**Title page**

**An investigation into utilising Gestational Body Mass Index as a screening tool for adverse birth outcomes and maternal morbidities in a group of pregnant women in Khayelitsha, South Africa.**

**Abstract**

**Objective:**The aim of this study was to investigate the ability of the GBMI method for screening adverse birth outcomes and maternal morbidities.

**Design:** This was a sub-study of a randomised controlled trial; the Philani Mentor Mothers Study (PMMS).

**Setting and subjects:** The PMMS took place in a peri-urban settlement, Khayelitsha, South Africa (2009-2010). Pregnant women living in the area during 2009-2010 were recruited onto the study.

**Outcome measures:** Maternal anthropometry and gestational weeks were obtained to calculate the gestational body mass index (GBMI). Birth outcomes and maternal morbidities were obtained after the birth from clinic cards.

**Results:**Pregnant women were recruited onto the study (n=1058). Significant differences were found between the different GBMI groups and the following birth outcomes; maternal (p-value = 0.019) and infant hospital stay (p-value = 0.03), infants staying over 24 hours in hospital (p-value = 0.001), delivery mode (p-value = 0.001) and pregnancy induced hypertension (p-value = 0.001).

**Conclusion:**To the best of our knowledge, this is the first study that has used the GBMI method in a peri-urban South African pregnant population. Based on the findings that this method can screen for some adverse birth outcomes, it is recommended that it is implemented in rural, peri-urban and urban primary health clinics and the effectiveness evaluated as a screening tool. Appropriate medical and nutritional advice can then be given to pregnant women to improve both their own and their infants’ birth-related outcomes and maternal morbidities.

**Keywords**

Maternal nutritional status

Birth outcomes

Gestational body mass index

Maternal morbidities

**D.Text**

**Introduction**

Maternal and child health has been one of the top health priorities in South Africa since the African National Congress came into power in 1994 and the Millenium Development Goals were implemented by the United Nations in 1990.**1** Despite some progress, maternal and child mortality rates are still unacceptably high in South Africa.**1** A mother’s nutritional status is one of the most important determinants of maternal and birth outcomes.**2,3** There are several methods of measuring nutritional status during pregnancy, although a universal method has not been accepted.**4** This has led to different methods being used in different studies and could explain some of the conflicting results reported.**4** The Institute of Medicine (IOM) method is similar to the majority of these methods which require the pregravid weight and Body Mass Index (BMI) of a pregnant woman and for her to be weighed at regular antenatal clinic appointments.**5** Attendance at antenatal clinics has increased in South Africa by 25% since 1994, mainly due to the implementation of basic free health care for pregnant women and children below the age of six.**6** The mean number of antenatal visits in South Africa is 3.8, with the Western Cape having the highest continuous attendance of 4.9.**6,7** Nevertheless, the reality in a peri-urban township setting is that many women attend these clinics later on in their pregnancy (mean=5.5 months).**6** The pregravid weight and BMI are therefore not always measured or known thus impacting the calculation method recommended by the IOM.

The Argentinian Ministry of Health developed a logarithmic equation to adjust maternal BMI for gestational age using an adaptation of the epi-nutrition software programme.**8** Using this software, the calculated gestational BMI (GBMI) can be grouped into categories.**8** Subsequently Cruz et al.**9**, utilized this equation, together with specific biochemical parameters.**9** They investigated the BMI of HIV (Human Immunodeficiency Virus) positive South American pregnant women and birth outcomes (n=697).**9** The main findings were similar to those of studies which observed accumulative weight gain and birth outcomes. Namely underweight women gave birth to infants of lower weight, shorter length and smaller head circumference (HC), compared to infants born from mothers in the normal or overweight category.**9,10** This method does not depend on the timing of the antenatal visit as it adjusts for gestational age.**8,9** It could therefore be used as an alternative method for screening for adverse birth outcomes and maternal morbidity in a South African peri-urban setting.

