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RESEARCH ARTICLE

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

Mohsen Soltanifar[1,2], Chandima Karunanayake[1], Dinesh Khadka[3], Raina Henderson[4], Niels Konehnck[1], Sylvia Abonyi[5], James A Dosman[1], Punam Pahwa[1,5], Mark Fenton[6*] and the First Nations Lung Health Project[1]

[1]Canadian Center for Health and Safety in Agriculture, University of Saskatchewan, Canada

[2]Dalla Lana School of Public Health, University of Toronto, Canada

[3]Community A, Saskatchewan, Canada

[4]Community B, Saskatchewan, Canada

[5]Department of Community Health and Epidemiology, University of Saskatchewan, Canada

[6]Division of Respirology, Critical Care and Sleep Medicine, Department of Medicine, University of Saskatchewan, Canada

***Corresponding author:** *Mark Fenton, M.D, Division of Respirology, Critical Care and Sleep Medicine, Department of Medicine, University of Saskatchewan, Canada, Tel: +1(306)844-1009*

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 (FEV_1), Forced Vital Capacity (FVC), their ratio (FEV_1/FVC) and Forced Expiratory Flow at 25%-75% (FEF_{25-75}) - 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],

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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 canvasing in order to complete an interviewer administrated 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:

$$\text{ABSI}=\frac{\text{Abdominal Girth}}{\text{BMI}^{\frac{2}{3}} * \text{Height}^{\frac{1}{2}}} \quad (1)$$

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 statistical significance and goodness-of-fit of the model. Nonparametric bootstrap regression produces $\sqrt{MSE}$ (MSE - Mean squared error) which is related to standard error estimate (SEE) produced by the ordinary least squared (ols) approach [36]:

$$\sqrt{MSE}\ (\text{bootstrap}) = \text{SEE (ols)} \quad (2)$$

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, ...X_p, was referred as:

$$Y = \text{lin}_{\text{bootstrap}}\ (X_1, \ldots.., X_p) \quad (3)$$

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.

Gender	Males (n = 13)		Females (n = 24)	
	Mean ± s.e.	**Min-Max**	**Mean ± s.e.**	**Min-Max**
Predictors				
Age (years)	24.23 ± 2.75	17 - 49	27.75 ± 2.75	17 - 71
Height (cm)	180 ± 1.68	171 - 189	164 ± 1.15	151 - 177
Weight (kg)	84.17 ± 5.07	90.4 - 114.4	78.39 ± 3.88	48.8 - 128.6
Abdominal Girth (cm)	98 ± 4.09	76 - 119	99 ± 3.48	73 - 133
BMI	26.08 ± 1.48	18.99 - 34.14	29.1 ± 1.48	18.94 - 43.27
ABSI	0.0831 ± 0.0009	0.0785 - 0.0894	0.082 ± 0.001	0.0725 - 0.0912
Outcomes				
FVC (l)	5.80 ± 0.26	3.97 - 7.61	3.86 ± 0.12	2.08 - 5.13
FEV_1 (l)	4.88 ± 0.22	3.07 - 6.08	3.27 ± 0.10	1.50 - 4.14
FEV_1/FVC (%)	84.33 ± 1.64	74.58 - 91.81	84.56 ± 1.11	70.96 - 93.88
FEF_{25-75} (l)	5.24 ± 0.38	2.73 - 7.10	3.84 ± 0.2258	0.98 - 5.36
Age Groups (years)				
17-20	7(53.8)*		8(33.3)	
20-29	3(23.1)		10(41.7)	
30-39	2(15.4)		3(12.5)	
40-49	1(7.7)		0(0.0)	
50-59	0(0.0)		2(8.3)	
60 +	0(0.0)		1(4.2)	
Total	13(100)		24(100)	

Note: FVC: Forced Vital Capacity; FEV_1: Forced Expiratory Volume during the first second; FEF_{25-75}: 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).

