



Two-Way Multivariate Analysis of Variance (MANOVA) of the Effect of Parity on Body Mass Index and Body Surface Area of Pregnant Women

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Authors' contributions

This work was carried out in collaboration between the two authors. Author IENH designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Then, authors IENH and BOE managed the analyses of the study. Author BOE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: In the determination of the effect of Parity on Body Mass Index (BMI) and Body Surface Area (BSA).

Study Design: Pregnant Women Body Mass Index (BMI) and Body Surface Area (BSA) measurements, Number were used in this study.

Place and Duration of Study: The data on the various measurements on pregnant women were collected from the Radiology department of University of Port Harcourt Teaching Hospital.

Methodology: The Two-way Classification Multivariate Analysis of Variance (MANOVA) was employed to obtain the MANOVA test statistics for Wilk's, Pillai, Lawley-Hotelling and Roy's Largest Root.

Results: Results showed that the MANOVA test statistics for Wilk's statistics showed no significant effect for the Parity level categorized on BMI (Factor A) and the Parity level categorized on BMI and BSA (Factor AB), while Lawley-Hotelling Root test showed no significant effect for the effect of the

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Parity level categorized on BSA (Factor B). However, two MANOVA test statistics (Pillai and Roy's Largest Root statistics) gave significant effect on BMI or BSA or both (or all Factors A, B and AB). These results confirmed that the effect of the Parity level has a significant effect on BMI or BSA or both in terms of the categories (normal, overweight and obese). These results are in agreement with known results by medical practitioners.

Keywords: Multivariate Analysis of Variance (MANOVA); parity level; two-way classification; body mass index; body surface area.

1. INTRODUCTION

Pregnancy is a special period in the life of a woman that leads to significant changes during the entire course of the pregnancy and even after it has resulted in motherhood. Some changes such as the cognitive function of women which may include memory and verbal learning occur during pregnancy.

According to a study, it was observed that pregnancy affected their verbal learning and caused their learning patterns to be ineffective and more random [1]. The study also showed that the emotional state of pregnant women was also affected. It has also been shown that pregnant women become very sensitive in their third trimester [2]. When a pregnant woman approaches delivery, sensitivity to her environment increases which might signal that she is preparing to nurture young ones. Since emotional and cognitive functioning is affected by pregnancy, it is expected to also affect relationships, that is, her thought pattern.

The [3] and [4], observed that a greater percentage of women with high BMI had a significant increment in SBP and DBP in comparison to those who have a relatively stable BMI. According to a study, symptoms of obesity are intensified by excessive gaining of weight during pregnancy and the inability to lose weight six months after child birth. The scarcity of data on body weight twelve months after postpartum can be associated with social and behavioral changes that may lead to the increment in weight [5].

Obesity during pre-pregnancy is strongly associated with some pregnancy complications and perinatal conditions. These complications therefore imply the need for weight loss and pre-pregnancy counseling in this group of women. In the first trimester, the blood pressure of pregnant women slightly reduces and is lowest during the second trimester. Compared to Hispanic and

white women, there is a tendency for African-American women to be obese and overweight and more prone to developing high blood pressure [6]. High blood pressure has been associated with obesity and parity and the relationship between obesity and parity is unclear. There is limited information on the correlation of parity and increased blood pressure and the aim of this study is to contribute to this body of knowledge.

Blood pressure can also be affected by pregnancy including some hemodynamic shifts. Blood flow to the uterus and kidneys increases during pregnancy but hepatic blood flow remains the same [7]. Occurrences of high blood pressure in a pregnant woman are influenced by either the number of pregnancies or her preeclampsia history before pregnancies.

In developed economies, it has been observed that high blood pressure and age has a positive correlation starting at childhood and developing into adulthood [8,9] reported that adults experienced an increment in systolic blood pressure than diastolic blood pressure when women reach child nurturing age.

The blood pressure in women increases slightly between twenty to twenty four years of age during which their fertility peaks. In their early thirties, women experience stable fertility but decline afterwards. For instance, the fertility rate of women between ages thirty to thirty five is between fifteen percent, to twenty percent below the maximum while the fertility rate decreases at a rate between twenty five to fifty percent.

