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Full Length Research Paper

Changes in airway resistance with cumulative numbers of cigarettes smoked

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This work was performed with smokers of Virginia tobacco cigarettes without taking into consideration brand or type of cigarettes. An experimental study was conducted for the variation of cigarettes number and the increments in airway resistance for both normal and respiratory disordered subjects using body plethysmograph for testing individuals. Seventeen (17) nonsmokers and ten smokers were studied. The investigation evaluated respiratory function in both smokers and nonsmokers: their airway resistances were recorded, and relationships between height, weight and age were documented. The findings reveal that smoking of higher numbers of self-reported cumulative cigarettes was associated with higher airway resistance and higher total airway resistance. Comparisons of age, height and weight versus airway resistance revealed only slight changes in comparison to those associated with cumulative lifetime cigarette consumption.

Key words: Air way resistance, total air way resistance, plethysmography, normal and disordered respiratory system.

INTRODUCTION

The first few breaths after birth are the most challenging breaths for the neonatal. The neonatal will have to work very hard to overcome the first breaths which are relatively the largest breath the new born conducts at his initial breathing experience. This process is thus done to:1) Inflate and deflate the lungs and chest wall outward (during inspiration) and inward (during expiration), throughout normal breathing; 2) move abdominal structures involved; overcome expected airway resistance (Shapiro et al., 1991; Al Sa'ady, 1997) plus any external resistance of assisting instruments if used during some modes of ventilation (Polese et al., 1991; Al Kadri, 1998);

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Abbreviations: VTG, Value by body plethysmograph; **VC,** vital capacity; **Lit/sec,** liter/second; **FVC,** forced vital capacity; **PFT,** pulmonary function test; **FEV1,**forced expiratory volume in one sec; **Raw,** airway resistance; **Rawt,** total airway resistance; **PA,** alveolar pressure; $\dot{V}$**,** =Vdot; **Flowrate,** volume/second ; **Lit,** Liter; **Pp,** plethysmography pressure ; **No,** number; **Pt,** patient; **Ht,** height ; **Wt,** weight; **Cig/day,** cigarette per day; **Yr,** year; **Total no of cig,** total number of cigarette; **R,** correlation factor.

3) overcome increased impedance may be created by disorders of the respiratory system that may lead to above normal respiratory muscle activity (Beydon et al., 1988; Al Kadri, 1998; Irving and Herman, 2007); 4) meet with demand because of increased ventilation during some circumstances such as exercise (Guyton and Hall, 2009; Al Kadri, 1998; Irving and Herman, 2007).

To fulfill the purpose of the project, instantaneous work and effort were exerted because of friction between molecules of gas itself and between the gas molecules against the tube walls. When flow is laminar or streamline, Raw varies directly with the viscosity of the gas, the length of the tubes and inversely with the fourth power of the radius of the lumen of tubes (Sykes and Vickers, 1970; Tortora, 2006; Goldman et al., 1976).

$$Raw = \frac{viscosity \times .length}{(radius)^4} \times \frac{8}{\pi}$$

If breathing is conducted normally and quietly, the resistance (R) should remain constant then the equation of the resistance remains:

$$Raw = \frac{\Delta P}{Vdot} \ldots\ldots\ldots \frac{cmH_2O}{lit/\sec}$$

This means that Raw = change in driving pressure ΔP in cmH_2O (trans- airway pressure minus atmospheric pressure) per unit change in flow rate $\dot{V}$ (Tortora, 2006).

The aim of the present study was to estimate the variability of airway resistance versus cumulative number of cigarettes. This is because resistance is expected to vary in normal and disordered system and also upon connecting the respiratory system to external circuits or ventilating devices.

MATERIALS AND METHODS

No specific selection was necessary in choosing volunteers, because the aim of the project was to make a clinical comparative study; accordingly, 27 subjects were taken to achieve the aim of the study at Al-Hussein Medical City. Ten of them were good smokers while 17 were nonsmokers. They were of different heights, weights and ages. For the completion of the study, each volunteer breathed (upon appropriate instructions) into the system inlet tube which was provided with mouth piece and gas pillows inside the cage in the glass-room. The subject was asked to sit on chair inside the glass room with the mouth piece linked to his mouth a nose clip on his nose, and the subject was asked to inspire a certain volume of air through the mouth piece. A transducer or sensor was attached in the way to measure the flow rate and pressure and then the body plethysmograph give the value of Raw and Rawt. Values were obtained in a report. Tables 1 and 2 show the information of the smokers and nonsmokers selected to the study respectively.

