Kufa Journal for Veterinary Medical Sciences Vol.5 No.1 (2014) 115-124

Kufa Journal for Veterinary Medical Sciences
www.vet.kufauniv.com

Evaluation of expiratory gas mass device as a measure of lung function test in healthy Iraqi subjects

Dr.Yesar MH Al-Shamma* Dr. Basim MH Zwain**
Nibrass HAS Al-Husnawee***

*MBChB, Ph. D. UK, Prof. of physiology, College of Medicine, University of Kufa
**B. D. S. ,M. Sc., Ph .D. , Prof. of physiology, College of Medicine, University of Jabir ibn Hayyan for Medical Sciences
***B. Sc. Ph, College of Pharmacy, University of Kufa

Abstract:

Several types of devices are used to perform spirometric tests based on the measurement of lung volumes and their subdivisions. Lung volumes, hence, are represented by the volume of expired air. There was a controversy about the difference between body and ambient temperatures which may extremely affect gas volume. The aim of this cross sectional study is to construct and evaluate a simple device called expiratory gas mass device as a reliable, reproducible, accurate and convenient tool to substitute Vitalograph spirometer as a measure of lung function in healthy Iraqi subjects.

Forced expiratory maneuver is done by(300) healthy Iraqi subject aged (20-50)years old 146 male and 154 female through the standardized spirometer and then through the newly constructed gas mass device. The accuracy (systematic error) and reproducibility (random error) were tested for the constructed gas mass device .

The results revealed that there were no significant differences in values of FVC and AGM measured by standard Vitalograph spirometer and gas mass device respectively between male and female .Regression lines indicated that there were strong positive correlations between gas mass (GM) and FVC in male and female.

It is concluded that gas mass device is simple, portable and easily handled device. It is also reproducible and accurate device for the measurement of GM in normal subjects.

Key words: Gas mass device, AGM, FVC and spirometers.

تقييم جهاز كتلة غاز الزفير كوسيلة لفحص وظائف الرئتين عند العراقيين الأصحاء

د. يسار محمد حسن الشماع* د. باسم متعب هادي زوين**
نبراس حسين عبد الساده الحسناوي

*أستاذ، دكتوراه في الفسلجة الطبية، كلية الطب، جامعة الكوفة
**أستاذ، دكتوراه في الفسلجة الطبية، كلية الطب، جامعة جابر بن حيان للعلوم الطبية
***بكالوريوس صيدلة، كلية الصيدلة، جامعة الكوفة

الخلاصة:

لقد أستخدمت العديد من الأجهزة لغرض فحص وظائف الرئتين تعتمد على قياسات حجوم الرئتين وأجزاءها والتي تتمثل في حجم الغاز الزفيري. ودار جدل حول الأختلاف بين درجة حرارة الجسم والمحيط الخارجي والذي يمكن أن يؤثر

بشكل كبير على حجم الغاز. الهدف من هذه الدراسة المقطعية تصنيع وتقييم جهاز بسيط يسمى (جهاز كتلة غاز الزفير) كوسيلة معتمدة وقابلة للتكرار ودقيقة وملائمة لفحص وظائف الرئتين لدى العراقيين الأصحاء بدلاً عن جهاز فحص كفاءة الرئتين القياسي (فايتالوغراف).
أجرى (300) شخصاً من العراقيين الاصحاء الذين تتراوح اعمارهم مابين (20-50) سنة 146 شخصا من الذكور و 154 من الاناث مناورة الزفير القسري خلال جهاز فحص كفاءة الرئتين القياسي ثم خلال جهاز كتلة الغاز الزفيري المصنع. وقد تم فحص الدقة (الخطا المنهجي) وقابلية التكرار (الخطأ العشوائي) للجهاز المصنع.
تمت المقارنة بين السعة الحيوية القسرية (FVC) وكتلة الغاز المعدلة (AGM) لدى مجموعتي الذكور و الإناث.وقد أظهرت النتائج أنه لايوجد هناك إختلافات معنوية في قيم (FVC) و(AGM) المقاسة في جهاز فيتالوغراف وجهاز كتلة غاز الزفير على التوالي. بينت خطوط الإنحدار بأن هناك إرتباط طردي قوي بين (GM) و(FVC) لدى الذكور والإناث.
حسب نتائج الدراسة يمكن الإستنتاج أن جهاز كتلة غاز الزفير هو جهاز بسيط وسهل الحمل والنقل كما أنه دقيق وقابل للتكرار لقياس كتلة الغاز عند الأصحاء.