It is necessary for pregnant women to take balanced diet. This is because balanced diet contains the necessary nutrient in the right proportion that will take care of the energy needed by the pregnant woman and also boosts her immune system in order to prevent diseases that are pregnancy related and also aid

the development of the fetus. A woman's nutritional status during pregnancy and the preconception period does affect both the outcome of the pregnancy's prenatal phase [8] and may cause cardiovascular diseases, high blood pressure and adult phase of diabetes mellitus which is noninsulin dependent [10].

2. METHODS

The data used in this work were basically secondary data obtained from the existing log books of UPTH, Port Harcourt, Nigeria. The one-way MANOVA is used to check if there are any

significant disparities between independent groups on more than one dependent variable.

The two way MANOVA were used to determine whether there exists any significant effect of parity on BMI and BSA. It is assumed that there are k independent random samples of size n in the multivariate case which is obtained from p-variate normal populations with equal covariance matrices which is the same as in the following layout for a balanced one-way MANOVA [11,12,13,14]. In practice, y_{ij} which represent observation vectors may be written in row and sample 2 will appear below sample 1, and so on as shown in the Table 1.

Table 1. MANOVA model

Sample 1 From $N_p(\mu_1, \Sigma)$	Sample 2 From $N_p(\mu_2, \Sigma)$	.....	Sample k From $N_p(\mu_k, \Sigma)$
y_{11}	y_{21}	.....	y_{k1}
y_{12}	y_{22}	.....	y_{k2}
.
.
.
y_{1n}	y_{2n}	.....	y_{kn}
Total y_1	y_2	.....	y_k
Mean y_1	y_2	.....	y_k

The mean and total are expressed as thus:

$$\text{Total of } i\text{th sample } y_i = \sum_i^k \sum_{j=1}^n y_{ij}$$

$$\text{Overall total } y_{..} = \sum_{j=1}^n y_{ij}$$

$$\text{Mean of } i\text{th sample } \bar{y}_i = y_i/n$$

$$\text{Overall mean } \bar{y}_{..} = y_{..}/kn$$

Model for entire observation vectors are expressed as

$$y_{ij} = \mu + \alpha_i + \varepsilon_{ij} = \mu_i + \varepsilon_{ij}, i = 1,2, \dots, k; j = 1,2, \dots, n \tag{1}$$

In terms of p variables in y_{ij} , Equation (1) becomes

$$\begin{pmatrix} y_{ij1} \\ y_{ij2} \\ \vdots \\ y_{ijp} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_p \end{pmatrix} + \begin{pmatrix} \alpha_{i1} \\ \alpha_{i2} \\ \vdots \\ \alpha_{ip} \end{pmatrix} + \begin{pmatrix} \varepsilon_{ij1} \\ \varepsilon_{ij2} \\ \vdots \\ \varepsilon_{ijp} \end{pmatrix} = \begin{pmatrix} \mu_{i1} \\ \mu_{i2} \\ \vdots \\ \mu_{ip} \end{pmatrix} + \begin{pmatrix} \varepsilon_{ij1} \\ \varepsilon_{ij2} \\ \vdots \\ \varepsilon_{ijp} \end{pmatrix} \tag{2}$$

Such that in the vectors expressed as y_{ij} , has model for r th variable ($r=1,2,\dots,p$) is

$$y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_{ij} + \varepsilon_{ijk} = \mu_{ij} + \varepsilon_{ijk} \quad (3)$$

in which " $i=1,2,\dots,a, j=1,2,\dots,b, k=1,2,\dots,n$ "

For a balanced data with a two-way model, the "total sum of squares and products matrix" can be partitioned as follows

$$T = H_A + H_B + H_{AB} + E \quad (4)$$

The structure of any of the hypothesis matrices is similar to that of H, thus H has the form:

$$H = \begin{bmatrix} SSH_{A11} & SPH_{A12} & \dots & SPH_{A1p} \\ SPH_{A12} & SSH_{A22} & \dots & SPH_{A2p} \\ & & \ddots & \\ & & & \ddots \\ SPH_{A1p} & SPH_{A12} & \dots & SSH_{Arr} \end{bmatrix} \quad (5)$$

