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Original Article

Physiology Section

Changes in Inspiratory and Expiratory Flow Rates with Sustained Hand Grip and their Correlation with Fat Free Mass Index in Healthy Young Adults

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ABSTRACT

Introduction: Aerobic exercises which are isotonic in nature have been proved to be beneficial in a number of cardiovascular and lifestyle diseases. But the effect of isometric exercises on cardiovascular and respiratory system is not fully evaluated. Existing literature on effect of isometric exercise on respiratory flow parameters are scanty and needs to be studied. Further, the impact of muscle mass on respiratory flow parameters need to be evaluated.

Aim: To investigate the change in respiratory flow parameters (Peak Inspiratory Flow (PIF), Maximal Inspiratory Flow (MIF) 50, Peak Expiratory Flow (PEF), Maximum Expiratory Flow (MEF) 25-75, MEF 25, MEF 50 and MEF 75) in response to Sustained hand grip exercise and to find out any correlation between these flow parameters and Fat Free Mass Index (FFMI).

Materials and Methods: A cross-sectional study was conducted at Department of Physiology, MKCG Medical College, Berhampur University, Odisha between October 2011 and August 2014. A total of 150 healthy volunteers aged between 17 to 25 years were included in the study. Anthropometric measurements were recorded using standardised instruments. Body fat percentage was measured by Bioelectric Impedance Analysis technique and then Fat Free Mass (FFM) and FFMI were calculated using standard formulae. Respiratory Flow parameters were assessed using Flow handy Spirometer as per the American Thoracic Society/European Respiratory Society (ATS/ERS) guidelines. Sustained hand grip exercise was performed with Physilab Grip Dynamometer. IBM SPSS Statistics Version 24.0, was used for statistical analysis. Paired sample t-test was used to compare lung volumes at baseline and after 3 minutes of sustained hand grip exercise. The p-value <0.05 was considered statistically significant. Karl Pearson Correlation coefficient was used to study the linear relationship between FFMI and various inspiratory and expiratory flow rates.

Results: The mean values of all respiratory flow parameters under study decreased at 3 minutes of sustained hand grip exercise as compared to baseline values. This change was statistically significant for PEF (p-value 0.012), MEF 25-75 (p-value 0.041), MEF 50 (p-value 0.001), MEF 75 (p-value 0.012) and MIF50 (p-value 0.004) ($p<0.05$). All the flow rates studied except MEF 25 showed significant positive correlation with FFMI (r-values between 0.231 to 0.380, $p<0.05$) but the strength of association was low.

Conclusion: There was a statistically significant reduction in both inspiratory and expiratory flow parameters with isometric sustained hand grip exercise. So, isometric exercises should be avoided in patients with obstructive airway diseases. But muscle mass should be improved for better ventilation as authors observed a positive correlation between FFMI and respiratory flow rates.

Keywords: Hand grip exercise, Isometric exercise, Lean body mass, Pulmonary function test

INTRODUCTION

Exercise provides definite health benefits, which serves as useful intervention in the primary as well as secondary prevention of a variety of chronic diseases [1]. Exercises are broadly categorised into two types depending on type of muscle contraction - Isotonic or dynamic exercise and Isometric or static exercise and each of these categories are further sub-categorised into two types depending on aerobic or anaerobic metabolism [2]. Dynamic exercise involves repetition of low-resistance motion and performance of external work which include exercises like walking, running, swimming etc., whereas Isometric exercise involves sustained muscular contraction of smaller muscle groups against fixed resistance without causing movement of the joints or axial skeleton. Dynamic aerobic exercises have proved beneficial in chronic diseases like coronary artery disease, diabetes mellitus, obesity, osteoporosis and are widely advised by clinicians and followed by patients. But some associated co-morbidities like bronchial asthma, obstructive airway disease or heart failure can worsen with dynamic exercises. So in these situations isometric exercises may be helpful [3-6]. Isometric exercise activates Autonomic Nervous System [7]. A previous study had shown that acute bout of static exercise like Hand grip exercise resulted in increase in Adrenomedullin (ADM), adrenaline (A) and Noradrenaline (NA) in healthy individuals [8]. As the Respiratory system function is under the control of autonomic nervous system, so the respiratory parameters may change when individuals are subjected to static (isometric) exercise. Airway resistance which plays a major role in influencing air flow and respiratory flow parameters, is regulated by neural and humoral agents through their effect on airway smooth muscle [9]. So, isometric exercise which activates autonomic nervous system might be influencing the airway resistance with resultant change in inspiratory as well as expiratory flow parameters [10].

