Is A Body Shape Index (ABSI) Predictive of Lung Function?

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Abstract

Rationale: The available spirometric lung function equations in Canadian context have been limited to age and height as predictors and Caucasian ethnicity. The plausible equations with other individual predictors and First Nations populations are missing in the current literature.

Objective: To set an initial investigation in terms of study sample size and simple reference spirometric equations on the association of the set of conventional predictors in companion with two new predictors BMI and ABSI with spirometric lung function equations in Canadian First Nations Cree Populations.

Methods: First Nations Lung Health Project (FNLHP) was conducted in rural Saskatchewan, Canada. For this analysis, we used data obtained on healthy non-smokers. There were 37 First Nations people (24 females, 13 males) from the FNLHP. Bootstrap regression technique was utilized to predict pulmonary lung functions in terms of age, weight, abdominal girth and body mass index (BMI), and a body shape index (ABSI).

Main results: Controlled for age, BMI had significant association for FEF25-75 for women and no significant association for men in other outcomes. Controlled for age, ABSI had significant association for FEV1 for women and significant association for FVC and FEV1/FVC for men. In overall, ABSI was better predictor of spirometric outcomes compared to BMI.

Conclusion: ABSI may be considered as a key predictor for spirometric lung functions in men and women for Canadian First Nation Populations with more significant results in men.

Keywords

Body mass index, A body shape index, Spirometric lung functions, Model goodness of fit, Bootstrap analysis

Introduction

Spirometry is used by physicians to diagnose, evaluate and monitor respiratory diseases via comparison of individual measurements with population-specific normal ranges. There have been multiple studies of spirometric measures including Forced Expiratory Volume (FEV1), Forced Vital Capacity (FVC), their ratio (FEV1/FVC ) and Forced Expiratory Flow at 25%-75% (FEF25-75) - with reasonable goodness of fit-as linear functions of age and height [1-5]; as linear functions of age, height and weight [6-9]; and as linear functions of age, height and Body mass index (BMI) [10,11] among American Indians, African Americans and Caucasian populations. The effect of BMI as a measure of obesity on pulmonary function has been inconclusive in the literature. While in some studies an increase in BMI has been associated with the reduction of lung function [12-15],
in others almost no impact has been observed [16,17]. As an alternative measure of obesity, the World Health Organization has proposed abdominal girth in order to evaluate relationships between obesity and disease risk in different fields [18]. However, due to high correlation between BMI and abdominal girth it is challenging to consider them as two distinct epidemiological risk factors [19]. A body shape index (ABSI) (a function of abdominal girth, BMI and height) was developed to address this issue. It has almost complete independence from BMI due to low correlation, better prediction of mortality risk, and a potential predictive role in other areas of epidemiologic research [20]. Areas of research to date that ABSI has been considered as a predictor include anthropometry [21], cardiovascular disease [24-26] and cancer [27].

To the best of our knowledge, there has been little research on prediction of spirometric lung function among First Nations people. Moreover, no studies to date have addressed ABSI as a potential predictor of lung function in any population. Hence, the primary objective of this study is to determine if ABSI is a predictive of lung function and further investigate if ABSI is a better predictor of lung function than BMI.

**Methods**

**Subjects and locations**

A total of 796 (396 male, 400 females) participants were considered from two Saskatchewan First Nations communities who had completed surveys and clinical assessments in 2012-2013 as part of the First Nations Lung Health Project (FNLHP) [28]. As a cohort study, the aim of FNLHP was to assess potential health determinants including individual factors (e.g. smoking, weight), contextual factors (e.g. SES, colonization) and principal covariates (e.g. age, sex) related to respiratory outcomes (e.g. asthma) among Aboriginals. A healthy subject was defined as a person with no self-reported history of asthma, bronchitis, chronic bronchitis, pneumonia, sinus trouble, emphysema, sleep apnea, tuberculosis, and chronic obstructive pulmonary disease (COPD). Because of a high prevalence of smoking in the communities surveyed, a non-smoker was defined as one who had a self-reported lifetime smoking record of less than 16 cigarette packages and had lived primarily in a smoke-free house. Based on the given criteria, the final sample was 37 (24 females, 13 males) healthy never-smokers.