Model						R^2	% Difference†	SEE
Outcome	**Predictors**							
	Constant (± S.E)	**Age (± S.E) (year)**	**Height (± S.E) (cm)**	**BMI (± S.E)**	**ABSI (± S.E)**			
FVC	-8.618 (± 7.200)	-0.043 (± 0.047)	0.086** (± 0.0394)			0.54	0	0.734
FEV_1	-6.481 (± 4.775)	-0.040 (± 0.032)	0.068** (± 0.0259)			0.577	0	0.584
FEV_1/FVC (%)	103.039* (± 53.294)	-0.142 (± 0.368)	-0.085 (± 0.2940)			0.060	0	6.2
FEF_{25-75}	-9.536 (± 10.142)	-0.036 (± 0.070)	0.087 (± 0.0546)			0.234	0	1.34
FVC	5.413** (± 1.402)	-0.078* (± 0.047)		0.086 (± 0.072)		0.417	-22.8	0.826
FEV_1	5.288** (± 1.203)	-0.059 (± 0.043)		0.039 (± 0.055)		0.369	-36	0.713
FEV_1/FVC (%)	97.258** (± 9.820)	0.023 (± 0.223)		-0.520 (± 0.390)		0.207	245	5.7
FEF_{25-75}	6.942** (± 2.197)	-0.033 (± 0.083)		-0.035 (± 0.075)		0.107	-54.3	1.447
FVC	7.910 (± 5.824)	-0.051 (± 0.068)			-10.863** (± 77.452)	0.269	-50.2	0.225
FEV_1	1.840 (± 4.848)	-0.051 (± 0.063)			51.271 (± 64.902)	0.362	-37.3	0.717
FEV_1/FVC (%)	-0.566 (± 39.499)	-0.220 (± 0.205)			1085.266** (± 479.60)	0.378	530	5.1
FEF_{25-75}	-10.701 (± 10.053)	-0.060 (± 0.083)			209.323* (± 126.149)	0.307	31.2	1.275

Note: FVC: Forced Vital Capacity; FEV_1: Forced Expiratory Volume during the first second; FEF_{25-75}: 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.

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

Model						**R^2**	**% Difference†**	**SEE**
Outcome	**Predictors**							
	Constant (± S.E)	**Age (± S.E) (year)**	**Height (± S.E) (cm)**	**BMI (± S.E)**	**ABSI (± S.E)**			
FVC	-4.805 (± 4.050)	-0.006 (± 0.015)	0.05** (± 0.020)			0.313	0	0.537
FEV_1	-2.747 (± 3.645)	-0.015 (± 0.010)	0.04* (± 0.020)			0.463	0	0.409
FEV_1/FVC (%)	109.82** (± 34.417)	-0.274** (± 0.107)	-0.10 (± 0.20)			0.399	0	4.430
FEF_{25-75}	-1.010 (± 8.484)	-0.037* (± 0.022)	0.04 (± 0.050)			0.325	0	0.951
FVC	4.903** (± 0.607)	-0.009 (± 0.019)		-0.027 (± 0.022)		0.207	- 33.9	0.577
FEV_1	4.211** (± 0.474)	-0.019 (± 0.012)		-0.015 (± 0.015)		0.364	- 21.4	0.446
FEV_1/FVC (%)	87.650** (± 3.992)	-0.308** (± 0.097)		0.189 (± 0.138)		0.435	+ 9.0	4.300
FEF_{25-75}	3.736** (± 0.804)	-0.064** (± 0.021)		0.064** (± 0.028)		0.425	+ 30.8	0.877
FVC	0.048 (± 2.530)	-0.026 (± 0.017)			55.374* (± 32.436)	0.274	- 12.5	0.552
FEV_1	0.346 (± 1.710)	-0.031** (± 0.012)			46.019** (± 22.811)	0.465	+ 0.4	0.409
FEV_1/FVC (%)	82.723** (± 16.600)	-0.272** (± 0.107)			114.806 (± 212.967)	0.399	0	4.400
FEF_{25-75}	2.422 (± 3.916)	-0.051* (± 0.025)			34.440 (± 51.136)	0.317	- 2.5	0.957

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 = $lin_{bootsrap}$(Age, Height), Y = $lin_{bootsrap}$ (Age, BMI) and Y = $lin_{bootsrap}$ (Age, ABSI) were considered as the more complete models such as Y=$lin_{bootsrap}$(Age, Height, BMI), Y = $lin_{bootsrap}$ (Age, Height, ABSI) and Y = $lin_{bootsrap}$ (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 for both genders, Age (negative effect) and height (positive effect) were significantly associated with the majority of outcomes. BMI had a significant positive effect only on FEF_{25-75} outcome in women but no significant association with any outcome in men. Finally, ABSI had significant positive effect only on FEV_1 outcome in women; however, it had significant negative effect on FVC outcome and significant positive effect on FEV_1/FVC outcome in men. It is also clear that at weakly 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:

A. For Men:

(i) FVC = $lin_{bootstarp}$ (Age, Height) the best fitting model;

(ii) FEV_1 = $lin_{bootstarp}$ (Age, Height) the best fitting model;

(iii) FEV_1/FVC = $lin_{bootstarp}$ (Age, ABSI) the best fitting model;

