Spirometry Profiles Among Pregnant And Non-Pregnant African Women

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Abstract

Background: Lung function tests are done to assess the working and possible mechanical deterioration of lungs, respiratory muscles, and chest wall. Spirometry is a commonly used test. Pregnancy derives an altered physiological state due to accompanied hormonal and anatomical changes that affect the respiratory system. Despite that, spirometry is rarely done in pregnancy, and if done test results are compared against non-pregnancy references.

Objective: This study aimed at determining spirometry profiles in pregnant and non-pregnant women and describing their differences.

Methodology: This cross-sectional study was conducted at Mnazi Mmoja antenatal clinic where pregnant women who met the inclusion criteria were randomly recruited. Also, non-pregnant women were recruited from MUHAS as controls. Lung function was assessed using a digital spirometer (EasyOne®) while adhering to standard operating procedures (SOPs) and infection prevention protocols. Data were entered and analyzed using SPSS version 23. The means of spirometry parameters of pregnant women were compared to parameters of non-pregnant women using an independent sample t-test. The level of significance was set to < 0.05 p-value.

Results: A total of 92 pregnant and 98 non-pregnant women were subjected to spirometry. Mean FVC (p <0.01), FEV1 (p <0.01), and PEF (p <0.01) of pregnant women were significantly lower than non-pregnant women.

Conclusion: Spirometry test values obtained from pregnant women were lower than those obtained from non-pregnant controls.

Recommendations: Spirometry test values of pregnant women should be carefully interpreted against non-pregnancy references otherwise can cause underestimation of their values, and hence over-hospitalization. There is also a need to evaluate the accuracy of non-pregnancy spirometry reference equations for predicting test values among pregnant women.

Background

Lung function tests are investigations done to assess the ability of lungs to exchange gasses and possible mechanical deterioration of lungs, respiratory muscles, and chest wall. They are widely used to confirm and classify respiratory disorders, also to monitor respiratory response to pharmacological, environmental, and developmental changes (1). They include spirometry, lung volumes test, lung diffusion capacity, pulse-oximetry, arterial blood gas analysis and fraction exhaled nitric oxide test. Of these, spirometry is the commonly used lung function test (1). Spirometry assesses functions of lung tissue, chest wall, respiratory muscles, and airways by measuring the volume of air and the rate at which a person can exhale from lungs that are filled at their full capacity (2). The most useful spirometry measurements are forced vital capacity (FVC), forced expiratory volume (FEV), and peak expiratory flow

(PEF) (3). FVC is the volume of air a person exhales maximally and forcefully after inhaling maximally. FEV1 is the volume of air exhaled in the first second of FVC measurement. PEF is a person's maximum rate at which air can be forcefully exhaled after inhaling maximally.

Interestingly, spirometry parameters vary depending on various factors like age, sex, height, weight, body position, and race or ethnic groups (4). Most of the parameters peak at 20-25 years before they start to decline (5). The most affected parameters are FVC and FEV1 (5). These parameters differ between males and females mainly due to biological and body size differences (6, 7). Also, the profile of common spirometry parameters differs between known races of the world (7) and varies when taken in different positions (sitting, standing, or lying) (8). The influence of age, sex, body size, race, and positions are thought to be due to their relation with expiratory muscles mass and strength, chest wall compliance, airway resistance, and lung tissue elasticity (5–11). A growing body of evidence shows that expiratory muscles mass and strength, chest wall compliance, airway resistance, and lung tissue elasticity appear to be influenced during pregnancy (12–15).

Even though pregnancy is not a disease, it derives an altered physiological state mostly due to accompanied hormonal changes (16). Progesterone and estrogen are the main triggers and drivers of pregnancy-induced physiological changes (17–19). Progesterone serum level increases linearly and is responsible for physiological alterations while estrogen modulates the effects of progesterone by increasing receptors number and sensitivity (17–19).

Like all other organ systems, the respiratory system is influenced by and has to adapt to anatomical and physiological factors of pregnancy (20, 21). Apparently, growing gravid mechanically interferes with lungs and respiration. The diaphragm and lungs are displaced upward (12), the ribcage volume (13) and chest wall compliance decreases (14) with uterine growth. Respiratory muscles and other abdominal muscles respond to increasing abdominal volume by increasing their separation breadth, stretch, and insertion angle (15) thereby dipping their strength. These changes often cause nocturnal dyspnea, chest discomfort, and difficulty in breathing, especially during late pregnancy (22).

Respiratory conditions are common in pregnancy (23) and restrictive disorders if occur during pregnancy severely affect lung function profile (14) more than the general population (24). Respiratory disorders are associated with adverse perinatal outcomes (25–27). Despite that, lung function tests including spirometry are less frequently performed among pregnant women even among those with conditions that affect the lungs (28). Furthermore, there is a lack of reference values for spirometry parameters and their associated factors among pregnant in Sub Saharan Africa including Tanzania. Few studies available only involved non-pregnant African women (29–31). Therefore, the test results among pregnant women are compared against the general population reference values. This is likely to underestimate the spirometry parameters among pregnant women, thus increasing the risk of mismanagement, particularly among those with respiratory conditions. Therefore, evaluation of the spirometry profile among the pregnant population was important.

Methodology

Study design

A cross-sectional design was used. Study participants were recruited from the antenatal clinic and the general population. Spirometry measurements and information about affecting factors were collected on the same encounter.

Study Population

This study involved pregnant women aged 18 to 35 years who were attending antenatal clinic services at Mnazi Mmoja hospital located in Dar es Salaam, Tanzania. This hospital was chosen among others because it receives women with uncomplicated pregnancies. Non-pregnant women of the matched group age, height, and weight range were recruited from among female persons at MUHAS.

Sample Size

The sample size was calculated using a formula for cross-section studies with quantitative variables published by Charan and Biswas (32) review.

Sample size = $Z_{1-\alpha/2}^2 SD^2 / d^2$ where;

$Z_{1-\alpha/2}$ is a standard normal variate for a given level of significance (*p*-value)

SD is a standard deviation for a variable obtainable from the previous or pilot study

d is an acceptable margin of error set by a researcher

This study used standard deviation (7.36) for mean FEV1/FVC ratio in the second trimester from the previous study (33), level of significance (P-value) of probability <0.05, and marginal error was set to 1.6. The sample size was adjusted to 10% non-response. Therefore, the sample was expected to be 182 women among whom 91 would be pregnant women and the same number of non-pregnant women. In the end, 190 women were included in this study among whom 92 were pregnant and 98 non-pregnant women as controls.

Sample Selection

A simple random sampling technique was employed to obtain pregnant women. Upon consenting to participate, those meeting all the criteria were assigned with numbers. Then 10 pregnant women were selected using a table of random numbers on each day until the total sample size was attained.

All eligible women at MUHAS who were not pregnant were welcomed to participate in this study. Convenient sampling was used to obtain non-pregnant controls in an attempt to match pregnant women group characteristics as much as it was possible. Then 10 women per day were scheduled for data collection until a total sample was attained. If found pregnant or fails to appear for data collection was replaced by the next woman.

Inclusion Criteria

Included in this study were African decency pregnant women of age 18 to 35 years and gestational age from 6 to 36 weeks. Pregnant women below 18 were not included since their presumed immature reproductive system could influence the observed spirometry profile. Meanwhile, women with more than 35 years were not included as they are likely to experience complications related to advanced maternal age pregnancy (34–36). The first five weeks were excluded due to the difficulty of certainly diagnosing pregnancy at this gestational age (37). Term pregnancy wasn't included due to safety issues related to increased intra-abdominal pressure during spirometry maneuver (38). Since first visit weight was to be used for the calculation of BMI in pregnancy instead of pre-pregnancy weight, only women who booked their first visit in the first trimester were included. Age, height, and weight group matched non-pregnant women were recruited for comparison.