For instance, " H_A has on the diagonal the sum of squares for factor A for each of the p variables. The off-diagonal elements of H_A are corresponding sums of products for all pairs of variables. Thus the r^{th} diagonal element of H_A corresponding to the r^{th} variable, $r=1,2,\dots,p$, is given by"

$$h_{Arr} = nb \sum_{i=1}^a (\bar{y}_{i..r} - \bar{y}_{...r})^2 = \sum_{i=1}^a \frac{y_{i..r}^2}{nb} - \frac{y_{i..r}^2}{nab} \quad (6)$$

where $\bar{y}_{i..r}$ and $\bar{y}_{...r}$ represent the r^{th} components of $\bar{y}_{i..}$ and $\bar{y}_{...}$, respectively, $y_{i..r}$ and $y_{...r}$ are totals corresponding to $\bar{y}_{i..r}$ and $\bar{y}_{...r}$. The $(rs)^{\text{th}}$ off-diagonal element of H_A is

$$h_{Ars} = nb \sum_{i=1}^a (\bar{y}_{i..r} - \bar{y}_{...r})(\bar{y}_{i..s} - \bar{y}_{...s}) = \sum_{i=1}^a \frac{y_{i..r}y_{i..s}}{nb} - \frac{y_{i..r}y_{i..s}}{nab} \quad (7)$$

From Equation (4) and Table 2, we obtain

$$h_{ABrr} = \sum_{ij} \frac{y_{ij..r}^2}{n} - \frac{y_{...r}^2}{nab} - h_{Arr} - h_{Brr} \quad (8)$$

$$h_{ABrs} = \sum_{ij} \frac{y_{ij..r}y_{ij..s}}{n} - \frac{y_{...r}y_{...s}}{nab} - h_{Ars} - h_{Brs} \quad (9)$$

$$E = T - H_A - H_B - H_{AB} \quad (10)$$

Table 2. Multivariate two-way analysis of variance

Source	Sum of square and products Matrix	df
A	$H_A = nb \sum_i (\bar{y}_{i..} - \bar{y}_{...}) (\bar{y}_{i..} - \bar{y}_{...})'$	a-1
B	$H_B = na \sum_j (\bar{y}_{.j.} - \bar{y}_{...}) (\bar{y}_{.j.} - \bar{y}_{...})'$	b-1
AB	$H_{AB} = n \sum_{ij} (\bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}_{...}) (\bar{y}_{ij.} - \bar{y}_{i..} - \bar{y}_{.j.} + \bar{y}_{...})'$	(a-1)(b-1)
Error	$E = \sum_{ijk} (y_{ijk} - \bar{y}_{ij.}) (y_{ijk} - \bar{y}_{ij.})'$	Ab (n-1)
Total	$T = \sum_{ijk} (y_{ijk} - \bar{y}_{...}) (y_{ijk} - \bar{y}_{...})'$	abn-1

Therefore, elements of E are expressed as:

$$e_{rr} = \sum_{ij} y_{ijkr}^2 - \frac{y_{...r}^2}{nab} - h_{Arr} - h_{Brr} - h_{ABrr} \quad (11)$$

$$e_{rs} = \sum_{ij} y_{ijkr} y_{ijks} - \frac{y_{...r} y_{...s}}{nab} - h_{Ars} - h_{Brs} - h_{ABrs} \quad (12)$$

For their mean and interaction effects, hypothesis matrices in this fixed effects model are comparable to E when making test. Thus for Wilk's "Λ", we utilize E in testing A, B, and AB as thus;

$$\hat{\Lambda}_A = \frac{|E|}{|E + H_A|} \text{ is } \Lambda_{0.05, p, a-1, ab(n-1)} \quad (13)$$

$$\hat{\Lambda}_B = \frac{|E|}{|E + H_B|} \text{ is } \Lambda_{0.05, p, b-1, ab(n-1)} \quad (14)$$

$$\hat{\Lambda}_{AB} = \frac{|E|}{|E + H_{AB}|} \text{ is } \Lambda_{0.05, p, (a-1)(b-1), ab(n-1)} \quad (15)$$

This distribution that is indicated is applicable when H₀ is true for the entire case. To evaluate the other MANOVA test statistics A, B, and AB, we utilize eigen values for E⁻¹H_A, E⁻¹H_B and E⁻¹H_{AB} [11,13].

