Performing Spirometry for Pulmonary Function Test for Non-Pregnant and Pregnant Women by using Different Biomedical Devices

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***Abstract* - The human respiratory system consists of a series of structures and organs that inhales oxygen from the environment, holds it inside the body and expels carbon dioxide as waste product. Many techniques and instruments are available for evaluating respiration, the aim of this research is to: i) study the Pulmonary Function Test (PFT) during different trimesters of pregnancy and do tests for ordinary non-pregnant women, which are performed by using Spirometer and PowerLab instruments and appropriate software; ii) study the influences of pregnancy on expiration of women, and iii) using Statistical Package for Social Sciences (SPSS) software to run t-test as an independent sample test, to compare the expiration of non-pregnant and pregnant women in the second and third trimester depending on their: Peak Expiratory Flow (PEF), Forced Expiratory Flow (FEF25, FEF50, FEF75), Forced Expiratory Volume (FEV1), and Forced Vital Capacity (FVC). The research was carried out on sixty-five women who performed PFT to obtain their Spirometric parameters. The results showed the differences in flow-volume and volume-time curves between the non-pregnant and pregnant women, while the results of the SPSS software showed a significant difference ($P<0.05$) between these non-pregnant and pregnant women in the third trimester specifically.**

Keywords* - *PFT, FEV1, FVC, PEF, FEF.

I. INTRODUCTION

The human respiratory system is the systems that take up oxygen from outside the body and expels the carbon dioxide 1, 2. There are three main parts of the human respiratory system:(1) the airway includes the nose, mouth, pharynx, larynx, trachea, bronchi, and bronchioles transport air from the lungs to the body's exterior and vice versa 1, 2, (2) the lung is the organ that is responsible for gas-exchange in the human body 2, 3, and (3) the muscles of respiration there are a set of muscles surrounding the lungs that have the ability to inhale or exhale the air from the lungs 4. Pulmonary function test (PFT) are tests of breathing. It measures volume and flow of air that can be inhaled and exhaled to find out how well lungs are functioning. There are several types of PFT; Spirometry is the most common lung function test. Spirometry is a simple and most common test of lung function. It is helpful in measuring breathing patterns that detect conditions such as pulmonary fibrosis, asthma, COPD and cystic fibrosis. It is also useful in health surveillance, in which measuring breathing patterns over time. The spirometry test can be performed by using a device which is called a spirometer 5.The pulmonary function tests include the following parameters: Forced Expiratory Volume in the first second (FEV1), Forced Vital Capacity (FVC), Forced Expiratory Flow (FEF25, FEF50, and FEF75), and Peak Expiratory Flow (PEF) these parameters are called 'spirometric parameters' that are used to identify if there are restriction or obstruction in the airways of the respiratory system and detects various types of diseases. During pregnancy, there are many physiological changes occurs in the organs and tissues of the woman's body as a result of a growing fetus 6, 7. In this study, the pulmonary function tests were studied and concerned for two groups of non-pregnant and pregnant in the different trimester of pregnancy to make a comparison between the expiration of them and to study the effect of pregnancy overload on women's breathing..

II. RELATED WORKS

There are some of the researches that are related to the pulmonary function tests which describing the comparison of the breath between non-pregnant and pregnant in the different trimester of pregnancy.

D. K. Sunyal, M. R. Amin, A. Yasmin, G. M. Molla, M. L. Ali, and M. Sultana in 2014 8, studied FEV1 and the ratio of FEV1/FVC %, 100 women were taken to perform the pulmonary function test by using spirometer, 25 cases of them are non-pregnant who takes as a control group, 25 cases are pregnant in the first trimester, 25 cases are in the second trimester, and 25 cases in the third trimester. All cases perform spirometer to obtain their PFT. The results show that the FEV1 and FEV1/FVC % decreases in the third trimester of pregnancy.

