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Estimation and Comparative Analysis of Pulmonary Function Parameters across Trimesters of Pregnancy and in Non-pregnant Women including Association of Peak Expiratory Flow Rate and Forced Expiratory Volume

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ABSTRACT

Introduction: Pregnancy is a physiological condition where numerous systemic changes are observed across the trimesters due to mechanical factors, hormonal influences and activity-related needs of the mother and the developing fetus.

Objectives: To determine changes in pulmonary function parameters across various stages of pregnancy and to compare these parameters with age-matched non-pregnant controls and to determine association between peak expiratory flow rate (PEFR) and forced expiratory volume (FEV1).

Methodology: It was a longitudinal study. The PFT parameters in pregnant women (1st-3rd trimesters, E) was compared with age, height and weight matched non-pregnant women (C). Convenient, purposive sampling technique was employed to collect the data for pregnant and non-pregnant women attending the obstetrics and gynecology department of Nobel Medical College and teaching hospital. Descriptive analysis of all the variables, comparison of the means of pulmonary function parameters and association were performed using SPSS version 24.

Results: The differences for age (p=0.471)), height (p=0.131), weight (p=0.440) were non-significant. Tidal volume (TV) and respiratory rate (RR) increased (p<0.001) but inspiratory reserve volume (IRV), expiratory reserve volume (ERV), PEFR, oxygen saturation (SO2) decreased (p<0.001), along with decrease in Forced vital capacity (FVC), FEV1 and FEV1/FVC (p>0.05).

Conclusion: Estimating PFT parameters across different trimester of pregnancy and non-pregnant women reported significant decrease in several parameters (IRV, ERV, PEFR, SO2), increase in TV and RR but no change in FVC, FEV1 and FEV1/FVC with a notable association between PEFR and FEV1.

Introduction

Pregnancy induces systemic changes across multiple organ system including metabolic, digestive, renal, endocrine, behavioral, and cardiopulmonary functions based on the physiological demands of the developing fetus.[1] Even in healthy women, pregnancy leads to significant changes in respiratory function as reflected in pulmonary function test results.[2]

One of the primary contributors to respiratory change is uterine distension, which affects lung volumes and chest wall mechanics.[3–5] These mechanical changes are further influenced by hormonal factor progesterone increases the slope of the ventilation curve, and estrogen enhances progesterone receptor sensitivity both of which stimulate the respiratory centers in the medulla.[6] Although respiratory rate tends to remain relatively stable, well-documented changes occur in lung

volumes and pulmonary function parameters during pregnancy.

A study has shown that spirometry parameters such as Forced Vital Capacity (FVC), FEV_1, and Peak Expiratory Flow (PEF) may remain within normal limits or show modest increase, with the FEV_1/FVC ratio typically unaltered.[7] However, another study reported gradual decrease in FEV_1 (Forced Expiratory Volume in one second) as pregnancy progresses, with a significant decline noted after 28 weeks of gestation.[8]

Among Indian populations, notable changes in FVC and FEV_1 have been reported during pregnancy. However, FVC did not significantly decline in the third trimester compared to the second.[9] Conversely, some studies found reduced FEV_1 and FVC with a stable FEV_1/FVC ratio,[10] in contrast, obstructive airway diseases lead to simultaneous reductions in both FEV_1 and FVC, causing the FEV_1/FVC ratio to drop below 60%.[11]

These observations underscore the importance of monitoring pulmonary function in pregnant women for both physiological assessment and clinical care. Although global data on pregnancy-induced changes in pulmonary function exist,[12] there is a lack of established data specific to Nepal. A study conducted in Ethiopia reported mean FVC values of 2.59± 0.26 L (Liter) in controls, and 2.13± 0.15 L, 1.93± 0.27 L, and 1.90± 0.11 L across the first, second, and third trimesters, respectively. Except for FEV_1%, all other pulmonary parameters (FVC, FEV_1, PEFR, and FEF 25–75%) were reduced in pregnant women compared to controls ($P < 0.05$).[13] PEFR showed decreasing trend from 329.12± 4.40 L/min at 3 months to 286.22± 3.81 L/min at 9 months and rose to 347.86± 2.93 L/min postpartum in one of the studies while measured in 60 pregnant women aged 20-28 years (average 24 years) height between 130-160 cm (average 154.5 cm).[14]