Introduction:

Lung function tests are very useful diagnostic, follow up and research measures for healthy and respiratory compromised subjects (1 - 4). The simplest, yet the most informative, lung function tests are the spirometric tests (5 - 7) .They involve the forced vital capacity (FVC), the forced expiratory volume in first one second (FEV_1) and the forced expiratory volume ratio (FEV%) (8-11). Several types of devices are used to perform spirometric tests (12,13) based on the measurement of lung volumes and their subdivisions. Lung volumes, hence, are represented by the volume of expired air. There was a controversy about the difference between body and ambient temperatures which may extremely affect gas volume , but this is thought to be solved by temperature correction (14,15). Temperature correction, however, may not be the precise solution in extremely fluctuating environmental temperatures. A fixed amount of expired gas has a constant mass despite the changes in pressure or volume as is implied by the law of conservation of mass in a closed system by Antoine Lavoisier (16).In present research, new trends to adopt the expired gas mass as new simple method to test lung function. The notion is simply benefitting and rearranging the general gas formula as follows(17,18) :

$$PV = nRT,$$

But $n = m/MW$

So, $PV = mRT/MW$

Where:

P is the partial pressure of gas
V is its volume
n is its number of moles and
m is the gas mass
MW is its molecular weight
R is the gas constant
T is the temperature in Kelvin

Hence, when other factors are constant, gas volume is directly proportional to its mass.

$V \alpha m$

Expired gas mass is simply measured with a sensitive balance inside the gas mass device which is locally constructed.Present research targets at testing the hypothesis that the expired gas mass (EGM) could significantly and acceptably alternate or conjugate the forced vital capacity (FVC) as a measures of lung function in healthy subjects.

Materials and Methods:

Measurements of forced vital capacity (FVC) and the expired gas mass (GM) were done for a total number of 300 healthy subjects (146 males and 154 females) aged 20-50 years (31.84 ± 9.28 years). Their heights being, collectively, ranging from 147 to 197 cm (166.54 ± 10.98 cm) and their weights ranging from 55 to 102 kg (72.38 ± 9.19 kg). They were randomly chosen from the general population (they were teachers, medical staff, university students…etc). Subjects with abnormal lung function such as smokers and subjects with respiratory diseases were excluded. The participants were classified according to gender into two groups, **Group A:** 146 male age range 20-50 years, (30.71 ± 8.26 years), height (176.78 ± 5.17 cm) , weight (80.09 ± 6.04 kg) and **Group B:** 154 female age range 20-50 years, (32.90 ± 10.04 years), height (158.12 ± 6.09 cm), weight (64.65 ± 6.45 kg). A well calibrated automatic height and weight measuring device was used which is the Digital Height and Weight Scale made by Jookoo Co. Ltd, Tokyo, Japan, which precisely measures the height (in centimeters) and weight (in kilograms).

A wedge bellows spirometer is used to record the measured FVC values(19). It is the standardized Vitalograph spirometer manufactured by Vitalograph Medical Instrumentation Co. Ltd, Buckingham, England. Spirometric measurements were done in sitting position after a period of resting time to achieve the steady state which means that the heart rate in consecutive minutes is changing by less than 3 beats per minute(19) .With a clipped nose, the subject is instructed to inspire forcefully as much as possible and then to blow out through the fully and tightly encircled mouthpiece of spirometer as forceful and as quick as possible until no more air can be blown from the lungs. This is the right forceful expiratory maneuver. which is allowed to be done in three trials with the best result to be recorded(20).

