whose HbA1C value at booking visit more than 5.5%).
- Mothers with medical disorders.

3.6. Sample Size Calculation

Calculation of the sample size by Lwanga and Lemeshow equation [35]

$$N = Z^2 P(1-P)/d^2$$

P = Anticipated population proportion for prevalence of gestational diabetes mellitus in Sri Lanka = 5.7% [23].

Z = Confidence level 95% = 1.96.

Absolute precision required on either side of proportion = 10%

$$N = 1.96^2 \times 0.057 \times 0.943 / 0.1^2$$

N = 40.

Nonresponsive = 10%.

Minimum Sample size = 44.

3.7. Data Collection Method

Mid circumference of the upper arm was measured according to the National Health and Nutrition Examination Survey (NHANES) anthropometry manual [30].

Instrument: A non-distensible tape (flexible) was used for anthropometric measurements.

Procedure: Asked the mother to stand upright on the floor in a manner that the body weight was equally distributed, the right arm bent should be 90˚ at the elbow, and the right palm facing up. Correct position was demonstrated if necessary. Lateral end of the spine of the right scapula was located by palpating the scapula towards the arm until it feels a sharp turn to the anterior side of the body. Using a pen/pencil, a horizontal line was drawn to the upper edge of the posterior border of the spine of the scapula, starting from the acromion process. Measuring tape was used to take measurements, starting from this mark and down to the tip of the olecranon process (the bony part in mid-elbow) along the posterior surface/aspect of the arm. The tape was placed on the center of posterior side of the arm. Then the midpoint was marked with a pencil and circumference of arm was measured perpendicular to it [30].

Thickness of tricipital skin fold also measured at the same point using skin fold caliper. Thickness of bicipital skin fold was also measured at the same level, but on anterior surface (**Figure 1**).

3.8. Data Collection Instrument

An interviewer-administered questionnaire was applied to collect the data. Research assistants were enrolled for data collection after a proper training with demonstrations. Training of data collectors were conducted by the principal investigator. All study instruments were pre-tested in same study setting one month prior to the study implementation.

3.9. Data Analysis

Statistical Package for the Social Science (SPSS version 25.0) was used to analyze the obtained anthropometric data. Data was evaluated in accordance with the objectives. All categorical scale data was described by using frequencies and percentages. Ratio and interval scale data were described by using measures of central tendency. Pearson's correlation coefficient and multivariate logistic regression model were used to determine the Associations. Receiver Operative Characteristics curve was applied to estimate the predictions. Associations will be assessed using odds ratio and 95% confidence interval.

3.10. Ethical Considerations

The ethical approval for study was obtained from Ethics Review Committee at Teaching Hospital-Kandy, Sri Lanka.

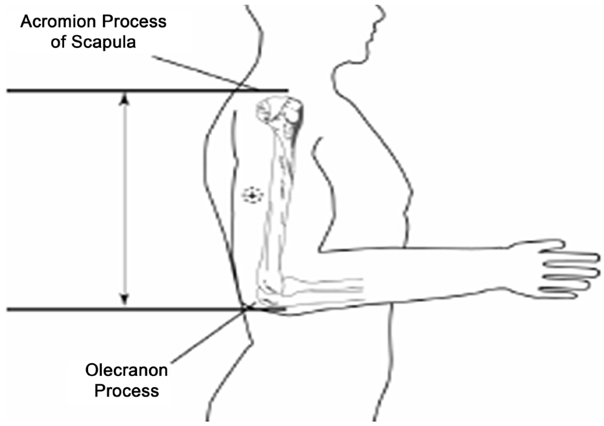

Figure 1. Mid circumference of upper arm.

4. Results

Study sample consisted of 48 participants and at the first stage all the study variables were descriptively analyzed. Then associations of selected main continuous variables were evaluated by using the Pearson's correlations coefficient. Multivariate logistic regression was used for anthropometric measurement comparisons between cases and controls. ROC curves were generated to calculate predictive abilities and predictive abilities were compared by using the area under curve.

Age of the study participants ranged from 20 years to 40 years. Majority of the study participants represented the 26 years to 30 years age group. Study participants from three ethnicities were included in the study sample and majority were Sinhalese. There were no study participants without school education. Majority were educated up to Advanced Level (N = 27; 56.3%). When their occupation was considered majority of the study participants were housewives (Table 1).

Table 2 reveals the distribution of general anthropometric measurements among the study participants. Height of the study participants ranged from 143 cm to 165 cm (Mean: 154.93; SD = 5.44). Majority represented the 151 cm to 160 cm height group (N = 17; 35.4%). Weight of the study participants ranged from 47 kg to 100 kg (Mean: 67.45 kg; SD = 11.80 kg). Majority was included into the 61 kg to 70 kg group.

Below Table 3 demonstrates the distribution of regional anthropometric measurements. Mid arm circumference of the participants ranged from 23 cm to 42 cm (Mean = 29.43 cm; SD = 3.96 cm). Majority of the study participants were included into the 26 cm to 30 cm group. Biceps skin fold thickness ranged from 7 mm to 37 mm. Majority were included into the 11 mm to 20 mm group (Mean = 12.92 mm; SD = 5.53 mm). When Triceps skin fold thickness was considered, it ranged from 10 mm to 46 mm (Mean = 2.48; SD = 8.56 mm). Majority were belonged to 21 mm to 30 mm group (N = 24; 50.0%).

Table 4 demonstrates the correlation of regional anthropometric measurements with each other. Skin fold thicknesses of Triceps and Biceps significantly

Table 1. Distribution of sociodemographic characteristics of study participants.