Different researchers have studied the respiratory parameters in response to static exercise with variable results [11,12]. Though the changes in respiratory static and dynamic lung volumes with isometric exercise like sustained hand grip have been studied but there are few studies evaluating changes in respiratory flow parameters with isometric exercise [13,14]. So, authors strongly felt the need of more data on the changes of respiratory flow parameters in response to isometric exercise.

At the same time, lung function is influenced by the amount of body fat and muscle and the extent to which these two compartments impinge upon the thorax. In the case of muscle, the primary and accessory muscles of respiration make a direct contribution to lung function [15]. There are studies showing correlation of fat mass and FFM on various static and dynamic lung function parameters [16,17]. But data regarding influence of muscle mass (as represented by FFM or FFMI) on respiratory flow parameters are inadequate and more research is required to substantiate the role of muscle mass in respiratory health and diseases.

So, with this background the present study was carried out to investigate the change in inspiratory and expiratory flow parameters (PIF, MIF50, PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75) in response to isometric exercise like Sustained hand grip and to determine any correlation between these flow parameters at 3 minutes of handgrip exercise and FFM index which is a surrogate of muscle mass in the body.

MATERIALS AND METHODS

A cross-sectional analytical study was undertaken in the Department of Physiology, MKCG Medical college, Berhampur, Odisha, between October 2011 and August 2014 after getting approval from the Institutional Ethics Committee (vide letter no 26/IEC dated 29/11/2011) and informed consent was obtained from the study participants.

Sample size calculation: Sample size was calculated for paired t-tests using G Power 3.1.9.4 assuming that an effect size of 0.3 would not be clinically significant, even though it is statistically significant [18]. For two tail test, alpha error probability-0.05, power of the test-0.950, total minimum sample size was computed as 147. However, the study considered the sample size of 150.

Inclusion criteria: Out of 150 students enrolled to MKCG Medical College in each academic year from 2011 to 2014, 50 students between 17 to 25 years of age, of both sexes were selected each year as the study population.

Exclusion criteria: Volunteers with known cardiovascular and respiratory disease, diabetes, hypertension or any other systemic disease, those who were on treatment for active respiratory tract infection, had history of smoking, alcoholism or Body Mass Index (BMI) of more than 30 were excluded from the study.

All the study participants were evaluated and the tests were performed between 9 and 11 am on the study days. It was ensured that the study subjects did not wear tight clothes that might restrict full movement of the chest and abdomen. The age of the participants was recorded from the date of birth in their school leaving certificates.

Measurement of Anthropometric Parameters and FFM Index

Weight was measured to the nearest 0.1 kg, in standing position, with light clothes and without footwear by using a standardised weighing machine. The standing height was measured without footwear by a stadiometer to the nearest centimeter. BMI was calculated using Quetlet's index (Body weight in Kg/Height in m^2) [19]. Body fat percentage was measured by Bioelectric Impedance Analysis technique using Omron Body Fat Monitor (HBF-306) after entering the data like age, sex, body weight and height. FFM and FFMI were calculated from BF% using standard formula

{FFM=[(100-BF%)×Weight (in Kg)]/100 and FFMI=FFM/Height (in m^2)} [20].