The same forceful expiratory maneuver is repeated with the use of the gas mass device which is newly constructed. It is composed of mouthpiece which is attached to an inflatable valve gated balloon through a flexible hose. The mass of expired gas is measured with the use of a well isolated three digits sensitive balance (0.000) type KERN PLE-N version 2.0 02/2009 GB produced in Germany by KERN & Sohn GmbH. After 5 minutes of rest, the same forceful expiratory maneuver is done with the use of the gas mass device to record the of expired gas mass (GM). The maneuver, here, is repeated two times only (for the sake of determination of device reproducibility). Sensitivity, accuracy and reproducibility of gas mass device are evaluated with the utilization of several statistical measures. Systematic errors have been calculated for comparisons between FVC and adjusted gas mass (AGM) values(21). Random errors have been calculated for duplicate records of GM. Paired differences between each two readings and 95% tolerance limit are calculated. For the sake of some graphical comparisons, gas masses were adjusted to volumes with the use of a statistically obtained conversion equation. The equation had been obtained from the simple regression analysis of GM on FVC in the whole population.Mean ± SD are calculated for all parameters in the whole research population. Student's t-test is employed to compare the means of some couples of parameters. Correlation coefficients are extracted between some other couples. Regression lines are drawn and linked to their yielding equations. Statistical decisions are regarded significant when (p) values are less than 0.05.(22)

Results:

To evaluate the accuracy and reproducibility of gas mass device for the measurement of gas mass (GM), several statistical analyses were done:

Determination of systematic error: In order to determine the systematic error (accuracy) of gas mass device, a comparison was held between adjusted gas mass (AGM) measured by gas mass device and forced vital capacity (FVC) measured by the standard Vitalograph spirometer in the total population at a steady state.The AGM is calculated by application of an equation derived from simple regression analysis of GM on FVC in the whole study population as follows:

y = 0.34 x + 0.9405 ……. (Figure: 1-1)

x = (y – 0.9405)/0.34 ….. So; AGM = (GM – 0.9405)/0.34

The results revealed that there were no significant differences in values of adjusted gas mass (AGM) and forced vital capacity (FVC) measured by gas mass device and standard Vitalograph spirometer respectively . (Table: 1-1, Figure : 1-2).

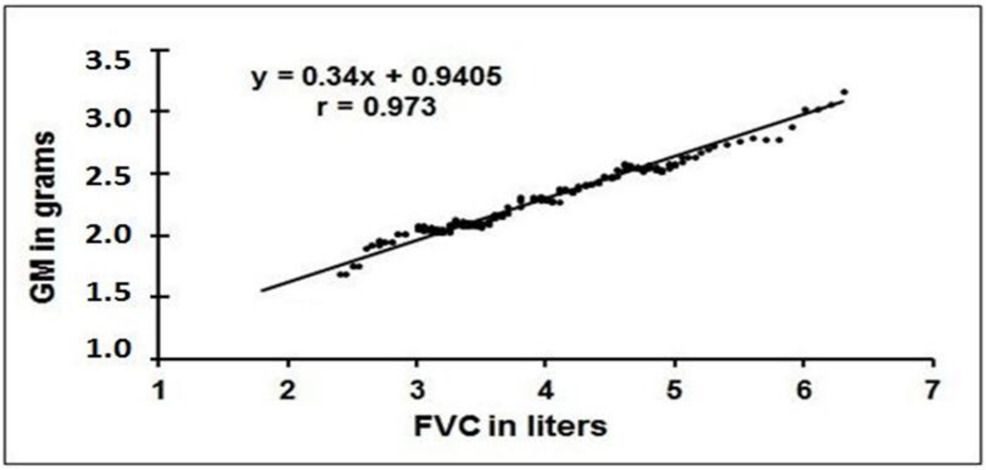

Figure (1-1): Regression of gas mass (GM) on forced vital capacity (FVC) in total study population of healthy Iraqi subjects

Table 1-1: Evaluation of gas mass device (systematic error)

Total population	**Vitalograph: forced vital capacity (FVC)L (M±SD)**	**Gas mass device: adjusted gas mass (AGM)L (M±SD)**	**p-value**
300	3.72±0.847	3.72±0.87	N.S.

