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THE CHARACTERISTICS AND DETERMINANTS OF MAXIMAL EXPIRATORY PRESSURE IN YOUNG, HEALTHY, INDIAN MALES

T. T. UKYAB AND MARIO VAZ*

Department of Physiology,
St John's Medical College,
Bangalore – 560 034

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Abstract : Maximal expiratory pressure (MEP) can be used as an index of respiratory muscle strength and of the ability of an individual to cough effectively. The influence of anthropometry, nutritional status and ethnicity on MEP was studied in 113 young healthy Indian males and 53 Tibetans between 18 and 30 years of age. All subjects underwent an anthropometric assessment. Anthropometric variables (BMI, log BMI) explained only 12.5% of the variance in MEP. MEP was significantly lower in chronically undernourished subjects when compared with anthropometrically similar underweight subjects ($P<0.05$). The Indian subjects had significantly lower MEP's than BMI matched Tibetan subjects ($P<0.01$). This difference may have been due to the higher chest circumferences in the Tibetans ($P<0.01$). While general muscle strength (maximal hand grip) and MEP were significantly correlated ($r=0.26$, $P<0.01$), the strength of the correlation was relatively low, suggesting that the determinants of the two measures were considerably different.

Key words : maximal expiratory pressure   anthropometry   undernutrition   Indian   Tibetan

INTRODUCTION

Maximal expiratory pressure (MEP) and maximal inspiratory pressures (MIP) together provide a composite index of respiratory muscle strength (1–4). The measurement of MIP in the field requires either a negative pressure gauge or a pressure transducer (5), which adds to the cost of the measurement. The measurement of MEP on the other hand is extremely cost effective requiring no more than an aneroid blood pressure gauge attached to a mouth-piece of standard dimensions. The equipment can be assembled virtually anywhere. The use of MEP as an independent measure of respiratory muscle strength would require a correlation between MIP and MEP. This is in fact true. Results from literature suggest that correlations between the two parameters over a wide range of pressures range from + 0.62 to + 0.68 (5, 6). Thus, MEP can be used as a screening test of respiratory muscle strength in situations where MIP cannot be measured. In addition, MEP is

*Corresponding Author

an independent indicator of the ability of an individual to cough effectively (7). This is an important assessment in susceptible groups, where the inability to cough effectively predicts the development of atelectasis and respiratory infection. A reduced MEP has also been shown to be associated with a sensation of dyspnoea (3).

There is limited data on the determinants of MEP in Indians (5), and no data to the best of our knowledge on the possible predictors of MEP in a normal Indian population. This study was carried out with the following aims:

1. To determine the anthropometric predictors of MEP in a population of healthy, young Indian males between the ages of 18 and 30 years.

2. To determine whether MEP was reduced in chronically undernourished subjects.

3. To determine differences in MEP between BMI-matched healthy Tibetans and Indians.

4. To determine whether MEP as an index of respiratory muscle strength was correlated with general muscle strength derived from hand dynamometry.

METHODS

Subjects: A total of 113 healthy, adult (between the ages of 18 and 30 years) Indian males were recruited as part of this study. The well nourished subjects were recruited from among the staff and students of the medical college, while the undernourished subjects were recruited from the surrounding urban slums and from the catchment area of a rural hospital. Exclusion criteria for subjects were the presence of asthma or other chronic respiratory ailments, habitual smoking, chronic disease and chronic medication. Subjects with BMI's (kg/m^2) less than 18.5 were divided into an undernourished group and an underweight group on the basis of socio-economic status (8) (Undernourished; BMI<18.5, SE Class IV, Underweight; BMI<18.5, SE class I and II). This differentiation has allowed for the uncovering of functional differences between these two groups in a variety of physiological parameters (9, 10, 11). In addition 53 healthy Buddhist monks were studied at the Sera Mahayana Buddhist University in Bylakuppe, Mysore Dt., Karnataka. Anthropometric data on this subgroup has been reported in an earlier paper (12). All subjects gave fully informed consent to the protocol which was approved by the Human Ethics Review Committee of the Medical College.

Anthropometry: Height was measured to the nearest 0.1 cm using a portable stadiometer (Nivotise Brivete-Depose, France). Weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale (Soehnle Digital S, Germany). Body mass index was calculated as weight (kg)/height^2 (m). Mid upper arm circumference (MAC) and chest circumference were measured using techniques described by Lohman (13) and adopted at the NIH sponsored Arlie Conference on the standardisation of anthropometric measurements. Maximal forearm circumference and the forearm skinfold were used to determine forearm muscle area from the equations of Heymsfield et al. (14) as done in earlier studies (11).