Variable	Category	Frequency (N)	Percentage (%)
Age			
	<20 Years	1	2.1
	21 - 25	7	14.6
	26 - 30	20	41.7
	31 - 35	15	31.3
	>36	5	10.4
Ethnicity			
	Sinhala	37	77.1
	Tamil	1	2.1
	Moor	10	20.8
Education			
	Up to O/L	8	16.7
	Passed A/L	27	56.3
	Graduated	13	27.1
Occupation			
	Housewife	28	58.3
	Laborer	5	10.4
	Non-Executive	10	20.8
	Professionals	5	10.4
Total		48	100

Table 2. Distribution of general Anthropometric measurements.

Height (cm)	Frequency (N)	Percentage (%)	
<150	9	18.8	Mean = 154.93 SD = 5.44
151 - 160	32	66.7	
>161	7	14.6	
Weight			
<60	13	27.1	Mean = 67.45 SD = 11.80
61 - 70	17	35.4	
71 - 80	13	27.1	
>81	5	10.4	
BMI			
19 - 24.9	12	25.0	Mean = 28.13 SD = 4.63
25 - 29.9	21	43.8	
>30	15	31.3	
Total	48	100	

BMI = Body Mass Index.

Table 3. Distribution of Regional anthropometric measurements among study participants.

Variable	Category	Frequency (N)	Percentage (%)	
MAC				
	<25	8	16.7	Mean = 29.43
	26 - 30	21	43.8	SD = 3.96
	31 - 35	16	33.3	
	>36	3	6.3	
BSFT				
	<10 mm	14	29.2	Mean = 12.92
	11 - 20	30	62.5	SD = 5.53
	>21	4	8.3	
TSFT				
	<20	9	18.8	
	21 - 30	24	50.0	Mean = 27.48
	31 - 40	11	22.9	SD = 8.56
	>40	4	8.3	
TOTAL		**48**	**100**	

MAC = Mid Arm Circumference, BSFT = Biceps Skin Fold Thickness, TSFT = Tricipital Skinfold Thickness.

Table 4. Distribution of degree of association of regional anthropometric measurements.

Combination	Pearson's r	P value
MAC & TSFT	0.714	<0.001
MAC & BSFT	0.629	<0.001
TSFT & BSFT	0.258	<0.001

MAC = Mid Arm Circumference, BSFT = Biceps Skin Fold Thickness, TSFT = Tricipital Skinfold Thickness.

and positively correlate with the mid upper arm circumference. When skin fold thickness is considered separately, skin fold thicknesses of Triceps and Biceps positively and significantly correlate with each other.

When general anthropometric measurements are considered height and weight significantly and positively correlate with each other. BMI shows a significant positive correlation with weight. BMI value of study participants positively correlate with the weight of the study participants. Height of the study participants shows a negative correlation with their BMI (Table 5).

Table 6 describes the distribution of each anthropometric parameter among participants with GDM and participants without GDM. Multivariate analysis using logistic regression showed weight (Odds ratio = 0.98, 95% CI = 0.89 - 1.16),

Table 5. Distribution of degree of association of general anthropometric measurements.

Combination	Pearson's r	P value
Height & Weight	0.399	0.008
BMI & Height	−0.009	0.953
BMI & Weight	0.921	<0.001

BMI = Body Mass Index.

Table 6. Association of anthropometric measurements with GDM.

Variable	OR	95% CI
Weight	0.98	0.89 - 1.16
Height	0.95	0.79 - 1.13
MAC	0.78	0.46 - 1.42
TSFT	1.21	1.05 - 1.42
BSFT	1.26	1.04 - 1.58

MAC = Mid Arm Circumference, BSFT = Biceps Skin Fold Thickness, TSFT = Tricipital Skinfold Thickness.

height (Odds ratio = 0.95, 95% CI = 0.79 - 1.13) and MUAC (Odds ratio = 0.78, 95% CI = 0.46 - 1.42) do not differ significantly. TSFT (Odds ratio = 1.21, 95% CI = 1.05 - 1.42) and BSFT (Odds ratio = 1.26, 95% CI = 1.04 - 1.58) differ significantly among participants who had GDM and not. Therefore, TSFT and BSFT are independently associated with GDM in this population.

Ability of predicting GDM by using the general anthropometric measurements is described in **Table 7**. According to the chart, a successful prediction can be achieved by using the BMI and the body weight (AUC > 0.5). According to the above ROC Curve, when 24.8 kg/m^2 is taken as the best cut off value to predict GDM, sensitivity is recorded as 79.2 and specificity is recorded as 29.2. best cut off value for body weight appears as 60 kg (Sn = 79.2; Sp = 32.3). When height is considered, the calculated best cut off value is 150cm (Sn = 80.1; Sp = 25.0). When the predictive variables are compared with each other, highest predictive ability was recorded by body mass index (AUC = 0.632) (**Figure 2**).

Table 8 describes the ability to predict GDM by regional anthropometric measurements. According to the chart all the regional anthropometric parameters can be used to predict GDM (AUC > 0.5). Among them, predictability of TFT and BSFT appeared significant.

27.0 cm can be considered as the most accurate cut off value of MAC (Sn = 80; Sp = 30). With regard to TSFT values best predictive cut off value was recorded as 22 mm (Sn = 80; Sp = 60). According to BSFT, best predictive cut off value is 10.5 mm (Sn = 83.3; Sp = 41.7). When all the regional anthropometric measurements are considered, best prediction is provided by TSFT values (AUC = 0.721; P = 0.009) (**Figure 3**).

Table 7. Predictive ability of general anthropometric measurements with GDM.

Variable	AUC	P value	95% CI
BMI	0.632	0.117	0.473 - 0.791
Height	0.444	0.509	0.277 - 0.612
Weight	0.614	0.117	0.454 - 0.774

AUC = Area Under The curve, BMI = Body Mass Index.