Exclusion Criteria

Women among whom spirometry is contraindicated (39) were excluded from the study. Screening for contraindications was done on every woman before enrolment. Also, women already known to have any lung disease or any other diseases affecting lung function or exposed to tuberculosis in the past year, had lax uterus or history of mid-trimester abortion (39), had a history of smoking, had multiple pregnancies, or failed to obtain any acceptable and repeatable spirometry measurement were excluded. Merely measurements without errors were accepted. Measurements were regarded repeatable if they didn't deviate by more than 150 ml (3). Women who were pregnant in the last 42 days before the day of data collection weren't used as a control to exclude the effects of previous pregnancy.

Variables

Independent variables were age, pregnancy status, parity, gestational age, height, and weight. Dependent variables were spirometry parameters which are FVC, FEV1, PEF, and FEV1/FVC ratio. All volumes and rates were measured in liters and liters per minute respectively.

Data Collection Tools

A structured checklist adapted from validated maternal recall questionnaires was used to collect demographic information. The checklist was used to collect anthropometry and spirometry measurements. The data collection tool was tested through a pilot test administered to 19 women who were equivalent to 10% of the total sample size which was expected. The test was based on the ability of a tool to collect information that was able to answer the research questions.

Data Collection Process

Demographic and pregnancy information was collected by interview using a structured checklist adapted from the maternal recall questionnaire (40). The absence of pregnancy was confirmed among the non-pregnant group using a standard urine pregnancy test at MUHAS physiology laboratory. Height was measured in an erect standing position using the SECA stadiometer. On-date weight was measured using the SECA adult weighing machine. Participants were asked to stand with feet on a scale placed on a flat surface looking straight ahead while hands positioned at their side (41). Weight on the first visit for pregnant women was obtained from antenatal cards and was used to calculate BMI in pregnancy instead of pre-pregnancy weight as it was not available. BMI was further categorized into underweight (BMI <18.5), normal weight (BMI =18.5-24.9), overweight (BMI = 25-29.9), and obesity (BMI ≥30).

Spirometry was done using a computerized EasyOne® Diagnostic spirometer in a sitting position with a nose clip. Test mode was set to DIAGNOSTIC, prediction reference was set to NHANES III, and select value was set to BEST VALUE. Women were coached for correct maneuvers using protocols adapted from NHANES 2011 spirometry examination manual (42) and synchronized with ATS and ERS spirometry standardization 2019 update (3). They were instructed to elevate the chin, straighten the neck, then take a deep breath to fill the lungs. Then place a mouthpiece in the mouth between teeth and above the tongue before blowing up as fast and forcefully as possible until when asked to stop after a minimum of six seconds. At least three acceptable and reproducible measurements according to ATS and ERS technical updates (3) were measured but the best value was recorded. Measurements were recorded on a checklist as continuous variables. Every participant and personnel washed and sanitized their hands before touching the mouthpiece and spirometer while staying at least one meter apart without facing each other directly. The participants were instructed about how to unwrap and insert the mouthpiece onto the spirometer on their own. Mouthpieces were discarded after use and the spirometer was properly sanitized before use by another participant.

Data Management And Analysis

Data were entered using SPSS version 23. Normality of spirometry test values was assessed and FVC, FEV1, and PEF were found to be normally distributed hence described using means while FEV1/FVC was slightly skewed to the right hence median was described. The one-way analysis of variance (ANOVA) was used to test the effect of factors on FVC, FEV1, and PEF in each group, and Kruskal-Wallis was used to test the effect on FEV1/FVC ratio. The difference between means of predicted and measured values was

analyzed using paired t-test. The means of spirometry parameters in pregnancy were compared to non-pregnant using an independent sample t-test (43, 44). Adjustments to potential confounders were done through analysis of covariance (ANCOVA). The level of significance was set to < 0.05 p-value.

Ethical Consideration

Ethical clearance was obtained from MUHAS institutional review board. Permission to conduct the study was obtained from Mnazi Mmoja hospital administration via Dar es Salaam regional administrative secretary, Ilala District Administrative Secretary, and Ilala Municipal Council Executive Director. Also, permission to include MUHAS female persons as controls was obtained from the Vice-Chancellor Research Academic and Consultancy. All methods were carried out in harmony with the Helsinki Declaration. Study protocols and objectives were revealed to women. Written informed consent was prearranged and signed by women before enrolment into the study. To maintain privacy, a pregnancy test among the non-pregnant group was conducted at the MUHAS physiology laboratory. Every participant undertook a test and received results privately. Personal identifying information was not collected and all other information collected was used for research purposes only. Women with abnormal findings were recommended for medical evaluation as per Mnazi Mmoja hospital protocol.

Generally, spirometry is considered safe during pregnancy as no complications have been reported (39). However, several safety precautions were taken to avoid potential complications related to the spirometry maneuver. Women among whom spirometry was contraindicated were excluded. All women who meet inclusion were screened for contraindications using a tool adapted from NHANES 2011 procedure manual, ATS/ERS 2019 update, and BMJ updates on spirometry contraindications (3, 39, 42). Also, spirometry was done in a seating position as a precaution against potential lightheadedness due to exertion during the spirometry maneuver.

Results

A total of 969 pregnant women who visited Mnazi Mmoja hospital during the study period were invited to participate in the study (Figure 1). Among eligible women, 92 randomly obtained participants were involved. Then 98 consecutively obtained eligible non-pregnant women were recruited as controls.

Description of characteristics of participants

The mean age of study participants was 27 years (SD = 5). Their mean height was 157.4 centimeters (SD = 6.7) ranging from 135 cm to 173 cm tall. The mean weight was 67 Kg (SD = 14.2) ranging from 47 to 117 Kg. Among all participants, 46.7% were overweight or obese while 7.6% were underweight and 52.4% had previously given birth at least once. (*Table 1*).

Table 1: Characteristics of participants (n = 190)

		Pregnant		Non-pregnant		
		Frequency (%)	Mean ± SD	Frequency (%)	Mean ± SD	*p*- value
Age	18-19	2 (24)		7 (7.1)		
	20-24	24 (25.5)		48 (48.7)		
	25-29	25 (27.5)		20 (20.4)		
	30-35	41 (44.6)		23 (23.7)		
	Total	92	28 ± 5	98	26 ± 5	0.040
Height	135-139	1 (1.1)		0		
	140-149	11 (11.8)		11 (11.2)		
	150-159	51 (55.3)		43 (43.9)		
	160-169	29 (31.7)		40 (40.8)		
	170-179	0		4 (4.1)		
	Total	92	156.3 ± 6.4	98	158.5 ± 6.8	0.290
Weight	41-50	6 (6.0)		20 (20.4)		
	51-60	16 (17.5)		28 (28.6)		
	61-70	24 (26.5)		24 (24.5)		
	71-80	23 (24.4)		15 (15.3)		
	81-90	15 (16.7)		8 (8.2)		
	91-110	8 (6.3)		3 (3.1)		
	Total	92	70.9 ± 13.8	98	62.6 ± 13.5	0.011
BMI	Underweight	6 (6.4)		9 (8.7)		
	Normal	37 (40.3)		50 (50.8)		
	Overweight	30 (33.0)		16 (16.7)		
	Obese	19 (20.3)		23 (23.7)		
	Total	92	25.8 ± 4.8	98	25.0 ± 5.4	0.131
Parity	0	32 (34.8)		57 (58.2)		
	1	32 (34.8)		16 (16.3)		
	2	14 (15.2)		12 (12.2)		
	3	12 (13)		6 (6.1)		
	4	2 (2.2)		7 (7.1)		
	Total	92		98		0.006
Gestation age	first trimester	7 (7.6)				
	second trimester	31 (34.0)				
	third trimester	54 (58.4)				
	Total	92	25.3 ± 7.9			

p -value for characteristic difference between pregnant and non-pregnant women

4.1 Description of spirometry test values of participants

Spirometry test values and their respective percentage predicted were normally distributed in a study sample except FEV1/FVC (in %) ratio (Figure 2).