There is no consensus as to which method is the most appropriate for screening for birth outcomes and maternal morbidity. Risk factors need to be identified and managed accordingly to prevent maternal and infant deaths.**6** A reliable and uni-occasion prediction method requires establishment and implementation as public health policy. Appropriate medical and nutritional intervention can then be given to pregnant woman before, during and after birth to improve maternal and birth outcomes. The aim of this study was to investigate the ability of the GBMI method to screen for adverse birth outcomes and maternal morbidities in a South African peri-urban setting.

**Materials and methods**

***Participants***

The current study used baseline data from participants (n=1058) in a community-based, cluster-randomized controlled trial, the Philani Mentor Mothers’ Study (PMMS).**11** The PMMS took place in Khayelitsha, Western Cape, South Africa between 2009-2010. Twenty-four matched neighbourhoods were identified in the peri-urban settlement. Twelve of these were randomly assigned to the intervention (described elsewhere**11** and the other twelve were assigned to the standard-care control. Recruiters knocked on the door of every house in each neighbourhood and invited all pregnant women in the household to participate in the PMMS. If no one was present at the house, the recruiter would return until someone was at home to ensure that no pregnant women were missed. All participants were given a personal participant identity number (PID).

Participants were included in the PMMS if the following inclusion criteria were met; over 18 years of age, pregnant, living in the study neighbourhood within Khayelitsha for the duration of the study and the ability to give informed consent.

***Ethics***

Ethical approval was obtained for the PMMS from both the University of California (No G07-02-033) and Stellenbosch University (No8/08/218) ethics committees. Each participant signed an informed consent form. Each participant was given a PID to maintain participant confidentiality.

***Procedure***

Participants willing to participate in the PMMS were collected from their homes, and taken to the data assessment centre in Khayelitsha, Cape Town. Once they had signed an informed consent form, assessment interviewers carried out interviews using population specific questionnaires (baseline questionnaires developed by the research team and translated into Xhosa, the predominant language spoken in Khayelitsha. Information was recorded using mobile phone technology.**12** Once the interview was uploaded to a central database, it was automatically deleted from the mobile phone. Participants were then given a food voucher and taken home. Participants were also given a card with their PID and the assessment centre phone number. They were asked to contact the assessment centre once the baby had been born. The assessment interviewers went to the participants’ homes two days after birth and carried out the birth questionnaire.

***Anthropometric measurements***

Maternal weight was measured to the nearest 0.1kgusing a calibrated Precision Health Scale (model UC321).**13**  Maternal height was measured to the nearest 0.01m using a calibrated stationary stadiometer (model-MM5). Duplicates of these measures were completed by three data collectors during the baseline questionnaire, using standardised methods.**13**

The infant’s birth weight, length and HC were obtained from the clinic card which was completed at the maternal obstetric unit. Duplicate measures of all three measurements were taken by the data collectors during the birth questionnaire.

***Gestational BMI***

Gestational BMI was calculated using the equation for adjusted BMI for gestational age at enrolment and categorised into; underweight (≥10 to ≤19.8 kg/m2), normal weight (≥19.8 to ≤26.1 kg/m2), overweight (≥26.1 to ≤29 kg/m2), and obese (≥29 to ≤50 kg/m2) [8, 9].

***Birth Outcomes***

The participants were asked the following birth outcomes in the birth questionnaire; delivery facility, delivery mode, length of maternal hospital stay, length of infant hospital stay, development of gestational diabetes (GDM) or pregnancy induced hypertension (PIHPT). The following birth outcomes were obtained from the infant’s clinic card; gestational age, weight, length and HC. Gestational age was classified as preterm ≤37 weeks, term ≥37 to ≤42 and post- term 42 weeks or more. Z-scores were calculated for birth weight, length and head circumference. They were then categorised into z-score1 (≤-2sd) z-score2 (≥-2sd, ≤+2sd) and z-score3 (≥+2sd). Weight was documented as; low birth weight (LBW) ≤2500g and macrosomia ≥4500g. The following other adverse birth outcomes were also documented; neonatal, infant and maternal deaths.