Measurement of Respiratory Flow Parameters

A baseline spirometry was done using Flowhandy ZAN100 USB spirometer using Betterflow ZAN100USB software as per guidelines of the American Thoracic Society/European Respiratory Society (ATS/ERS) Task Force-2005 [21]. Before performing the spirometry, the subjects were explained how to perform the test, also there were given live demonstrations. The subjects were seated comfortably with the spirometer positioned at their mouth level. The nose-clip was applied tightly and the participants breathed in and out through his/her mouth to the mouthpiece which was held firmly and tightly. With the recording system on, the participants were instructed to breathe at least 6-8 times slowly, at a rate of about 30 breaths/minute and depth around 0.5-1.0 L. After that, the subjects were asked to inspire slowly to their total lung capacity and then expire as quickly and deeply as possible with the expiration lasting for atleast 6 seconds. Various values for lung volumes, capacities and flow rates were automatically recorded in the System. The flow volume/time graphs were taken and out of three acceptable curves, the best was selected as the recording. The parameters which were specifically documented were PIF, MIF50, PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75. The similar procedure was repeated after 3 minutes of Sustained Hand Grip exercise and the same parameters were recorded again.

Sustained Hand Grip Exercise with Hand Grip Dynamometer

Physilab Grip Dynamometer (H L Scientific, Ambala, Haryana) was used to perform the isometric exercise. The subjects were instructed to hold the dynamometer in the dominant hand and asked to squeeze the dynamometer with maximum effort, which was maintained for about 3 seconds. Then subjects were asked to squeeze the Grip Dynamometer with 30% of the Maximum Voluntary Contraction (MVC) value for 3 minutes and then release the grip [22]. Immediately after release of the grip participants were instructed to repeat the spirometry again exactly by the same method as base line spirometry and the PIF, MIF 50, PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75 were documented.

STATISTICAL ANALYSIS

The statistical analysis was performed with IBM SPSS Statistics version 24.0 software (SPSS South Asia Pvt. Ltd.). Descriptive variables like gender were expressed as percentage. For continuous variables, the mean and standard deviation was computed following descriptive statistics procedure and comparison of mean value of inspiratory and expiratory flow parameters at baseline and at 3 min of Sustained hand grip exercise was done following paired t-test. The p-value <0.05 was considered significant. Correlation analysis was done following Karl Pearson Correlation coefficient to study the linear relationship between FFMI and other inspiratory and expiratory flow rates like PIF, MIF50, PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75 at 3 minutes of sustained hand grip exercise. Correlation was significant at the 0.05 level (2-tailed).

RESULTS

The baseline characteristics of the study participants like age, gender, height, weight, BMI, fat percentage, FFM and FFMI is shown in the [Table/Fig-1].

Variables		Mean±SD
Age (in years)		19.42±1.10
Gender (N=150)	Male n (%)	86 (57.3)
	Female n (%)	64 (42.7)
Weight (in Kg)		63.04±11.55
Height (in meter)		1.92±0.27
BMI (in kg/m^2)		23.91±3.58
Fat%		27.23±7.47
FFM (in Kg)		45.58±8.13
FFMI (Kg/m^2)		17.25±2.5

[Table/Fig-1]: Shows baseline characteristics of study participants.
FFMI: Fat free mass index; FFM: Fat free mass; BMI: Body mass index

The inspiratory flow parameters like PIF and MIF 50 and expiratory flow parameters PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75 (mean±SD) decreased at 3 minutes of handgrip exercise as compared to baseline as shown in [Table/Fig-2]. The decrease was significant (p<0.05) for PEF, MEF 25-75, MEF 50, MEF 75 and MIF50. The decline in mean flow rates for PIF (p=0.083) and MEF 25 (p=0.401) were not significant (p>0.05).

Flow parameters (L/s)	At baseline (Mean±SD)	At 3 mins of exercise (Mean±SD)	Mean difference	p-value
PIF	5.27±1.737	5.13±1.686	0.140	0.083
MIF50	5.05±1.733	4.81±1.674	0.247	**0.004***
PEF	6.91±1.644	6.67±1.856	0.233	**0.012***
MEF 25-75	4.23±1.037	4.1±1.151	0.127	**0.041***
MEF 25	2.35±0.787	2.31±0.851	0.047	0.401
MEF 50	4.85±1.297	4.63±1.393	0.227	**0.001****
MEF 75	6.53±1.67	6.28±1.715	0.253	**0.012***

[Table/Fig-2]: Shows the Inspiratory and Expiratory flow parameters at base line and at 3 minutes of exercise with mean difference and p-value.
p<0.05 was considered statistically significant; L: Litre; s: Second; PIF: Peak inspiratory flow; MIF: Migration inhibitory factor; PEF: Peak expiratory flow; MEF: Maximum expiratory flow

Analysis of correlation of inspiratory and expiratory flow parameters with FFMI showed that PIF, MIF 50, PEF, MEF 25-75, MEF 50, MEF 75 had significant positive correlation with FFMI p<0.05. The correlation coefficients ranged between 0.231 to 0.380 [Table/Fig-3]. MEF 25 did not show any significant correlation with FFMI. This implies that the inspiratory and expiratory flow parameters had significant positive correlation with FFMI though the correlation was weakly positive.