2.1 Roy's Test Statistic

We need linear combination $z_{ij} = a' y_{ij}$ which would maximizes spread of this transformed mean $\bar{z}_i = a' \bar{y}_i$. as compare to within-sample spread of points, in union intersection technique. Therefore, we need vector which would maximize

$$F = \frac{n \sum_{i=1}^k (\bar{z}_i - \bar{z}_{..})^2 / (k-1)}{\sum_{i=1}^k \sum_{j=1}^n (z_{ij} - \bar{z}_i)^2 / (kn-k)} \quad (16)$$

The Roy's test statistic is given by

$$\theta = \frac{\lambda_1}{1+\lambda_1} \quad (17)$$

2.2 Lawley-Hotelling and Pillai Test

We have two more test statistic for $H_0: \mu_1 = \mu_2 = \dots = \mu_k$ based on this eigenvalue $\lambda_1, \lambda_2, \dots, \lambda_s$ the formula below represents Pillai statistic

$$V^{(s)} = tr[(E + H)^{-1}H] = \sum_{i=1}^s \frac{\lambda_i}{1+\lambda_i} \quad (18)$$

3. RESULTS AND DISCUSSION

3.1 Data Analysis

The data obtained from UPTH, Port Harcourt, were on pregnant women measurement. The measurement is age, weight, height, parity, left and right kidney length, width and thickness. The BMI and BSA were evaluated with the formula in Section two (Equation 1 and 2). Also, the four categories of BMI were used to categorize the

data and the parity level was also categorized into two parts (no child before the pregnancy and those women who had children before the pregnancy).

Table 3. BMI categories

BMI Categories	Frequency	Percentage (%)
Underweight	-	-
Normal	55	36.7%
Overweight	52	34.6%
Obese	43	28.7%
No child	53	64.7%
Children	97	35.3%

From Table 3, 36.7% of the pregnant women have normal BMI, 34.6% of the women were overweight, while 28.7% of the pregnant women were obese. Table 3 also showed that 64.7% of the pregnant women had no child before the current pregnancy, while 35.3% had children (one or more) before the pregnancy.

3.2 MANOVA Analysis

Two-way classification of the expected measurements on the variables of the pregnant women are summarized in Table 4. That is the expected measurements at each combination of BMI and BSA on the parity level were obtained using the categories scale for a total of 150 observations in Table 4.

Table 4. Two-way classification of the expected measurements on pregnant women

Categories	A ₁		A ₂	
	Y ₁	Y ₂	Y ₁	Y ₂
B ₁	-	-	-	-
B ₂	23.88	1.70	25.51	1.70
B ₃	29.46	1.81	29.28	1.84
B ₄	37.47	1.83	37.04	1.94

Parity (A): A₁ = no child and A₂ = children before the pregnancy; Categories (B): B₁ is the underweight B₂ is normal, B₃ is the overweight and B₄ is the obese; Y₁ is the BMI and Y₂ is the BSA

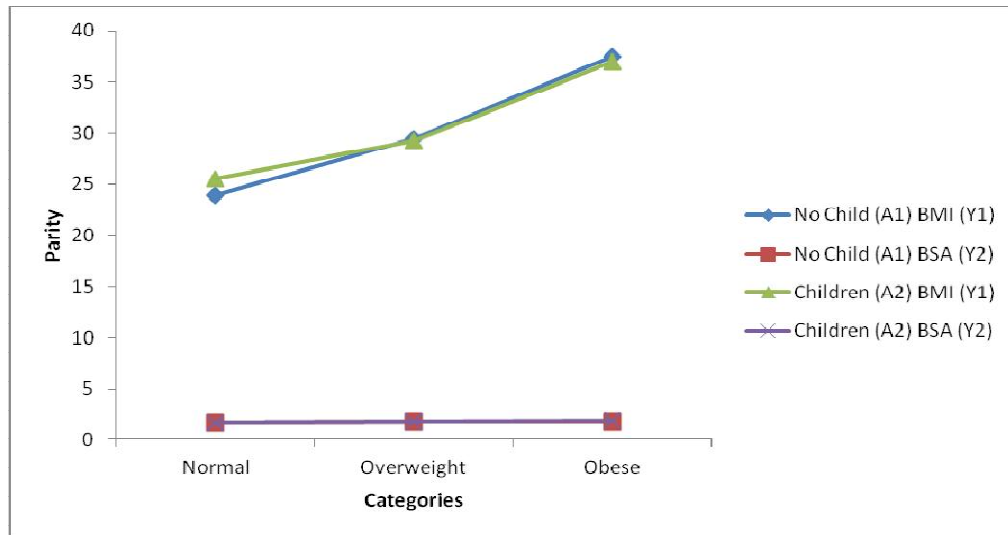


Fig. 1. Profile of the categories (or groups) for BMI and BSA on parity level

The experiment comprised of 2×4 design having 4 replications, but since no underweight. It reduced to a 2 × 3 design with 3 replications.