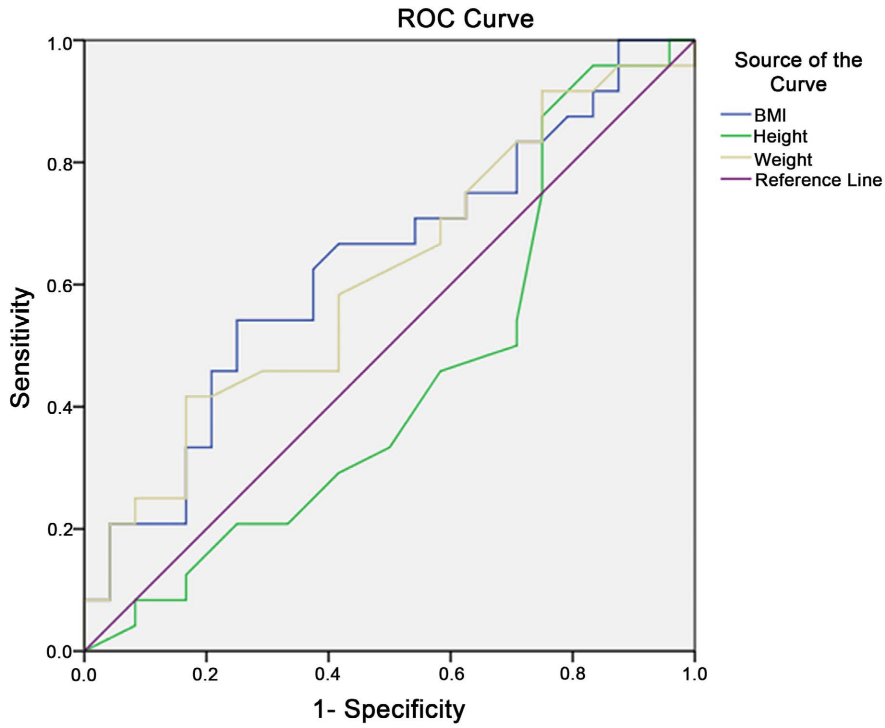

Figure 2. Predictive ability of general anthropometric measurements with GDM.

Table 8. Predictive ability of regional anthropometric measurements with GDM.

Variable	AUC	P value	95% CI
MAC	0.617	0.164	0.458 - 0.776
TSFT	0.721	0.009	0.576 - 0.867
BSFT	0.690	0.024	0.538 - 0.842

AUC = Area Under The curve, MAC = Mid Arm Circumference, BSFT = Biceps Skin Fold Thickness, TSFT = Tricipital Skinfold Thickness.

Predictability of the anthropometric parameters used in the study is summarized in Figure 4. According to the findings it is clear that height of the study participants cannot be used to predict GDM (AUC = 0.444, P = 0.509). Although body mass index, body weight and MAC can be used to predict GDM they do not possess a significant predictive ability to be used independently. TSFT and BSFT show a significant predictive ability and they demonstrate a possibility of applying them as independent parameters.

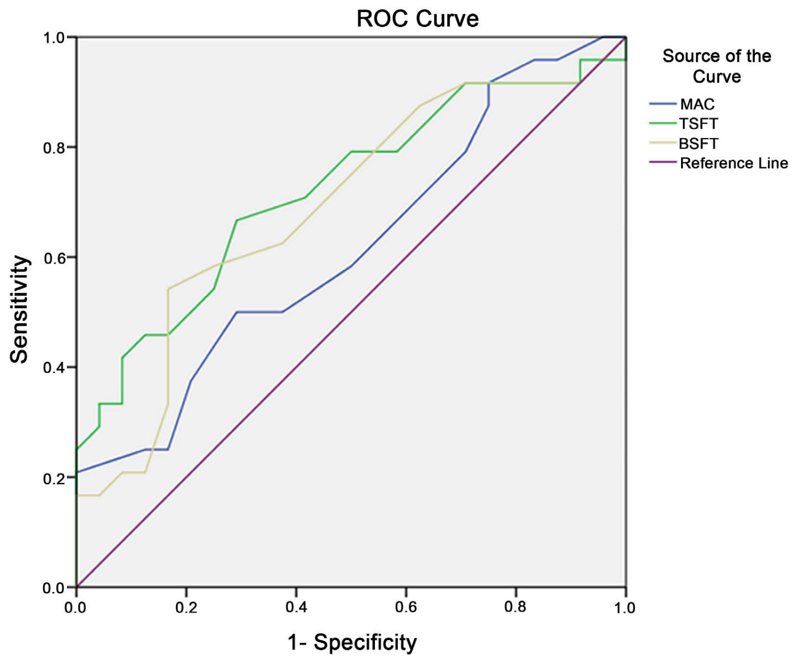

Figure 3. Predictive ability of regional anthropometric measurements with GDM.

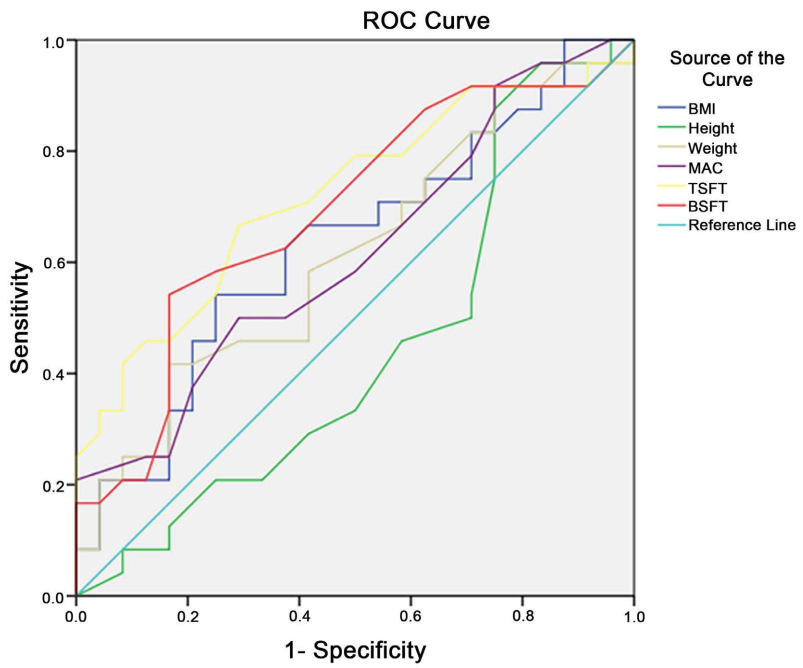

Figure 4. Comparison of predictive ability of all anthropometric measurements with GDM.