The mean FVC for all participants was 2.8 L (SD = 0.52) which was 94.9% (SD = 16.3) of the values predicted by age and height. Their mean FEV1 was 2.4 L (SD = 0.43) which was 90% (SD = 14.5) of predicted. The Median FEV1/FVC ratio was 84.3% (48.8-99.8). The mean PEF was 329.3 L/min (SD = 78.5) L/min which was 84.2% (SD = 19.8) of predicted (*Table 2*).

Table 2: Summary of spirometry test values of participants (n = 190)

		Pregnant	Non-pregnant			
		Mean ± SD		t-value	df	*p* -value
FVC (L)	predicted	2.9 ± 0.28	3.1 ± 0.32			
	measured	2.7 ± 0.54	2.9 ± 0.48	-3.041	189	0.006
	FVC%	92.9 ± 18.6	96.3 ± 13.4	-1.431	167	0.179
FEV1 (L)	predicted	2.6 ± 0.22	2.7 ± 0.3			
	measured	2.2 ± 0.42	2.5 ± 0.41	-4.512	189	0.000
	FEV1%	86.9 ± 15.1	93.1 ± 13.4	-2.990	189	0.003
PEF (L/min)	predicted	387.6 ± 23.6	397.9 ± 29.5			
	measured	303.2 ± 84.5	353.8 ± 63.6	-4.647	169	0.000
	PEF%	78.4 ± 21.8	89.7 ± 15.8	-4.100	166	0.000
		Median (Range)				
FEV1/FVC (%)		83.7 (48.8-99.8)	85.1 (65.0-98.1)			0.281

p- value for respective difference between pregnant and non-pregnant women

Factors affecting spirometry profiles

Age and spirometry test values

The relationship between age and spirometry profile appeared to be phasic with an increase to peak then decrease. However, the pattern was marked by earlier peak age with lower peak values in pregnant women as compared to non-pregnant women (*Figure 3*). The pattern was statistically significant for FVC [F (3, 88) =2.83; p =0.043] and FVC% [F (3, 88) =2.89; p =0.04] among pregnant women even after adjusting for height but not after including weight in the analysis of covariance (ANCOVA). The pattern was statistically significant for FVC [F (16, 81) =2.44; p <0.01], FVC% [F (16, 81) =1, 79; p =0.05], FEV1 [F (16, 81) =2.53; p <0.01], FEV1% [F (16, 81) =1.81; p =0.04], PEF [F (16, 81) =2; p =0.02], PEF% [F (16, 81) =2.59; p <0.01] and FEV1/FVC (p =0.042) among non-pregnant women even after adjusting for height and weight.

Height and spirometry test values

Spirometry values appeared to increase as height increased (*Figure 4*) except for means of FVC%, FEV1%, and median FEV1/FVC of non-pregnant women which appeared to decrease as height increased. The pattern was statistically significant for FVC [F (25, 66) = 1.88; p = 0.02], FEV1 [F (25, 66) = 2.54; p < 0.01] and PEF [F (25, 66) = 1.79; p = 0.03] among pregnant women but was no longer significant for FVC and PEF after adjusting for weight and age. The pattern was statistically significant for FVC [F (3, 94) =7.96; p <0.01] and FEV1 [F (3, 94) =6.65; p <0.01] among non-pregnant women even after adjusting for age and weight.

Weight and spirometry test values

The means of FVC, FEV1, and PEF of pregnant women increased with weight until 60-70 Kg then decreased. Median FEV1/FVC of pregnant and non-pregnant women remained unchanged as weight increased (*Figure 5*). No pattern was statistically significant except for PEF (p =0.010) of non-pregnant women which also was no longer significant after adjusting for age and height.

While mean spirometry test values of pregnant women increased with BMI, mean values of non-pregnant women decreased as BMI increased and medians of the FEV1/FVC ratio remained fairly unchanged (*Figure 6*). But all the patterns were not statistically significant.

Parity and spirometry test values

The mean FVC, FEV1, and PEF parous women were higher than the means of nulliparous women. Median FEV1/FVC of nulliparous women was higher than parous women (*Figure 7Figure 7*). However, the pattern was only statistically significant for median FEV1/FVC among pregnant women (p = 0.035) and mean of FVC% [F (4, 93) =2.88; p =0.03] and FEV1% [F (4, 93) =3.89; p =0.01] among non-pregnant women and persisted when adjusted to height but disappeared when age and weight were included in the ANCOVA model.

Gestational age and spirometry test values

The means of FVC, FEV1, PEF, and their % predicted decreased as gestational age increased. The decrease was steeper from the first to the second trimester. The median FEV1/FVC decreased just slightly as gestational age increased (*Figure 8*). This pattern was statistically significant for FVC [F (2, 89) =4.03; p =0.02], FVC% [F (2, 89) =6.81; p <0.01], FEV1 [F (2, 89) =3.15; p =0.048] and FEV1% [F (2, 89) =5.91; p <0.01] even after adjusting for maternal age, height and weight.

Difference between pregnant and non-pregnant spirometry test values

The measured FVC [t (91) = -3.97; p <0.001], FEV1 [t (91) = -8.39; p <0.001] and PEF [t (91) = -9.69; p <0.001] among pregnant women as well as FVC [t (97) = -2.86; p =0.001], FEV1 [t (97) = -5.17; p <0.001] and PEF [t (97) = -7.12; p <0.001] among non-pregnant women were significantly lower than values predicted based on age and height.

Meanwhile, the mean FVC [t (189) = -3.04; p =0.006], FEV1 [t (189) = -4.51; p <0.01], FEV1% [t (189) = -2.99; p =0.003], PEF [t (169.5) = -4.65; p <0.001] and PEF% [t (165.9) = -4.1; p <0.01] of pregnant women were significantly lower than non-pregnant mean values even after adjusting for age, weight and parity (*Table 2*).

Discussion

The respiratory system is affected by anatomical and physiological changes associated with pregnancy. This was the base of our hypothesis that spirometry profiles of pregnant women are different from those predicted by their age and height if they were not pregnant. Therefore this study was designed to examine

the profiles of lung function of pregnant African women using spirometry and compare them to profiles of non-pregnant women. In this study, FVC, FEV1, and PEF values of pregnant and non-pregnant women were lower than the values predicted by their age and height. Also, FVC, FEV1, and PEF values of pregnant women were lower than values of non-pregnant women.

We report mean spirometry test values in pregnant women which are lower than the means reported in Brazilians (20). The non-pregnant means of FVC, FEV1, PEF and their % predicted in this study are comparable to values reported from other studies done in Tanzania (29), Rwanda (30) and Mozambique (31). Our values were slightly higher than the other studies because of the age difference as the mean age of non-pregnant women was less than 30 years in this while it was more than 35 in the other studies. Also, the values of non-pregnant women in this study were lower than values recorded in Europeans and Australians (45), Asians (46), and Scandinavians (47) but FEV1/FVC ratio was higher. Like ours, other studies have reported lower spirometry profiles in African decency which could not be explained by anthropometric and skin color differences alone (5, 48). A portion of this could be explained by lower seating height and socio-economic status which were reported to relate to lower values. Even so, the values are considered normal since the prognosis has not been different (49–52). In addition to ethnic differences, we found lower values probably because we did not administer a bronchodilator prior to spirometry unlike in the previous studies.