Body plethysmography

A plethysmographs was used .The one in Jordan (Al Hussain Medical Center) is of Sensor Medics (Cardiopulmonary care company); 6200 Auto box Dl Automated Body Plethysmograph. By making VTG and Raw measurement at rapid rate (panting), very small leaks are acceptable. “Slow” leaks are sometimes introduced to facilitate thermal equilibrium by connecting along tube of small –bore to the atmospheric side of the box pressure transducer or connecting it to a glass bottle within the box. Pressure plethysmograph is suited to measure small volume change (100 ml or less).

The flow box uses a flow transducer in the box wall to measure volume changes into the box. The subject breathes through a pneumotachometer which is connected to the room. Gas in the box is compressed or decompressed to measure the pressure change as gas flows out of the box through the flow opening.

Flow through the wall is integrated and correction is made to record the volume change as the total volume passes through the wall. The volume will be compressed. The flow type of plethysomgraph requires computerization assessment. In addition, maximal-breathing maneuvers such as the VC may be recorded with the subject in the flow box.

Computerized plethysmographs offer the advantage of providing lung volume and airway resistance information immediately after the completion of the manoeuvre. This aids the technologist to select appropriate manoeuvres to get the average.

Most plethysmographs include the necessary hardware to perform physical calibration. Computerized systems allow automated calibration of transducers by means of software – generated correction factors , along with the actual physical calibration . A few manufacturers supply quality control devices such as the isothermal lung analogue. Subjects have ease in performing the required manoeuvres because it is an important feature of the plethysmograph investigations since many subjects may become claustrophobic inside the box. New boxes made of durable plastic transparent and less confining for the subject were also provided by communication system to allow voice contact with the subject.

Here are some of the tests that the subject had to pass with the help of the body plethysmograph to diagnose respiratory system state:

Pulmonary function tests (pft)

Forced vital capacity (FVC)

Forced vital capacity (FVC) is the maximum volume of gas that can be expired as forcefully and rapidly as possible after maximal inspiration.

Forced expiratory volume within the first second (FEV1)

The FEV1% is a statement of FEV for a given interval expressed as a percentage of the subjects actual FVC. It has been reported that a normal subject can expire 50-60% of the FVC in 0.5 s, 75-85% in 1 s, 94% in 2 s, and 97% in 3 s. Slightly, lower ratios may be observed in elderly adults, but in general, subjects without airway disorders obstruction and restriction expire their VC within 4 s. Conversely, subjects with obstructive disease will show a reduced FEV1 in most cases; an FEV1 % lower than 70% is the hallmark of obstructive disease.

Table 1. The values for non- smokers.

Serial number	Sex	Age	Height	Weight	Raw<2.24	Rawt<3.06	Cigarette /day	Year of smoking	Total number of cigarette
1	Male	33	176	96	2.76	4.03	20	2	14600
2	Male	28	175	78	2.56	3.49	10	10	36500
3	Male	32	168	73	1.72	3.12	12	10	43800
4	Male	31	165	75	1.52	2.62	20	10	73000
5	Male	34	165	72	2.57	3.46	20	15	109500
6	Male	39	176	82	3.17	5.16	20	19	138700
7	Male	33	177	82	2.41	5.94	30	13	142350
8	Male	38	167	59	3.49	4.79	40	12	175200
9	Male	32	167	82	4.79	6.05	30	16	175200
10	Male	30	168	103	2.9	3.65	40	12	175200
	Sum	330	1704	802	27.89	42.31	242	119	1084050
	Average	33	170.4	80.2	2.789	4.231	24.2	11.9	108405
	Standard deviation	3.367	4.949	12.381	0.922	1.191	10.475	4.557	62,229.854
	Variance	11.333	24.489	153.289	0.850	1.417	109.733	20.767	3,872,554,694.4
	f-test	0.021835872	2.7884E-05	8.95741E-09	4.55694E-42	4.54672E-41		4.5569E-42	4.54672E-41
	t-test	5.46486E-11	4.62884E-16	8.90334E-09	0.000375992	0.000376028		0.00037599	0.000376028

To change units of pressure from cmH_2O to Pascal (Pa) we multiplied by 98.1; to change earway resistance from cmH_2O/Lit/Sec to Pascal/m^3/Sec we multiplied by 98.1×10^3; To change unit of resistance from KPa/Lit/Sec to Pa/m^3/Sec we multiplied 1×10^6.