N.S. : not significant
M±SD: mean ± standard deviation

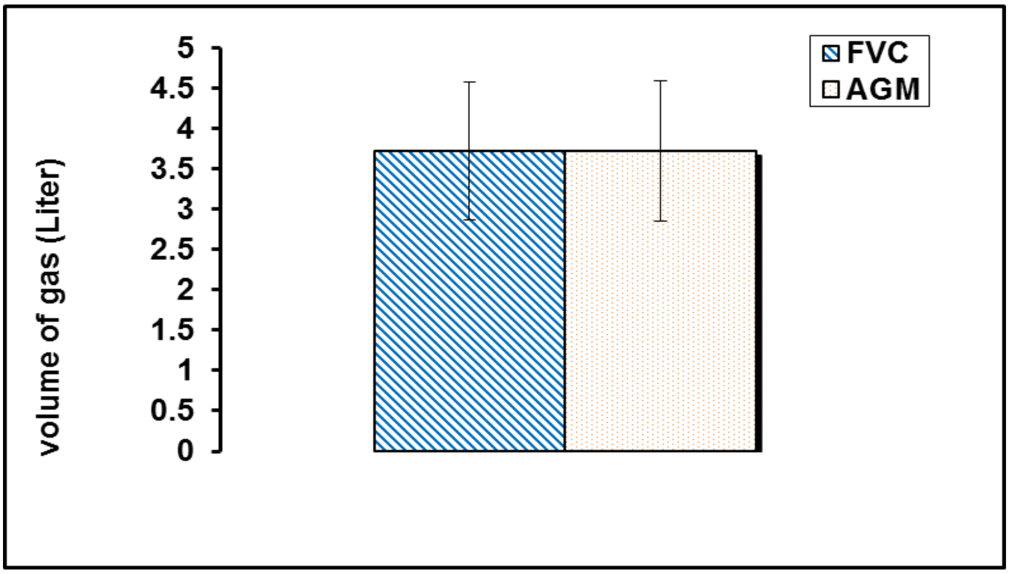

Figure (1-2): Comparison between forced vital capacity (FVC) and adjusted gas mass (AGM) in the total population of healthy Iraqi subjects.

Determination of random error:

In order to determine the random error (reproducibility or repeatability) of gas mass device ; a duplicate estimate of gas mass was made on 300 normal healthy subjects then the differences of paired estimate were determined. The result of this evaluation revealed that there was no significant difference in mean of paired differences. The calculation of 95% tolerance limit of the system was made by the equation: **2SD/Mean×100%** [22]

Tolerance limit was found to be 4.262 for gas mass ,which indicated that the gas mass device is a reproducible device . furthermore it is simple, portable and easy to be used by the patients (Table 1-2).

Table (1-2): Evaluation of Gas Mass Device (Random error)

Parameter	No.	Mean ± SD (1st reading)	Mean ± SD (2nd reading)	Mean ± SD of paired differences	95% tolerance limit	P-value
GM	300	2.2054±0.296	2.2192±0.301	0.013±0.047	4.262 %	N.S.

N.S. = not significant

M±SD: mean ± standard deviation

Comparisons between forced vital capacity (FVC) and adjusted gas mass (AGM) in both male and female of healthy Iraqi subjects:

The comparison between FVC and AGM was made on two main groups , the male group and female group: as shown in (table :1-3 , figures: 1-3 ,1-4).

1-Group A (total male): which included 146 male aged (20-50) years, the result revealed that there was no significant difference between FVC and AGM.

2- Group B (total female): which included 154 female aged (20-50) years, the result revealed that there was no significant difference between FVC and AGM .

Table (1-3): Comparison between forced vital capacity (FVC) and adjusted gas mass (AGM) in both male and female of healthy Iraqi subjects

Group	No.of subjects	FVC(L) Mean ± SD	AGM (L) Mean ± SD	p-value
Group A(Total male)	146 male	4.353 ± 0.688	4.341±0.647	N.S.
Group B(Total female)	154female	3.120 ± 0.457	3.132±0.606	N.S.