A. Fadia and M. Dhadse in 2016 9, compare dynamic pulmonary function tests of non-pregnant and pregnant women. In this research 65 cases are performed spirometry, and these 65 cases divide into two group: 30 cases of non-pregnant (control group) and 35 cases of pregnant in the

third trimester of pregnancy (study group). Statistical analysis was carried out by using special software to applied t-test on the parameters (FEV1/FVC%, PEFR, and FEF 25-75) that obtained by a spirometer. The results of this research found that there are not statistically significant in the means of these parameters and the PEF is changed in the third trimester of pregnancy.

Rasika R Takee, D. A. in 2017 10, studied the effect of pulmonary function tests that happened in each trimester of pregnancy. This study involves 30 pregnant women their age range from 20 to 30 years, and they performed a pulmonary function test by using the spirometer, and the results of these tests were denoted and recorded. This research aims to study the effect that observed on FEV1, FVC, and the ratio FEV1/FVC during pregnancy of different trimester. After the results denoted, the parameters (FEV1 and FVC) and the ratio FEV1/FVC were unchanged during pregnancy and the three trimesters have no effects on these spirometric parameters.

When compared the recent study with other studies for other countries, it observed the spirometric.

III. CASES CLASSIFICATION

Sixty-five different women were selected in this study. The respiration activity was measured to them by using a spirometer in Al-Kadhimia Teaching Hospital. The flow-volume loop shows abnormal results for 25 cases of them due to asthma or smoking. Therefore, twenty-five unhealthy women were excluded. The other 40 healthy women can be classified as follow:

Group I: Control group, 25 cases of ordinary healthy non-pregnant women

Group II: the experimental group, 15 cases of ordinary healthy pregnant women (5 cases in their second trimester and 10 cases in their third trimester). Twenty-five women were picked from the forty healthy women. Respiration activity was re-measured to them using the PowerLab instrument in Al-Nahrain University. FEV1 and FVC were obtained for each case, and they are classified as follow:

Group III: Control group, 15 cases of ordinary healthy non-pregnant women.

Group IV: the experimental group, 10 cases of ordinary healthy pregnant women. All instances of pregnant women in this group are in their third trimester.

The age of these women are range from 20 to 40 years, their height is range from 147 to165 cm, and their weight range from 43 to 117 kg, So this study is applied only for the women in these limitations.

IV. EQUIPMENT AND APPARATUSES

In this paper, two devices were used to perform pulmonary function tests to obtain the spirometric parameters. These devices are a PowerLab with LabTutor software and Spirometer with SPCS.

A. Equipment and Apparatuses of PowerLab

The following apparatuses are used to perform spirometry:

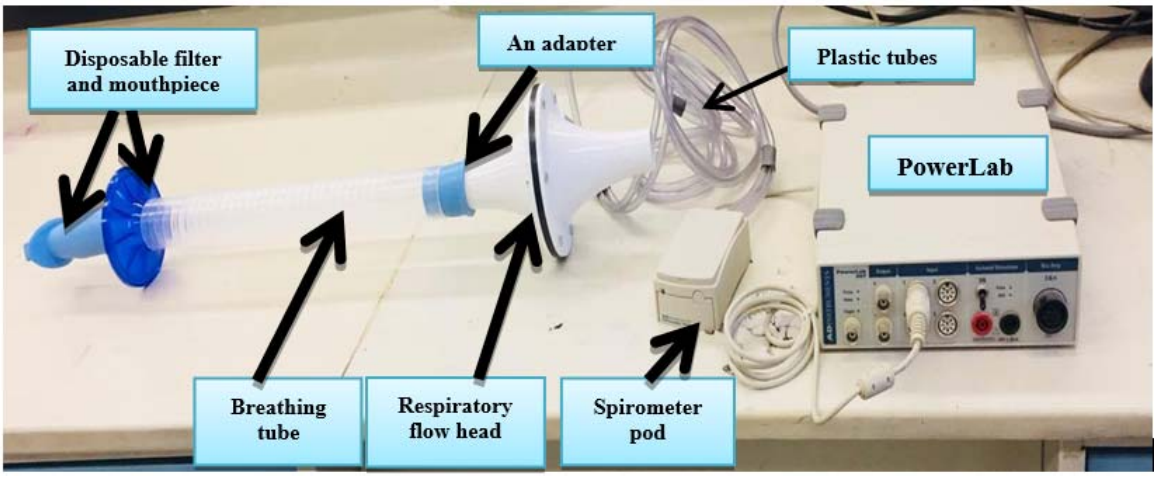

Fig. 1: PowerLab (26T) with spirometry

1. PowerLab (26 T): The PowerLab 26T (AD Instruments, Australia) is a high-performance and real-time DAQ instrument which is reliable for a wide range of teaching applications and research on life science. The 26T contains both LabTutor and LabChart software for analysis and recording data. AD Instruments offers a various range of results for sensitive and accurate measurements of respiratory to complement the applications of human research 11. Respiratory parameters like FEV1 and FVC are calculated using spirometry with LabTutor software, as shown in Fig.1.

2. UPS and PC with appropriate software (LabChart or LabTutor) for analyzing data and charting results.
3. Spirometer Pod: The Spirometer Pod (signal amplifier) is used to measure respiratory flow rates in adults in combination with suitable PowerLab and respiratory flow head. The features of the spirometer pod are: it has low air flow resolution and low noise, and it is inbuilt 30Hz LPF. Its Operating conditions: 0–90% humidity, 0–35 ˚C.
4. Respiratory Flow Head 1000 L: R respiratory flow head appropriate for use on a human for pulmonary function tests or during exercise including exercise testing or hard breathing. The respiratory flow head is made from ABS plastic, and its weight is 260 g.
5. Breathing Tube and an Adapter: The length of the breathing tube is 25 cm, and its inner diameter is 4 cm. It connects the respiratory flow head to a disposable filter. An adapter is used to connect the breathing tube to the respiratory flow head.
6. Disposable Filter: Disposable filters used in experiments of human respiration to eliminate water droplets from the stream of air and protect against infection.
7. Reusable Mouthpiece: The reusable mouthpiece is made from a thermoplastic elastomer which is reusable material and a blue Kraton material
8. Plastic Tubes: Plastic tubes are used to connect respiratory flow head to spirometer pod.
9. Nose clip
10. Weight and height scale.

B. Equipment and Apparatuses of Spirometer

- Spirometer, (spirometer, Germany) it is a well standard technique used to provide information about lung capacities, volumes, and resistance. It is an airtight box in shape and used to measure PEF, FEF25, FEF50, and FEF75 that are necessary to diagnosis restrictive and obstruction disease, as shown in Fig.2 A.
- Computer with Spirometry PC software (SPCS) for analyzing data and charting results, as shown in Fig.2 C, and Fig.2
- Printer for obtaining results in a hard copy, as shown in Fig.2 C
- Disposable or sterilized mouthpiece, as shown in Fig.2 E
- Nose clip, as shown in Fig.2 D
- Weight and height scale, as shown in Fig.2 B.

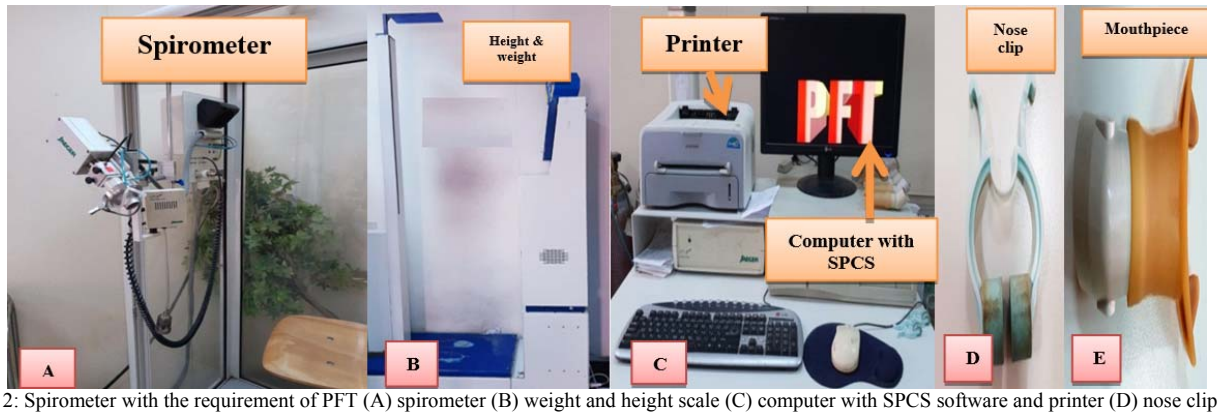

Fig. 2: Spirometer with the requirement of PFT (A) spirometer (B) weight and height scale (C) computer with SPCS software and printer (D) nose clip (E) mouthpiece

