TRENDS OF LUNG FUNCTION INDICES, ARTERIAL BLOOD OXYGEN SATURATION AND PULSE RATE AMONG THE FIRST AND THIRD TRIMESTER PREGNANT WOMEN IN ADDIS ABABA, ETHIOPIA

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ABSTRACT:

OBJECTIVE: Comparative analysis of the effects of middle-level altitude pregnancy on lung function indices, blood oxygen saturation and pulse rate as a function of gestational weeks.

STUDY DESIGN: This is a Cross-sectional descriptive study conducted in Tikur Anbessa hospital, a tertiary university hospital and Lideta Health Center a public health center located in Addis Ababa, Ethiopia.

Participants: 123 pregnant women including 40 in their first and 83 in their third trimester

RESULTS: maternal height was positively correlated with FVC and FEV1 but not with PEFR ($r=0.68$; $p<0.01$). BMI and FEV1% were also positively and negatively correlated in normal and obese subjects respectively. As term approaches, there is a decreasing pattern of PEFR, IC, VT, ERV, ($p< 0.005$) and hence FRC. However, pulse rate, VE and BF had shown a rising trend. On the other hand, FEV1%, VC, and TLC didn't change significantly. Chest size had no statistically significant effect on most of the indices. Minimal coffee intake habit and having more children were shown to have desirable pregnancy outcomes.

CONCLUSIONS: Based on the present study it is concluded that at moderate altitude, as pregnancy proceeds, some lung function indices like tidal volume and breathing frequency show an increasing tendency unlike most of the static lung function parameters. We recommend that pregnant women should be guided through the predictable physiologic and emotional changes that occur during pregnancy and help them develop coping life style strategies.

KEY WORDS: Peak expiratory flow rate, lung function indices, pulse rate, SaO_2, body mass index, chest size, middle-level altitude, first and third trimester.

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INTRODUCTION

The influence of pregnancy on the respiratory tract originates from both anatomical and physiological changes. Early maternal homeostatic changes occur due to the increased metabolic demands brought by the fetus, placenta and uterus and, in part, by the increasing level of pregnancy hormones, particularly progesterone and estrogen [1, 2]. An elevated level of progesterone observed during pregnancy may have an effect on the activity of the respiratory drive [3, 4]. Later changes, starting in mid-pregnancy, are anatomical in nature and are caused by mechanical pressure from the expanding uterus [2]. Research data and clinical observations showed that the disturbances of ventilatory function of the lungs during pregnancy are often seen in overweight and obese women [5].

As evidenced from a study on Africa-American, poor African-Americans had larger $FEV_{1\%}$ and higher BMI, but lower sitting height, FEV_1 and FVC than whites [6]. This is attributed to two socioeconomic status indicators: poverty index, a measure of current family income, and education. Poverty index accounted for about 7.5% and 2.5% of racial difference in lung function in women and men, respectively, whereas the effect of education accounted for about 2% in women and 4.7% in men [7]. Thus socioeconomic status, as measured by poverty index, was a better explanatory variable for the racial difference in women [7].

Furthermore, the functional efficiency of the lung deteriorates with age, genetic factor, and altitude. For instance, FEV1 and FVC measured in the Ethiopians are found to be lower than in whites, but higher than other Africans, Chinese and Indians [8]. Compared to sea level values, highland women (Leadville - 3,658 m above sea level) have higher ventilation and haemoglobin values, and the pregnant women had a higher hypoxic ventilator response and resting ventilation (VE) than their non-pregnant counterparts [9] yielding arterial oxygen content (SaO2) as high as pregnant women at sea level. The mean SaO_2 of Aymara adult (3,900-4000 m) was 2.6% higher than Tibetan subjects living at 3,800-4,065mt. No sex differences was noted [10]. Beall (11) also found out that Ethiopian highlanders maintain venous haemoglobin concentrations and SaO2 within the ranges of sea level populations.

Thus, ventilation and haemoglobin concentration were important variables contributing to oxygen transport during pregnancy at high altitude [12]. Hypoxic responses assess the relationship between ventilatory output and arterial O_2 concentration in the presence of a stable arterial PCO_2 [13].

Because we could not find similar studies in pregnancy in any of the African countries to make a comparison, in this study, we presented an investigation of changes of maternal lung function parameters, SaO_2 and pulse rate. Common to most studies which have been done in the area is the lack of consideration of relevant confounding variables such as altitude, socioeconomic status, education, and race.