***Data analysis***

Microsoft Excel® was used to capture the data and SPSS (version 18) was used to analyse the data. Summary statistics described the variables. Medians and quartiles or means and standard deviations (sd) were used to describe ordinal and continuous responses. A MANOVA was used to determine if there was a statistical difference between intervention and control groups. If groups were significantly different, results were calculated separately, if there was no significant difference, results were calculated using the combined data. The association of gestational BMI and GRS at enrolment with categorical birth outcomes was evaluated using contingency tables and the likelihood ratio Chi-square test. If cells had a count less than 5%, data was transformed using (x+0.5).**14** Randomised block ANOVA was then calculated using this transformed data. Student Newman Keuls post-hoc tests were performed to analyse the significant difference between categories and outcome groups. *P-value* < 0.05 represented statistical significance.

**Results**

***Characteristics of the participants***

Baseline characteristics collected at enrolment of 1058 pregnant women participating in the PMMS are shown in Table 1. Participants had an average age (± standard deviation) of 26±5.4 years. Most of the participants (50.8%, n=537) were in the third trimester. Xhosa (99.5%, n=1053) was the predominant language spoken by participants.

**Table 1 Socio-economic and demographic (SED) characteristics of participants (mean ± standard deviation(sd) or percentage, number and 95% Confidence Interval (CI)**

|  |  |  |  |
| --- | --- | --- | --- |
| **SED characteristics** | **(n)** | **Mean± sd or %** | **95% CI** |
| Age | 1058 | 26.3 ± 5.4 |  |
| Smokers | 38 | 3.6.% | 2.6 to 4.9 |
| Identity document | 946 | 89.40% | 87.4 to 91.1 |
| Xhosa speaking | 1053 | 99.50% | 98.9 to 99.8 |
| Third trimester | 537 | 50.80% | 47.7 to 53.8 |
| Booked at Antenatal clinic | 832 | 78.60% | 76.1 to 81.0 |
| Planned pregnancies | 278 | 26.30% | 23.7 to 29.0 |
| Babies born in hospital | 709 | 67.00% | 64.1 to 69.8 |
| ***Marital Status*** |  |  |  |
| Single | 454 | 42.90% | 40.0 to 45.9 |
| Married/Cohabiting | 604 | 57.10% | 54.1 to 60.0 |
| ***Education*** |  |  |  |
| Primary | 80 | 7.60% | 6.1 to 9.3 |
| Secondary | 939 | 88.80% | 86.7 to 90.5 |
| Tertiary | 39 | 3.60% | 2.7 to 5.0 |
| ***Employment and Income*** |  |  |  |
| Employed | 208 | 19.7 | 17.4 to 22.2 |
| Unemployed | 850 | 80.30% | 77.8 to 82.6 |
| > 2000 South African Rand | 478 | 45.50% | 42.2 to 48.2 |
| < 2000 South African Rand | 580 | 54.50% | 51.8 to 57.8 |
| ***Housing*** |  |  |  |
| Formal structure | 322 | 30.40% | 27.7 to 33.3 |
| Informal structure | 736 | 69.60% | 66.7 to 72.3 |
| ***TB or HIV status*** |  |  |  |
| TB positive of those who tested (20.3%,18.0 to 22.9%, n=215) | 3 | 1.40% | 0.5 to 4.0 |
| HIV positive of those who tested (91.9%, 90.2 to 93.5, n=973) | 255 | 26.20% | 23.5 to 29.1 |

Few of the participants (3.6%, n=38) reported to be smokers. Approximately ninety percent (89.4%, n=946) of the participants had identity documents (ID). IDs are essential for booking into the antenatal clinics of which 78.6% (n=832) had done. The majority of births took place in a hospital (67.0%, n=709)