Subjects with restrictive disease often show a normal or supranormal FEV1 % since their flow rates may be minimally affected, and the FEV1 and FVC are usually reduced in equal proportion. Following this point, both respiratory compliance and resistance of each volunteer were measured by: closing the mouth by a shutter at the end of the tidal inspiration from the spirometer and after one to two s; mouth pressure was measured and then compliance was obtained and releasing the shutter at the inset of flow, both pressure and volume rate of change (i.e. flow) were determined and resistance was calculated (Tortora, 2006; Camroe et al.,1962).

Resistance (Raw)

Airway resistance is the difference in pressure between the mouth (atmospheric) and that in the alveoli, related to gas flow at the mouth.

This pressure difference is created primarily by the friction of gas molecules coming in contact with the conducting airways. Raw is the ratio of alveolar pressure (P_A) to airflow ($\dot{V}$). Its unit is cm H_2O / lit / sec. Gas flow can easily be measured with a pneumotachograph and P_A is measured with a body plethysmograph.

For gas to flow into the lungs (inspiration), P_A must fall below atmospheric pressure; the opposite occurs during expiration. Since the total volume of gas in the lungs and plethysmograph remains constant, the changes in alveolar volume are reflected by reciprocal change in the plethysmograph. Changes in $\dot{V}$ are plotted simultaneously against plethysmographic pressure changes (which is proportional to alveolar volume change) on a storage oscilloscope. The slope of this is $\dot{V}$/Pp Where, $\dot{V}$ is airflow and Pp is the plethysmographic pressure. Immediately after this measurement, an electronic shutter at the mouth piece is closed and changes in plethysmographic pressure are plotted against airway pressure at the mouth, just as is done for measurement of the volume since there is no airflow into or out of the lungs, the mouth pressure approximates P_A.

The slope of this line is P_A/Pp where P_A equal alveolar pressure. This step serves to calibrate changes in P_A to change in Pp for each subject. Raw is then calculated by taking the ratio of these two slopes:

$$Raw = \frac{P_A / P_P}{\dot{V} / P_P} \quad \text{......................................2.10}$$

Table 2. The values for smokers.

Serial number	Sex	Age	Height	Weight	Raw<2.24	Rawt<3.06
1	Male	34	170	89	1.32	2.8
2	Male	22	170	70	0.62	1.36
3	Male	30	168	74	1.96	2.94
4	Male	28	183	73	1.89	2.79
5	Male	38	176	73	2.79	4.06
6	Male	29	164	68	3.39	4.56
7	Male	34	168	87	2.86	3.66
8	Male	38	166	82	3.61	5.09
9	Male	31	178	78	1.25	2.27
10	Male	31	168	85	0.71	6.85
11	Male	28	176	76	2.96	5.28
12	Male	32	163	80	1.3	2.85
13	Male	22	158	71	1.35	2.21
14	Male	32	165	60	2.62	2.72
15	Male	35	174	85	2.72	4.16
16	Male	35	165	63	0.58	1.25
17	Male	31	170	64	2.07	3.07
	Sum	530	2882	1278	34	57.92
	Average	31.17647	169.5294	75.17647	2	3.407058824
	Standard deviation	4.572134	6.246175	8.705137	0.97638363	1.45801991
	Variance	20.90441	39.01471	75.77941	0.953325	2.125822059
	Sum	1.28E-07	1.16E-09	6.76E-12		0.119003898
	Average	2.51E-15	1.11E-25	4.92E-17		0.00130165

Where, $\dot{V}$ is air-flow, P_A is alveolar pressure and PP is plethysmographic pressure, which is measured with the shutter open and closed.

RESULTS

In all experiments values of Raw , Rawt were obtained for a full procedure period and for each successive resistance test and a comparison was done between variables age, weight and height for nonsmokers (Table 1). Figures 1 and 2 show the Raw and Rawt values versus the three variables, age, height and weight respecttively. They illustrate that correlation factors shown on the figures for each of them on the curve associated the trend line equation with R^2 fixed at each curve. The values of ($R=\sqrt{R^2}$) were given as follow for Raw versus the three variables (height, age and weight); R height = 0.32, R age = 0.4 and R weight = 0.053 (Figure 1). Figure 2 shows values of Rawt versus the three variables height, age and weight; R height = 0.19, R age = 0.42 and R weight = 0.46

Values of t-test and f-test for non-smokers were << 0.05. The figures gave the trend lines of airway resistances that varied with height, weight and age.