MATERIALS AND METHODS

Study area and clients:

Addis Ababa is a mid-level altitude metropolis with an altitude range of 2300 – 2800 meters above sea level which is believed to impose mild hypoxic condition to inhabitants. Pregnant women who came to Tikur Anbessa Hospital and Lideta Health Center, for ANC, within the age range of nineteen to forty five and with singleton gestation, who consented to particpate in the study, were included. Those with respiratory diseases, obstetrics complications and painted fingernail were excluded.

Eighty-four pregnant women in their third trimester were recruited and compared with forty pregnant women in their first trimester.

Study design, methods and data analysis:

This is a cross-sectional. Maternal study .body weight and height were obtained while lightly clothed. Background information was obtained by questionnaire on the initial visit. All oxymetric (Oxi-sat 510) and spirometric (Spiro pro, Jaeger) measurements were done in morning hours in sitting positions in the antenatal clinic of the Tikur Anbessa Hospital and Lideta Health Center (Addis Ababa, Ethiopia).

The index finger was used to determine the oxygen saturation and pulse rate at rest. The haemoglobin oxygen saturation (SaO_2) measurements were taken after assessing any barriers such as nail paint (nail polish), nicotine staining, or dirt. The reading that was most displayed or the average of the most displayed numbers of the three trials was considered.

Following proper explanation and demonstration of the respective procedures by the principal investigator, subjects took rest for three to five minutes. Afterwards, six spirometry trials (three to slow vital capacity and three manoeuvres to forced vital capacity parameters) were done for each subject and the best performed trial was taken, based on the recommendation given by American Thoracic Society [16]. The Spiro pro was calibrated by a syringe of known volume (1L), every time preceding the measurement. The calibrated Spiro pro was regularly checked for ambient conditions (temperature of 17-20°C and relative humidity of 65-74% and barometric pressure of 1018-1025 hpa).

The data from each respondent was entered and analysed using SPSS version 10.0 for windows and Microsoft excel statistical software packages. Double data entry technique was used to maximize quality. Frequency distributions and cross tabulations were done for the variables. Data was also evaluated using student's t test, correlation and analysis of variance (one-way ANOVA). A p-value of less than 0.05 was declared significant.

Ethical considerations:

All subjects were briefed on the objectives and procedures of the study by the principal investigator and a nurse in the clinics. Volunteered clients underwent a medical assessment and provided written informed consent to participate. Those women who need support while being investigated were treated appropriately. Privacy and confidentiality were maintained. This study was approved by the Faculty Research and Publication Committee (FRPC) of Addis Ababa University (Ethiopia).

RESULTS

Anthropometric characteristics

The distribution of study participants with age groups is presented in table 1. Mean height was 154.9± 4.8cm in women in their first trimester and 157.8± 6.0 cm for those in their third trimester. To categorize subjects into body mass index groups, non-pregnant weight was taken retrospectively from records. The percentage increase with respect to gestational weeks was considered (Table 1) and there is a direct correlation between BMI values calculated using pregnant and non-pregnant weight. The mean BMI values were 23.7±4.7 and 22.4 ±4.6in the first and third trimester respectively.

According to the WHO criteria, adults with BMI of less than 18.5 kg/m^2 were underweight and considered to have chronic energy malnutrition and 23 women (18.7%) were found to be in this range. Normal weight–height proportions women (BMI 18.5-24.99 kg/m^2) was found in 62, overweight grade I (BMI 25.0 - 29.99 kg/m^2) in 23 women (18.7%), over weight grade II or obese (30.0 - 39.99 kg /m^2) and overweight grade III (above 40.0 kg/m^2) were in 15women (12.2%) (Figure 1).

Lung function indices

The mean values of FEV_1, FVC, $FEV_{1\%}$, peak expiratory flow rate (PEFR) and forced expiratory flow (FEF_{25}, FEF_{50}, FEF_{75}) were within the normal limits. Differences in the arithmetic mean of these parameters in the first and third trimesters of pregnancy were not statistically significant (with the exception of PEFR; Table 2).

Slow vital capacity parameters including vital capacity (VC), expiratory reserve volume (ERV), inspiratory capacity (IC), and tidal volume (VT) showed no significant difference. There was, however, a significant difference in minute ventilation (MV) and breathing frequency (BF) between the first and third trimesters ($P< 0.05$, Table 5).