More than half (57.1%, n=604) of the participants were either married or cohabiting, but 88.8% (n=939) had completed high school. Unemployment was high at 80.3% (n=850) and over half (54.5%, n=580) had a monthly household income of less than 2000 South African Rands (SAR) (US$290). Nearly two thirds of the participants (69.6%, n=736) lived in an informal dwelling (wood and iron structure, which does not meet basic building standards). During their current pregnancy, 20.3% (n=215) and 91.9% (n=973) had been tested for TB and HIV respectively. Of those tested, 1.4% (n=3) had TB and 26.2% (n=255) were HIV positive.

***Anthropometry and GBMI***

Anthropometry and calculated GBMI scores can be seen in Table 2. Participants had an average height of 1.59m ± 0.06 and GBMI of 27.19 ± 5.83, with the majority of the group (44.2%, n=468) in the normal GBMI category.

**Table 2 Anthropometry, Adverse events, Gestational BMI (GBMI) of participants (number (n) of total, mean and**

**standard deviation (sd) or percentage (%)and 95 Confidence Interval (CI))**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Anthropometry** | **(n of total)** | **Mean(±sd) or %** | **95% CI** | **Adverse events** | | | | | |
| **Miscarriage**  **%(n)**  **2.5 (26)** | **Stillbirth**  **%(n)**  **1.9(21)** | **Neonatal death**  **%(n)**  **1.4(15)** | **Abortion**  **%(n)**  **0.5(5)** | **Infant death**  **%(n)**  **2.2(23)** | **Maternal death**  **%(n)**  **0.4(4)** |
| **Height** | 1058 | 1.59 ± 0.06 |  |  |  |  |  |  |  |
| ***Gestational body mass index (GBMI)*** |  |  |  |  |  |  |  |  |  |
| **GBMI** |  | 27.19 ± 5.83 |  |  |  |  |  |  |  |
| % Underweight | 60 | 5.70% | 4.4 to 7.2 | 3.8(1) | 4.8(1) | 6.7 (1) | 0.0 (0) | 0.0 (0) | 0.0 (0) |
| % Normal | 468 | 44.20% | 41.3 to 47.2 | 38.4(10) | 42.8(9) | 20.0(3) | 40.0(2) | 73.8(17) | 0.0 (0) |
| % Overweight | 180 | 17.00% | 14.9 to 19.4 | 26.9(7) | 14.3(3) | 26.7(4) | 20.0(1) | 13.1(3) | 75.0(3) |
| % Obese | 350 | 33.10% | 30.3 to 35.9 | 30.9(8) | 38.1(8) | 46.6(7) | 40.0(2) | 13.1(3) | 25.0(1) |

***Birth outcomes***

Adverse events categorised according to GBMI categories can be seen in Table 2. The most common adverse event were miscarriages (2.5%, n=26), followed by infant deaths (2.3%, n=23)

**Table 3: Birth outcomes and maternal morbidities (% (no of total), overall and according to gestational body mass index (GBMI) at enrolment**