N.S. = not significant **M±SD**: mean ± standard deviatio

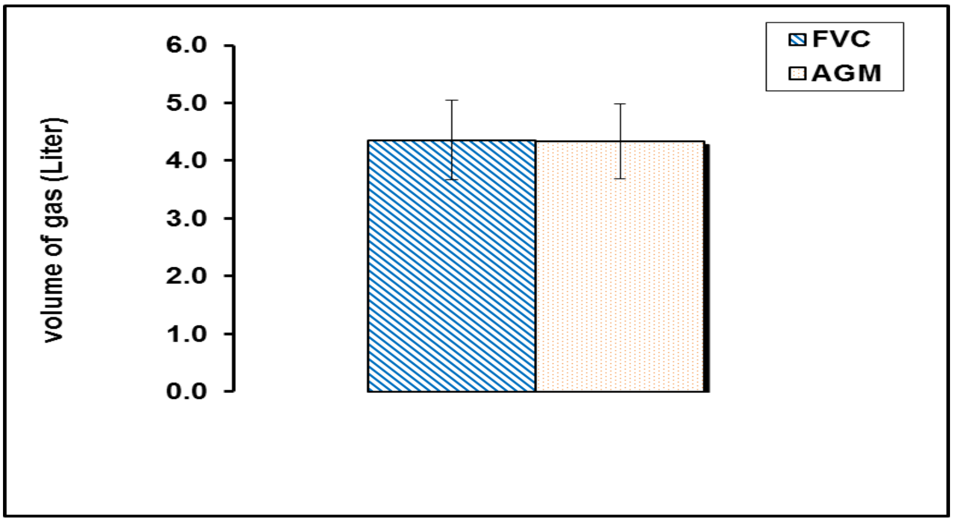

Figure (1-3): Comparison between forced vital capacity (FVC) and adjusted gas mass (AGM) in total male group of healthy Iraqi subjects.

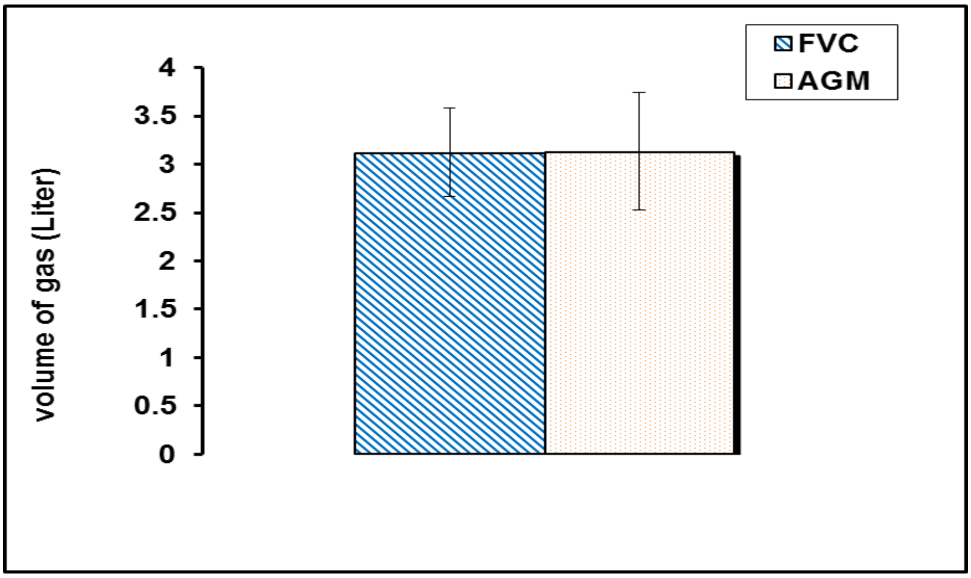

Figure (1-4): Comparison between forced vital capacity (FVC) and adjusted gas mass (AGM) in total female group of healthy Iraqi subjects

Regression lines of gas mass (GM) on forced vital capacity (FVC) in the study groups: In all of the regression lines, there were strong positive correlations between GM and FVC in the total study population ,male and female, r =0.973, 0.987 , 0.922 respectively as shown in figure (1-1,1-5 and 1-6).