A rise in BMI was associated with increment in $FEV_{1\%}$; however; in obese subjects in the first trimester, there was a relative fall in $FEV_{1\%}$ value (Table 4, Figure 2). Though statistically insignificant, there was an increasing trend in the value of $FEV_{1\%}$ in the third trimester ($p =0.41$; $r= 0.135$). Though marginally significant ($p = 0.046$), mean PEFR in the first trimester (5.11±1.85) was larger than in the third trimester (4.79±1.49, Figure 1).

In the third trimester, maximum values of PEFR (4.98 litres/sec), FVC (3.27 litres) and FEV_1 (2.67 litres) and $FEV_{1\%}$(84.4 %) were observed in the late thirties as depicted in Table 3; While in the first trimester, we found peak values of PEFR (5.65 litres/sec), FVC (3.31 litres) and $FEV_{1\%}$(85.4 %) within the age range of 18-27 years. $FEV_{1\%}$ was found to be maximum in the mid-thirties.

As compared to other variables, there is a moderate positive correlation between maternal height and FVC, both in the first and third trimester ($P<0.001$). The association is more pronounced when weight is also considered (BMI).

As body mass index increased, there was a general increment in the forced respiratory parameters (FVC, FEV_1, FEF_{25}, FEF_{50}, and FEF_{75}, PEFR, & $FEV_{1\%}$). Maximum values were recorded in the BMI range of 26.1 – 29 years (Table 4). A slight decrement from the overall rising trend of the parameters was also observed in obese subjects (BMI > 29), especially of forced expiratory flow indices ($FEF_{25,\ 50,\ \&75\%}$).

There was a normal distribution of mean values of FVC with respect to chest width, maximum values being observed in the mid-range (0.17 – 0.21), and there was a corresponding decrease in FVC values as chest circumference increases further, both in the first and third trimesters.

Both chest depth and width had no statistically significant effect on changing PEFR, FEV_1, and FVC ($p>0.05$) in the third trimester. During the first trimester, there was a statistically significant difference between mean PFT values (PEFR, FEV_1, and FVC) and chest size ($p<0.001$). There was also a correlation between chest size (as approximated from chest width) and PFT values in the first trimester with FEV_1 (r=0.48), FVC(r=0.54), and PEFR (r=0.61).

Minute Ventilation was significantly increased from the first to third trimester of gestation (p=0.042, two tailed; r = 0.27). These findings were related to an increase in VT/TI (p=0.005,). It was also observed that during pregnancy there was a statistically significant increment in breathing frequency which is the major cause for the increase in minute ventilation (p = 0.009).

As depicted from table 6 and figure 2, lower level of percentage saturation of arterial blood haemoglobin (SaO_2) was associated with larger BMI value. The variation was insignificant except the slight significance in the BMI range of 19.8 – 26 kg/m^2. Obesity appeared to be synergistic in the presence of hypoxemia (r = -0.46).

The average pulse rate in women before 12 weeks of gestation was lower (88±12.48 beats/minutes) and there was a statistically significant increment in the third trimester, 93.60±9.13 beats/minutes (p = 0.0003).

As pregnancy advances, there was an increasing tendency of pulse rate (as illustrated in figure 4). Maximum value of pulse rate was measured near term. The lower and upper 95% confidence intervals in the first and third trimesters were 84.7 versus 92.7 and 91.6 versus 95.6 respectively. It is also noted that, the pulse rate but SaO_2 which is correlated positively with weeks of gestation (p = <0.001; r = 0.367).

Life style, parity, socioeconomic status and education on PFT and SaO_2

There was a negative relationship between coffee drinking habit and percentage saturation of arterial blood reference values.

Slight increase in PEFR value is also observed but in other Indian studies declining trend was observed [18]. The values in our finding are lower than those observed in Indians and Europeans [18, 19]. In addition, no change in PEFR during pregnancy was observed in European study [19]. This might be attributed to circadian rhythm i.e. maximal expiratory flow is at its lowest level during the early hours of the morning (4.00-6.00 am) and it was demonstrated that the level reaches its peak in the afternoon. This effect reflects predominately on PEFR [20]. Our tests were performed during early morning; between the hours 9.00 - 11.00 a.m. and PEFR values might be affected.

Though statistically insignificant, there is a slight increase in the value of $FEV_{1\%}$ which can possibly be due to the slight decrease in partial pressure of oxygen in Addis Ababa as compared to sea level which can stimulate the breathing centre and relieve airflow limitation. The positive correlation between PEFR and FEV_1 is in agreement with other study [21] but not in conformity with another study [18].