| **Maternal gestational BMI (kg/m2) at enrolment** | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Birth Outcome** | **Overall**  **% (n of total)**  **100 (1058 of 1058)** | **Underweight (≥10.0-≤19.8)**  **% (n of total)**  **5.7(60 of 1058)** | **Normal weight (≥19.8-≤26.1)**  **% (n of total)**  **44.2(468 of 1058)** | **Overweight (≥26.1-≤29.0)**  **% (n of total)**  **17.1(180 of 1058)** | **Obese (≥29.0-≤50.0)**  **% (n of total)**  **33(350 of 1058)** | **Test statistic** | **P-value** |
| ***Delivery mode*** |  |  |  |  |  | X2=23.03 | <0.001\* |
| Vaginal delivery  Caesarean section | 75.5 (799)  24.5 (259) | 83.3(50)  16.7(10) | 81.4(381)  18.6(87) | 72.7(131)  27.3(49) | 67.7(237)  32.3(113) |
| ***Maternal hospital stay***  ≤ 1 day  1 day  ≥1 day | 21.7 (230)  31.6 (334)  46.7 (494) | 16.7 (10)  38.3 (23)  45.0 (27) | 23.3 (109)  37.2 (174)  39.5 (185) | 23.9 (43)  28.3 (51)  47.8 (86) | 19.4 (68)  24.6 (86)  56 (196) | X2=15.06 | 0.022\* |
| ***Baby staying over 24 hours in***  ***Hospital***  ***No***  ***Yes*** | 42.7 (452)  57.3 (606) | 41.6 (25)  58.4 (35) | 48.5 (227)  51.5 (241) | 42.8 (77)  57.2 (103) | 35.1 (123)  64.9 (227) | X2=7.46 | 0.024\* |
| ***Baby staying over 24 hours in hospital*** | 52.3(606) | 5.8(35 of 606) | 39.8(241 of 606) | 16.9(103 of 606) | 37.5(227 of 606) | F5,11=18.63b | 0.001\* |
| ≤3 days | 47.7(289) a | 62.9(22) | 51.5(124) | 47.6(49) | 41.4(94) |
| ≥3 days, ≤2 weeks | 45.7(277) a | 34.3(12) | 41.1(99) | 45.6(47) | 52.4(119) |
| ≥2 weeks | 6.6(40) a | 2.8 (1) | 7.4 (18) | 6.8 (7) | 6.2 (14) |
| ***Gestational period*** |  |  |  |  |  | X2=5.43 | 0.487 |
| Preterm | 28.7 (304) | 36.6(22) | 28.6(134) | 28.9(52) | 27.4(96) |  |  |
| Term | 56.6 (598) | 51.7(31) | 58.2(272) | 57.2(103) | 54.9(192) |  |  |
| Overterm | 14.7 (156) | 11.7(7) | 13.2(62) | 13.9(25) | 17.7(62) |  |  |
| \*P<0.05, a Significant difference between groups <-2sd and >-2sd and <+2sd and groups >-2sd and <+2sd and >=2sd, b Significant difference between underweight and normal GBMI categories and underweight and obese GBMI categories , c Significant difference between developing GDM and not developing GDM, F = Manova test statistic, X2=Chi square test statistic | | | | | | | |
| ***Mean current birth weight (2 -7 days after birth) = 3.6 kg (±0.74)*** |  |  |  |  |  |  |  |
| ***Birthweight z scores*** |  |  |  |  |  | F5,11=10.40 | 0.006\* |
| Below -2sd | 7.1 (75) a | 16.7(10) | 7.5 (35) | 6.1 (11) | 5.4 (19) |
| ≥-2 sd, ≤+2sd | 90.5(958) a | 81.7(49) | 89.9(421) | 92.7(167) | 91.7(321) |
| Above +2sd | 2.4 (22) a | 1.6 (1) | 2.6 (9) | 1.2 (2) | 2.9 (10) |
| ***Mean length (2-7 days after birth) =51.2cm(±3.12)*** |  |  |  |  |  |  |  |
| ***Birth length z scores*** |  |  |  |  |  | F5,11=9.89 | 0.007\* |
| Below -2sd | 12.6(134) a | 23.3(14) | 12.8(60) | 11.7(21) | 11.1(39) |
| ≥-2 sd, ≤+2sd | 82.1(869) a | 70.0(42) | 83.5(391) | 83.9(151) | 81.4(285) |
| Above +2sd | 5.3 (52) a | 6.7 (4) | 3.7 (14) | 4.4 (8) | 7.5 (26) |
| ***Mean HC (2-7 days after birth) = 35.7cm (±2.01)***  ***Birth HC z score*** |  |  |  |  |  | F5,11=9.89 | 0.007\* |
| Below -2sd | 7.3 (77) a | 18.3(11) | 7.7 (36) | 4.4 (8) | 6.3 (22) |  |  |
| ≥-2 sd, ≤+2sd | 80.2(849) a | 73.3(44) | 82.7(387) | 84.4(152) | 76.0(266) |  |  |
| Above +2sd | 12.5(129) a | 8.4 (5) | 9.6 (42) | 11.2(20) | 17.7(62) |  |  |
| \*P<0.05, a Significant difference between groups <-2sd and >-2sd and <+2sd and groups >-2sd and <+2sd and >=2sd, b Significant difference between underweight and normal GBMI categories and underweight and obese GBMI categories , c Significant difference between developing GDM and not developing GDM, F = Manova test statistic, X2=Chi square test statistic | | | | | | |  |  |  |  |  |  |  |
| ***Low birthweight*** ≤***2500g*** |  |  |  |  |  | F4,7=7.08 | 0.07 |
| No | 96.6(1022) | 96.7(58) | 96.8(453) | 93.3(170) | 97.4(341) |
| Yes | 3.4 (36) | 3.3 (2) | 3.2 (15) | 6.7 (10) | 2.6 (9) |
| ***Macrosomic*** ≥***4500g*** |  |  |  |  |  | X2=1.138 | 0.768 |
| No | 91.5(968) | 90.0(54) | 91.5(428) | 93.3(168) | 90.9(318) |
| Yes | 8.5 (90) | 10.0(6) | 8.5 (40) | 6.7 (12) | 9.1 (32) |
| ***Gestational Diabetes*** |  |  |  |  |  | F4,7 =9.44 | 0.048\* |
| No | 97.8(1028)c | 100.0(60) | 97.4(456) | 97.8(176) | 96.0(336) |  |  |
| Yes | 2.8 (30) c | 0 (0) | 2.6 (12) | 2.2 (4) | 4.0 (14) |  |  |
| ***Pregnancy induced hypertension*** |  |  |  |  |  | X2=15.83 | 0.001\* |
| No | 82.4 (872) | 83.3(50) | 87.2(408) | 81.1(146) | 76.6(268) |  |  |
| Yes | 17.6 (186) | 16.7(10) | 12.8(60) | 18.9(34) | 23.4(82) |  |  |