Interestingly, a phasic relationship between age and spirometry test values of non-pregnant women was noted. There was an increase to a peak, followed by a decrease in spirometric values. A similar pattern was observed in pregnant women for FEV1/FVC, PEF, and PEF%. However, the peak age for FVC, FEV1, and PEF was earlier with lower values in pregnant women. The spirometry test values have been known to increase with age then peak around 25 years before starting to decline (5, 47, 53, 54). This is thought to occur as a part of the aging process. After peak age, pulmonary elastic recoil decrease with age due to progressive loss of lung tissue elasticity and increase of chest wall stiffness resulting in the decline of lung function (55–59). Also, it could be partly due to a decrease in spirometry performance with aging. Hence, age has been an important factor in spirometry test values predicting equations. Pregnancy factors could have influenced the pattern observed among pregnant women in our study.

Similar to previous studies, FVC, FEV1, and PEF of both pregnant and non-pregnant women increased with height (29, 30, 47). Height also has been an important factor in spirometry prediction equations together with age (3, 29, 53, 60–65). However, FVC% and FEV1% decreased as height increased. This could mean that as height increased participants were more likely to have lower than expected FVC and FEV1 values but also it could be a reference equation over predicting expected values. Reference values have been reported to over predict spirometry test values in different populations (60, 61, 64). Other studies have found a difference in prediction even when references were derived from a closely related population such that abnormal findings in one reference were deemed normal by the other (65). There was no significant relationship between height and FEV1/FVC in pregnant and non-pregnant women. This was in line with other studies (47) and it could be due to the equal effect of height on FEV1 and FVC.

FVC, FEV1, and PEF of pregnant women increased with weight, peaked at 61-70Kg then decreased. Non-pregnant women's values decreased when women were becoming overweight and obese. Despite such a pattern, neither weight nor BMI appeared to statistically significantly affect FVC, FEV1, or PEF in neither pregnant nor non-pregnant women after adjusting for age and height. This has been found by several other studies (29, 30, 66, 67). However other studies have demonstrated a negative effect of the increasing waist to hip ratio (WHR) and weight gain on FEV1 and FVC (68, 69). This could be for the reason that quantification of body mass and its index is not specific to the distribution of body composition while fats in hips, thighs, gluteal regions, and breasts are less likely to affect lungs, diaphragm, and chest wall mechanics (46). While this study was limited to FVC, FEV1, and PEF, other studies have found an inverse relationship between increasing BMI and vital capacity, total lung capacity, and functional residual capacity (70, 71).

The mean FVC, FVC% FEV1%, PEF, and PEF% were higher in parous than nulliparous and first birth showed the greatest effect on the pattern in both pregnant and non-pregnant. Despite that, only FVC% and FEV1% were statistically significantly related to parity in non-pregnant women and the relationship disappeared after adjusting for age, height, and weight. Similar results were found in a longitudinal study that involved pregnant women (20). However, other studies found a significant adjusted positive effect of parity on spirometry test values (54, 67). It has been postulated that the hormonal effects of pregnancy to compensate for mechanical changes and maintain lung function persists even after the uterus have returned to its small size (67, 72). The median FEV1/FVC ratio was lower in parous than nulliparous in both pregnant and non-pregnant women but was statistically significant only in pregnant women after adjusting for age, height, and weight. Similar findings have been presented by other studies (20). This could be due to disproportionate changes between FVC and FEV1.

Spirometry test values decreased as gestation age advanced. This is in line with other studies conducted previously (20, 73, 74). This decline has been attributed to the limited maternal effort as gestation advances due to an increase of maternal weight, uterine enlargement, and a degree of pulmonary edema (Brancazio, Laifer, and Schwartz, 1997). However, spirometry test values have been observed to remain within normal limits (18, 19). Other studies have reported values that increased during pregnancy and persisted to the postpartum period (33, 66, 67). But those studies concentrated on whether spirometry test values were normal as compared to a known range or not. In our study, we compared absolute values and their % of predicted values of pregnant women at different gestational periods.

FVC, FEV1, and PEF values of pregnant women were significantly lower than values predicted by age and height if they were not pregnant. The observation was similar for non-pregnant women. The other study that was done in Tanzania also reported a similar finding (76). This suggests that the reference equation derived from non-African settings could have over-predicted expected values. Also, the other study done on young men in Tanzania concluded that spirometry reference equations developed from non-African populations tended to overpredict measurements of black Africans (76). Likewise, it has been noticed by other studies in which reference values over-predicted expected values (60, 61, 64).

Nevertheless, when compared to non-pregnant women; FVC, FEV1, and PEF of pregnant women were significantly lower even after adjusting for age, weight, and parity. This could be explained by ribcage and volume displacement long known to take place during pregnancy (13, 15, 19, 77). However, Le Merre et al discussed that changes during pregnancy do not cause significant respiratory functional changes since mechanical effects are balanced by hormonal factors (78). Unlike other studies which compared pregnant values against the established normal range, this study compared values of pregnant women against values of non-pregnant women.

To our knowledge, this is the first study on lung function conducted among pregnant women using spirometry in African settings. Spirometry test values of pregnant women were compared against values of non-pregnant women rather than comparing against the established normal range of values. This study was able to adhere to standard operating procedures and infection prevention protocol

This study was not without limitations. Non-pregnant healthy women were likely to hesitate to participate in the study as they would feel a lack of need for tests. Only women who booked their first visit in their first trimester were included in a study. Pregnant women were obtained by random sampling while non-pregnant controls were obtained consecutively. Also, many potential participants hesitated to participate worrying that they were tested for the Coronavirus. These could have influenced the nature of women who participated in this study and limited our ability to match the characteristics of pregnant women. Our study was limited to spirometry, therefore, could not explain other observations which would be well explained by other lung function testing methods such as measuring static lung volumes. Also, we did not quantify hormonal effects on the spirometry profile by hormonal assay.

Conclusion

Spirometry test values of pregnant women decreases as gestational age advance and they are lower than profiles predicted by their age and height if they were not pregnant. Moreover, spirometry profiles of pregnant women are lower than the profiles obtained from non-pregnant controls. Spirometry profiles of pregnant women and non-pregnant African women vary according to their age, height, and parity. Weight and BMI does not affect the spirometry profile of pregnant and non-pregnant women.

This study recommends the use of spirometry in pregnancy to assess lung function. However, spirometry test values of pregnant women should be carefully interpreted against non-pregnant references. There is also a need to evaluate the accuracy of non-pregnant spirometry reference equations in predicting pregnant test values. The relationship between spirometry test values and age is phasic, therefore non-linear models should be considered for calculating predicted values of young African women. Also, there is a need of evaluating the suitability of various reference equations in predicting spirometry test values of young African women. Weight and BMI may not be suitable for studying the effect of body composition on spirometry profile hence other measures should be considered.