Due to limited clarity and conflicting results in existing literature, this study was conducted to further elucidate the findings. Therefore, the aim of this study was to determine values of commonly used pulmonary function test (PFT) parameters including Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV), Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV_1), FEV_1/FVC ratio, Peak Expiratory Flow Rate (PEFR), respiratory rate (RR), and oxygen saturation (SO_2) across different trimesters of pregnancy, to compare and to correlate them with PFT values from healthy non-pregnant women and across different trimesters, in order to establish normative reference data relevant to the national population.

Methodology

The present study was conducted at Nobel Medical College and teaching hospital (NMCTH) over a period of 15 months, from June 2021 to August 2022. The study included pregnant and non-pregnant women aged 25 to 40 years who regularly attended the Antenatal Care Unit and the Department of Obstetrics and Gynecology at Nobel Medical College Teaching Hospital, for routine check-up. Ethical clearance was granted for the study by ethical review committee of Nobel Medical College and teaching hospital, Biratnagar, Nepal (IRC-NMCTH 435/2021).

It was a longitudinal study to determine the pulmonary function values for the pregnant women at first trimester (10-12 weeks), second trimester (20-24 weeks), third trimester (34-40 weeks) of pregnancy to maintain consistency across the subjects and was compared with age and height matched non-pregnant women attending antenatal care unit for family planning vaccine and other purposes. Convenient, purposive sampling technique was employed to collect the data. Sample size was calculated using formula $N= 2(Z1-\alpha/2+Z1-\beta)^2/ D2$, assuming medium effect size (Cohen's d = 0.5) a significance level of 0.05, and a power of 80%. Although the estimated sample size was about 63 participants per group according to above formula, a total of 80 pregnant women voluntarily provided written informed consent. All participants had neither history of cardiovascular or respiratory conditions, nor any recent or past acute or chronic illnesses. Out of 80 participants, 76 pregnant women consistently followed up in the department throughout the study period. For control, total 76 age and height matched non-pregnant women were recruited in the study.

Thus, the non-pregnant (Control, C) and pregnant group (1st-3rd trimesters, E) consisting of 76 participants in each group. All the participants in pregnant group were followed throughout the study period. Age (years), Height (Ht.) in meter (m), Weight (Wt.) in kilogram (Kg) and Body mass index (BMI=Kg/m^2) for non-pregnant and pregnant women were recoded. The height was measured by portable stadiometer having vertical ruler with bare foot looking straight ahead and weight was measured in digital weighing machine having scale in kilograms for every subject wearing light clothing and barefoot. Weight of pregnant women was recorded during each trimester of pregnancy and the weight before conception for each subject was recorded by taking history to match with non-pregnant women. Weight of non-pregnant women was also recorded accordingly.

Collection of the PFT parameters was confined to a speculated time at around gestational age of 10-12 weeks for first trimester, 20-24 weeks for 2^{nd} trimester, and 34–40 weeks for third trimester to maintain consistency across the subjects.

The PFT parameters, Forced vital capacity (The maximum volume of air the participants can forcibly exhale after a full inhalation), Inspiratory reserve volume (maximum amount of additional air that can be inhaled beyond a normal tidal inspiration), Expiratory reserve volume (maximum amount of additional air that can be exhaled beyond a normal tidal expiration), Forced Expiratory Volume in the first second (FEV1= The volume of air exhaled during the first second of a forced expiration following full inspiration), the FEV1/FVC ratio (expressed as a percentage) and peak expiratory flow rate (PEFR= The maximum flow rate achieved during a forceful expiratory maneuver) were measured in both healthy pregnant and non-pregnant controls. The instrument used to assess pulmonary function was automatic spirometer (RMS Spirometer Helios 702 Portable) ™. The test was performed with subjects sitting on the chair as relaxed as possible before and during the tests, were asked to avoid smoking, wearing restrictive clothes, alcohol consumption, vigorous exercise, and large meal 2 hours prior to test, as per guideline of the American Thoracic Society (ATS) at room