\*P<0.05, a Significant difference between groups <-2sd and >-2sd and <+2sd and groups >-2sd and <+2sd and >=2sd, b Significant difference between underweight and normal GBMI categories and underweight and obese GBMI categories , c Significant difference between developing GDM and not developing GDM, F = Manova test statistic, X2=Chi square test statistic

Birth outcomes can be seen in Tables 3. Over three quarters (75.5%, n=799) of the births were vaginal deliveries. Over half of the births were term (56.6%, n=598). Most of the infants were in the normal z-score range for birth weight (90.5%, n=958), birth length (82.1%, n=869) and birth head circumference (80.2%, n=849). There was a low percentage of LBW infants (3.5%, n=36). There were 90 (8.5%) infants who were macrosomic. Only 2.8% (n=30) of the women developed GDM whereas more developed PIHPT (17.6%, n=186).

A significant difference was found between the GBMI groups, where the highest percentage of women were found in the obesity group and the following birth outcomes; caesarean sections (*p-value =* 0.001), and PIHPT (*p-value =* 0.001). There was a significant difference between the four GBMI categories and maternal hospital stay (*p-value =* 0.02). The greatest proportion of women who stay in hospital longer than one day were found in the overweight (47.8, n=86) and obese (56%, n=196) groups. There was a significant difference between the GBMI categories and the number of babies staying more than 24 hours in hospital (*p-value =* 0.024). The majority of the infants from women in the obese GBMI category stayed longer than 24 hours. A significant difference was found between the underweight and normal weight GBMI groups and underweight and obese GBMI groups and the infants staying over 24 hours (*p-value =* 0.001). The majority of infants from mothers in the underweight, obese and normal GBMI categories stayed ≤3 days, ≥3 days but ≤2 weeks and ≥2 weeks respectively.