Many studies [22, 23 and 24], utilizing within-subject comparisons of small groups of pregnant women, showed that FVC and FEV_1 remained essentially unchanged during pregnancy which is an indication that function of the larger pulmonary airways was not altered much in reference values.

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Many studies [22, 23 and 24], utilizing within-subject comparisons of small groups of pregnant women, showed that FVC and FEV_1 remained essentially unchanged during pregnancy which is an indication that function of the larger pulmonary airways was not altered much in haemoglobin. As pregnancy progressed, the effect becomes more significant ($r = -0.41$; $p = 0.005$). High PEFR value was associated with stable emotional state while low values, though statistically insignificant ($r = -0.116$ and $p = 0.202$) were correlated with aggressiveness.

We also observed that the disturbances of ventilator function of the lungs during pregnancy are often seen in women with the highest BMI than normal women (Table 4 & Figure 1) and was more pronounced in the first trimester

After controlling for age, height, weight, and smoking, parity is associated with a higher FEV_1 ($P = 0.0002$). That is, women with greater number of children experienced an increment of FEV_1 in all reproductive age groups.

DISCUSSION

FEV_1 and FVC for females are correlated positively with height. A study in Kenya that has been done on non-pregnant men and women (17) supports our finding. Orie's work also depicts the positive correlation of height with PEFR, which is not in accordance with this study. As compared to the available values used as a non-pregnant reference (8) and the result obtained in this study, the expiratory ratios ($FEV_{1\%}$) were smaller than age-matched in the study done in Kenya [17].

Measured PEFR values for all age groups are based on the currently used reference values [8]. Observed values in both trimesters and in all age groups are compared to the reference values.

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Many studies [22, 23 and 24], utilizing within-subject comparisons of small groups of pregnant women, showed that FVC and FEV_1 remained essentially unchanged during pregnancy which is an indication that function of the larger pulmonary airways was not altered much in pregnancy. In consistent with ours, studies also confirm that $FEV_{1\%}$ is unchanged during pregnancy [25 and 26]. There was, however, no statistically significant change regarding vital capacity and total lung capacity. Cugell and associates [27] demonstrated that there is no alteration in the lung volume profile until the second half of pregnancy, at which time a decrease in both ERV and RV combine to produce an 18% mean decrease in FRC. The VC was unchanged; therefore the total lung capacity (TLC) was slightly diminished at term. Still, another group of researchers claim that while tidal volume increases, there is a progressive decrease in ERV and RV throughout pregnancy. A decrease of up to 25% in FRC occurs after the fifth to sixth month of pregnancy [5 and 28].

In this study, small decline (though statistically insignificant) in inspiratory capacity (IC) and the expiratory reserve volume (ERV) is observed as a result of which RV falls, and hence leading to a consistent decline in FRC. Many studies are in consistent with ours [5 and 28] but a study by Grace and colleagues found otherwise [25].

The study by Tracada and colleagues [29] is in consistent with this finding. This condition, consequently, will result in increased low ventilation to perfusion regions in the lung. These alterations are worsened in the supine position with its concomitant increase in intra-abdominal pressure, causing the oxygen gradient (A-aPO_2) to increase [29]. The finding of Knuttgen and colleagues is not in line with our study [26].

We found an increment of MV by 22% in the third trimester. Weinberger [28], however, found a raise in MV before the end of the first trimester which remains constant throughout pregnancy. Rees et al. [31] proved that respiratory frequency did not change during pregnancy and yet both resting VT and MV increased. Our finding also ascribes the observed hyperventilation to a rise in the frequency of breaths. The contribution of slight increment in depth of breathing as depicted from a rise in tidal volume is statistically insignificant. This sign of chronic hyperventilation is more pronounced in the third trimester. In addition to progesterone, altitude might also have a potentiating effect on hyperventilation. At the altitude of Addis Ababa, the pregnancy-associated rise in alveolar ventilation increases arterial O_2 saturation nearly to sea level values.

Socio-environmental risk factors may differ based on individuals' status. Such risk factors, for instance, may be higher exposure to airborne pollutants, poorer housing conditions, or lower consumption of fruit and vegetables [32]. In our study, PFT parameters were found to be significantly lower in the low-income group, which is approximated from educational level and income.