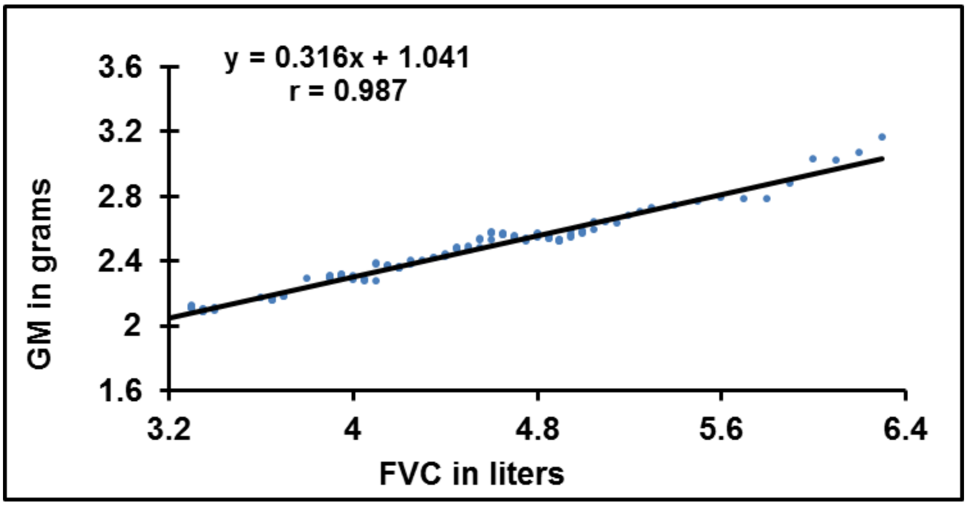

Figure (1-5): Regression of gas mass(GM) on forced vital capacity(FVC) in total male group of healthy Iraqi subjects (Solid line is the regression line)

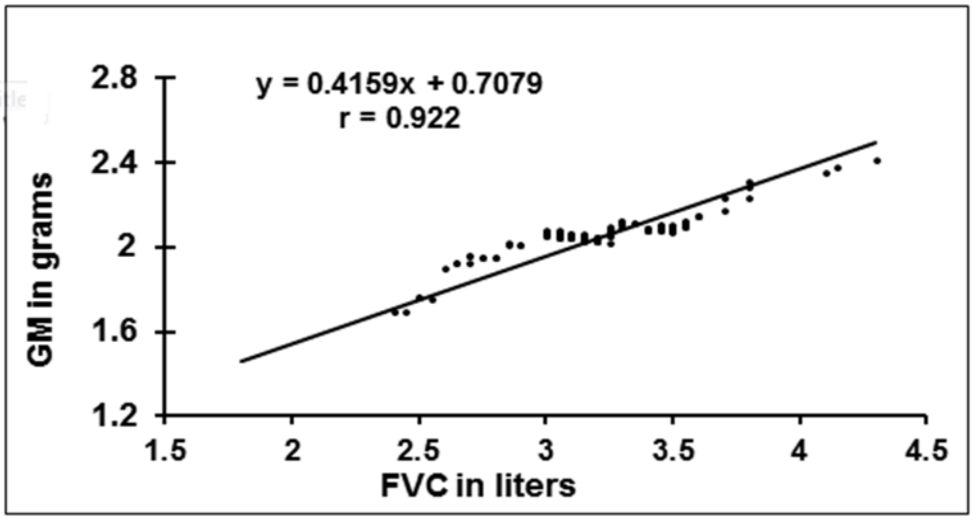

Figure (1-6): Regression of gas mass(GM) on forced vital capacity(FVC) in total female group of healthy Iraqi subjects (Solid line is the regression line)