Measurement of general and respiratory muscle strength : General muscle strength was measured as the maximal voluntary contraction (MVC) on the nondominant side using a Harpenden handgrip dynamometer (CMS Weighing Equipment Ltd. England). Three measurements were taken with the subject standing up and the dynamometer held slightly away from the body. The highest of the three readings was taken for analysis.

Respiratory muscle strength was assessed by measuring maximal expiratory pressure (MEP). This was determined using a modified Black's apparatus (1). This consisted of a small cylinder of specific dimensions, as described by Black, connected to an aneroid pressure gauge. A three way connector allowed the cylinder and the pressure gauge to be connected to a mercury manometer for calibration checks. Maximal expiratory pressure was determined by asking the subject to blow into the cylinder after a maximal inspiratory effort. Three readings were obtained on each subject and the highest of the three readings was used in the statistical analysis.

Statistical analysis : All data are presented as mean ± SEM (standard error of the mean). For the analysis of differences between Indian and Tibetan subjects, the Indian study sample was divided into five groups, using BMI quintiles. The Tibetan subjects were assigned to the quintiles generated for Indians so that the two groups could be compared while controlling for BMI. Comparisons between Indians and Tibetans were made using a Two-way ANOVA (BMI × Group). Differences between the BMI quintiles in each group were assessed using a One-way ANOVA, with Scheffe as the post-hoc test. Linear associations were established using Pearson's Correlations. A multiple stepwise regression was performed to predict MEP using various anthropometric indices. Differences between the "underweight" group and the "undernourished" group were assessed using an independent 't' test. In all instances the null hypothesis was rejected at $P<0.05$

RESULTS

An analysis of the correlations between MEP and the anthropometric measurements showed that log transformed BMI was the only significant correlate of MEP ($r=0.19$, $P<0.05$) although several other anthropometric parameters including BMI ($r=0.17$, $P=0.09$) had correlates that were just short of statistical significance. When all the anthropometric variables were included into a stepwise regression model for the prediction of MEP, only BMI and log BMI were accepted into the model. However, the multiple correlation coefficient of the model was only 0.353 accounting for just 12.5% of the variance in MEP. The resultant prediction equation was given by :$-16.01*BMI + 856.3*\log BMI-688.7$.

Comparisons between underweight and undernourished subjects (Table II revealed that undernourished subjects had MEP's that were ~15% lower when compared with underweight subjects. This reduction was

TABLE I : A comparison of key anthropometric, muscle and respiratory parameters between underweight and undernourished Indian subjects.

Parameter	*Underweight*	*Undernourished*
Sample size	11	17
Anthropometry		
BMI (kg/m^2)	17.3 ± 0.3	17.0 ± 0.2
Weight (kg)	52.0 ± 1.2	48.3 ± 1.0
Foream muscle area (cm^2)	37.4 ± 1.4	39.9 ± 1.0
Chest circumference (cm)	75.0 ± 0.8	76.9 ± 0.7
Muscle/Respiratory		
MVC (kg)	36.3 ± 1.1	36.8 ± 1.1
MVC/FAMA (kg/cm^2)	0.94 ± 0.03	0.92 ± 0.02
Maximal expiratory Pressure (mm Hg)	105.4 ± 6.6	88.7 ± 4.6*

*P=0.05, independent 't' test

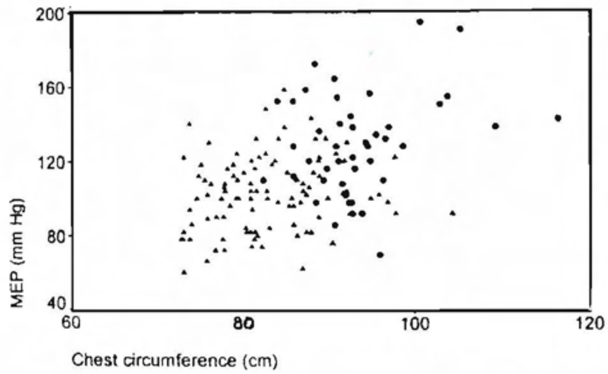

Fig. 1 : The correlation for the pooled data of Indians and Tibetans between chest circumference and maximal expiratory pressure (r=0.43, P<0.01). Circles represent Tibetans, triangles represent Indians.

statistically significant despite the two groups being closely matched for whole body anthropometry. The reduction in muscle strength was, however, confined to the

TABLE II : Anthropometric, respiratory and peripheral muscle characteristics of the Indian and Tibetan subjects based on the BMI quintiles for Indians.