The finding that obesity disturbs ventilatory function is in accordance with the results obtained by another study [33]. Consequently, maternal obesity carries significant risks for the mother and fetus [34].

There is a significant association between parity and values of SaO_2, pulse rate, MV, BF, PEFR, and $FEV_{1\%}$. A study by Harik-Khan supports our findings [35].

Income is also related to SaO_2, pulse rate, PEFR, and $FEV_{1\%}$ ($P<0.001$). This is consistent with other finding which states that lower income, inferior dietary intake and patient choice of substandard prenatal care are incompatible with healthful living [36]. Prescott [37] also found that poverty appears to have a greater effect on lung function in healthy women than in healthy men. The same study showed that FEV_1 and body mass index are related to educational level in males but not in females. It is noted that during pregnancy, lung compliance is not changed but chest wall compliance is decreased [38]. Previous study [8] had found no association between free fat mass and lung function indices. Expiratory flow rate accurately and reliably in the management of pregnant women with asthma. As compared to emotionally stable, courageous and spiritless pregnant women, those who are unstable, aggressive and hot-tempered have low PEFR value. Therefore, having patience and creating psychologically calm state during pregnancy might improve the process of gas exchange, which is detrimental to both the mother and the growing

fetus.

In conclusion, pregnancy raised maternal ventilation and arterial O_2 saturation, with the result that arterial oxygen content was similarly maintained at non-pregnant levels. BMI at the baseline seems to predict the increase in MV, SaO_2 and $FEV_{1\%}$ with correlation observed between these values. Pregnancy does not change the FEV_1, FVC, or forced expiratory flow ($FEF_{25,\ 50\ \&\ 75\%}$); therefore, obstructive patterns during pregnancy should be thought of as abnormal rather than the result of pregnancy. Both BF and MV showed a significant increase during pregnancy, which seems to be the response to the increased demands of the growing fetus.

We believe that further studies are needed for establishment of local reference norms for Pulmonary Function Tests in different regions of altitude range of Ethiopia. By extension, the relative effect of exercise during pregnancy at altitude on PFT and SaO_2 should be worked.

ACKNOWLEDGMENT

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Table 1: Distribution of the study population with respect to age range in each trimester. Addis Ababa .Feb. 2005.

Gestational Week		Age group			
Trimester		18-27	28-37	38-47	Total
First	1-12	16	23	1	40
Third	28-40	34	43	6	83
	Total	50	66	7	123

Table 2: Measured lung function parameters including forced expiratory flow at 75%, 50%, 25% of FVC according to the trimester of pregnancy compared.

Parameters	First Trimester		Third Trimester		
	Mean	SD	Mean	SD	P value
FVC(in litres)	3.13	0.75	3.14	0.66	0.93
FEV_1(in litres)	2.28	0.51	2.23	0.49	0.64
$FEV_{1\%}$	84.91	6.08	82.78	9.59	0.20
PEFR(in litres/sec)	5.11	1.85	4.79	1.49	0.046*
$FEF_{25\%}$(in litres/sec)	3.48	1.35	3.24	1.06	0.29
$FEF_{50\%}$(in litres/sec)	3.15	1.14	2.91	0.99	0.22
$FEF_{75\%}$(in litres/sec)	2.17	0.68	2.02	0.70	0.24

Table 3: Mean values of some standard pulmonary function values classified in age groups across trimester

Age group		Lung function indices			
		FVC (l) Mean (SD)	FEV1 (l) Mean (SD)	FEV1% Mean (SD)	PEFR (l/sec) Mean (SD)
18-27	Non-pregnant	3.16 (0.42)	2.65 (0.39)	83.89 (7.76)	6.76 (0.90)
	1st trimester (n=16)	3.31 (0.49)	2.70 (0.39)	84.55 (4.64)	5.65 (1.98)
	3rd trimester (n=34)	2.94 (0.74)	2.40 (0.63)	84.05 (5.99)	4.50 (1.54)
28-37	Non-pregnant	3.04 (0.53)	2.49 (0.39)	81.76 (7.18)	6.50 (0.94)
	1st trimester (n=23)	3.00 (0.89)	2.46 (0.67)	85.40 (6.99)	4.77 (1.73)
	3rd trimester (n=43)	3.27 (0.58)	2.56 (0.51)	81.55 (11.9)	4.98 (1.46)
38-47	Non-pregnant	2.82 (0.51)	2.29 (0.42)	80.91 (5.26)	5.42 (0.81)
	1st trimester (n=4)	2.91(0)	2.24 (0)	79.21 (0)	4.28 (0)
	3rd trimester (n=6)	3.27 (0.57)	2.67 (0.32)	84.40 (6.15)	5.02 (1.24)