We display the expected measurements for every variable utilized in computation. The numbers inside box are cell totals (over the three replication except underweight), and marginal totals are for each level of A (Parity) and B (Body Categories):

Y ₁ =BMI			
	A ₁	A ₂	Total
B ₂	23.88	25.51	49.39
B ₃	29.46	29.28	58.56
B ₄	37.47	37.04	74.08
Total	90.20	91.83	182.03

Y ₂ =BSA			
	A ₁	A ₂	Total
B ₂	1.70	1.70	3.40
B ₃	1.81	1.84	3.65
B ₄	1.83	1.94	3.77
Total	5.34	5.48	10.82

Using computational forms for h_{Arr} in Equation (6), the (1, 1) element of H_A (corresponding to Y_1) is given as follows

$$h_{A11} = \frac{(90.20)^2 + (91.83)^2 + (182.03)^2}{(3)(3)} + \frac{(182.03)^2}{(3)(3)(2)} = 0.1476$$

For the 2.2 element of H_A that corresponds to Y_2 , we have

$$h_{A22} = \frac{(5.34)^2 + (5.48)^2 + (10.82)^2}{(3)(3)} + \frac{(10.82)^2}{(3)(3)(2)} = 0.0011$$

For the 1.2, element of H_A that corresponds to Y_1Y_2 , we use equation (7) to obtain h_{A12} . Thus we have:

$$h_{A12} = \frac{(90.20)(5.34) + (91.83)(5.48)}{(3)(3)} + \frac{(182.03)(10.82)}{(3)(3)(2)} = 0.0127$$

Then, the H_A matrix is

$$H_A = \begin{pmatrix} 0.1476 & 0.0127 \\ 0.0126 & 0.0011 \end{pmatrix}$$

Thus, we obtain H_B similarly:

$$h_{B11} = \frac{(49.39)^2 + (58.56)^2 + (74.08)^2 + (182.03)^2}{(3)(2)} + \frac{(182.03)^2}{(3)(3)(2)} = 51.9197$$

$$h_{B22} = \frac{(3.40)^2 + (3.65)^2 + (3.77)^2 + (10.82)^2}{(3)(2)} + \frac{(10.82)^2}{(3)(3)(2)} = 0.0119$$

$$h_{B12} = \frac{(49.39)(3.40) + (58.56)(3.65) + (74.08)(3.77)}{(3)(2)} + \frac{(182.03)(10.82)}{(3)(3)(2)} = 0.7383$$

Then, the H_B matrix is

$$H_B = \begin{pmatrix} 51.9197 & 0.7383 \\ 0.7383 & 0.0119 \end{pmatrix}$$

For H_{AB} matrix, we have

$$h_{AB11} = \frac{(23.88)^2 + (29.46)^2 + (37.47)^2 + \dots + (37.04)^2 + (182.03)^2}{(3)} + \frac{(182.03)^2}{(3)(3)(2)} - 51.9197 - 0.1476 = 0.2952$$

$$h_{AB22} = \frac{(1.70)^2 + (1.81)^2 + (1.83)^2 + \dots + (1.94)^2 + (10.82)^2}{(3)} + \frac{(10.82)^2}{(3)(3)(2)} - 0.0011 - 0.0119 = 0.00108$$

$$h_{AB12} = \frac{(23.88)(1.70) + (29.46)(1.81) + \dots + (37.04)(1.94)}{(3)} + \frac{(182.03)(10.82)}{(3)(3)(2)} - 0.0127 - 0.7383 = -0.01268$$

Then, the H_{AB} matrix is

$$H_{AB} = \begin{pmatrix} 0.2952 & -0.01268 \\ -0.01268 & 0.001078 \end{pmatrix}$$