Parameter	*BMI Quintiles*				
BMI (kg/m^2)	*I*	*II*	*III*	*IV*	*V*
range	≤ 18.1	$>18.1 \leq 19.6$	$>19.6 \leq 21.4$	$>21.4 \leq 23.8$	>23.8
Indians					
Sample size	23	23	22	23	22
Age (yrs)	21.9 ± 0.8	20.9 ± 0.7	20.9 ± 0.7	21.7 ± 0.8	20.6 ± 0.7
Weight (kg)	49.1 ± 0.9	54.5 ± 0.8	59.3 ± 1.1	65.0 ± 1.2	75.8 ± 1.6
Height (cm)	$170.8 \pm 1.6^{a,b,c,d}$	$168.8 \pm 1.2^{a,b}$	$169.7 \pm 1.5^{a,b}$	168.9 ± 1.4^{a}	170.6 ± 1.4
Chest Circ (cm)	76.2 ± 0.6	79.8 ± 0.7	81.6 ± 0.6	87.1 ± 0.6	92.0 ± 1.4
MEP (mm Hg)	$98.7 \pm 4.0^{a,b,c,d}$	$100 \pm 3.5^{a,b}$	$112.6 \pm 3.8^{a,b}$	108.3 ± 4.5^{a}	100.9 ± 3.5
MVC (kg)	36.2 ± 1.0	39.0 ± 0.7	40.0 ± 1.2	39.6 ± 0.9	40.8 ± 1.7
Tibetans					
Sample size	0	11	15	14	13
Age*		21.2 ± 1.2	23.5 ± 0.9	24.1 ± 0.9	27.1 ± 0.9
Weight		55.5 ± 1.6^{a}	58.5 ± 1.0	63.7 ± 1.3	77.1 ± 3.5
Height		169.1 ± 2.5^{a}	169.0 ± 1.2^{a}	167.7 ± 1.5^{a}	168.8 ± 1.1
Chest circ*		89.1 ± 1.3	90.3 ± 1.1	92.5 ± 0.7	106.0 ± 1.9
MEP*		130.8 ± 9.1^{a}	122.5 ± 4.9^{a}	121.8 ± 5.4^{a}	136.5 ± 9.3
MVC	35.1 ± 1.3	39.6 ± 1.4	38.9 ± 1.7	40.7 ± 1.3	

Values are Mean (SEM). Statistical Analysis: One Way ANOVA with Scheffe as the post-hoc test.
a=P<0.05 as compared to Group V, b=P<0.05 as compared to Group IV, c=P<0.05 as compared to Group III, d=P<0.05 as compared to Group II.
*indicate significant differences between Indians and Tibetans (Two way ANOVA)
MEP=maximal expiratory pressure, MVC=maximal voluntary contraction

respiratory muscles, since maximal handgrip was comparable in the two groups.

Table II compares anthropometric parameters, and general and respiratory muscle strength in Indians and Tibetans. A Two-way ANOVA indicated that the Tibetans were significantly older than the Indians (P<0.01). Height, weight and BMI were comparable in the two groups. Chest circumference and mid arm circumference were both greater in the Tibetans (P<0.01) as was MEP (P<0.01). In contrast, maximal hand grip (MVC) was similar in the two groups. When the data of the two groups was pooled to determine what anthropometric parameters were best correlated with MEP for both the groups, chest circumference emerged as the best correlate of MEP (r=0.43, P<0.01) (Fig 1).

Table III compares the anthropometric correlates of respiratory and general muscle strength in Indians. MVC and MEP were significantly correlated, although the strength of the correlation was relatively low (r=0.26, P<0.01). In general, whole body anthropometric indices were better correlated with MVC than with MEP.

TABLE III : A comparison of the correlation coefficients (r) between indices of general and respiratory muscle function and anthropometric indices in the Indian subjects.