Table 2 gives also values and relations between Raw and Rawt versus total number of cigarettes smoked. Figures 3 and 4 illustrate the trend lines with their equations and correlation factors for the three variables (height, weight and age). For Raw, correlation factors are given in Figure 3; R (height) = 0.5, R (age) = 0.43 and R (weight) = 0.21. Rawt for smokers and R values are given on the curves in Figures 3 and 4; R values for weight and age were higher than for nonsmokers' and so on for height; R (weight) = 0.46, R (age) =0.42 and R (height) = 0.19.

Values of t-test and f-test for smokers were << 0.05. Figures 5 and 6 show the values of Raw and Rawt respectively versus cumulative number of cigarettes smoked. They gave the same trend and a noticeable influence of the cumulative number of cigarettes against either Raw or Rawt and the value of R = 0.873 (3).

Values of t-test and f-test were too small << 0.05.

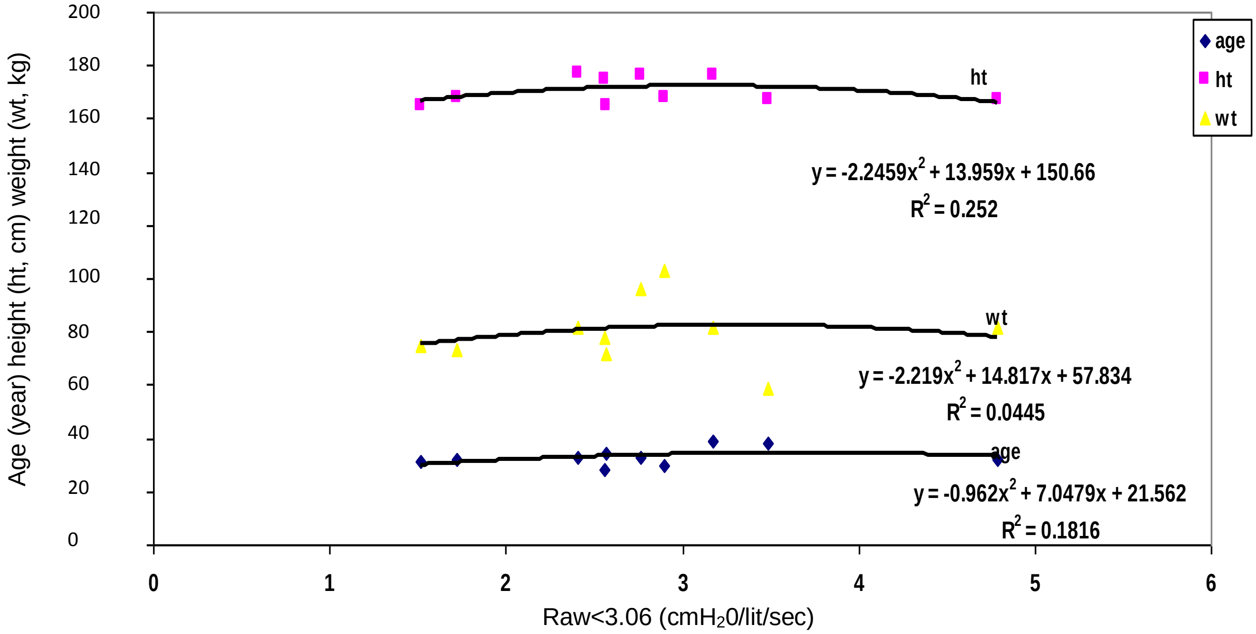

Figure 1. Raw versus age, height and weight.