**Assessment procedures and variables**

Each subject was invited to visit the health care center in the community via door-to-door canvassing in order to complete an interviewer administered questionnaire, which included individual determinants (e.g. age, smoking status), contextual determinants (e.g. income, lifestyle) and health outcomes (e.g. bronchitis, asthma) related to respiratory health; and to participate in pulmonary function testing, including measurement of anthropometric variables (age, height, weight, abdominal girth and blood pressure) and usage of Sensormedics rolling seal spirometer [29-32] in order to measure pulmonary function variables (e.g. FEV$_1$, FVC, FEV$_1$/FVC (%) and FEF$_{25-75}$). These measurements were done in accordance with the standards of the American Thoracic Society [33]. A signed study participation consent form was obtained from each prospective subject before their participation in the study, and at the end of their participation, each was remunerated. Finally, using individual variables of weight, height, and abdominal girth, the subjects’ ABSI [20] was calculated via the following formula:

$$\text{ABSI} = \frac{\text{Abdominal Girth}}{\text{BMI}^{\frac{2}{3}} \cdot \text{Height}^{\frac{1}{2}}}$$

(1)

**Statistical analysis**

As the FNLHP sample used for this analysis was small and the outcome variables FEV1 and FEV1/FVC (%) were not normally distributed, nonparametric bootstrap regression was applied [34,35]. The nonparametric bootstrap multiple regression model with $=$ 1000 iterations were fitted for the outcome variables FVC, FEV$_1$, FEV$_1$/FVC (%), and FEF$_{25-75}$ using statistical software STATA 11 (College Station, TX: StataCorp LP). Age was always retained in the models because of its biological significance and combinations of other variables were assessed for their biological significance and goodness-of-fit of the model. Nonparametric bootstrap regression produces $\sqrt{\text{MSE}}$ (MSE - Mean squared error) which is related to standard error estimate (SEE) produced by the ordinary least squared (ols) approach [36]:

$$\sqrt{\text{MSE}} \text{ (bootstrap)} = \text{SEE (ols)}$$

(2)

The later value was reported in order to enable the reader to compare the current study results with other publications. Furthermore, a bootstrap linear model of outcome variable Y predicted by $X_1, \ldots, X_p$ was referred as:

$$Y = \text{lin}_{\text{bootstrap}} (X_1, \ldots, X_p)$$

(3)

Conventional descriptive statistics, nonparametric bootstrap regression and plots comparing predictive values of two genders based on specific values of age, height, BMI and ABSI were reported.