Abbreviations

ATS:	American Thoracic Society
BMI:	Body Mass Index
BMJ:	British Medical Journal
CI:	Confidence Interval
Cm	Centimeter
ERC:	Ethical Review Committee
ERS:	European Respiratory Society
FEV1:	Forced Expiratory Volume in 1 Second
FVC:	Forced Vital Capacity
Kg:	Kilogram
L:	Liter
ml:	milliliter
MUHAS:	The Muhimbili University of Health and Allied Sciences
NHANES:	National Health and Nutrition Examination Survey
Non-preg:	non-pregnant
PEF:	Peak Expiratory Flow
SD:	Standard Deviation
SEM:	Standard Error of Mean
SOP:	Standard Operating Procedures

Declarations

Ethics approval and consent to participate

Ethical clearance was obtained from MUHAS institutional review board. Permission to conduct the study was obtained from Mnazi Mmoja hospital administration via Dar es Salaam regional administrative secretary, Ilala District Administrative Secretary, and Ilala Municipal Council Executive Director. Also, permission to include MUHAS female persons as controls was obtained from the Vice-Chancellor Research Academic and Consultancy. All methods were carried out in harmony with the Helsinki Declaration. Study protocols and objectives were revealed to women. Written informed consent was prearranged and signed by women before enrolment into the study. To maintain privacy, a pregnancy test among the non-pregnant group was conducted at the MUHAS physiology laboratory. Every participant undertook a test and received results privately. Personal identifying information was not collected and all

other information collected was used for research purposes only. Women with abnormal findings were recommended for medical evaluation as per Mnazi Mmoja hospital protocol.

Several safety precautions were taken to avoid potential complications related to the spirometry maneuver. Women among whom spirometry was contraindicated were excluded. All women who meet inclusion were screened for contraindications using a tool adapted from NHANES 2011 procedure manual, ATS/ERS 2019 update, and BMJ updates on spirometry contraindications. Also, spirometry was done in a seating position as a precaution against potential lightheadedness due to exertion during the spirometry maneuver.

Consent for publication

Not applicable (NA)

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors contributions

All authors worked together to write and review the manuscript.

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Figures

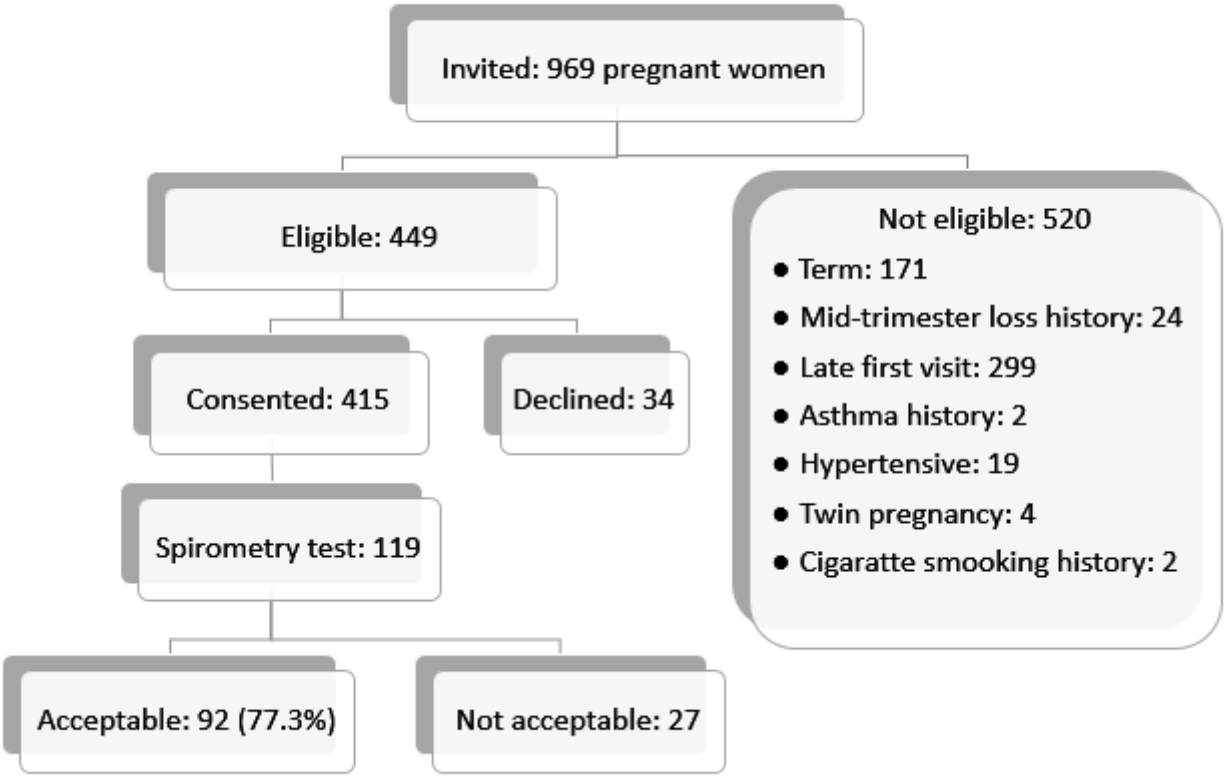

Figure 1

Schematic for recruitment of pregnant participants

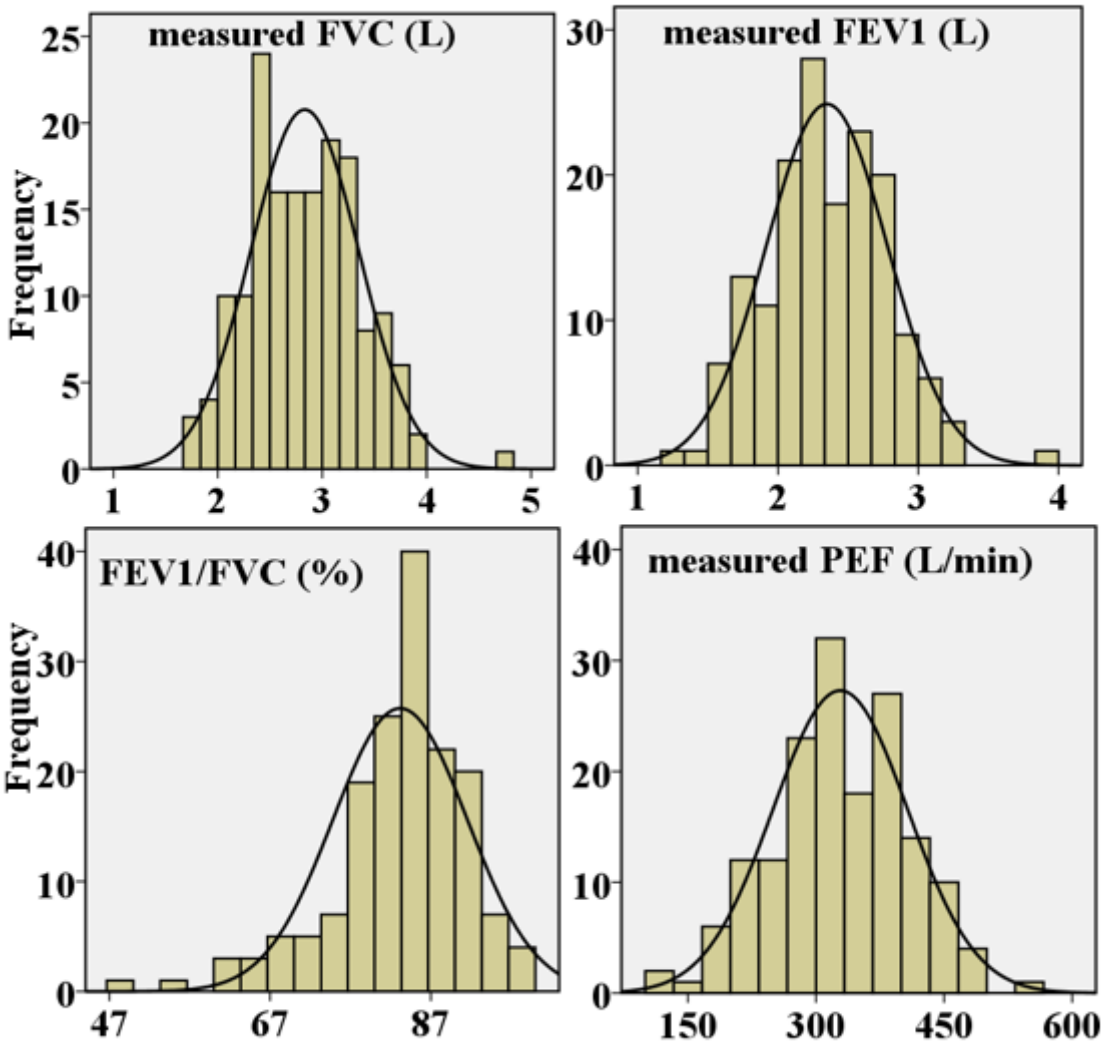

Figure 2

Histogram describing the distribution of spirometry test values of participants (n = 190)