Variables	r-value	p-value
PIF vs FFMI	0.380	**<0.001****
MIF50 vs FFMI	0.369	**<0.001****
PEF vs FFMI	0.321	**<0.001****
MEF 25-75 vs FFMI	0.231	**0.004***
MEF 25 vs FFMI	0.090	0.274
MEF 50 vs FFMI	0.269	**<0.001****
MEF 75 vs FFMI	0.334	**<0.001****

[Table/Fig-3]: Shows r-value and p-value of correlation of inspiratory and expiratory flow parameters versus FFMI.
*Correlation is significant at the 0.05 level (2-tailed); **highly significant, p<0.001; FFMI: Fat free mass index

DISCUSSION

The present study was conducted to find out the influence of isometric exercise on respiratory flow parameters and to evaluate any correlation between muscle mass and flow parameters. In this cross-sectional study, we investigated the change of inspiratory and expiratory flow parameters like PIF, MIF 50, PEF, MEF 25-75, MEF 25, MEF 50 and MEF 75 between baseline values and at 3 minutes of sustained hand grip exercise. It was observed that there was a reduction in all the flow parameters under study at 3 minute of sustained hand grip as compared to baseline values. This exercise induced decrease of flow parameters were statistically significant (p<0.05) for all flow parameters under study except PIF and MEF 25 (p>0.05). Change in respiratory parameters after isometric exercise has been studied by different researchers with variable observations. Imms FJ and Mehta D in their study found that with isometric exercise of skeletal muscles there was an increase in ventilation and oxygen consumption. Further they found that the magnitude of increase in ventilation was related to the maximal voluntary contraction (20% versus 40%) [11]. Fontana GA et al., in their study of respiratory response to static handgrip exercise at 15, 20 and 30% of maximal voluntary contraction observed that during 25% and 30% of Maximal voluntary Contraction (MVC), MIF, Tidal volume and minute ventilation increased [23]. Hazari MAH et al., in their study of effect of ongoing isometric hand grip exercise on the inspiratory and expiratory reserve volumes (IRV and ERV) observed that there was no significant change in both IRV (p=0.15) or ERV (p=0.78) after 3 minutes of exercise. The expiratory flow parameters they studied were PEFR (p=0.09) and PEF 25-75 (p=0.19) which also showed no significant change between baseline and after 3 minutes of exercise [13].

The observation of reduction in flow parameters in the present study can be explained by the basic physiological principle that spirometric maximal flow parameters are determined by airway resistance along with elastic recoil pressure of lungs and force generated by inspiratory muscles [24]. Resistance of the airways inturn is regulated by neural and humoral agents through their effect on airway smooth muscles. Though airway smooth muscle tone is mediated by β2 adrenergic receptors that predominate in the airways, the parasympathetic tone is greater than the sympathetic tone. So, when parasympathetic post-ganglionic fibers are stimulated either directly or reflexively it causes airway constriction and resultant increase in airway resistance. The possible mechanism leading to a decrease in respiratory flow parameters after isometric exercise could be a disturbed balance between sympathetic bronchodialating activity and parasympathetic bronchoconstriction activity during and after exercise. Though, there is increased sympathetic activity during exercise, after exercise an increased parasympathetic drive remains from sensitized mechanoreceptors and perhaps from bronchial smooth muscle causing bronchial constriction post-exercise. Simonsson BOG et al., demonstrated that atropine showed a significant blocking effect on post-exercise bronchoconstriction [25]. Further there may be another cause of exercise induced bronchoconstriction, Such as release of mediators acting directly on airways smooth muscles. Bradykinin has been mentioned as a possible cause of decreased flow by Mcneill RS et al., [26]. Seaton A et al., have also found that in majority of patients with airways obstruction bradykinin seems to act mainly on the vagal reflex [27]. A more complicated but possible post-exercise bronchoconstriction could be a partial β-blockade and an α-receptor stimulation. Simonsson BOG et al., elicited a significant bronchoconstriction by α-stimulation (phenylephrine) after intravenous atropine & propranolol in their study [25].