**Results**

**Descriptive analysis**

Table 1 presents a summary of descriptive statistics of population characteristics for participants. First, almost twice as many women as men were recruited overall; second, the study population was relatively young consistent with known population dynamics within the First Nations population [37].
### Table 1: Characteristics and age distributions of subjects in the First Nations Lung Health Project (FNLHP) 2012-2013.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Males (n = 13)</th>
<th>Min-Max</th>
<th>Females (n = 24)</th>
<th>Min-Max</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± s.e.</td>
<td></td>
<td>Mean ± s.e.</td>
<td></td>
</tr>
<tr>
<td>Predictors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>24.23 ± 2.75</td>
<td>17 - 49</td>
<td>27.75 ± 2.75</td>
<td>17 - 71</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180 ± 1.68</td>
<td>171 - 189</td>
<td>164 ± 1.15</td>
<td>151 - 177</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>84.17 ± 5.07</td>
<td>90.4 - 114.4</td>
<td>78.39 ± 3.88</td>
<td>48.8 - 128.6</td>
</tr>
<tr>
<td>Abdominal Girth (cm)</td>
<td>98 ± 4.09</td>
<td>76 - 119</td>
<td>99 ± 3.48</td>
<td>73 - 133</td>
</tr>
<tr>
<td>BMI</td>
<td>26.08 ± 1.48</td>
<td>18.99 - 34.14</td>
<td>29.1 ± 1.48</td>
<td>18.94 - 43.27</td>
</tr>
<tr>
<td>ABSI</td>
<td>0.0831 ± 0.0009</td>
<td>0.0785 - 0.0894</td>
<td>0.082 ± 0.001</td>
<td>0.0725 - 0.0912</td>
</tr>
<tr>
<td>Outcomes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FVC (l)</td>
<td>5.80 ± 0.26</td>
<td>3.97 - 7.61</td>
<td>3.86 ± 0.12</td>
<td>2.08 - 5.13</td>
</tr>
<tr>
<td>FEV₁ (l)</td>
<td>4.88 ± 0.22</td>
<td>3.07 - 6.08</td>
<td>3.27 ± 0.10</td>
<td>1.50 - 4.14</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td>84.33 ± 1.64</td>
<td>74.58 - 91.81</td>
<td>84.56 ± 1.11</td>
<td>70.96 - 93.88</td>
</tr>
<tr>
<td>FEF₂₅-₇₅ (l)</td>
<td>5.24 ± 0.38</td>
<td>2.73 - 7.10</td>
<td>3.84 ± 0.2258</td>
<td>0.98 - 5.36</td>
</tr>
<tr>
<td>Age Groups (years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17-20</td>
<td>7 (53.8)</td>
<td>8 (33.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29</td>
<td>3 (23.1)</td>
<td>10 (41.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-39</td>
<td>2 (15.4)</td>
<td>3 (12.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40-49</td>
<td>1 (7.7)</td>
<td>0 (0.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50-59</td>
<td>0 (0.0)</td>
<td>2 (8.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60+</td>
<td>0 (0.0)</td>
<td>1 (4.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>13 (100)</td>
<td>24 (100)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: FVC: Forced Vital Capacity; FEV₁: Forced Expiratory Volume during the first second; FEF₂₅-₇₅: Forced Expiratory Flaw during the middle half of the forced vital capacity; BMI: Body Mass Index; ABSI: A Body Shape Index; *: Data are presented as No (%).

### Table 2: Bootstrapped linear regression coefficients, R-values and SEE’s in the First Nations lung health project 2012-2013 (males).

<table>
<thead>
<tr>
<th>Model Outcome</th>
<th>Predictors</th>
<th>R²</th>
<th>% Difference†</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td>Constant (± S.E)</td>
<td>-8.618 (± 7.200)</td>
<td>0.54</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Age (± S.E)</td>
<td>-0.043 (± 0.047)</td>
<td>-0.086 (± 0.0394)</td>
<td>0.0577</td>
</tr>
<tr>
<td></td>
<td>Height (± S.E)</td>
<td>-0.040 (± 0.032)</td>
<td>0.068 (± 0.0259)</td>
<td>0.060</td>
</tr>
<tr>
<td></td>
<td>BMI (± S.E)</td>
<td>-0.142 (± 0.368)</td>
<td>-0.085 (± 0.2940)</td>
<td>0.234</td>
</tr>
<tr>
<td></td>
<td>ABSI (± S.E)</td>
<td>-0.036 (± 0.070)</td>
<td>0.087 (± 0.0546)</td>
<td>0.0289</td>
</tr>
<tr>
<td>FEV₁</td>
<td>Constant (± S.E)</td>
<td>-5.288 (± 1.203)</td>
<td>0.039 (± 0.055)</td>
<td>0.369</td>
</tr>
<tr>
<td></td>
<td>Age (± S.E)</td>
<td>-0.059 (± 0.043)</td>
<td>0.056 (± 0.0647)</td>
<td>0.417</td>
</tr>
<tr>
<td></td>
<td>Height (± S.E)</td>
<td>-0.033 (± 0.223)</td>
<td>-0.035 (± 0.075)</td>
<td>0.207</td>
</tr>
<tr>
<td></td>
<td>BMI (± S.E)</td>
<td>-0.033 (± 0.038)</td>
<td>0.086 (± 0.072)</td>
<td>0.107</td>
</tr>
<tr>
<td></td>
<td>ABSI (± S.E)</td>
<td>-0.051 (± 0.068)</td>
<td>-10.863 (± 77.452)</td>
<td>0.269</td>
</tr>
<tr>
<td>FEV₁/FVC (%)</td>
<td>Constant (± S.E)</td>
<td>-1.840 (± 4.848)</td>
<td>51.271 (± 64.902)</td>
<td>0.362</td>
</tr>
<tr>
<td></td>
<td>Age (± S.E)</td>
<td>-0.051 (± 0.063)</td>
<td>0.056 (± 0.0643)</td>
<td>0.378</td>
</tr>
<tr>
<td></td>
<td>Height (± S.E)</td>
<td>-0.220 (± 0.205)</td>
<td>1085.266 (± 479.60)</td>
<td>0.307</td>
</tr>
<tr>
<td></td>
<td>BMI (± S.E)</td>
<td>-0.060 (± 0.083)</td>
<td>209.323 (± 126.149)</td>
<td>0.0725</td>
</tr>
<tr>
<td></td>
<td>ABSI (± S.E)</td>
<td>-0.051 (± 0.068)</td>
<td>-10.863 (± 77.452)</td>
<td>0.269</td>
</tr>
</tbody>
</table>

