ABSTRACT

The spirometric measurements are very sensitive, accurate and reliable parameters, which have diagnostic as well as prognostic values. We aimed to find the reliability of two simple measurements, namely chest expansion and voluntary breath holding, which are often suggested as tools for screening and monitoring of respiratory diseases. A cross-sectional descriptive study was conducted on students of Nepal Medical College. Measurements of spirometry (forced vital capacity, FVC in liter; forced expiratory volume in first second, FEV₁ in liter; and peak expiratory flow rate, PEF in liter per second), cirtometry (average of maximum chest expansion, CE in centimeter), and breath-holding time (maximum voluntary apnea at end-inspiration, MVAIT and maximum voluntary apnea at end-expiration, MVAET in second) were performed. Degrees of correlation (Pearson’s r) were determined between different parameters; setting level of significance at 95%. Total 308 students (M=164, 53.25%; F=144, 46.75%) participated. Owing to very highly significant differences between males and females, gender-separate correlations were determined. In males, CE correlation was very highly significant (p=0.000) with FVC and FEV₁ but not with PEF. MVAET correlated significantly with FVC, FEV₁, and PEF; MVAIT correlation was not significant with any parameters. In females, CE correlation was significant with FVC and FEV₁ but not with PEF; MVAET and MVAIT correlations were not significant with any of the parameters. In conclusion, the correlation of CE with different spirometric parameters is significant but not very strong (0.3<r<0.5). Also, gender differences exist. Therefore, using CE and breath-holding time may not be appropriate to assess respiratory ventilatory function.

KEYWORDS

Breath-holding time, cirtometry, spirometry

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INTRODUCTION

Spirometry is commonly used means to assess lung ventilatory function in various diseases. Forced vital capacity (FVC), forced expiratory volume in first second (FEV₁), and peak expiratory flow (PEF) are some of the important spirometric parameters. Chest size and mobility, strength of respiratory muscles, and size of the airways are some of the important factors affecting spirometric findings.¹,²,³

Chest expansion (CE) is defined as the difference between chest circumferences at maximal inhalation and maximal exhalation.⁴ Normal chest wall mobility is important for lung expansion and subsequent ventilation; thus measurement of CE, that is cirtometry, is one of the simplest techniques to evaluate respiratory function. CE demonstrates high inter-rater and intra-rater reliability.⁵,⁶ Its correlation with lung volumes and capacities is diverse, hence making its use as an alternate to spirometry is arguable.⁷

The other measurement, breath holding time (BHT) or voluntary apnea time is determined as the breaking point of voluntary breath hold which occurs when urge to resume breathing exceeds the will to hold the breath.⁸,⁹ It can be determined for maximal voluntary apnea expiratory time (MVAET, MVAIT). BHT has been found to be well correlated with FEV₁ and magnitude of dyspnea in patients.¹⁰,¹¹

Owing to their simplicity and cost effectiveness, the CE and BHT have been suggested as reasonable alternatives to spirometry in resource-poor settings with the advantage of independence from technician and machine.¹²,¹³ This study aims to verify this claim.

MATERIALS AND METHODS

The study was conducted on the first and second year medical and dental students of Nepal Medical College Teaching Hospital (NMCTH), from November 2013 to October 2014. Students were asked to abstain from strenuous physical activity and large meal for a day and to wear comfortable clothes on the day of the test. Smokers, those on regular exercises, having common cold and other respiratory disorders, oral and facial pain, and musculoskeletal problems of the chest wall were excluded from the study. Ethical clearance was obtained from the Institutional Review Committee of the NMCTH. Informed written consent was obtained from participants.

CE was performed with the help of the tailor’s inelastic measuring tape with the subject standing erect and hands on the waist. Upper thoracic level was marked at the fifth thoracic spinous process at the back and the third intercostal space at the mid-clavicular line in the front; the lower thoracic level was marked at the tenth thoracic spinous process at the back and the tip of the xiphoid process in the front. Thoracic circumferences were measured in maximum inspiration and maximum expiration at both levels, three times with five minutes rest in between, and the best values were taken (highest for inspiration and lowest for expiration). CE (in centimeter) was calculated as the difference between maximum (end-inspiratory) and minimum (end-expiratory) thoracic circumferences.¹⁴

Breath-holding time (BHT) was also calculated. For maximal voluntary apnea inspiratory time (MVAIT in second), subjects were asked to take three deep breaths and to hold breath at last end-inspiration, then counting to breaking point. For maximal voluntary apnea expiratory time (MVAET in second), subjects were asked to take three deep breaths and to hold breath at last end-expiration till breaking point. Each maneuver was repeated three times and the best (highest) values were considered.¹⁵