Error matrix E is obtained using computational forms that are given for e_{rr} in Section 2 [Equation (11) and (12)] and sum of square of (Y_1 , Y_2 and Y_1Y_2), we have

$$e_{11} = 909.5456 - 0.1476 - 51.9197 - 0.2952 = 857.1831$$

$$e_{22} = 3.2977 - 0.0011 - 0.0119 - 0.001078 = 3.2450$$

$$e_{12} = 53.8373 - 0.0127 - 0.7383 - (-0.011268) = 53.0989$$

Then, the error matrix E is

$$E = \begin{pmatrix} 857.1831 & 53.0989 \\ 53.0989 & 3.2450 \end{pmatrix}$$

With degree of freedom $E = ab(n-1) = (2)(3)(3-1) = 12$

Note: $a=2$, $b=3$ and $n=3$

Table 5. Summary of MANOVA

Source	Sum of square and products Matrix	Df
A	$H_A = \begin{pmatrix} 0.1476 & 0.0127 \\ 0.0126 & 0.0011 \end{pmatrix}$	$(a-1) = 1$
B	$H_B = \begin{pmatrix} 51.9197 & 0.7383 \\ 0.7383 & 0.0119 \end{pmatrix}$	$(b-1) = 2$
AB	$H_{AB} = \begin{pmatrix} 0.2952 & -0.01268 \\ -0.01268 & 0.001078 \end{pmatrix}$	$(a-1)(b-1) = 2$
Error	$E = \begin{pmatrix} 857.1831 & 53.0989 \\ 53.0989 & 3.2450 \end{pmatrix}$	$Ab(n-1) = 12$
Total	$T = \begin{pmatrix} 909.5456 & 53.8372 \\ 53.8372 & 3.25903 \end{pmatrix}$	$abn-1 = 17$

To test main impact of A with Wilks, we evaluate Wilks A as

$$\hat{\Lambda}_A = \frac{|E|}{|E + H_A|} = \frac{-37.973}{-37.8999} = 1.00193$$

Since $\hat{\Lambda}_A$ greater than $\Lambda_{0.05, 2, 1, 12} = 0.607$ from Wilks' Table, we conclude that parity level has nono table effect on Y_1 (BMI) or Y_2 (BSA) or both.

For the B main effect (Categories), we have

$$\hat{\Lambda}_B = \frac{|E|}{|E + H_B|} = \frac{-37.973}{62.37132} = -0.60882$$

Since $\hat{\Lambda}_B$ is less than $\Lambda_{0.05, 2, 2, 12} = 0.437$ from Wilks' Table, we infer that categories has a notable effect on Y_1 (BMI) or Y_2 (BSA) or both.

For the AB interaction, we obtain

$$\hat{\Lambda}_{AB} = \frac{|E|}{|E + H_{AB}|} = \frac{-37.973}{-34.7443} = 1.09293$$

Since $\hat{\Lambda}_{AB}$ greater than $\hat{\Lambda}_{0.05, 2, 2, 12} = 0.437$ from Wilks' Table, we inferred that AB interaction effect is insignificant on Y_1 (BMI) or Y_2 (BSA) or both.

3.3 MANOVA Test Statistics for Pillai, Lawley-Hotelling and Roy's Largest Roottests

We then obtain other MANOVA test statistics for each test in Section 2 (Equation 13 to 15). For A, the non-zero eigen value of $E^{-1}H_A$ is -0.00194

$$E^{-1} = \begin{pmatrix} 0.08545 & 1.3983 \\ 1.39833 & 22.5734 \end{pmatrix} \quad \text{And}$$

$$E^{-1}H_A = \begin{pmatrix} 5.1457E-03 & 4.52897E-04 \\ -8.0289E-02 & -7.07201E-03 \end{pmatrix}$$

Recall that eigen value is $|E^{-1}H_A - \lambda I| = 0$.