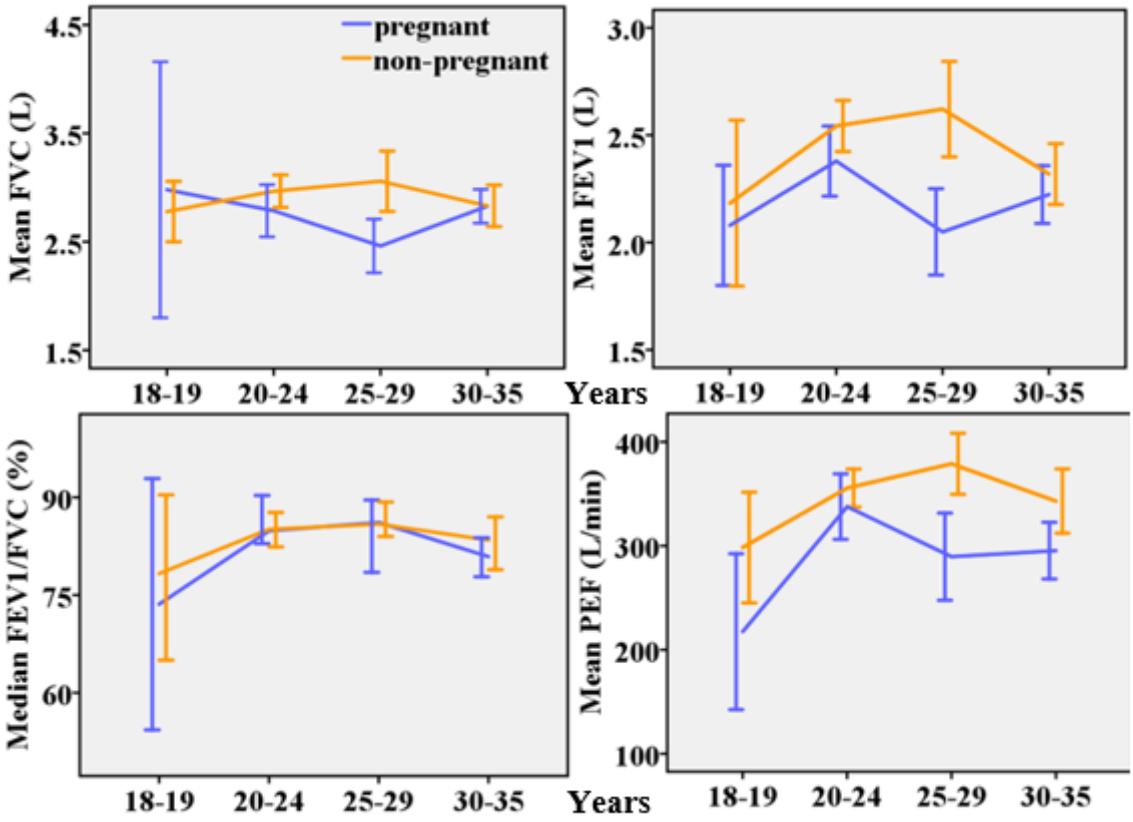

Figure 3

Plots of spirometry test values against age [n = 190, Error bar: ±2SEM (95%CI)]

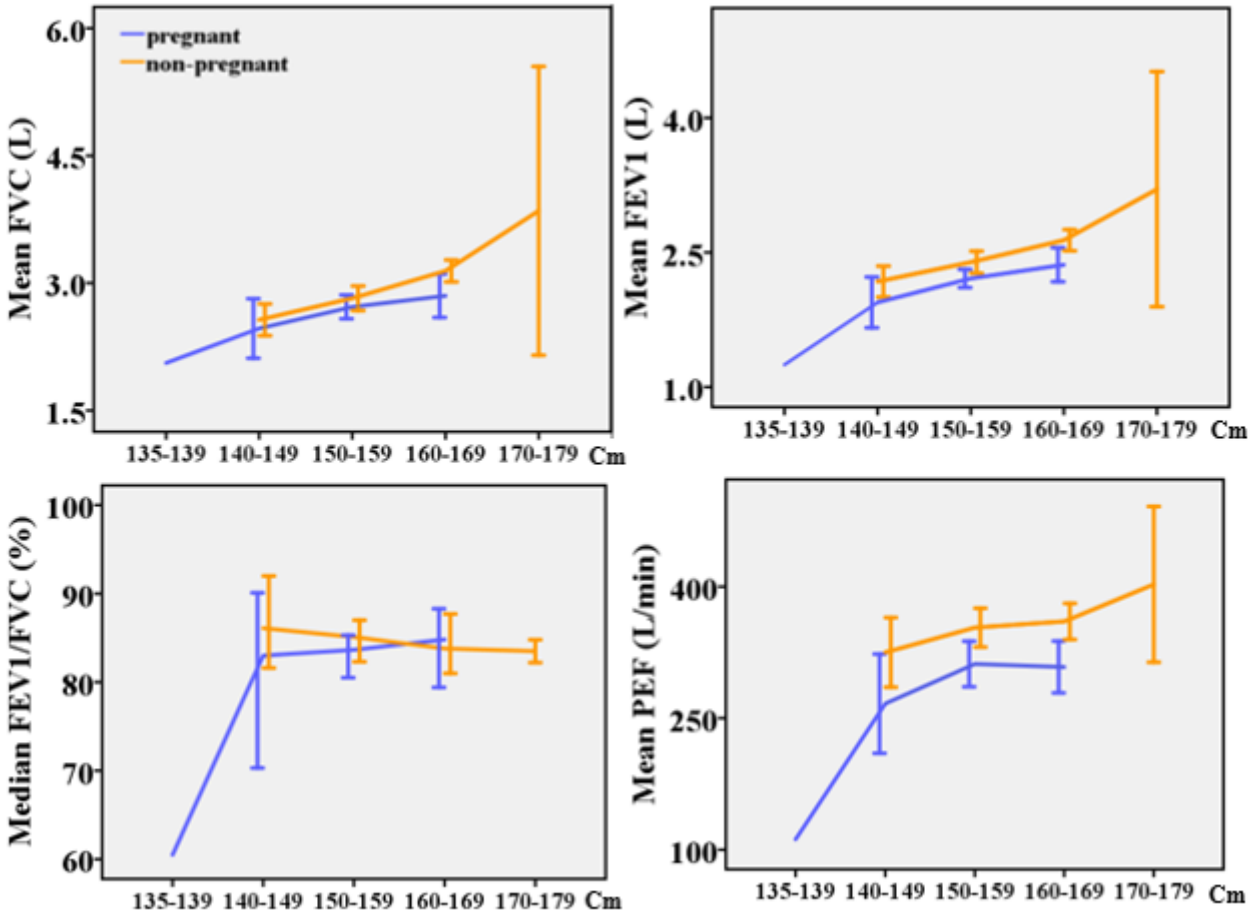

Figure 4

Plots of spirometry test values against height [n = 190, Error bar: ±2SEM (95%CI)]