5. Discussion

5.1. Summary of Results

Age of the study participants ranged from 20 years to 40 years and the calculated mean value was the 29.67 years (SD = 4.76 years). Majority of the study participants were represented by Sinhala ethnicity (n = 37.77%). Majority were educated up to GCE A/L and greater part of the study participants were housewives. Mean height of the study participants was 154.93 cm and mean weight of the participants was 67.45 kg. BMI value of the majority of the participants ranged from 25 kgm^2 to 9.9 kgm^2 and mean BMI value was recorded 28.13 kgm^2. Mean mid arm circumference was 9.43 cm. According to the multivariate analysis done by using logistic regression, calculated TSFT and BSFT values were independently associated with GDM in the population.

Successful prediction can be achieved by using the BMI and the body weight (AUC < 0.5). When 24.8 kg/m^2 is taken as the best cut off value to predict GDM, sensitivity is recorded as 79.2 and specificity is recorded as 29.2. Best cut off value for body weight appears as 60 kg (Sn = 79.2; Sp = 32.3). When height is considered, calculated best cut off value is 150 cm (Sn = 80.0; Sp = 25.0). When the predictive variables are compared with each other, highest predictive ability was recorded by body mass index (AUC = 0.632).

According to the findings all the regional anthropometric parameters can be used to predict GDM (AUC > 0.5). Among them, predictability of TFT and BSFT appeared significant. 27.0 cm can be considered as the most accurate cut off value of MAC (Sn = 80; Sp = 30). With regard to TSFT values best predictive cut off value was recorded as 22mm (Sn = 80; Sp = 60). According to BSFT, best predictive cut off value is 10.5 mm (Sn = 83.3; Sp = 41.7). When all the regional anthropometric measurements are considered, best predictive is provided by TFST values (AUC = 0.721; P = 0.009). According to the findings it is clear that height of the study participants cannot be used to predict GDM (AUC = 0.444; P = 0.509). Although Body Mass Index, body weight and MAC can be used to predict GDM they do not possess a significant predictive ability to be used independently. TSFT and BSFT show a significant predictive ability and they demonstrate a possibility of applying them as independent parameters.

5.2. Factors Associated with Study Findings

Today, there is a high level of knowledge in diabetes control and treatment. The techniques of digital blood glucose measurements have reached the domestic level. The correct prediction will achieve the maximum output of management of gestational diabetes mellitus. Diabetes is not a problem which can be interfered with every pregnancy. Because of accurate prediction of GDM, risky women will be able to take specified precautions to avoid or delay the occurrence of GDM in late pregnancy period. Not only diabetes but also other illnesses cannot be predicted by laboratory investigations or other diagnostic methods. Even gold standard methods have some margin of error. Therefore, it is necessary to constantly focus on new diagnostic tests.

Study findings clearly identified that GDM predictions can be successfully achieved by mid upper arm anthropometric measurements. This is one of the ways that it is not necessary for higher skills and low cost.

Mid arm area anthropometric measurements can be taken by a health worker who does not have specialized skill or training. Training of a minor staff members will be possible to measure these regional anthropometric measurements. So, this procedure can easily introduce into existing health management guidelines. On the other hand, this method is more likely to become popular among pregnant mothers because it does not require procedures such as skin piercing or insertion of foreign materials into the body. Therefore, it is necessary to look into this new system and to identify if any unknown adverse events.

Higher predictability of TSFT for gestational diabetes mellitus is emphasized by the findings of this study. Its predictability was as high as 0.721 and probability was less than 0.001. When skin fold thickness was considered, special attention was pain on BSFT. According to the study findings, both parameters, BSFT and TSFT show a significant predictability for gestational diabetes mellitus. These measurements can be obtained with ease and there is a higher feasibility of widely using these parameters for predicting gestational diabetes mellitus.

Specially, these parameters are suitable for in detail studies of the ability of using as predictors at the early stages of pregnancy if it was possible to use these anthropometric measurements. For obtaining an early gestational diabetes mellitus prediction, this method can be easily applied to domiciliary antenatal care practices. It gives an opportunity to obtain measurements via the field level public health midwives and direct for specific interventions according to the risk levels. Especially when the manner of organizing the maternal health care delivery system of Sri Lanka is considered, prediction of gestational diabetes mellitus by anthropometric measurements acquires a greater value.

Individual attention can be provided to high-risk mothers and primordial and primary prevention strategies can be activated. It is an additional benefit to have an organized health care system which facilitates regular supervision by the medical officer of health. Need of specialized health care can be reduced by minimizing the risk of gestational diabetes mellitus, when third trimester is reached. It indirectly reduces the need of hospitalization. When generally considered, it helps to achieve a positive impact on reducing prevalence of gestational diabetes mellitus in the health care system of Sri Lanka. Therefore, it is possible to use prediction of gestational diabetes mellitus by anthropometric measurements as a cost-effective intervention, which appears to be a true benefit in the health economic field. It is possible to identify a positive trend in global interest regarding prediction of gestational diabetes mellitus by biological parameters other than blood sugar measurements. In Sri Lanka there are many incidences which measurements of visceral fat thickness and red cell indices were used for predicting gestational diabetes mellitus at experimental stages. But the method used in the present study appears simpler and it requires less amount of physical and human resources. Therefore, it is more appropriate to conduct further studies to identify the feasibility of using this method of predicting gestational diabetes mellitus by applying the anthropometric measurements.