Note: FVC: Forced Vital Capacity; FEV₁: Forced Expiratory Volume during the first second; FEF₂₅-₇₅: Forced Expiratory Flaw during the middle half of the forced vital capacity; BMI: Body Mass Index; ABSI: A Body Shape Index; *: indicates p-value < 0.10; **: indicates p-value < 0.05; †: indicates difference % with respect to the model containing only Age and Height.
Men were found to be younger and taller than women but had similar measures of weight and abdominal girth. As measured by BMI, women were more obese than men.

Bootstrap regression analysis

Tables 2 and Table 3 provide results of bootstrap linear regression, $R^2$ and SEE values for study participants. For the spirometric outcome $Y$ of FVC, FEV$_1$, FEV$_1$/FVC or FEF$_{25-75}$, only models $Y = \text{lin bootstrap}(\text{Age, Height})$, $Y = \text{lin bootstrap}(\text{Age, BMI})$ and $Y = \text{lin bootstrap}(\text{Age, ABSI})$ were considered as the more complete models such as $Y = \text{lin bootstrap}(\text{Age, Height, BMI})$, $Y = \text{lin bootstrap}(\text{Age, Height, ABSI})$ and $Y = \text{lin bootstrap}(\text{Age, Height, BMI, ABSI})$ had either poor goodness of fit or their majority of covariates were not significant. The best fitting model determined by maximum $R^2$ and minimum SEE values as indices of goodness of fit. On one hand, looking at the best models within each gender the following results were observed:

A. For Men:

(i) FVC = $\text{lin bootstrap}(\text{Age, Height})$ the best fitting model;

(ii) FEV$_1$ = $\text{lin bootstrap}(\text{Age, Height})$ the best fitting model;

(iii) FEV$_1$/FVC = $\text{lin bootstrap}(\text{Age, ABSI})$ the best fitting model;

(iv) FEF$_{25-75}$ = $\text{lin bootstrap}(\text{Age, BMI})$ the best fitting model;

B. For Women:

(i) FVC = $\text{lin bootstrap}(\text{Age, Height})$ as the best fitting model;

(ii) FEV$_1$ = either $\text{lin bootstrap}(\text{Age, Height})$ or $\text{lin bootstrap}(\text{Age, ABSI})$ as the best fitting model;

(iii) FEV$_1$/FVC = $\text{lin bootstrap}(\text{Age, BMI})$ as the best fitting model;

(iv) FEF$_{25-75}$ = $\text{lin bootstrap}(\text{Age, BMI})$ as the best fitting model.