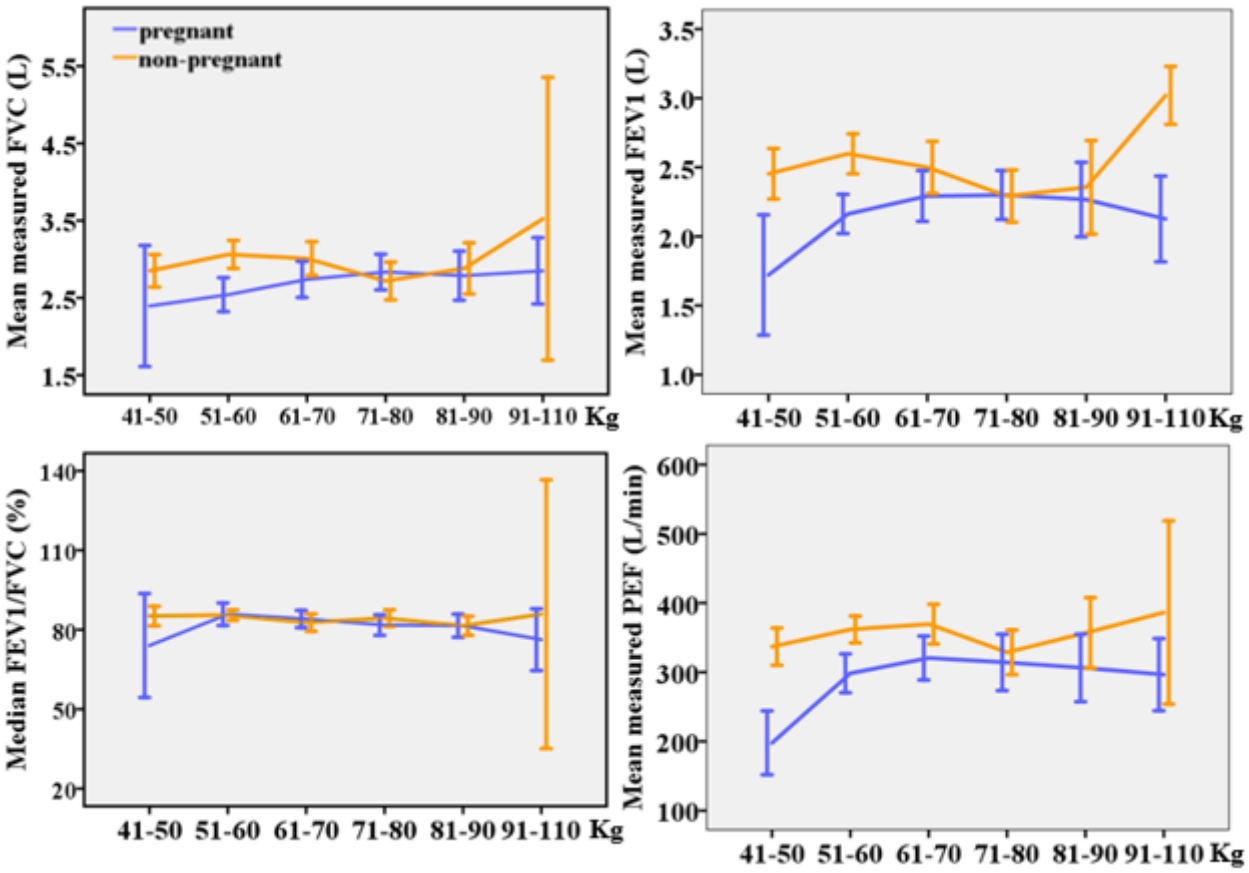

Figure 5

Plots of spirometry test values against weight [n = 190, Error bar: ±2SEM (95%CI)]

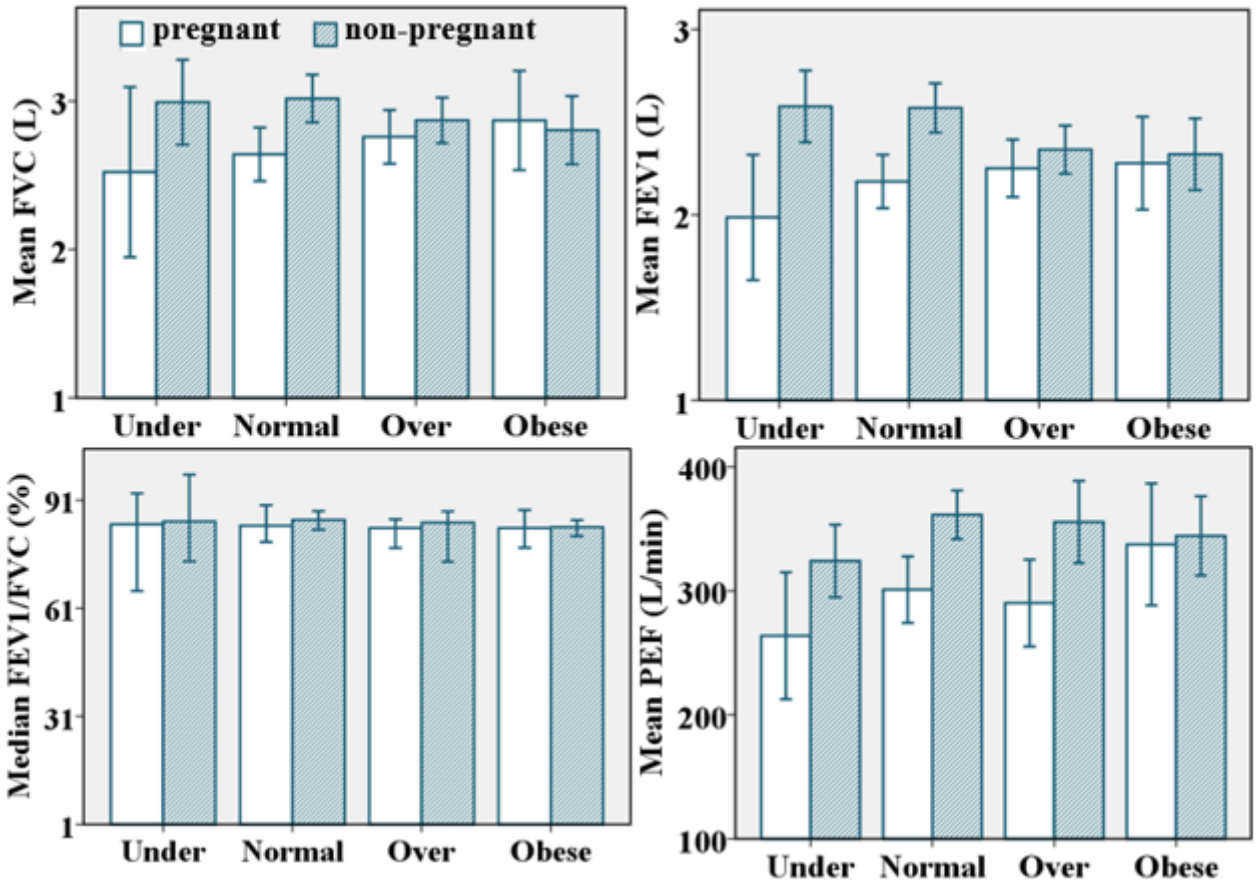

Figure 6

Plots of spirometry test values against BMI [n = 190, Error bar: ±2SEM (95%CI)]