The three test statistics for A are summarized as

$$\text{Pillai } V^{(s)}: = \sum_{t=1}^s \frac{\lambda_t}{1 + \lambda_t} = -0.00190$$

$$\text{Lawley-Hotelling } U^{(s)}: = \sum_{t=1}^s \lambda_t = -0.00194$$

$$\text{Roy's Largest root } \theta: = \frac{\lambda_t}{1 + \lambda_t} = -0.00190$$

For B, $V_H=3$ and $p = s = 2$. The eigen values of $E^{-1}H_B$ are 2.6413 and -0.0007, from

$$E^{-1}H_B = \begin{pmatrix} 3.40436E-01 & -4.6451E-02 \\ 5.5935E+01 & 7.6376E-01 \end{pmatrix}$$

and we obtain the three test statistics for B are summarized as:

$$\text{Pillai } V^{(s)}: = \sum_{t=1}^s \frac{\lambda_t}{1 + \lambda_t} = 0.7246$$

$$\text{Lawley-Hotelling } U^{(s)}: = \sum_{t=1}^s \lambda_t = 2.6406$$

$$\text{Roy's Largest root } \theta: = \frac{\lambda_t}{1 + \lambda_t} = 0.7254$$

For AB, $V_H=3$ and $p = s = 2$. The eigen values of $E^{-1}H_{AB}$ are -0.0851 and 0.000, obtain from

$$E^{-1}H_{AB} = \begin{pmatrix} -4.2957E-02 & 2.5910E-03 \\ 6.9902E+01 & -4.2065E-02 \end{pmatrix}$$

and we obtained the three test statistics for AB and its summarized as

$$\text{Pillai } V^{(s)}: = \sum_{t=1}^s \frac{\lambda_t}{1 + \lambda_t} = -0.0930$$

$$\text{Lawley-Hotelling } U^{(s)}: = \sum_{t=1}^s \lambda_t = -0.0851$$

$$\text{Roy's Largest root } \theta: = \frac{\lambda_t}{1 + \lambda_t} = -0.0930$$

From Table 6, MANOVA Test Statistics for Wilk's statistics show insignificant impact for Factor A (or the effects of the Parity level categorized on BMI) and AB (or the effects of the Parity level categorized on BMI and BSA), while Lawley-Hotelling Root tests showed no significant effect

Table 6. Summarized results of the MANOVA tests statistics

Factor	Wilks'	Pillai	Lawley-Hotelling	Roy's largest root
Factor A ($\hat{\Lambda}_A$)	1.00193	-0.00190**	-0.00194**	-0.00190**
Factor B ($\hat{\Lambda}_B$)	-0.60882**	0.7246**	2.6406	0.7254**
Factor AB ($\hat{\Lambda}_{AB}$)	1.09293	-0.0930**	-0.0851**	-0.0930**

**= $\hat{\Lambda}_A$, $\hat{\Lambda}_B$ and $\hat{\Lambda}_{AB}$ are significant at 5%, if MANOVA test statistics are less than one (or 1.0000)

for Factor B (or the effects of the Parity level categorized on BSA). However, two MANOVA test statistics gave similar results for all Factors (A,B and AB); [i.e. Pillaiand Roy's Largest Root statistics] since their statistics are less than 1.

Thus, these results confirmed that the effect of the Parity level (categories) has a significant effect on BMI (Y_1) or BSA (Y_2) or both. Hence, the two MANOVA test statistics are show that the parity level which is women with no child before the pregnancy and those women who had children before the pregnancy have BMI and BSA are significant in term of the categories (normal, overweight and obese).

4. CONCLUSION

This research paper has contributed to the body of knowledge that Body Mass Index, Body Surface Area and their interaction has significant effect on categories and parity level on pregnancy outcomes using two ways MANOVA Model. Thus, a woman's pregnancy leads to significant changes in the life of a woman during and after child birth. The MANOVA test statistics for Wilk's results showed no significant effect for both the Parity level categorized on BMI and the Parity level categorized on BMI and BSA (or Factor A and AB), while Lawley-Hotelling Root test showed no significant effect for the effect of the Parity level categorized on BSA (Factor B). However, Pillaiand Roy's Largest Root statistics test gave significant effect for all Factors (A, B and AB) at 5%. These results confirmed that the effect of the Parity level has a on BMI or BSA or both in terms of the categories (normal, overweight and obese). These results are in agreement with known results by medical practitioners.

The following recommendations are made based on the result finding:

- i. Pregnant women should always exercise to check being obese or overweight.
- ii. Pregnant women should check their weight on regular basis to ensure balanced and normal weight.
- iii. Medical practitioners should always ensure that pregnant women have a balanced Body Mass Index with respect to their parity level.

ETHICAL APPROVAL

As per international standard or university standard written ethical approval has been collected and preserved by the author(s).

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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