### Table 3: Bootstrapped Linear Regression Coefficients, R- values and SEE’s in the First Nations Lung Health Project 2012-2013 (Females).

<table>
<thead>
<tr>
<th>Model</th>
<th>Outcome</th>
<th>Predictors</th>
<th>Constant (± S.E)</th>
<th>Age (± S.E) (year)</th>
<th>Height (± S.E) (cm)</th>
<th>BMI (± S.E)</th>
<th>ABSI (± S.E)</th>
<th>$R^2$</th>
<th>% Difference†</th>
<th>SEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>FVC</td>
<td></td>
<td></td>
<td>-4.805 (-4.050)</td>
<td>-0.006 (± 0.015)</td>
<td>0.05** (± 0.020)</td>
<td></td>
<td></td>
<td>0.313</td>
<td>0</td>
<td>0.537</td>
</tr>
<tr>
<td>FEV$_1$</td>
<td></td>
<td></td>
<td>-2.747 (-3.645)</td>
<td>-0.015 (± 0.010)</td>
<td>0.04* (± 0.020)</td>
<td></td>
<td></td>
<td>0.463</td>
<td>0</td>
<td>0.409</td>
</tr>
<tr>
<td>FEV$_1$/FVC (%)</td>
<td></td>
<td></td>
<td>109.82 (± 34.417)</td>
<td>-0.274** (± 0.107)</td>
<td>-0.10 (± 0.20)</td>
<td></td>
<td></td>
<td>0.399</td>
<td>0</td>
<td>4.430</td>
</tr>
<tr>
<td>FEF$_{25-75}$</td>
<td></td>
<td></td>
<td>-1.010 (± 8.484)</td>
<td>-0.037* (± 0.022)</td>
<td>0.04 (± 0.050)</td>
<td></td>
<td></td>
<td>0.325</td>
<td>0</td>
<td>0.951</td>
</tr>
</tbody>
</table>

- Significant level ($p < 0.10$)
- The number of equations including significant ABSI versus significant BMI are three versus none in males; and, two versus one in females, respectively.
- On the other hand, looking at the best models within each gender the following results were observed:

**Table 2:** Significant results of the best models for each gender. Significant level ($p < 0.10$), the number of equations including significant ABSI versus significant BMI are three versus none in males; and, two versus one in females, respectively. On the other hand, looking at the best models within each gender the following results were observed:
Figure 1: Three Dimensional Plots of forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), their associated ratio (FEV₁/FVC) and Forced Expiratory Flaw during the middle half of the forced vital capacity (FEF₂₅-₇₅) of Males and Females by Age and Height (a-d); and Age and BMI (e-h); and Age and ABSI (i-l).

Figure 1(a-d), Figure 1(e-h) and Figure 1(i-l) plot predicted outcome variables as bootstrap linear functions of age and Height, age and BMI and age and ABSI, respectively. As it is shown, controlled for age, height, BMI or ABSI, male have higher FVC, FEV₁ and FEF₂₅-₇₅ outcome values versus females. Furthermore, from equation (1) it follows that

\[ \text{ABSI} = \text{Abdominal Girth} \times \text{Weight}^{ \frac{2}{3} } \times \text{Height}^{-\frac{5}{6}} \]
consequently, one expects for fixed Abdominal Girth and Weight to observe similar spirometric outcome prediction trends given by Height or ABSI. This is clear from such parallel trends in Figure 1a and Figure 1i for FVC (females), Figure 1b and Figure 1j for FEV₁ (both genders), Figure 1c and Figure 1k for FEV₁/FVC (females) and, Figure 1d and Figure 1l for FEF₂₅-₇₅ (both genders).

Discussion

The current study is among the investigations on establishing spirometric lung function equations (in terms of well-known predictors such as age and height and new predictors such as BMI) among Canadian First Nation populations; and, more importantly, among the ones introducing ABSI as potential predictor of the spirometric lung function in the entire pulmonology literature.