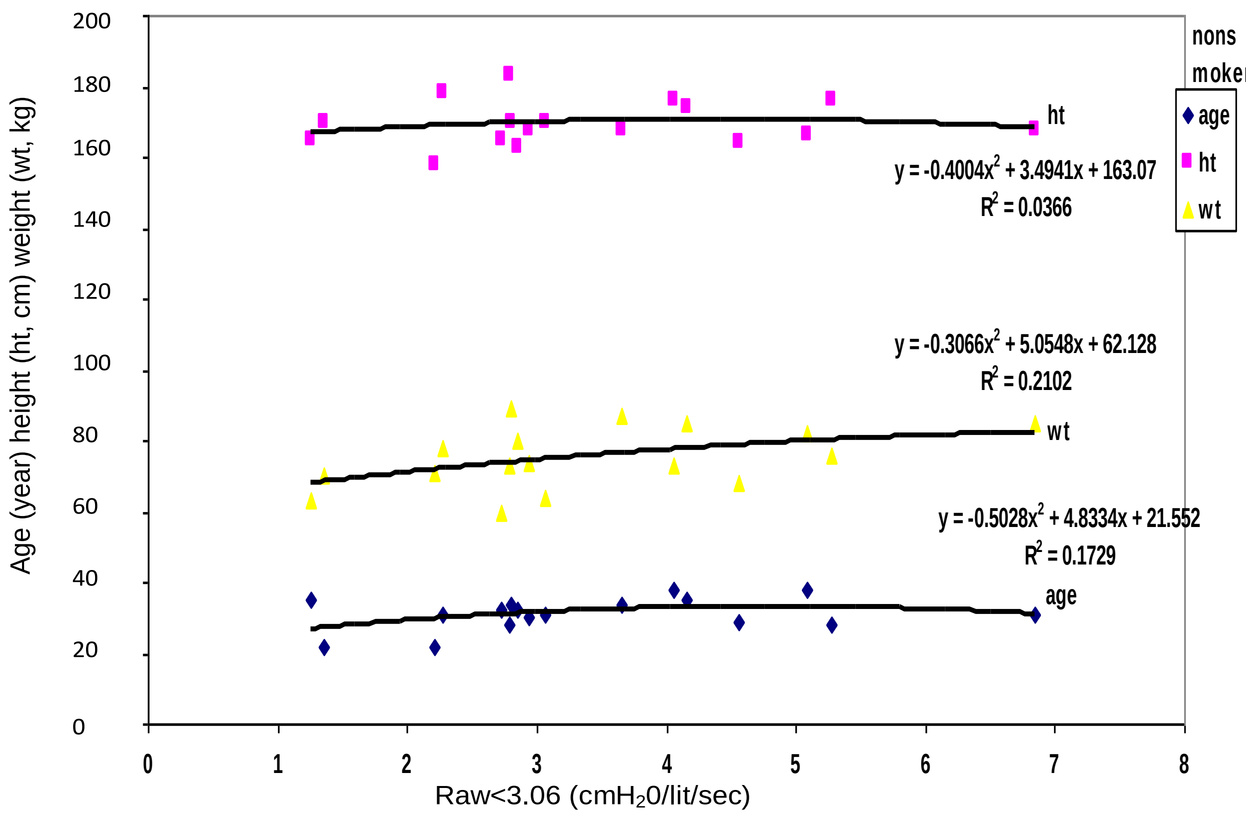

Figure 2. Rawt versus age, height and weight.