temperature. The test was performed by trained technician, and all the cases were measured by same person throughout the study for consistency in measurement technique. The test was performed three times, and the average value was used to improve its reliability and validity.[15] Respiratory rate and oxygen saturation were also recorded for both groups by portable pulse-oximeter. All the data were computed as mean ± SD for both groups and the values were compared. Statistical analysis was performed using one-way ANOVA (Post Hoc) to compare the means of PFT parameters and Pearson correlation test to see the association between PEFR and FEV1. Software package, SPSS version 24.0 was taken for data analysis. P-values were obtained to determine the level of significance where P< 0.05 was considered statistically significant.

Results

The mean age of pregnant women (n=76, 1st to 3rd trimester=E) was 32 ± 3.77 years and of the non-pregnant (n=76, control=C) was 32.47 ± 4.30 years. The mean height of the pregnant and non-pregnant women was 1.58 ± 0.02 and 1.57± 0.02 meter respectively. The weight of pregnant women before pregnancy was 56.81± 1.04 Kg and that of non-pregnant women 56.67± 1.06 Kg. Mean BMI of pregnant women before pregnancy was 22.80± 0.62 Kg/m^2 and that of non-pregnant women was 22.74± 0.52 Kg/m^2. The data on anthropometric parameters are tabulated in table 1. On comparison of age, height, weight and BMI there was no significant difference (p> 0.05) observed between non-pregnant (C) and pregnant (E) group.

Table 1: Distribution of anthropometric variables in Non-pregnant and Pregnant groups.

Anthropometric variables	No. of Sample (N)	Minimum	Maximum	Mean± SD	P value
Age (E, years)	76	27	40	32± 3.77	0.471
Age (C, years)	76	25	40	32.47± 4.30	
Ht (E, m)	76	1.53	1.60	1.58± .02	0.131
Ht (C, m)	76	1.52	1.60	1.57± .02	
Wt (Ebp, kg)	76	54	59	56.81± 1.04	0.440
Wt (C, kg)	76	53	59	56.67± 1.06	
BMI (Ebp, kg/m2)	76	21.63	24.78	22.80± .62	0.384
BMI (C, kg/m2)	76	21.63	24.46	22.74± .52	

C= control, E=Experiment, Ebp= Experiment group before pregnancy,

Ht=height, Wt=weight, BMI=Body mass index, m=meter, kg=kilogram

Mean and standard deviation of pulmonary function test parameters are displayed in table 2 that describes the mean value for pregnant women in all three trimesters and non-pregnant control women.

Table 2: Distribution of pulmonary function values in the Non-pregnant and Pregnant groups.

PFT Variables	Control (n=76, mean±SD)	ET1 (n=76, mean±SD)	ET2 (n=76, mean±SD)	ET3 (n=76, mean±SD)	Mean Square	p value
TV* (L)	0.33 ±0.02	0.35 ±0.02	0.36 ±0.02	0.42 ±0.02	0.112	<0.001
ERV* (L)	0.71 ±.01	0.72 ±.01	0.70 ±.02	0.69 ±.02	0.013	<0.001
IRV* (L)	2.87 ±0.11	2.57 ±0.17	2.36 ±0.12	2.17 ±0.11	6.772	<0.001
FVC (L)	3.63 ±0.08	3.61 ±0.09	3.62 ±0.08	3.61 ±0.09	0.013	0.130
FEV1 (L)	2.84 ±0.11	2.84 ±0.13	2.82 ±0.14	2.79 ±0.15	0.037	0.082
FEV1/FVC	0.78 ±0.04	0.79 ±0.05	0.78 ±0.05	0.78 ±0.05	0.002	0.304
PEFR* (L/min)	396.45 ±21.09	382.37 ±22.63	370.26 ±22.69	359.08 ±21.43	19596.930	<0.001
RR* (b/min)	13.92 ±1.28	15.88 ±1.06	17.37 ±1.15	20.32 ±1.28	552.144	<0.001
SO2* (%)	97.66 ±0.85	95.08 ±0.65	93.93 ±0.67	92.79 ±0.64	329.845	<0.001