Specially, a minimum sample size was used for the present study and as a result external applicability of the study findings could be critical up to a certain extent. Therefore, it is essential to conduct further studies on the same study variables using a relatively larger sample of study participants. When the procedure of the current study is considered, it will not create many hassles to select a larger sample with a higher representativeness. On the other hand, it is possible to obtain anthropometric measurements even at each and every clinic visit. It will help to determine the time frame which provides the highest predictability. These findings can be used more effectively to achieve successful benefits. On the other hand, further studies should be conducted to find out the possibility of achieving an accurate predictability by combining regional and general anthropometric measurements.

5.3. Comparison of Study Findings with Other Studies

The main issue raised by the longitudinal study on Gestational Diabetes Prediction is that fat content in your body is the best measure of diabetic predictions. In addition, to parameters such as skinfold thickness, mid-circumference, family history of blood pressure and diabetes in previous pregnancies, the study findings further stated that diabetes guessing could be measured by measuring the size of the waist and thighs. The present study focuses on the body mass index of the entire body and the skin fat content associated with the upper body. But it also confirmed that regional metabolic rates can be successfully done by guiding diabetes. As in the previous study, the measurements were taken during the first three months of pregnancy. General body mass index was associated with the gestational diabetes. Some previous studies have reviewed this matter, but most of them were used parameters like body weight, height, waist circumference and hip measurements.

The study, in Waste and Hip measurement ratio, is elaborated in the study, however, that studies in waste and hip measurements in the bulk did not make it possible to compare the risk factors together with a better predictor, clear. However, statistical concepts used in the current study did not elaborate on prediction of gestational diabetes mellitus. Gestational diabetes mellitus is a disease condition which occurs due to an alteration of cellular sensitivity of blood glucose. Usually, this condition is restored with natural termination of pregnancy and all the pregnant mothers do not experienced GDM state. On the other hand, mothers with GDM complicated pregnancies will experience pregnancy associated complicated deliveries. Due to these consequences, scientists were interested in predicting GDM since olden times. Biomarkers identifications and risk factor analysis were major concerns of their studies.

Anthropometric parameters are identified as reliable indicators for predicting the incidence of diabetes in several studies published in electronic and printed data bases. During pregnancy high BMI has been associated with adverse feto-maternal and neonatal outcomes. High BMI is a known risk factor for GDM and insulin resistance [31] [32]. But the present study focused on regional anthropometric measurements such as mid upper arm circumference, TSFT & BSFT. The present study findings were not sufficient to produce some causative relationship between mid-upper arm anthropometric measurements and prediction of gestational diabetes mellitus. Among the mid upper arm anthropometric measurements, the bicipital and triceps skinfold thicknesses had the predictive ability (**Table 8**). Also, according to the present study results, body mass index does not have the capability of predicting gestational diabetes mellitus (**Table 7**).

A study done in 2010 has demonstrated tricipital, bicipital, subscapular, subscapular, costal, supra-iliac, and knee skin folds were associated with occurrence of gestational diabetes mellitus [29]. Subscapular skin fold is a known important and independent factor which could be used to detect pregnant mothers who are at risk and for implementing preventive policies [29]. But it is a relatively difficult measure to obtain in routing clinic settings and it is high tendency of having errors during the process of measurements. Present study concerns only bicipital and tricipital skin fold thickness with mid upper arm circumference. The internal and external validity of the results may be increased if more parameters will be used by using combined diagnostic test accuracy methods such as parallel or series interpretation. Only single parameter prediction ability estimation was conducted in current study. In 2015 Australian study has found that BMI and waist to hip ratio are good predictors of gestational diabetes in their native aboriginal mothers [16]. But this study was targeted only for well demarcated ethnic community, so the external validity of the study findings is not sufficient to apply other communities in the world. Present study also demarcated to a single study setting but not a certain ethnic or sociodemographic group. But the sample size was relatively low. On the other hand, the waist and hip ratio was not among the study parameters.

There was a systematic review conducted by Susan *et al.* in 2008 targeting maternal obesity and the assessment of risk associated with gestational diabetes mellitus [33]. They have taken studies published mainly in the journals published in USA and elsewhere in the world as well. They have reported that considerable number of studies had found that there is a clear association with the status of obesity and overweight within incidence of gestational diabetes mellitus. There is a high risk in women with obesity compared to women with lean body mass. Overall consistency of findings was identified. But the magnitude and the association between obesity and gestational diabetes mellitus were uncertain. Present study was not able to produce a result compatible with the findings that systematic review. Because current study suggests that there is no sufficient evidence to prove the association between maternal obesity and overweight with the gestational diabetes mellitus (**Table 7**).

According to the comprehensive results of reviewed twenty studies, the unadjusted Odds Ratios of developing gestational diabetes mellitus in third trimester of pregnancy were 3.56 (95% CI = 3.05 - 4.21) for obese people, 2.14 (95% CI 1.82 - 2.53) for people with overweight, and 8.56 (95% CI = 5.07 - 16.04) among severely obese participants when compared to pregnancies with women of normal body weight. But present study produced the findings which against that association concept of general body mass and gestational diabetes mellitus (**Table 6**). Previous study used meta regression analysis model and present study used multiple logistic regression model to evaluate the association. In previous selected studies were not able to produce evidence which can estimate prevalence of gestational diabetes mellitus among pregnant women with normal body weight. But in present study had adequate evidence to suggest mid upper arm skin fold thicknesses can be used as predictive parameters in women who have normal body weight also. Usually in routing clinical practices risk factor modification strategies are applied during the pregnancy period. So, the retrospective stud findings might be associated with considerable degree of systematic errors. In that meta-analysis the investigators have taken studies have both retrospective and prospective studies. So, the applicability of the findings of the meta-analysis is less. On the other hand, gestational diabetes mellitus and other endocrinological disorders usually associated with some regional, ethnic and sociocultural variations. So those facts should be considered before the applications of the findings.