	Maximal voluntary contraction (MVC)	*Maximal expiratory pressure (MEP)*
Height	0.33**	– 0.09
Weight	0.41**	0.128
BMI	0.29**	0.19*
Chest circ.	0.41**	0.19*
MVC	0.29**	

*=P<0.05, **=P<0.01

DISCUSSION

Our data suggests that anthropometry can explain only a small percentage of the variance in MEP. This is in contrast with some earlier data obtained in a western population (15), where body weight was found to be a significant predictor of MEP. In the earlier study, however, no attempt was made to control for gender, although gender is an important determinant of MEP (5). Similarly, the low body weight subjects had major illnesses resulting in relatively recent weight losses prior to the MEP measurements (15). Other variables that have been shown to predict respiratory muscle strength include age (6) and respiratory parameters such as vital capacity (15, 16). Since vital capacity may in part be determined by the level of physical training of the individual (17), the physical activity level of the individual may also predict MEP. However, the inclusion of these predictor variables requires special measurements which may not be available at the bedside of a patient.

Chronically undernourished subjects are characterised by sarcopenia, a reduction in muscle mass (11). This reduction results in diminished hand grip strength, even when corrected for local muscle area (11). The reduction in muscle strength may be related to the effects of food deprivation on the rates of protein synthesis and degradation in skeletal muscle (18) and on enzyme profiles (19). In addition, undernutrition is also characterised by a preservation of Type I fibres, a selective atrophy of Type II fibres and an increased conversion of Type II to Type I fibres (20). Acute starvation in rats is associated with a reduction in diaphragmatic weight accompanied by reduced strength and endurance capacity (21). These findings have been confirmed in necroscopic studies in humans which have indicated that diaphragmatic weight is also reduced in poorly nourished subjects (22). This reduction in muscle mass would have been expected to result in reduced respiratory muscle strength. In order to control for changes in anthropometry, we compared undernourished subjects with anthropometrically similar underweight subjects and found that MEP was lower in the undernourished group. Assuming proportional diaphragmatic weights in the two groups based on body weight, the data would suggest that the reduction in MEP in the undernourished group was not related to muscle mass but to some other factor.

The practical consequences of diminished respiratory muscle strength in undernourished subjects need to be evaluated prospectively. However, reduced MEP has been associated with reduced maximal voluntary ventilation (15). It is conceivable, therefore, that the reduction in MEP may in part contribute to the reduced work capacity described in undernourished subjects (23), since cardio-respiratory factors are also operative in addition to skeletal muscle factors in limiting whole body exercise (17).

The data also demonstrates that BMI matched Tibetans have greater MEP's than Indians. The significantly higher chest circumference in the Tibetans could have resulted in the higher MEP in this group. The enhanced chest circumference in the Tibetans is in keeping with earlier descriptions of the anthropometry of Tibetans and other highland groups (24). The average residence of the Tibetans at the monastery (altitude: ~3000 ft.) was 6.6 ± 1.0 yrs. The location of the prior residence of the Tibetan monks was not ascertained. This is a lacuna since chest size and shape is both genetically and environmentally determined (24). In the case of the latter, lung growth is stimulated by hypoxia in children born and raised at high altitudes (25). It would be interesting to explore the possibility of enhanced MEP as an adaptation in native highlanders. Despite considerable research into respiratory physiology at high altitudes (24), there is little information about the changes in respiratory muscle strength.

Our data further demonstrates that while respiratory and general muscle strength are correlated, the strength of the correlation is quite low. This suggests that the determinants of respiratory muscle strength and hand grip are considerably different. This is not surprising given that skeletal muscle is quite heterogeneous and that the fibre composition varies in different muscle groups (17).

Limitations of the study : The dietary intake of the undernourished and underweight groups was not assessed in the present study. The quality of the diet, especially protein intakes is important in determining muscle strength (26). Earlier studies have indicated that the energy intakes of underweight subjects similar to the group in the present study are approximately 10

MJ/day as compared to ~8.5 MJ/day for the undernourished subjects (27). Maintenance of body weight at the same level in the two groups, in the presence of differential energy intakes could only be achieved by either greater physical activity or reduced metabolic efficiency in the underweight subjects. Differential physical activity patterns resulting in differential levels of aerobic fitness could thus conceivably explain the lower MEP's in the undernourished group of our study. It would therefore be pertinent to evaluate the role of diet and habitual physical activity as causes of the differences in undernourished and underweight subjects.

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