Discussion:

The evaluation of gas mass device which was carried out by comparison with the standard technique for measurement of lung function test, the Vitalograph, revealed that there were no significant differences in values of AGM measured by gas mass device and FVC measured by standard Vitalograph spirometer as shown in figure (1-2).Moreover, In all of the regression lines, there were strong positive correlations between GM and FVC as shown in figures (1-1, 1-5 and 1-6). These results indicated that gas mass device is an accurate device for the measurement of lung function. Such type of evaluation has been made by other researchers for some newly introduced devices such as Al-Shamma and Al Zubaidy(23) , Al-Shamma and Al Mudhafer(24) , Al-Shamma *et al.*(25), Al-shamma *et al.*(26).

The random error which tests the reproducibility of gas mass device was made by taking the differences between pairs of estimates of GM in consecutive measurements in gas mass device at steady state. Thus, the standard deviation of the differences between the pairs of estimates gives a measure of the errors of the gas mass device and would not be greatly influenced by variation of lung function test Hainsworth and Al-shamma [27] .

The 95% tolerance limit of GM is 4.262 %. This result seems to be better than other reports measuring lung function test when 95% tolerance limit of FVC was 5.74% Al-Shamma and Al Zubaidy[23] , and near to other reports measuring lung function test when 95% tolerance limit of FVC was 3.25% and 3.22% Al-Shamma *et al*.[25] and Al-shamma *et al*.[26] respectively.Therefore, gas mass device is simple, portable and easily handled device. It is also reproducible and accurate device for the measurement of GM in normal subjects.

For the best of available literature search, there are no previous researches that measure the expiratory gas mass as a test of lung function[28].Accordingly, present results are not compared with previous similar researches. Instead, some explanations for these results are discussed.

In figures (1-3 and 1-4) there were no significant differences between FVC and AGM values for both groups. so we can conclude that, the expiratory gas mass may be of benefit as a measure of lung function testing instead of (or in conjugation with) FVC because that a fixed amount of expired gas has a constant mass despite the changes in pressure or volume as is implied by the law of conservation of mass in a closed system by Antoine Lavoisier. In the other hand, gas mass is constant despite the changes in temperature from body to ambient environments[29].

References:

1. Mehrparvari AH, Rahimian M and Mirmohammadi SJ (2012). Comparison of FEV3, FEV6, FEV1/FEV3 and FEV1/FEV6 with usual spirometric indices. Respirology: Official Journal of the Asian Pacific Society of Respirology (online journal).

2. Takase M, Sakata H and Shikada M (2012). Development of reference equations for spirometry in japanese children aged 6–18 years. Pediatric pulmonology (online journal).

3. Shibata1 Y , Watanabe1 T, Osaka1 D, Abe1 S and Inoue1 S (2011). Impairment of Pulmonary Function is an Independent Risk Factor for Atrial Fibrillation: The Takahata Study. Int J Med Sci; 8(7):514-522.

4. Jordan RE, Cheng KK, Miller MR and Adab P (2011). Passive smoking and chronic obstructive pulmonary disease: cross-sectional analysis of data from the Health Survey for England. BMJ; 1(2): Open.

5. Verbanck S, Vandevoorde J, Vincken W (2011). Internal consistency of reference equations. Eur Respir J. Jul;38(1):233-4.

6. Aaron SD, Dales RE, Cardinal P (1999).How accurate is spirometry at predicting restrictive pulmonary impairment? Chest;115(3):869-73.

7. Rassler B, Waurick S, Meinecke CD (1994). The prognostic relevance of preoperative pulmonary function tests. Anaesthesist;43(2):73-81.

8. Hegewald MJ, Crapo RO. Pulmonary function testing. In: Mason RJ, Broaddus VC, Martin TR, et al, eds. Murray and Nadel's Textbook of Respiratory Medicine. 5th ed. Philadelphia, Pa: Saunders Elsevier; 2010:chap 24.