5.4. Prediction of GDM and Its Importance

Obtaining the mid upper arm anthropometric measurements of a patient is a simple and easy procedure which does not need special training or long-term experience. Health care workers at any level can be trained to take mid upper arm anthropometric measurements. Therefore, there is a higher feasibility of including assessment of mid upper arm anthropometric measurements as a guideline to the health care system. GDM is an identified obstetrics morbidity which requires a deliberate effort to achieve proper control. It can create many maternal and neonatal complications.

GDM is an obstetric complication, of which onset can be postponed and on the other hand the whole pregnancy period is not hindered with GDM. Therefore, a significant impact can be created by a more successful prediction. Many opportunities can be developed to implement a strategic management plan based on a biomedical prediction obtained at the early stage of pregnancy period. According to the study finding BMI and weight of the participants showed some predictive ability but it was not significant. Among the regional anthropometric parameters, TSFT and BSFT showed a significant ability to predict GDM. When all the anthropometric parameters are considered, it is identified that TSFT was the most significant and predictive parameter to anticipate GDM.

Prevalence of young DM patients is rising in Sri Lanka at present and the number of individuals with a higher BMI is increasing among the younger population. Also, in the present study sample, calculated mean value of BMI was higher than the normal physiological BMI value range which is 19.1 to predict 24.9 kg/m^2. On the other hand, risk level for getting DM has become higher with these sedentary lifestyle and unhealthy dietary habits practiced at present. Therefore, to minimize obstetric complications, application of primary prevention strategies relevant to GDM during the early trimesters of pregnancy could be more beneficial. GDM creates many complications not only to the mother, but also the newborn child could suffer with many adverse outcomes such as increased birth weight, endocrinological disturbances and respiratory tract complications. Complicated child births could occur due to macrosomia and these problems create a higher tendency to emerge adverse perinatal morbidities.

In a country such as Sri Lanka which provides free health care facilities to the whole population, rising morbidities can be considered as an extra burden to the prevailing system. Therefore, it is timely need to identify pathways for preventive strategies. When estimating the health conditions of the country, higher predominance is granted for maternal and childcare indicators. When prevalence of GDM is increased, perinatal morbidities also get elevated, and it indirectly raises the perinatal morality rates. Therefore, it is essential to maintain prevalence of GDM at minimum levels. GDM is identified as an obstetric morbidity which can be delayed up to a certain extent by behavioural modifications such as lifestyle changes, dietary habit alterations and regular exercises. Therefore, identification of vulnerable individuals by early detection strategies can be considered as a cost-effective approach.

6. Limitations

Diabetes mellitus is a multifactorial disease condition. During the present study attention was paid on anthropometric measurements only. Therefore, it was possible to expect only limited reliability of the predictions. Other biological factors which affect GDM were not considered during this study. As a result, internal validity of the study findings was affected. Specially, the hormonal changes which occur during the pregnancy period are responsible for appearing GDM among pregnant mothers. Probability of getting GDM is higher among mothers with favourable conditions such as dietary and lifestyle factors, conditions of the body, family history of DM and the phycological status of the pregnant mothers. But it was not possible to study these features with complex combinations within this study methodology.

According to the variables used during this study it was not possible to elicit a dose effect relationship between the exposure and outcome variables. According to the existing knowledge, it is not possible to describe any direct relationship between body mass index and other anthropometric measurements with blood sugar levels. A contributary association is observed between blood sugar and regional and general anthropometric values which were considered as exposure variables of the study. Relationship appears more distant when values are compared with gestational diabetes mellitus. Pregnancy is considered as a special psychological condition of the female body which the sensitivity pattern of the cells is completely altered. Those are complex physiological interactions, observed among the hormonal changes, body fat content and blood sugar levels during the pregnancy period. These complexities and their effect on study findings and measured variables of the study were not descriptively addressed during the study. As a result, effects of confounding factors were strongly associated with the study findings. The sample size which was used for the study was relatively small. Possibility of using a highly randomized sample selection for equal distribution of confounding factors was limited. As a result, internal validity of the study findings was limited. According to the multiple logistic regression findings, the regional anthropometric measurements show a significant association with gestational diabetes mellitus. But it is not adequate to introduce a causative conclusion.

According to the study findings, all the regional anthropometric measurements significantly correlate with each other. This is a finding which can be further used as a positive observation. During the study, separate anthropometric parameters were studied to identify the feasibility of using them for gestational diabetes mellitus predictions. Calculations of effects on gestational diabetes mellitus predictability by using them collectively were not done. Further research should be planned to study predictions of gestational diabetes mellitus, by using anthropometric parameters in adequate and more accurately selected study samples. Because these parameters demonstrate a higher feasibility of using as a predictive screening methodology. On the other hand, ability to predict gestational diabetes mellitus, by using anthropometric parameters should be studied on mothers from different categories. Further studies should be conducted to identify the ability of using this method on several categories which differ with their parity, age of the mother, pre-pregnancy Body Mass Index, family history of diabetes mellitus or gestational diabetes mellitus. Also, it is possible to calculate the optimum gestational age, during which anthropometric measurements should be obtained in order to achieve an accurate prediction. It was difficult to address the above-mentioned aspects due to the financial and time limitations associated with the present study. Although it did not create any effect on the measurement's reliability with relevance to parameters of the study, internal and external validity of the study were significantly affected. These obstacles can be easily avoided in future studies.