 Forced spirometry was performed in computerized spirometer (Spiro Excel Machine Spirometer, Medicaid System, Chandigarh, India, 2003). Spirometer was prepared, calibrated, and subject was properly instructed. In comfortable standing position, the subject inspired maximum deeply, then expelled as much air as he/she can with maximum effort into the mouthpiece (nose clip-closed). Three satisfactory readings were taken, allowing 5 minutes rest between efforts, and the best value was considered.¹³ Forced vital capacity (FVC in liter), forced expiratory volume in first second (FEV₁ in liter), and peak expiratory flow rate (PEF in liter per second) were considered for comparisons and correlations.

The collected data was entered in Microsoft Excel worksheet and analysed with the SPSS version 16.0. Degrees of correlation between variables were determined by Pearson’s correlation coefficient (r); level of significance was set at 95% (p value 0.05).

RESULTS

Total 308 students participated in the study; the female and male populations differed significantly in age and anthropometric variables (Table 1).

Similarly, respiratory parameters were also significantly different between females and males (Table 2). Next, the correlation (Pearson correlation, r) between different parameters were determined for female and male participants (Table 3).
In either sex, CE was significantly correlated (positive correlation) with FVC and FEV\textsubscript{1} but not with PEF; the correlations were highly significant in males. Expiratory voluntary apnea time (MVAET) correlated significantly (positive correlation) with all three spirometric parameters in males but not in females. The inspiratory voluntary apnea time (MVAIT) had no significant correlation with any of the spirometric parameters in either sex. Also, there was weak (not statistically significant) positive correlation between CE and BHT (\(r<0.15, p>0.05\); not shown in table).

**DISCUSSION**

The spirometry as the tool of pulmonary function tests, in providing objective, quantifiable measures of lung function is established and widely used\textsuperscript{16}. Accurate and reliable results depend on accurate equipment, operator competence, and cooperative patient, and its biggest limitation is the interpretation of results of poorly performed tests\textsuperscript{17}. Some simpler tools such as single parameter measurements (vital capacity), CE, BHT, exercise tolerance tests, and even smart phone based games have been tried. This study aimed to assess whether CE and BHT have strong correlations with select spirometric parameters to be useful as screening tools for respiratory health assessment. Such studies are scantily available in literature search.

In this study, spirometry, cirtometry, and voluntary apnea times were determined in 308 young adults. Nepal \textit{et al} (2014) reported spirometric evaluation in a similar population of Nepalese medical students (n=174, 103 males and 71 females). While the age is similar, the spirometric values in their study are lower for males as well as females. The comparison of average of age and anthropometric variables of male and female participants is shown in Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Female, n=144 (mean±SD)</th>
<th>Male, n=164 (mean±SD)</th>
<th>ANOVA (F)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.1±1.1</td>
<td>19.6±1.2</td>
<td>15.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>159.4±5.7</td>
<td>172.5±6.6</td>
<td>341.1</td>
<td>0.000</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>54.7±8.4</td>
<td>65.5±10.8</td>
<td>93.2</td>
<td>0.000</td>
</tr>
<tr>
<td>BMI (kg/m\textsuperscript{2})</td>
<td>21.5±3.3</td>
<td>21.9±3.1</td>
<td>1.4</td>
<td>0.237</td>
</tr>
</tbody>
</table>

Table 2: Comparisons of BHT, cirtometry, and spirometric parameters between females and males

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Female, n=144 (mean±SD)</th>
<th>Male, n=164 (mean±SD)</th>
<th>ANOVA F</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVAIT (sec)</td>
<td>39.6±12.9</td>
<td>54.5±40.8</td>
<td>17.06</td>
<td>0.000</td>
</tr>
<tr>
<td>MVAET (sec)</td>
<td>25.6±8.6</td>
<td>30.1±22.1</td>
<td>4.89</td>
<td>0.028</td>
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<tr>
<td>FVC (l)</td>
<td>2.8±0.3</td>
<td>4.2±0.5</td>
<td>378.92</td>
<td>0.000</td>
</tr>
<tr>
<td>FEV\textsubscript{1} (l)</td>
<td>2.5±0.3</td>
<td>3.6±0.5</td>
<td>333.14</td>
<td>0.000</td>
</tr>
<tr>
<td>PEF (l/s)</td>
<td>5.8±1.1</td>
<td>9.3±1.4</td>
<td>369.78</td>
<td>0.000</td>
</tr>
<tr>
<td>CE (cm)</td>
<td>5.6±1.4</td>
<td>8.7±2.2</td>
<td>180.98</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 3: Correlation of voluntary apnea time and chest expansion with spirometric parameters in females and males