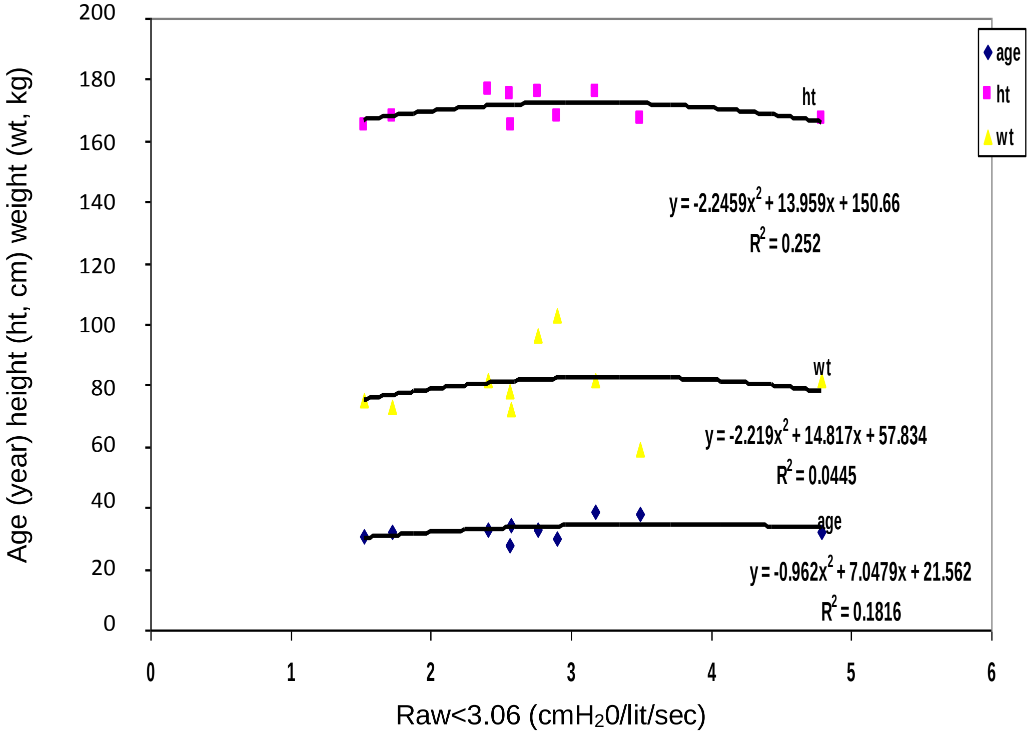

Figure 3. Values of Raw versus height, weight and age in smokers.

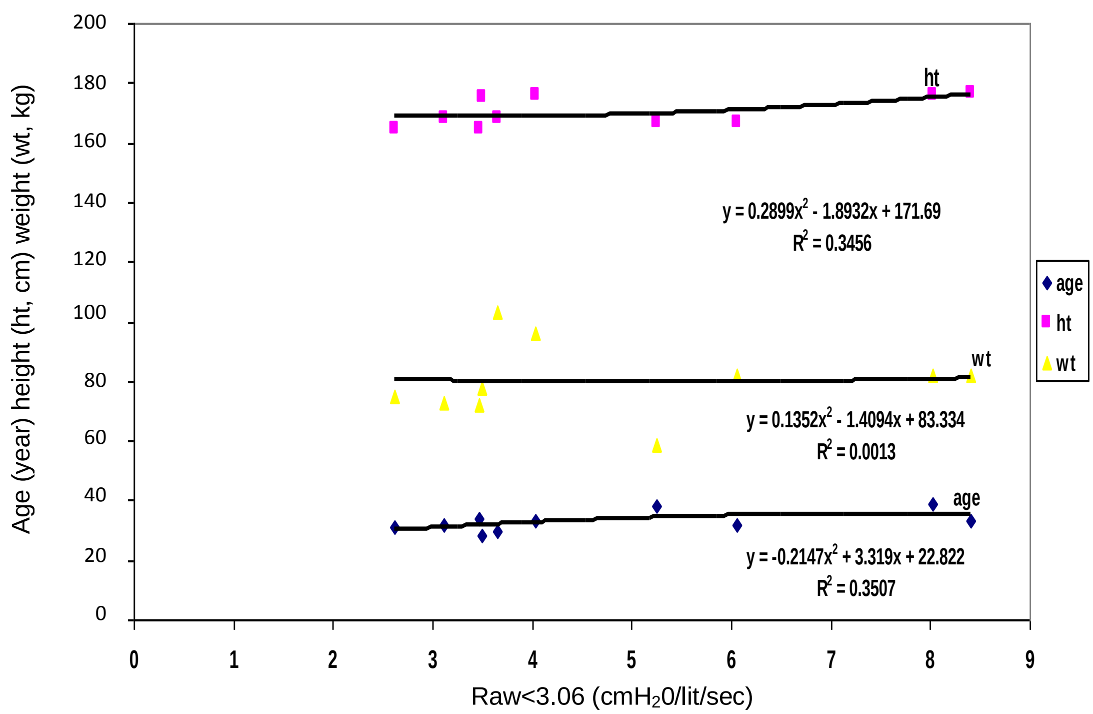

Figure 4. Values of Rawt versus height, weight and age in smokers.