A significant difference was found between birth and current (2-7 days after birth) birth weight, length and HC. A significant difference was found between the z-score1 and z-score2 and z-score2 and z-score3 for birth weight (*p-value =* 0.006), length (*p-value =* 0.01) and HC (*p-value =* 0.01) and post (2-7 days) birth (*p-value =* 0.006), length (*p-value =* 0.007) and HC (*p-value =* 0.07). A significant difference was also found between those women who developed GDM and those who did not (*p-value =* 0.048). Although significant differences were found between groups, post-hoc tests revealed that there was no significant difference between the GBMI categories.

**Discussion**

This study found significant results for the ability of the GBMI method to screen for adverse birth outcomes and maternal morbidities. The following adverse events occurred; miscarriages (2.5%, n=26), stillbirths (1.9%, n=21), neonatal deaths (1.4%, n=15), abortions (0.5%, n=5), infant deaths (2.3%, n=23) and maternal deaths (0.4%, n=4). No significant difference was found between the four GBMI categories and adverse events as the frequency counts were too low to analyse.

South Africa’s caesarean (C) – section rate (16.1%, range 3.2-32.5%) is higher than the World Health Organisation’s (WHO) recommended rate of 15%.**15** Western Cape (20.4%) is at the upper end of the South African range.**16** C-section rate is an important indicator for obstetric care in low income countries.**17** Several factors influence this high rate, one of which is the high HIV prevalence, although HIV is not a clinical indicator for a C-section.**17** C-Sections impact on the cost to the health system and the well-being of the mother and child.**16** Knowledge regarding the reasons behind these differences in rates in South Africa is required.**16** In the present study, women in the obese GBMI had significantly more C-sections, as have other studies.**17-19** Only a quarter (24%) of the births in the peri-urban settings are performed by a skilled health personnel.**6** This highlights the need for a more accurate way to classify women at risk, so high risk births can be carried out by a doctor and more post-partum care given.**6**

Significantly more mothers and babies staying over 24 hours in hospital were found in the obese GBMI category in this study. Public hospitals in middle-low income countries consume the majority of the healthcare resources compared to the primary and preventative clinics.**20** Approximate costs of hospital stay per day without drugs and diagnostic testing varies between clinics and hospitals (primary clinic US$60.89, secondary hospital US$79.44, tertiary hospital US$108.51).**21** Olukoga.**20** reported that the unit cost per day in district South African hospitals was highest for maternal inpatients.**20** Women identified as being in the obese GBMI category could be allocated more antenatal clinic appointments. This could potentially decrease the risk of both them and their babies staying longer in hospital post-natally which would also have a positive impact on the economic cost to the health service.

The majority (95.6%, n=1012) of women in the PMMS had clinic cards. Of these 91.1%, 53.0% and 86.1% of birth weight, length and HC respectively were measured and documented. These measures were repeated at the birth questionnaire and there was a significant difference between results. Z-scores were therefore calculated for both time measures. Although this study showed a significant difference between the z-score categories and birth and post-birth anthropometry, no significant differences were found between GBMI categories. These findings disagree with other considerably larger studies, that have found GBMI to be positively associated with both birth weight, length and HC.**20-24** One of these studies also found that a low GBMI was a predictor for preterm and neonatal mortality, whereas this study did not.**25** This could be due to the fact that only 5.7% of women were in the underweight GBMI category.