This study shows that after controlling for age, BMI is a significant predictor of Spirometric lung function outcomes in women FEF₂₅-₇₅. In addition, its negative association with FVC and FEV₁ in females is in agreement with findings in the past publications [12-15]; however, given its positive association with mentioned outcomes in males more investigations required. The overall results of the study indicate that age and height were significant predictors of FVC and FEV₁ for both First Nations men and women as is well established in the literature.

This study presents a comparison of spirometric lung equations between BMI and ABSI. Overall, given equal number of spirometric equations with best fit in two predictors and higher number of spirometric equations with (weakly) significant ABSI versus BMI in both genders, our findings suggest that ABSI was better predictor than BMI for spirometric volumes. One explanation for this result may be attributed to higher level of the subject’s biological information in definition of ABSI given in equation (2-1) where the ABSI includes information regarding Abdominal Girth, weight and height while BMI only incudes the later two.

The low sample size is a consequence of a very high prevalence of smoking in the population sampled in which the prevalence of current smoking was 77.6% in the FNLHP [28,38]. This low percentage of non-smokers’ proportions may contribute to imprecision of regression models for this population making direct comparison to other studies challenging despite the use of the bootstrap technique to try and compensate. As such, our regression models may be limited in terms of fewer significant covariables, underestimated R² values and overestimated SEE values. This can result in bias as well as difficulty when comparing our models with those of other studies with more comprehensive set of covariates in their reference models [39].

This study was an initial investigation on establishing spirometry reference equations for Canadian First Nations Populations. The more comprehensive investigation on establishing such reference equations should consider several key features in terms of data and analysis: First, it requires a higher sample size preferably collected across Canadian provinces and territories; second, it may consider age in the equation in a non-linear association; third, it may consider a more complex models with more than two significant predictors in the reference equation; and, finally considering a more robust statistical methodology than maximum R² and minimum SEE criteria in choosing the plausible variable and best fitting spirometric reference equations.

In conclusion, this study suggests ABSI may be a useful predictor of lung function in both genders. However, until more data is available to validate and expand the findings of this study, we cannot make any firm recommendations regarding routine use of ABSI in day to day practice.

Declarations

Ethics approval and consent to participate

A Certificate of Approval for the study was obtained from the University of Saskatchewan’s Biomedical Research Ethics Board (Bio#:12-189). Participants provided informed written consent before clinical testing commenced.

Consent for publication

Not Applicable.

Availability of data and materials

Currently the data from the FNLHP are not publically available.

Competing interests

The authors declare that they have no competing interests.

Funding

This study was funded by a grant from the Canadian Institutes of Health Research “Assess, Redress, Re-assess: Addressing Disparities in Respiratory Health among First Nations People”, CIHR MOP-246983-ABHCCA-11829. It was also funded by an open doctoral fellowship by University of Toronto 2018-2019.

Authors’ contribution

MS conducted the statistical analysis and wrote the first draft with critical inputs from MF, CK, and PP. JD, PP, and SA are the co-principal investigators of the FNLHP. MF, CK, SA, JD, and NK contributed to grant writing, study design and questionnaire development, and study coordination. All other co-authors significantly contributed to manuscript preparation. All authors read and approved the final manuscript.
Acknowledgements

The authors are very thankful to the constructive comments offered by anonymous reviewers on the original manuscript draft. They are also grateful to the contributions of the First Nations Lung Health Project team including: Late Jo-Ann Episkenew, John Gordon, Bonnie Janzen, Shelley Krychuk, Joshua Lawton, Donna Rennie, Louise Hagel, Roland Dyck, Thomas Smith Windsor (University of Saskatchewan); Greg Marchildon, Amy Zarzeczny (University of Regina); Malcolm King, Ambikaipakan Senthilselvan (University of Alberta); Lesly McBain (First Nations University of Canada); Breann Davis, John Dosman (Prince Albert Medical Clinic). The authors are also thankful to the contributions of the Saskatchewan Rural Health Study team including: Yue Chen (University of Ottawa); William Picket (Queens University); Roger Pitblado (Laurentian University).

References