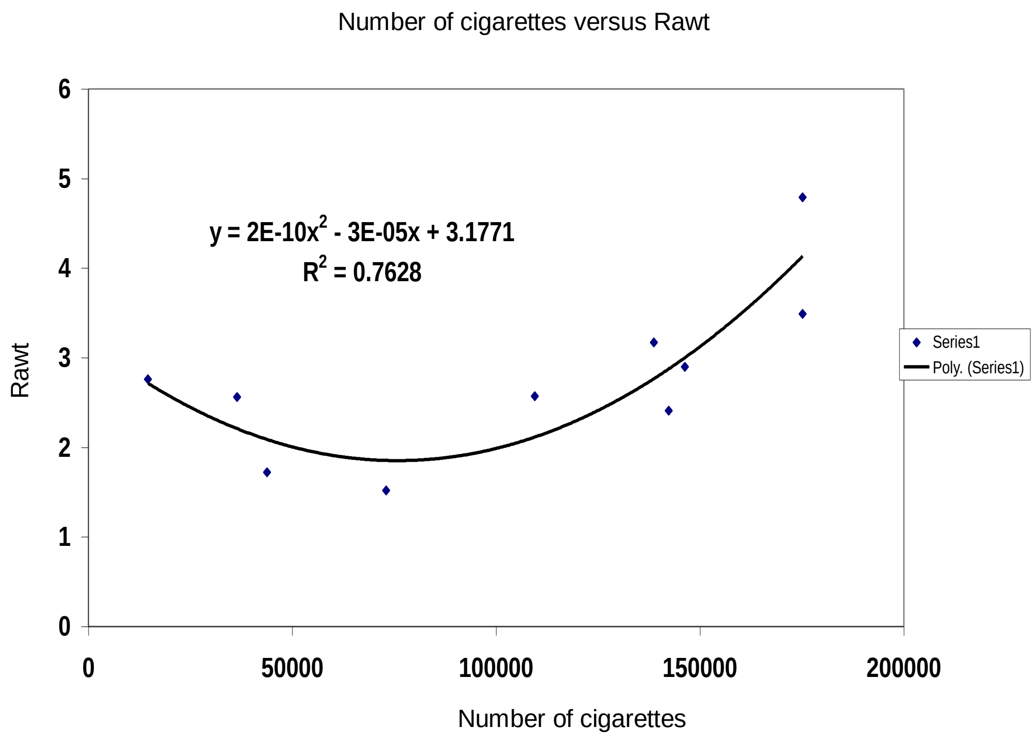

Figure 5. Values of Rawt versus total number of cigarettes smoked.

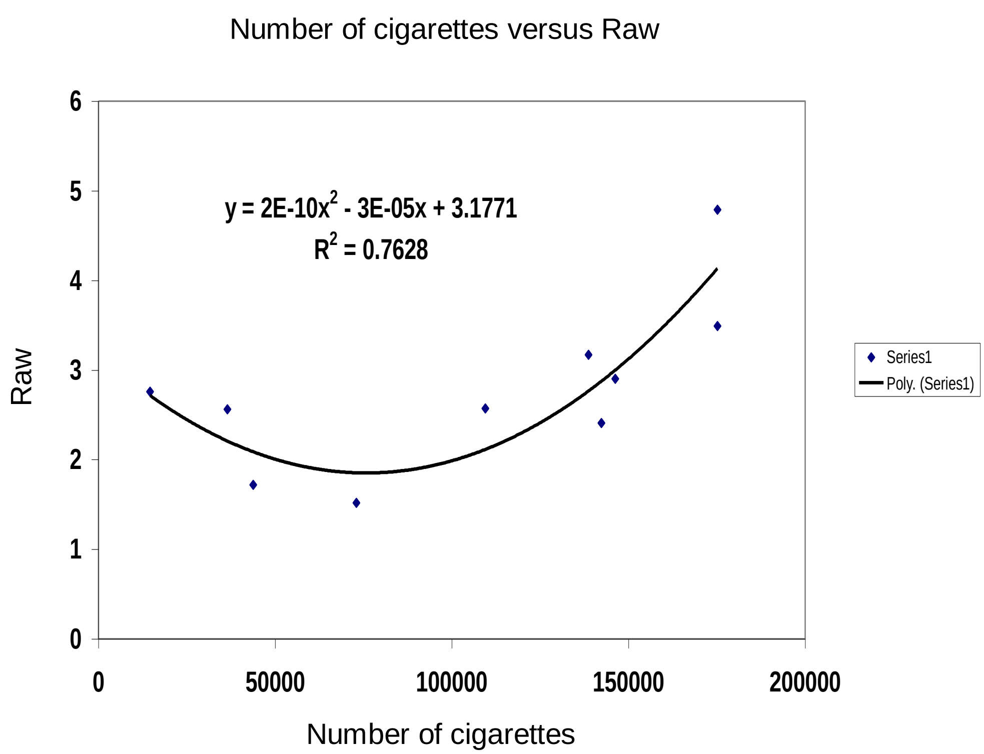

Figure 6. Values of Raw versus total number of cigarettes smoked.