C. Preparation and Procedure

The same procedure was applied and repeated for both spirometer and PowerLab instruments to obtain values that are important for making a comparison between pregnant and non-pregnant women. The following process explains how the woman prepared to performs spirometry:

The age and sex of the woman were recorded

The weight and height of the woman were recorded by using weight and height scale

A disposable, one-way, sterilize, clean mouthpiece was attached to the spirometer

The woman sat straight on a chair that able her to use the mouthpiece, as shown in Fig.3 comfortably.

The nose of the women was closed by a nose clip to prevent air escaping from the nose, and then the mouthpiece was inserted into her mouth.


Fig.3: Non-pregnant woman perform PFT by using the PowerLab instrument

The woman was relaxed and breathed normally for a few times and then breathed enforceably as far as possible to obtain spirometric parameters. The procedure was repeated with a continuous reading of normal breathing and maximum inhalation and exhalation. The women removed the nose clip and mouthpiece. The reading obtained was checked if it is satisfactory or not. Repeat it if necessary.

V. RESULTS AND DISCUSSION

Most types of spirometers show the flow-volume and volume-time graphs, which is called spirograms.

A. Flow–Volume Loop

The flow–volume loop can be indicative of a variety of disease patterns such as asthma or Chronic Obstructive Pulmo-nary Diseases (COPD). It shows the rate of airflow along the y-axis and the total volume expired or inspired along the X-axis. In this research, Spirometer with SPCS software was used to obtain flow-volume loop and spirometric parameters. These spirometric parameters are:Peak Expiratory Flow (PEF) is the measure of the expired air from the trachea-bronchi in the large upper airways. Forced Expiratory Flow (FEF25, FEF50, and FEF75) are the measurements of the expired air from the narrowing of small airways. It meant the flow of air between the points FEF25 and FEF 75 and called the FEF25-75. At the start of the test, both volume and flow are equal to zero.

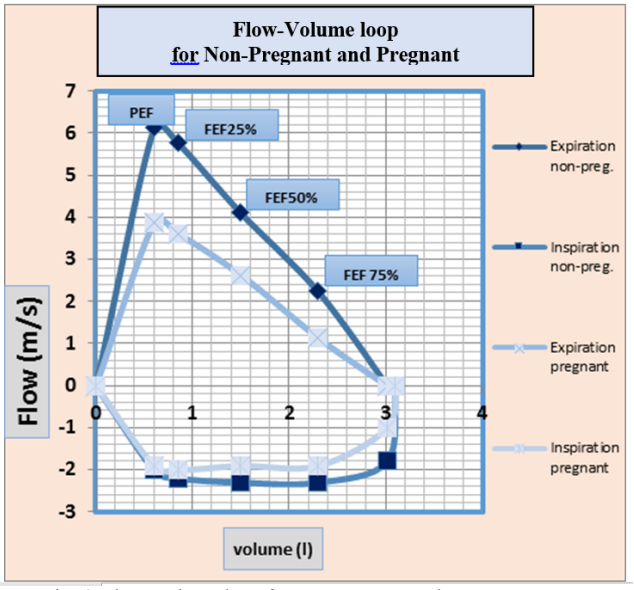

Fig. 4: Flow-Volume loop for non-pregnant and pregnant women

As non-pregnant women exhale, the curve rapidly raises to the peak expiratory flow (PEF) followed by a uniform, steady drop until all of the air is exhaled, and the flow reaches the x-axis, as the woman inhales back in, the loop returns to the zero (negative air flow) as shown in Fig. 3. While for pregnant women, the flow-volume loop has the same normal shape as for a flow-volume loop for non-pregnant but there is an absolute reduction in the volume, as shown in Fig. 4.