There are studies showing correlation of fat mass and fat free mass on various static and dynamic lung function parameters. Sutherland TJT et al., in their study of relationship between body fat and respiratory function in young adults concluded that increased adipocity is associated with impairment in lung function across broad range of static and dynamic lung volumes [28]. Similarly, Park JE et al., in their study of effect of body composition on pulmonary function observed that in case of males, FFMI showed positive correlation with FVC and FEV1 which is opposite to body fat percentage whereas in case of females, FFMI showed some level of reverse effect on expiratory reserve volumes and inspiratory capacity and concluded that not only age, gender or body weight but body fat percentage, muscle mass, FFM, FFMI and Waist-hip ratio also affected FEV1 and PEF 25-75 [17].

In the present study, authors have tried to find out the correlation between the inspiratory and expiratory flow parameters and FFMI. We observed a significant positive correlation of PIF, MIF50, PEF, MEF 25-75, MEF 50 and MEF 75 with FFMI. The r values were in the range between 0.231 and 0.380 and the association was low.

This positive correlation of inspiratory flow parameters with FFMI can be explained by the fact that the force that is generated by the inspiratory muscles is one of the major factors responsible for maximum inspiratory flow rate. In contrast, different physiologic phenomenon occurs during expiration. During exhalation maximal flow occurs in the first 20% of the maneuver (early) and flow rates decrease progressively, a phenomenon called expiratory flow limitation. Maximal flow early in the expiratory maneuver is effort dependent and is related to the strength of expiratory muscles. So, greater muscle mass ensures higher peak and mid expiratory flow rates [24]. This explains finding of this study positive correlation of PEF and MEF 25-75 with FFMI.

Though, there are less number of studies on correlation of respiratory flow parameters with FFMI, these findings are in agreement with observations of other researchers with similar studies in relation to some of the flow parameters whereas it differs for some other variables. Pradhan BB and Behera S in their study of Fat free mass and FFMI as reference variables for expiratory and inspiratory Flow rates had observed that PEF (r=0.05), PIF (r=0.388) and MIF50 (r=0.38) were having positive correlation with FFM and FFMI. But they observed negative correlation of MEF 50 (r=-0.123) and MEF 75 (r=-0.151) with FFMI [29]. In their study of correlation between BMI, body fat percentage and pulmonary function in underweight, overweight and normal weight adolescents, Lad UP et al., concluded that BMI and body fat percentage were negatively correlated with FVC and FEV1 in males and females of the overweight group and PEF 25-75 had a strong negative correlation with the body fat percentage only in the overweight group (r value range-0.29 to -0.48) [16]. Lorenzo AD et al., in their study also observed that PIF and MIF 50 had a positive correlation with FFMI [30]. So, we can opine that improving muscle mass, respiratory muscles in particular can have beneficial effect on ventilation due to improvement in inspiratory as well as expiratory flow rates.

Limitation(s)

The limitation of this study was in its design. It was a cross-sectional study, carried out in a single centre on a smaller group of participants. A multi-centric study with larger population is needed.

CONCLUSION(S)

There was a reduction in both inspiratory as well as expiratory flow rates due to sustained hand grip. So isometric exercises, may not be helpful in improving ventilation. In fact, such exercises should be avoided or practised with caution in patients with obstructive airway disease like COPD, Bronchial Asthma or Bronchiectasis as this may further compromise the flow rates and worsen symptoms. As a positive correlation between FFMI and Peak inspiratory as well as expiratory flow rates was observed, patients with cardiorespiratory disease specifically those with obstructive pulmonary diseases should emphasise on building muscle mass which may help in improving ventilation.

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