DISCUSSION

The respiratory system is regarded as a continuously variable pressure generator (Mecklenburg et al., 1990; Macklem, 1980; Shapiro et al., 1991; Irving, 2007). Its action would result into maintaining continuous respiretory cycles, thereby facilitating volumes of air to be transported into and out of the lungs (Shapiro et al., 1991; Al Kadri, 1998). The final outcome of this process would be an exchange of gases across the alveolar membrane to provide the body with its needs for oxygen and to expel CO_2 carried into the lungs by the circulation (Cameron et al., 1999; Shapiro et al., 1991; Irving, 2007). Throughout this respiratory process, air with smoking deposits, then work is done and defined as the product of muscle pressure output and volume. Work and efforts are variable with time and both muscle pressure output and also volume are cyclic in their behavior. This description into the status of work is valid whether the respiratory system is normal or disordered but there must be differences in the work done when breathing between disordered status is compared with normal system. The determinants of such variabilities are resistance and compliance if the respiratory muscles are working normally.

In the present study which depends on both of these two parameters, Raw and Rawt were determined by the variation of total number of cigarettes smoked. The application of the study is dependent on its validity which was previously confirmed on both practical and theoretical grounds (Mecklenburg et al., 1992). The study itself covered the determination of the whole of muscle pressure taking into consideration total compliance and resistance of the respiratory system in addition to including any external resistance that may be available in the breathing circuit. The scope of the study spreads to cover the increase in Raw and Rawt values versus total number of cigarettes; or the situation when connecting the subject to external breathing circuits with unknown resistance to breathe through (Mushin et al., 1980; Banner et al., 1994; Sykes, and Vickers 1970; Jason et al., 2006) .

Coats et al. (1994) reported that pulmonary impedance (including elastic and resistive loads) can express the severity and mechanism of lung disease. This is because breathing would be expected to be hindered upon large increase in impedance which would affect pressure generated by the muscles. Coats et al. (1994) found a linear relationship between (Impedance x (min. ventilation)^2) and rate of work of breathing throughout the impedance range used. In the present study, only resistive loading was varied and work was found to increase up to a load (of nearly 1.3269 kP_a/(lit/sec) until work done was nearly diminished.

Respiratory muscle fatigue is induced experimentally by adding high external resistance to breathing (Fitting, 1992a; b; Fitting, 1994; Stephan et al., 2005; Al Sa'ady, 1997), and it is quite possible that in this study, fatigue approached as the resistance reached its maximal values.

In a preface to a book entitled loaded breathing, Pengelly, Rebuck and Campbell wrote:

"Common to many conditions causing breathlessness is the disturbance of mechanism of breathing producing an alteration in the load opposing the respiratory muscle. Clearly therefore an understanding of the way the act of breathing is affected by added mechanical loads is essential to an appreciation of the common clinical problems. Conversely, understanding of the physical processes responsible for homeostasis should be improved by studying patients in which breathing is loaded by disease" (Pengelly et al., 1974; Stephan et al., 2005; Martine et al., 2009).

A great accordance of the present study with the others, increase in smoking leads to increase in tobacco deposits which may lead to restrictive diseases, where values of t-test and f-test were highly significant.

Undoubtedly, the argument must therefore spread into the consideration of the form of generator of work (energy) and on which part of the energy is applied during expiration. The latter point may lead to clarification of whether the respiratory muscles always contribute to the energy stored in the compliance or not. The present method of determining WOB and the variability of external resistances offer expressions of some known forms of WOB in addition to producing a segmentation into its applied portions; investigation into the pressure generator (and thus WOB) will be more attainable in the future.

Conclusion

From the present work, it can be concluded that the respiratory system improves itself when the external resistance is less but at the increase in smoking and the total number of cigarettes, it is expected that the respiratory muscle will suffer disorders until it reaches fatigue, with the high increase in resistance value because of the increase in resistance by smoking. This increase will lead to restrictive diseases (Stephan et al., 2005; Martine et al., October 2009), and if the increase in Raw reaches the three folds, this will create problems with ventilators if used in hospitals at certain cases (Almaasfeh, 1995). Finally, cigarettes are best factor to increase Raw.

RECOMMENDATIONS

It is recommended that further studies should be made on more subjects and on two variables, (airway compliance and resistance), to prove these variables as the best factors to diagnose, to compare the curve of anybody examined or to deduce a standard figure for certain subjects.

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