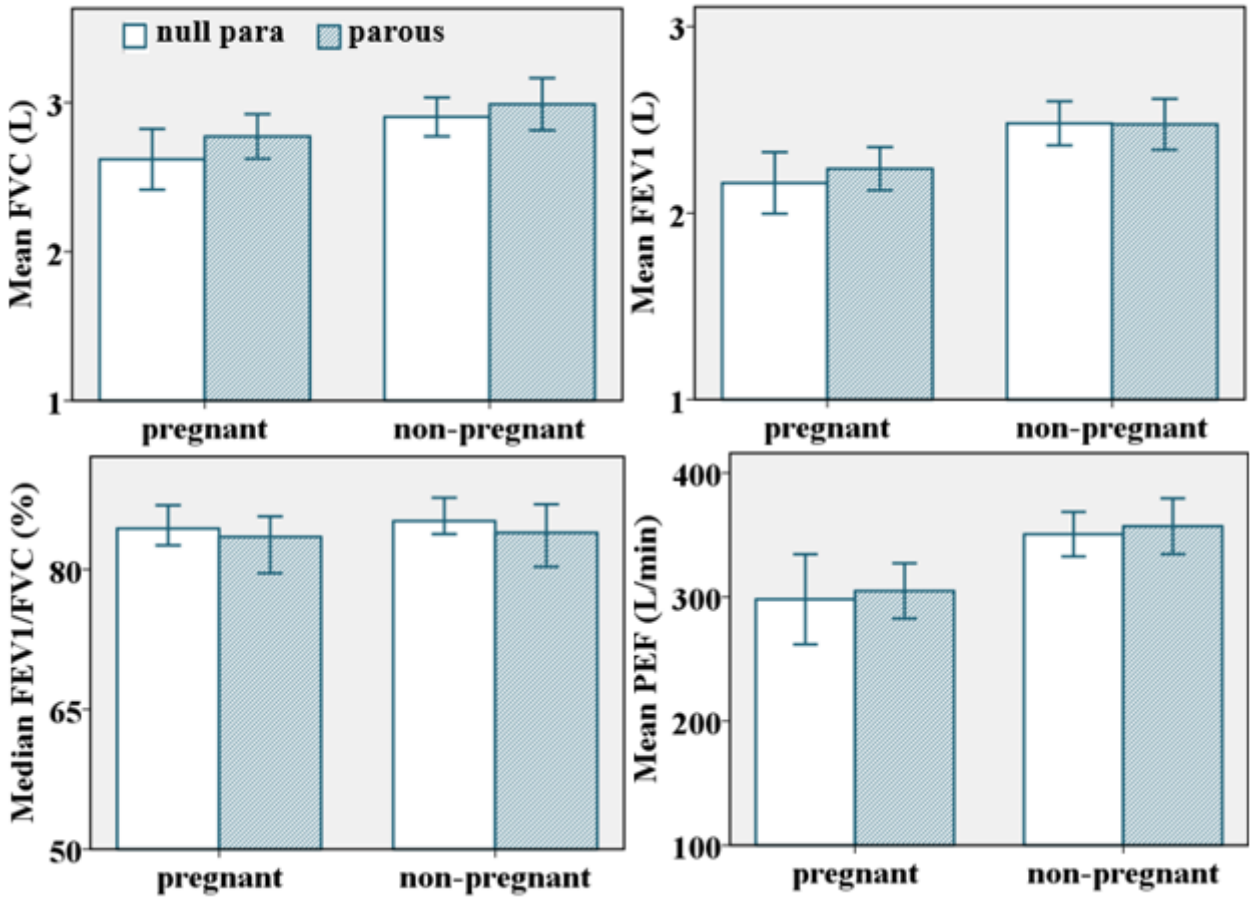

Figure 7

Plots of spirometry test values against parity [n = 190, Error bar: ±2SEM (95%CI)]

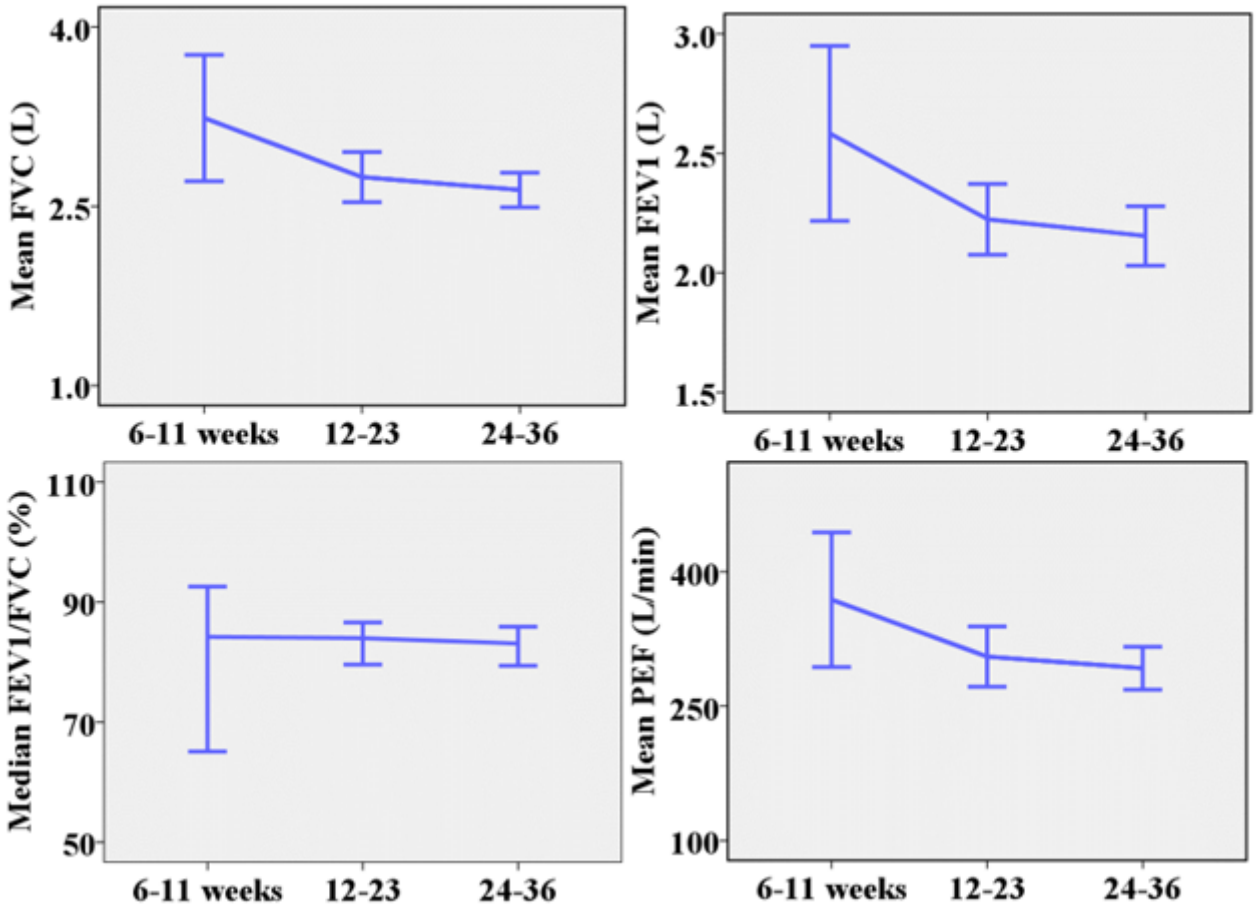

Figure 8

Plots of spirometry test values against gestational age [n = 92, Error bar: ±2SEM (95%CI)]