C= control, E=Experiment, ET1=1st trimester, ET2= 2nd trimester, ET3=3rd trimester, TV=Tidal volume, ERV= Expiratory reserve volume, IRV= Inspiratory reserve volume, FVC=Forced vital capacity, FEV1= Forced expiratory volume in 1st second, PEFR=Peak expiratory volume, RR=Respiratory rate, b/min=breathe per minute, SO2= Oxygen saturation. L= Liter, L/min=Liter per minute, (*) = statistically significant.

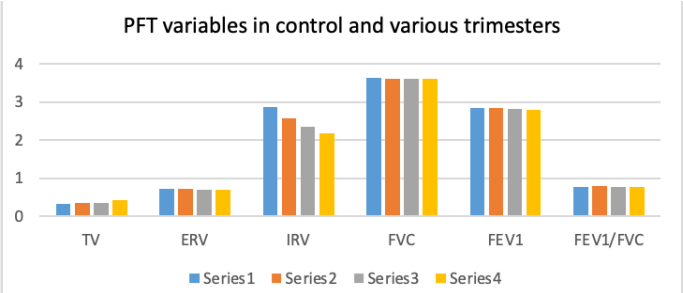

Fig 1: Changes seen in PFT variables (Liter) in non-pregnant and pregnant groups.

Series 1; Control, Series 2; 1st trimester, Series 3; 2nd trimester, Series 4; 3rd trimester

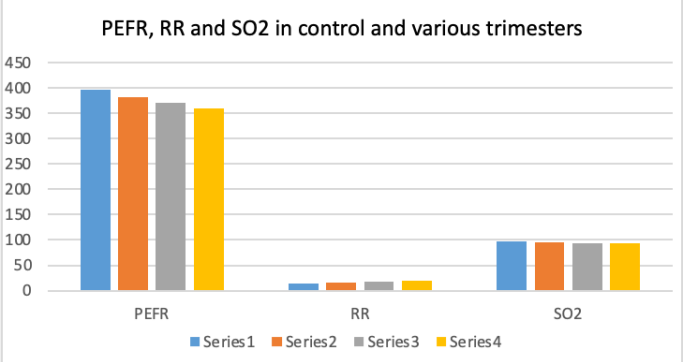

Fig 2: Changes seen in PEFR (Liter/minute), RR (breathe/minute) and SO2 (%) in non-pregnant group and in various trimesters of pregnancy.

Series 1; Control, Series 2; 1st trimester, Series 3; 2nd trimester, Series 4; 3rd trimester