Studies indicate that women with a lower**26** and higher**22-24** pregravid BMI are more at risk of giving birth to a LBW baby. There was a relatively low percentage (3.4%) of LBW babies in the present study compared to the rates (9.7-29.2%) from the most recent saving babies report (2008-2009). This lower rate could be due to the low percentage (5.7%, 60 of 1058) of women in the underweight GBMI category and no data for women under 18 years of age was obtained. Teenage pregnancies are at a higher risk for LBW babies.**27**

There was a relatively higher percentage (8.5%) of macrosomic babies compared to other South African studies (2.3%-3.43%) focusing on the black African population.**28, 29** There are various risk factors for macrosomia, the strongest being GDM, followed by high gestational BMI.**30-32** The later could be the reason for the higher macrosomic incidence in this sub-study. However no significant difference was found between GBMI categories and macrosomia. Worldwide GDM prevalence is 2-19% and it is at the lower end in poor to middle-income countries.**33** Mothers who develop GDM have an increased risk of developing Type 2 Diabetes Mellitus and infants born from mothers who have GDM are at an increased risk for adverse birth outcomes, including macrosomia and childhood obesity.**34,35** A systematic review undertaken between 1999-2011 established that there was only one study by Mamabola et al.**36**, that examined the prevalence of GDM in the black South African population (n=262)**36,37** They found a similar (2.8%, 30 of 1058) low prevalence of GDM (1.5%) and a higher prevalence of gestational impaired glucose intolerance (8.8%). A reason for this low prevalence could be the low mean age (26.3 ± 5.4 years) which is comparable with Mamabola et al.**36** The highest proportion of women who developed GDM were categorised in the obesity group and were in the high GRS category. This is in agreement with Mamabola et al.**36**, who also found that the women who developed GDM were significantly heavier.**36**

Prevalence of hypertension (HPT) is increasing in South African women (25%) mainly due to obesity.**38** Approximately 16% of maternal deaths were due to complications of pregnancy induced HPT (PIHPT).**39** Over half (58.5%) of maternal deaths are deemed avoidable due to PIHPT.**39** The majority of the adverse events are due to postpartum problems.**39** In the present study, more than twice as many women (17.6%) had PIHPT compared to other South African studies.**38,39** This could possibly be because the majority of the participants in the other studies were from more rural regions of South Africa, whereas this study’s participants had the influence of urbanisation on their diet and weight.**38** Black South Africans are particularly at risk due to a genetic susceptibility to low rennin low aldosterone hypertension.**40** In agreement with others**41-43**,this study found significantly more women in the obese GBMI category developed PIHPT.**42-43** If the women are placed in a high risk category, more observation, monitoring and appropriate intervention can take place.**41** PIHPT is frequently exposed by pregnancy and the mother often develops hypertension later in life. PIHPT is regularly associated with other co-morbidities, such as cardiovascular disease and diabetes which are public health concerns.**43** .

Weight and height have been recorded in the majority of antenatal clinics in the Western Cape (97% and 90.4% respectively).**5** With appropriate training and calibrated equipment, the GBMI method is simple to calculate and can be used to identify women at high risk during their pregnancy and labour.

***Limitations to the study***

The participants were not informed of the distinction between PIHPT and pre-eclampsia, therefore the two different morbidities could not be separated in the analysis. No participants under the age of 18 were included in the study. Teenage pregnancies are at a higher risk for the following adverse birth outcomes; LBW, premature infants, smaller length and HC**27**. There was inter-variable reliability as infant anthropometric measurements (birth weight, length and HC) were obtained from the clinic card and post birth weight, length and HC and maternal weight and height were measured by trained data-collectors. Most of the information was from participant’s memory recollection making accuracy of recall is a potential limitation. No significant difference was found between gestational period and GBMI categories. The gestational period in the sub-study is questionable as it was calculated using the last menstrual cycle method.

**Conclusion**

To the best of our knowledge, this is the first study that has used the GBMI method in a peri-urban South African pregnant population. Based on findings it is recommended that the GBMI one-off methods is implemented in rural, peri-urban and urban primary health clinics and the effectiveness evaluated as a screening tool. The GBMI method could be a useful and practical tool to aid in identifying high risk pregnancies. With appropriate training it is relatively easy to use. Appropriate medical and nutritional advice can then be given to pregnant women to improve both their own, birth related outcomes and maternal morbidities.

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