P<0.05, mean difference between the groups is statistically significant

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	3rd trimester (n=6)	3.27 (0.57)	2.67 (0.32)	84.40(6.15)	5.02(1.24)

Table 4: Trends of forced expiratory parameters (FVC, FEV1, FEF25, FEF50, and FEF75, PEFR, & FEV1%) in accordance with the body mass index.

BMI	FVC	FEV_1	$FEV_{1\%}$	$FEF_{25\%}$	$FEF_{50\%}$	$FEF_{75\%}$	PEFR
<18.5 (Group 0)	2.91(0.59)	2.34(0.53)	83.13(7.85)	2.90(1.08)	2.63(0.90)	1.87(0.75)	4.34(1.46)
18.5 – 24.9 (Group 1)	3.11(0.75)	2.47(0.61)	82.39(9.72)	3.16(1.10)	2.80(1.03)	1.91(0.66)	4.69(1.56)
25 – 29.9 (Group 2)	3.23(0.58)	2.61(0.45)	84.31(9.37)	3.60(.88)	3.23(0.89)	2.32(0.63)	5.23(1.24)
>30 (Group 3)	3.43(0.37)	2.78(0.36)	83.86(7.25)	3.55(0.99)	3.32(1.01)	2.29(0.66)	5.18(1.39)

Table 5: Respiratory pattern parameters in the group of pregnant women studied

PFT values	First Trimester	Third Trimester	p-value
Vital capacity (litres)	2.39 (0.26)	2.36 (0.47)	>0.05
Expiratory Reserve Volume(litres)	0.69 (0.16)	0.60 (0.22)	>0.05
Inspiratory Capacity (litres)	1.79 (0.36)	1.74 (0.51)	>0.001
Tidal Volume(litres)	0.46 (0.13)	0.52 (0.19)	0.054
Minute Ventilation(l/minutes)	12.16 (6.41)	14.87 (5.65)	0.042
Breathing Frequency (breaths/minutes)	18.15(9.82)	19.87 (6.24)	0.009*
TI(time of inspiration in seconds)	1.23 (0.75)	0.78 (0.91)	0.034*

- P<0.05, mean difference between the groups (mean±SD) is statistically significant

Table 6: Measured SaO_2 and pulse rate according to the trimester of pregnancy compared.

Parameters	1st trimester	3rd trimester	p-value	Pearson correlation
	Mean (SD)	Mean (SD)		
SaO_2 (%)	95.15 (1.59)	95.33(1.89)	0.613	0.046
Pulse rate (beats/minutes)	88.73(12.48)	93.60(9.13)	<0.001	0.367*

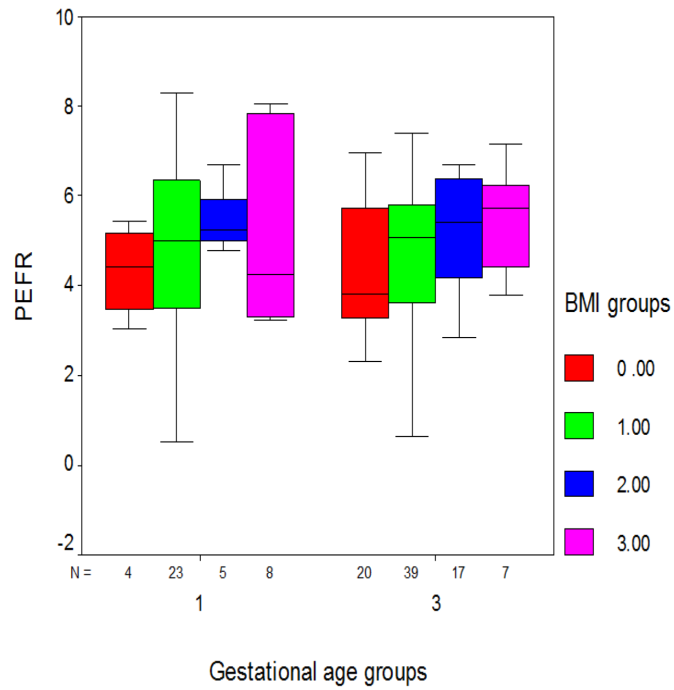

Figure 1: A linear positive correlation between maternal gestational age and PEFR in pregnant women both in the first and third trimester.