B. Volume-Time Curve

A volume-time curve displays volume on the y-axis and time on the x-axis. The most important parameters needed to graph a volume-time curve are obtained by using the PowerLab instrument with Spirometry and LabTutor software. These im-portant parameters are:

Forced Expiratory Volume in the first second (FEV1) is the volume of air that the woman can exhale in the first second of a forced expiration.

Forced Vital Capacity (FVC) is the total volume of air that the woman can forcibly exhale in one breath; it appears as the width of the widest portion of the curve.

In this study, we observed that there are differences between the values of volumes (FEV1 & FVC) for the same group, these differences are due to age, weight, height, and clinical situation for each woman. The results show that FEV1 ranges from 2.03 to 3.3 (L) and FVC from 2.35 to 3.45 (L) for non-pregnant women. When comparing these resulting values with standards values of related works it was found that the expiration of these women are healthy and there are no obstruction and disease in their airways and lungs. The results (FEV1 & FVC) for non-pregnant women are shown in Fig.5.

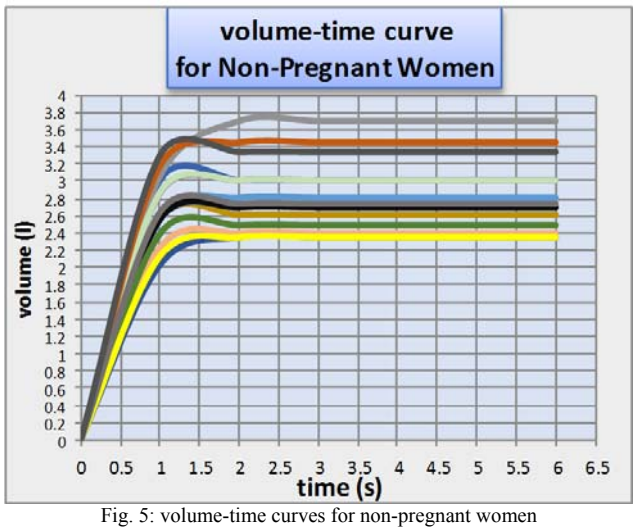

Fig. 5: volume-time curves for non-pregnant women

For pregnant women, results show that FEV1 is range from 1.80 to 2.45 (L) and FVC is range from 1.92 to 2.55 (L). From these results observed that there are decreases in the values of volumes (FVC & FEV1) during the third trimester of pregnancy. The results of FEV1 and FVC for pregnant women are shown in Fig.6.

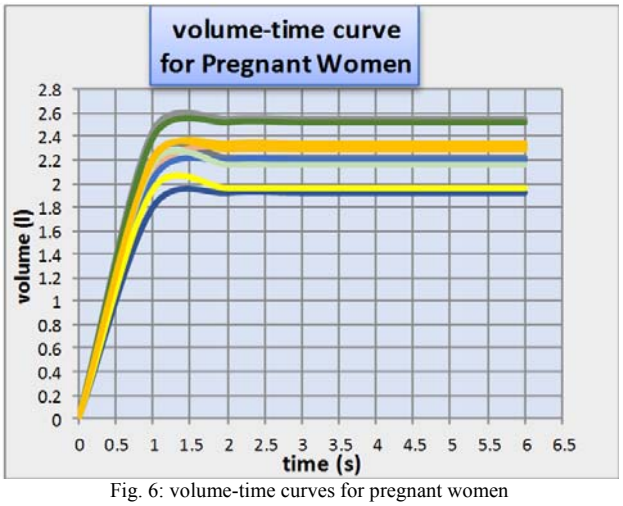

Fig. 6: volume-time curves for pregnant women

VI. CONCLUSION

Based on the results obtained by using Spirometer and PowerLab with SPSS software, we conclude the following:

1. There was a significant difference in PEF ($t=8.284$, $p < 0.001$), FEF75 ($t=-6.108$, $p < 0.001$) and FEF50 (-3.489, $p < 0.002$) between non-pregnant and pregnant women in the second trimester of pregnancy, it means that the spirometric parameters (PEF, FEF75, and FEF50) were decreased in the second trimester of pregnancy, while there was no significant difference (unchanged) in FEF25 ($t=-0.419$, $p = 0.678$) between them.