On multiple comparison of each pulmonary function parameters among groups, a significant difference was observed for TV (C= 0.33± 0.02 L, ET1= 0.35± 0.02 L, ET2= 0.36 ± 0.02 L, ET3=0.42± 0.02 L, p <0.001) and RR (C= 13.92± 1.28 b/min, ET1= 15.88± 1.06 b/min, ET2= 17.37± 1.15 b/min, ET3=20.32± 1.28 b/min, p <0.001) being more in 3rd trimester compared to control, 1st and 2nd trimester. The trend was in a decreasing order for ERV (C= 0.71± 0.01 L, ET1= 0.72± 0.01 L, ET2= 0.70± 0.02 L, ET3=0.69± 0.02 L, p <0.001), IRV (C= 2.87± 0.11 L, ET1=2.57± 0.17 L, ET2=2.36± 0.12 L, ET3=2.17± 0.11 L, p <0.001), PEFR (C= 396.45± 21.09 L/min, ET1= 382.37± 22.63 L/min, ET2= 370.26± 22.69 L/min, ET3=359.08± 21.43 L/min, p <0.001), and SO2 (C=97.66± 0.85 %, ET1= 95.08± 0.65 %, ET2=93.93± 0.67 %, ET3=92.79± 0.64 %, p <0.001) comparing control with 1st to 3rd trimester of pregnancy. There was no difference in FVC (C=3.63± 0.08 L, ET1=3.61± 0.09 L, ET2=3.62± 0.08 L, ET3= 3.61± 0.09 L, p >0.05), FEV1 (C = 2.84± 0.11 L, ET1= V, ET2=2.82± 0.14 L, ET3=2.79± 0.15 L, p >0.05) and FEV1/FVC (C=0.78± 0.04, ET1= 0.79± 0.05, ET2= 0.78± 0.05, ET3= 0.78± 0.05, p >0.05) as compared among non-pregnant (control, C) and pregnant women (1st-3rd trimesters, E).

Table 3 shows association between PEFR and FEV1 separately for control (non-pregnant), ET1 (1st trimester), ET2 (2nd trimester) and ET3 (3rd trimester) using Pearson correlation. Except ET1 (p=0.024, r=0.26) which is positively correlated, non-pregnant group and ET2 shows non-significant positive correlation, whereas ET3 shows negative correlation.

Table 3: Correlation between PEFR and FEV1

Variables	PEFR (Mean ±SD, L)	FEV1(Mean ±SD, L)	Correlation (r)	P value
Non-Pregnant (n=76)	396.45 ± 21.09	2.84 ± 0.11	0.11	0.36
ET1 * (n=76)	382.37 ± 22.63	2.84 ± 0.13	0.26	0.024*
ET2 (n=76)	370.26 ± 22.69	2.82± 0.14	0.11	0.39
ET3 (n=76)	359.08 ± 21.43	2.79 ± 0.15	-0.008	0.947

ET1=1st trimester, ET2= 2nd trimester, ET3=3rd trimester, L=Liter, (*) = statistically significant.

Discussion

Present study reported age, height, weight and BMI were comparable between the pregnant and non-pregnant group from 1st to 3rd trimester. Comparing physiological changes of pulmonary function test parameters between non-pregnant and pregnant women, there are notable differences reported in TV, ERV, IRV, PEFR, RR, SO2 and slight changes seen in FVC, FEV1, FEV1/FVC.

This study reported forced vital capacity (FVC) in a decreasing trend (C=3.63 ±0.08 L, ET1=3.61 ±0.09 L, ET2=3.62 ±0.08 L, ET3= 3.61 ±0.09 L, p>0.05) but not significant which is supported by a study7 where FVC decreased (controls, first, second, and third trimesters were 2.59 ± 0.26 L, 2.13 ± 0.15 L, 1.93 ± 0.27 L, and 1.90 ± 0.11 L, respectively, p<0.05). Similarly, the decrement in FVC was observed in some studies by Puranik BM et al (FVC in 3rd month= 2.19 ±10.25 L to 9th month= 2.17 ±0.24 L), and Vikhe BB (control= 2.58± 0.60 L, 1st = 2.26± 0.44 L, 2nd= 1.95± 0.36 L and 3rd= 1.70± 0.42 L).[16,17] The results obtained in a study by Takke R Rasika et al[18] indicated that, there was no significant difference in FEV1 (1st=94.7± 6.557 %, 2nd=84.5± 12.686 %, 3rd=87.5± 11.778 %), FVC (1st=85.1± 6.557 %, 2nd=73.1± 13.136 %, 3rd=77.4± 14.073 %) and FEV1/ FVC (1st= 111.1± 1.828, 2nd= 115.1± 2.418, 3rd= 112.8± 3.140) while comparing different trimesters of pregnancy. Differences seen within groups were statistically insignificant (p> 0.05). The trend of FEV1 (C = 2.84± 0.11 L, ET1= V, ET2=2.82± 0.14 L, ET3=2.79± 0.15 L, p >0.05), and FEV1/FVC (C=0.78± 0.04, ET1= 0.79± 0.05, ET2= 0.78± 0.05, ET3= 0.78± 0.05, p >0.05) were in a decreasing order on comparison between control and all three trimesters of pregnancy in present study. The PFT parameters such as IRV (C= 2.87± 0.11 L, ET1=2.57± 0.17 L, ET2=2.36± 0.12 L, ET3=2.17± 0.11 L, p<0.001), ERV (C= 0.71± 0.01 L, ET1= 0.72± 0.01 L, ET2= 0.70± 0.02 L, ET3=0.69± 0.02 L, p<0.001) and PEFR (C= 396.45± 21.09 L/min, ET1= 382.37± 22.63 L/min, ET2= 370.26± 22.69 L/min, ET3=359.08± 21.43 L/min, p<0.001) were significantly decreased from 1st to 3rd trimester compared to control in present study. A study conducted in Kerala, comparing