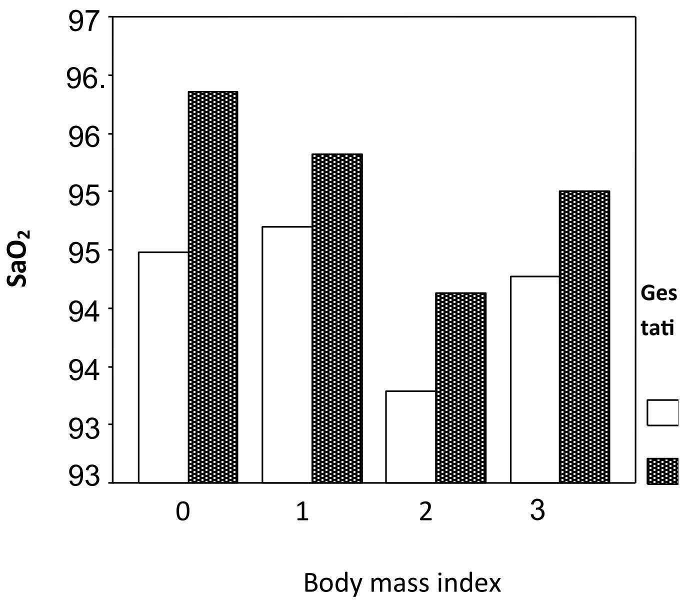

Figure 2: Percentage of SaO_2 in the first and third trimesters in each BMI class

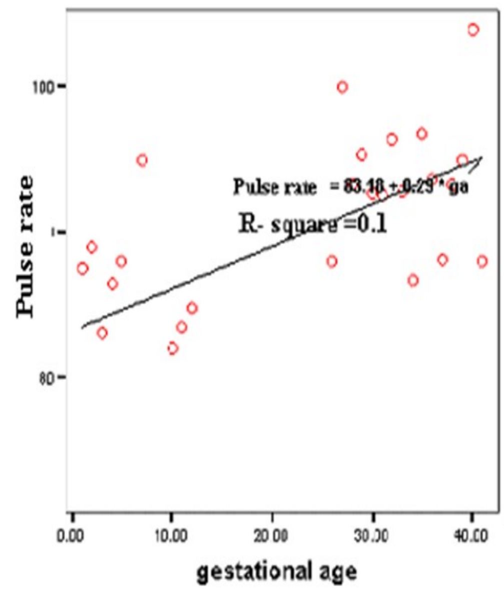

Figure 3. Regression line of pulse rate when gestational ages progresses

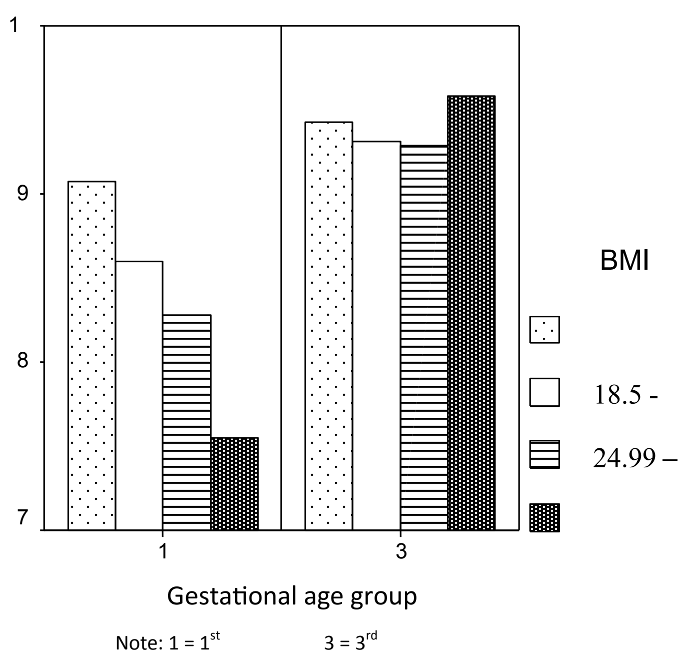

Figure 4: comparison of mean pulse rate between the 1st & 3rd trimester groups as classified in each body mass group.

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