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Statistics</th>
<th>Female (n=144)</th>
<th>Male (n=164)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FVC</td>
<td>FEV\textsubscript{1}</td>
</tr>
<tr>
<td>MVAIT</td>
<td>Pearson correlation</td>
<td>0.092</td>
<td>0.204</td>
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<tr>
<td></td>
<td>P value</td>
<td>0.460</td>
<td>0.097</td>
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<tr>
<td>MVAET</td>
<td>Pearson correlation</td>
<td>0.070</td>
<td>0.153</td>
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<tr>
<td></td>
<td>P value</td>
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<td>0.217</td>
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<tr>
<td>CE</td>
<td>Pearson correlation</td>
<td>0.357</td>
<td>0.288</td>
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<tr>
<td></td>
<td>P value</td>
<td>0.002</td>
<td>0.015</td>
</tr>
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</table>
females compared to our findings. Closers values of 
VFC, FEV\textsubscript{1}, and PEF have been reported by 
Bandyopathay et al (2013) in a group of 87 male 
university students in Kolkata, India. Studies 
conducted on wider range of age or on patients 
would find variable measurements. Reddy et al 
(2019) have reported higher FVC (5.1±0.8 l) and 
FEV\textsubscript{1} (5.1±0.6 l) values in an all male study (n=25, 
mean age = 23.6±5.3 years). \(^{13}\)

Regarding CE, the mean CE of 8.72 cm in males 
in this study is considerably higher than the 5.6 
\text{cm} reported by Reddy et al, which is closer to 
the CE of females in this study (5.57±1.39 cms). 
Bockenhauer et al (2007), also reported a mean 
upper thoracic CE of 4.2±0.8 cm, and suggested 
that cloth tape measurement of the thoracic 
excursion is a highly reliable procedure. \(^{4}\) Adedoyin 
et al (2012) reported mean upper thoracic CE 
of 3.5±1.6 cms and 2.9±1.7 cm for males and 
females, respectively in an African population 
(age range 20-29 years). The mean CE is lower 
in patients of ankylosing spondylitis (3.05±1.63 
cms)\(^{20}\) and chronic obstructive pulmonary disease 
(3.7±0.8 cms). \(^{13,14}\) Fisher et al found a very strong 
correlation (r=0.71, p<0.001) between CE and VC in 
the patients with ankylosing spondylitis. \(^{20}\) Reddy 
et al also found very strong correlation of CE at 
upper thoracic level with FVC (r=0.678, p<0.001) 
and FEV\textsubscript{1} (r=0.595, p<0.001) in healthy controls. \(^{13}\) 
The correlations in our study were weaker, and 
significantly strong only for males (FVC and FEV\textsubscript{1}). 
In one study in COPD patients, chest wall mobility 
was found to be highly reliable and associated 
with inspiratory capacity, yet not found to infer 
pulmonary function to satisfactory level. \(^{7}\)

Regarding BHT, Palaniyandi et al (2017) found 
strong correlations of BHT (end-inspiratory) with 
FVC, \text{FEV}_{1}, and PEF (r=0.552, 0.560, and 0.333; all 
p<0.001). They suggested BHT to be a reasonable 
alternative to spirometry in a resource-poor 
setting. \(^{21}\) Similarly, Aggarwal et al (2018) reported 
a mean end-inspiratory tidal BHT in second of 
34.56±18.74 in a mixed age and sex population of 
100 healthy volunteers, which is different from 
our findings. \(^{12}\) Also, the correlation coefficients 
of 0.447 and 0.455 (both highly significant) were 
found with post-bronchodilator FVC and FEV\textsubscript{1} 
respectively. On this basis, they recommended 
BHT as a reasonable non-technician, non-machine 
dependent alternative to spirometry. However, 
BHTs had weak correlations with spirometry in 
our study, only MVAET in males having significant 
correlation with FVC and FEV\textsubscript{1}.

In conclusion, our study found correlations having 
statistical significant strength of spirometry with 
chest expansion but not with breath holding 
time and gender differences were observed in 
all. This could be due to the difference in the 
mechanisms responsible for each parameter. The 
chest excursion is principally dependent on the 
chest wall mobility and muscular efforts. On the 
other hand, breath holding time is importantly 
and additionally governed by the chemoreceptor 
regulation of respiration which overrides the 
voluntary control. \(^{4}\) In pathologic conditions, these 
correlations would be less predictable, therefore 
making their use as an alternative of spirometry 
less reliable.

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