control and pregnant women in 1st, 2nd and 3rd trimesters IRV was C=1.02± 0.60 L, T1=0.78± 0.47 L, T2=0.75± 0.54 L and T3=0.92± 0.55 L which was significantly decreased.[19] PEFR was (C=70.92± 11.68 L/min, T1= 64.62± 18.82 L/min, T2= 58.52± 18.69 L/min, T3= 56.02± 16.47 L/min) significantly decreased with advancement of gestational period compared to control in a study by SA Krithika.[20] The mean Expiratory Reserve Volume (ERV) in 3rd trimester subjects have shown a statistically significant decrement by 9.87 % as compared to the control subjects (p value < 0.0005). The mean TV showed significant increment by 30.51% when compared with non-pregnant subjects (p value < 0.0005) which was consistent with our study.[21] Present study also reported significant increase in TV (C= 0.33± 0.02 L, ET1= 0.35± 0.02 L, ET2= 0.36± 0.02 L, ET3=0.42± 0.02 L, p<0.001) comparing control with different trimesters of pregnant women. Similarly, respiratory rate significantly increased from 1st to 3rd trimester (p<0.001) but oxygen saturation (SO2) significantly decreased (p<0.001) compared to control in present study. Yosef Eshetie[7] reported a strong negative correlation between SO2 and RR (r= −0.865; P <0.01) where respiratory rate was in increasing order whereas oxygen saturation was in decreasing order as the gestational age advances.

As SA Krithika[20] reported decrement in both PEFR and FEV1 during pregnancy compared to control, no correlation was assessed. Present study has reported quite similar decreasing trend. Except ET1 (p=0.024, r=0.26) which shows significant correlation, non-pregnant group and ET2 shows non-significant positive correlation whereas ET3 shows negative correlation.

Conclusion

The study concluded that PFT parameters; IRV, ERV, PEFR including oxygen saturation decreases as the gestational age advances. PFT parameters; FVC, FEV1 and FEV1/FVC also decreases, but tidal volume and respiratory rate increases during pregnancy.

Recommendation

Pulmonary function test may predict various pathophysiological abnormalities related to cardiopulmonary system. Establishing a normative scale across our geographical area and recommending antenatal exercises to strengthen respiratory muscles, precautions for potential risk factors affecting respiratory system, suggesting proper dietary chart and providing iron and calcium supplements for the subjects should be standardized. The study reports would be a valuable reference for pulmonologist to assess antenatal as well as Obstetrics and Gynecology patient's pulmonary function.

Limitations

Since the pregnant subjects were not assessed prior to pregnancy, their pre-pregnancy vitals were based on self-reported history, which is a limitation. A further analysis of pulmonary function data in the post-pregnancy state may add useful information. Additionally, collecting samples from government hospitals and including participants from various socioeconomic groups could strengthen the validity of the findings.

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Conflict of Interest

The authors report there are no conflict of interest.

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