2. There was a significant difference (decreases) in PEF and FEF25 between non-pregnant and pregnant women in the third trimester (for PEF $t=15.914$, $p < 0.001$ and for FEF25 $p < 0.001$, $t=7.3$). This indicates, at the beginning, the expiration is more easily to occur and normal amount of air exit from the lungs which means that the lungs has held enough amount of air, and there was no obstruction in the airway for non-pregnant, while for pregnant the expiration become harder, and the values of PEF and FEF25 are lower than the same values for non-pregnant due to reducing the capacity of lungs to hold normal amount of air, so not enough or normal amount of air exit from lung during expiration.

3. There was no significant difference (unchanged) in FEF50 ($t=2.122$, $p = 0.41$) and FEF75 ($t=-1.331$, $p = 0.192$) between non-pregnant and pregnant women in the third trimester. This indicates at the end of breathing. The expiration becomes more easily for pregnant and non-pregnant women. It means there is no obstruction in the narrowing of small airways.

4. There was a significant difference (decreases) in FEV1 ($t= 3.930$, $p < 0.001$) and FVC ($t=4.234$, $p < 0.001$) between non-pregnant and pregnant women this is mainly due to a pregnant overload as explained previously in this chapter.

5. This study confirmed that the reduction in the spirometric parameters is due to the inability of the lungs to expand and hold enough amount of air because during pregnancy (especially in the third trimester) the uterus is enlarged and takes up more space and being pressured against the diaphragm and the muscle below lungs. Therefore the lungs are compressed, this compression in lungs preventing them from fully expands and take a reasonable amount of air. So that PEF, FEF25-75, FEV1, and FVC of pregnant are smaller than the PEF, FEF25-75, FEV1, and FVC of non-pregnant.

REFERENCES

[1] Ionescu Claramihaela. The Human Respiratory System. London: Springer London LTD; 2013.
[2] Tu J. Computational fluid and particle dynamics in the human respiratory system, Springer Science & Business Media, 2012.
[3] Scanlon VC, Sanders T. Essentials of anatomy and physiology. Philadelphia: F.A. Davis Company; 2006.
[4] Respiratory System | Interactive Anatomy Guide [Internet]. InnerBody. [cited 2018Oct22]. Available from: http://www.innerbody.com/anatomy/respiratory#continued
[5] Bellamy D, Booker R. Spirometry in practice: a practical guide to using spirometry in primary care. Cookham: Direct Pub. Solutions; 2000.
[6] Stages of pregnancy [Internet]. womenshealth.gov. 2018 [cited 2018Oct22]. Available from: http://www.womenshealth.gov/pregnancy/youre-pregnant-now-what/stages-pregnancy.
[7] Huffman JW. Pregnancy [Internet]. Encyclopædia Britannica. Encyclopædia Britannica, inc.; 2018 [cited 2018Oct22]. Available from: http://www.britannica.com/science/pregnancy#ref607328.
[8] Sunyal DK, Amin MR, Yasmin A, Molla GM, Ali ML, Sultana M. Study of Forced Expiratory Volume in First Second (FEV1) and Ratio of Forced Expiratory Volume in First Second and Forced Vital Capacity in Percentage (FEV1/FVC%) in Pregnant Women. Journal of Enam Medical College. 2012;2(1).
[9] Fadia A, Dhadse M. A comparative study of static pulmonary function tests in Indian pregnant and non-pregnant women. International Journal of Research in Medical Sciences. 2016;:545–8.
[10] Rasika R Takke, D. A. Effects of different trimesters of pregnancy on pulmonary function test. International Journal of Multidisciplinary Research and Development. 2017;:168-171.
[11] S. Y. Al-Rubaie, S. J. Abbas, and A. F. Al-Hashimi. Comparison of the Low-Level Laser Irradiation Effect on Skeletal Muscle Fatigue Using Different Wavelength and Doses. The International Journal of Engineering and Science (IJES). 2017, 49-56.