9. Bapoje SR, Whitaker JF, Schulz T, Chu ES, Albert RK. Preoperative Evaluation of the Patient with Pulmonary Disease.Chest 2007;132:1637-1645.

10. Yesar M. H. Al Shamma ; Hussein S. Al Janabi ; Basim M. H. Zwain

(1998). Lung function test in Kufa cement factory .Al-kufa J. vol.2 No.1.

11. Reynolds HY. Respiratory structure and function: mechanisms and testing. In: Goldman L, Schafer AI, eds.Cecil Medicine. 24th ed. Philadelphia, PA: Saunders Elsevier; 2011:chap 85.

12. Salas T, Rubies C, Gallego C, Muñoz P, Burgos F, Escarrabill J (2011). Technical requirements of spirometers in the strategy for guaranteeing the access to quality spirometry. Arch Bronconeumol;47(9):466-9.

13. Liistro G, Vanwelde C, Vincken W (2006). Technical and functional assessment of 10 office spirometers. A multicenter comparative study. Chest; 130: 657-665.

14. Madsen F, Frølund L, Ulrik CS, Dirksen A (1999). Office spirometry: temperature conversion of volumes measured by the Vitalograph-R bellows spirometer is not necessary. Respir Med.;93(10):685-8.

15. Linn WS, Solomon JC, Gong H Jr, Avol EL, Peters JM (1998). Temperature standardization of multiple spirometers. J Occup Environ Med.;40(2):148-52.

16. Law of conservation of mass (1987). Encycolopedia Brittanica.;15, p653-656.

17. Effective Alternative Secondary Education (2012). Chemistry module 9: Gas laws. Bureau of secondary education. Department of Education. DepEd Complex, Meralco Avenue, Pasig City.

18. Guch, I (2003). The Complete Idiot's Guide to Chemistry. Penguin Books Inc. P:173-183.19.

19. R.Hainsworth and Yesar M. H. Al Shamma(1988). Cardiovascular responses to upright tilting in healthy subjects. Clinical sciences ; 74,17-22.20.

20. Ra SW, Oh JS, Hong SB, Shim TS, Lim CM and Koh YS (2006). Effect of the changing the lower limits of normal and the interpretative strategies for lung function tests. Tuberc Respir Dis.;61:129–136.

21. Miller, M.R. ;Crapo, R. ;Hankinson, J., *et al*., (2005). General considerations for lung function testing. Eur Respir J., 26:153-61.

22. Daniel, W.W. (2009). Biostatistics, Student Solutions Manual: A Foundation for Analysis in the Health Sciences (Wiley Series in Probability and Statistics) 9th ed.

23. Al-Shamma Y. M.H. and Al Zubaidy A.M. (1999). Evaluation of a system for the assessment of lung function test. Kufa med.J. 2(1):53-55.

24. Al-Shamma Y. M. H. and Al Mudhafer Z.A. (2005). Evaluation of peak flow meter for the measurement of peak expiratory flow rate. Kufa med. J 8(1):227-230.

25. Al-Shamma, Y. M.H. ; Hussain, M.H. and Al-Shamma, Z.Y. (2009). Evaluation of spirolabII spirometer for the assessment of lung function test. Kufa Med.J.12(2):126-131.

26. Al-shamma Y.M.H. ; Al-Mudhaffer, Z.A. and Hussain M.H. (2012). Evaluation of spirolabIII spirometer for the assessment of lung function test. Kufa Med.J.15(2):261-265.

27. Hainsworth, R. and Al-shamma ,Y.M.H. (1988). Cardio vascular responses to upright tilting in healthy subjects. Clinical science 74:17-22.

28. Kiraly, A. (2005). History of Spirometry. The journal for Pre-Health Affiliated Students , Volume 4, Issue 1.

29. Law of conservation of mass (1987). Encycolopedia Brittanica.;15, p653-656 , cited from Zwain, B.M.H. ,Wasna'a, M.A. ,Al-Shamma, Y.M.H. (2012). Correlations between expiratory gas mass and pressure with forced vital capacity in healthy subjects. Al-Kufa Journal,15(1):64-73.