7. Conclusions & Recommendations

7.1. Conclusions

- Among the pregnant women who participated in the current study, regional anthropometric measurements showed a positive correlation with each other.
- Tricipital skin fold thickness and bicipital skinfold thickness showed a significant contributory association with gestational diabetes mellitus.
- It is not possible to identify a significant ability to predict gestational diabetes mellitus, with consideration of general anthropometric measurements only.
- Ability of predicting gestational diabetes mellitus is significantly higher in tricipital skinfold thickness and bicipital skinfold thickness.

7.2. Recommendations

- Ability of predicting gestational diabetes mellitus by regional anthropometric measurements should be used at antenatal care practices.
- Conducting a broad study regarding the ability of obtaining early gestational

diabetes mellitus predictions by combining several anthropometric measurements should be initiated. Then strategies based on these findings should be included into the maternal care guidelines.

- It is possible to obtain successful obstetric outcomes by conducting target oriented gestational diabetes mellitus prevention on mothers identified by predictions of anthropometric measurements.

Acknowledgements

We wish to express our greatest gratitude to all the members of Board of study of Obstetrics and Gynaecology, Post Graduate Institute of Medicine Colombo, for all the courage, support and guidance given to us throughout our research. We would like to thank the Director, teaching hospital Peradeniya for granting permission to collect data during the study period. A special word of appreciation goes to Dr. S. K. Ranaraja, consultant Obstetrician and Gynaecologist for giving me immense support to collect data from the patients. A special word of appreciation goes to all the non-academic staff attached to the Post Graduate Institute of Medicine and the course co-ordinators of MD Obstetrics and Gynaecology. Finally, our sincere thanks offered to our beloved wife and other family members for their kind support and encouragement.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Galtier, F. (2010) Definition, Epidemiology, Risk Factors. *Diabetes & Metabolism*, **36**, 628-651. https://doi.org/10.1016/j.diabet.2010.11.014

[2] World Health Organization (1999) Definition, Diagnosis and Classification of Diabetes Mellitus and Its Complications. WHO, Geneva.

[3] Association, A.D. (2016) Classification and Diagnosis of Diabetes. *Diabetes Care*, **1**, 13-22.

[4] NICE Guideline (2015) Diabetes in Pregnancy: Management from Preconception to the Postnatal Period. https://www.nice.org.uk/guidance/ng3/resources/diabetes-in-pregnancy-management-of-diabetes-and-its-complications-from-preconception-to-the-postnatal-period-51038446021

[5] Metzger, B.E., Lowe, L.P., Dyer, A.R., Trimble, E.R., Chaovarindr, U., Coustan, D.R., *et al.* (2008) Hyperglycemia and Adverse Pregnancy Outcomes. *The New England Journal of Medicine*, **358**, 1991-2002. https://doi.org/10.1056/NEJMoa0707943

[6] National Institute for Health and Care Excellence (2015) Diabetes in Pregnancy: Management of Diabetes and Its Complications from Preconception to the Postnatal Period, NICE Guideline 3.

[7] Reece, E.A. (2010) The Fetal and Maternal Consequences of Gestational Diabetes Mellitus. *The Journal of Maternal-Fetal & Neonatal Medicine*, **23**, 199-203.

https://doi.org/10.3109/14767050903550659

[8] Xiang, A.H., Peters, R.K., Trigo, E., Kjos, S.L., Lee, W.P. and Buchanan, T.A. (1999) Multiple Metabolic Defects during Late Pregnancy in Women at High Risk for Type 2 Diabetes. *Diabetes*, **48**, 848-854. https://doi.org/10.2337/diabetes.48.4.848

[9] Ministry of Health Sri Lanka (2015) Anual Health Bulleting 2015.

[10] Sudasinghe, B.H., Ginige, P.S. and Wijeyaratne, C.N. (2016) Prevalence of Gestational Diabetes Mellitus in a Suburban District in Sri Lanka: A Population Based Study. *Ceylon Medical Journal*, **61**, 149-153. https://doi.org/10.4038/cmj.v61i4.8379 http://cmj.sljol.info/article/10.4038/cmj.v61i4.8379/

[11] World Health Organization (2006) Neonatal and Perinatal Mortality: Country, Regional and Global Estimates. World Health Organization, Geneva.

[12] Turok, D.K., Ratcliffe, S.D. and Baxley, E.G. (2003) Management of Gestational Diabetes Mellitus. *American Family Physician*, **68**, 1767-1772.

[13] Sweeting, A.N., Ross, G.P., Hyett, J., Molyneaux, L., Constantino, M., Harding, A.J., *et al*. (2016) Gestational Diabetes Mellitus in Early Pregnancy: Evidence for Poor Pregnancy Outcomes Despite Treatment. *Diabetes Care*, **39**, 75-81. https://doi.org/10.2337/dc15-0433

[14] White, S.L., Lawlor, D.A., Briley, A.L., Godfrey, K.M., Nelson, S.M., Oteng-Ntim, E., *et al*. (2016) Early Antenatal Prediction of Gestational Diabetes in Obese Women: Development of Prediction Tools for Targeted Intervention. *PLOS ONE*, **11**, e0167846. https://doi.org/10.1371/journal.pone.0167846

[15] Hedderson, M.M., Gunderson, E.P. and Ferrara, A. (2010) Gestational Weight Gain and Risk of Gestational Diabetes Mellitus. *Obstetrics & Gynecology*, **115**, 597-604. https://doi.org/10.1097/AOG.0b013e3181cfce4f

[16] Torloni, M.R., Betran, A.P., Horta, B.L., Nakamura, M.U., Atallah, A.N., Moron, A.F., *et al*. (2009) Prepregnancy BMI and the Risk of Gestational Diabetes: A Systematic Review of the Literature with Meta-Analysis. *Obesity Reviews*, **10**, 194-203. https://doi.org/10.1111/j.1467-789X.2008.00541.x

[17] Watanabe, N., Morimoto, S., Fujiwara, T., Suzuki, T., Taniguchi, K., Mori, F., *et al*. (2013) Prediction of Gestational Diabetes Mellitus by Soluble (Pro)Renin Receptor during the First Trimester. *The Journal of Clinical Endocrinology & Metabolism*, **98**, 2528-2535. https://doi.org/10.1210/jc.2012-4139

[18] Bhavadharini, B., Mahalakshmi, M.M., Anjana, R.M., Maheswari, K., Uma, R., Deepa, M., *et al*. (2016) Prevalence of Gestational Diabetes Mellitus in Urban and Rural Tamil Nadu Using IADPSG and WHO 1999 Criteria (WINGS 6). *Clinical Diabetes and Endocrinology*, **2**, Article No. 8. https://doi.org/10.1186/s40842-016-0028-6

[19] Shaw, J.E., Sicree, R.A. and Zimmet, P.Z. (2010) Global Estimates of the Prevalence of Diabetes for 2010 and 2030. *Diabetes Research and Clinical Practice*, **87**, 4-14. https://doi.org/10.1016/j.diabres.2009.10.007

[20] Gujral, U.P., Pradeepa, R., Weber, M.B., Narayan, K.M.V. and Mohan, V. (2013) Type 2 Diabetes in South Asians: Similarities and Differences with White Caucasian and Other Populations. *Annals of the New York Academy of Sciences*, **1281**, 51-63. https://doi.org/10.1111/j.1749-6632.2012.06838.x http://www.ncbi.nlm.nih.gov/pubmed/23317344

[21] Diabetes, G. (2013) Gestational Diabetes Burden Report. 1-20.

[22] Nanda, S., Savvidou, M., Syngelaki, A., Akolekar, R. and Nicolaides, K.H. (2011) Prediction of Gestational Diabetes Mellitus by Maternal Factors and Biomarkers at 11 to 13 Weeks. *Prenatal Diagnosis*, **31**, 135-141. https://doi.org/10.1002/pd.2636

[23] Mbc, M. and Td, D. (2015) Diabetes Mellitus in Pregnancy. 1-6.

[24] Gynaecologists, R.C. (2011) Diagnosis and Treatment of Gestational Diabetes. https://www.rcog.org.uk/globalassets/documents/guidelines/scientific-impact-papers/sip_23.pdf

[25] Lavery, J.A., Friedman, A.M., Keyes, K.M., Wright, J.D. and Ananth, C.V. (2017) Gestational Diabetes in the United States: Temporal Changes in Prevalence Rates between 1979 and 2010. *BJOG*, **124**, 804-813. https://doi.org/10.1111/1471-0528.14236

[26] Yang, W., Lu, J., Weng, J., Jia, W., Ji, L., Xiao, J., *et al.* (2010) Prevalence of Diabetes among Men and Women in China. *The New England Journal of Medicine*, **362**, 1090-1101. https://doi.org/10.1056/NEJMoa0908292

[27] Jayathilaka, K., Dahanayake, S., Abewardhana, R., Ranaweera, A., Rishard, M. and Wijeyaratne, C. (2012) Diabetes in Pregnancy among Sri Lankan Women: Gestational or Pre-Gestational? *Sri Lanka Journal of Diabetes Endocrinology and Metabolism*, **1**, 8-13. https://doi.org/10.4038/sjdem.v1i1.4181 http://www.sljol.info/index.php/SJDEM/article/view/4181

[28] Siribaddana, S.H., Deshabandu, R., Rajapakse, D., Silva, K. and Fernando, D.J. (1998) The Prevalence of Gestational Diabetes in a Sri Lankan Antenatal Clinic. *The Ceylon Medical Journal*, **43**, 88-91.

[29] Huidobro, A., Prentice, A., Fulford, T., Parodi, C. and Rozowski, J. (2010) Anthropometry as a Predictor of Gestational Dibetes Mellitus. *Revista Médica de Chile*, **138**, 1373-1377. http://www.ncbi.nlm.nih.gov/pubmed/21279249(08/06/2016)

[30] National Health and Nutrition Examination Survey (2005) Anthropometry and Physical Activity Monitor Procedures Manual.

[31] Basraon, S.K., Mele, L., Myatt, L., Roberts, J.M., Hauth, J.C., Leveno, K.J., *et al.* (2016) Relationship of Early Pregnancy Waist-to-Hip Ratio versus Body Mass Index with Gestational Diabetes Mellitus and Insulin Resistance. *American Journal of Perinatology*, **33**, 114-121. https://doi.org/10.1055/s-0035-1562928

[32] Rayanagoudar, G., Hashi, A.A., Zamora, J., Khan, K.S., Hitman, G.A. and Thangaratinam, S. (2016) Quantification of the Type 2 Diabetes Risk in Women with Gestational Diabetes: A Systematic Review and Meta-Analysis of 95,750 Women. *Diabetologia*, **59**, 1403-1411. https://doi.org/10.1007/s00125-016-3927-2

[33] Rasmussen, S.A., Chu, S.Y., Kim, S.Y., Schmid, C.H. and Lau, J. (2008) Maternal Obesity and Risk of Neural Tube Defects: A Metaanalysis. *American Journal of Obstetrics & Gynecology*, **198**, 611-619. https://doi.org/10.1016/j.ajog.2008.04.021 http://www.sciencedirect.com/science/article/pii/S0002937808004122

[34] Martin, K.E., Grivell, R.M., Yelland, L.N. and Dodd, J.M. (2015) The Influence of Maternal BMI and Gestational Diabetes on Pregnancy Outcome. *Diabetes Research and Clinical Practice*, **108**, 508-513. https://doi.org/10.1016/j.diabres.2014.12.015

[35] Lwanga, S.K. and Lemeshow, S. (1991) Sample Size Determination in Health Studies: A Practicle Manual. World Health Organization, Geneva.