(iv) FEF_{25-75} = $lin_{bootstrap}$ (Age, ABSI) the best fitting model;

B. For Women:

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

(ii) FEV_1 = either $lin_{bootstarp}$ (Age, Height) or $lin_{bootstrap}$ (Age, ABSI) as the best fitting model;

(iii) FEV_1/FVC = $lin_{bootstrap}$ (Age, BMI) as the best fitting model

(iv) FEF_{25-75} = $lin_{bootstrap}$ (Age, BMI) as the best fitting model

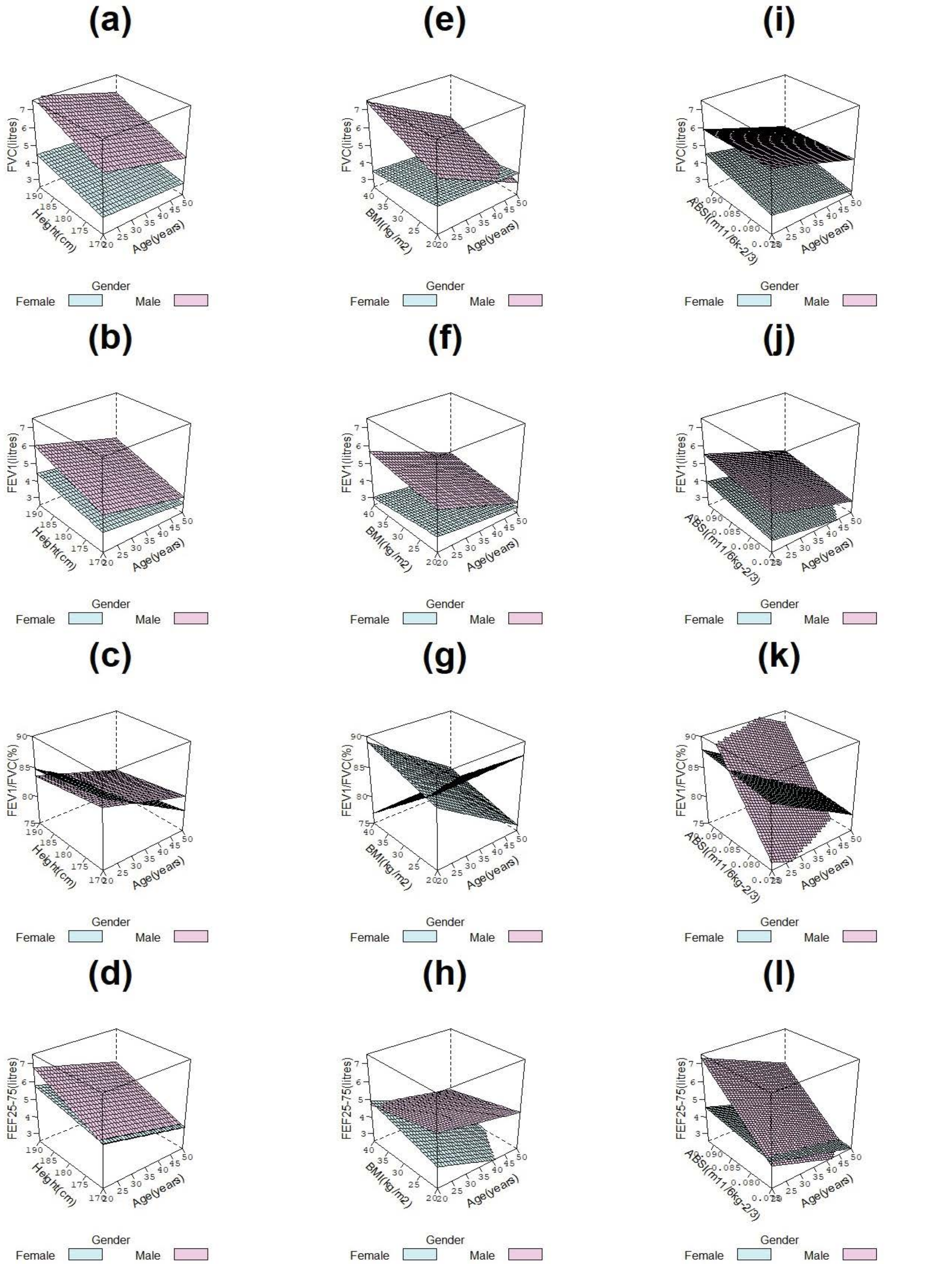

Figure 1: Three Dimensional Plots of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), their associated ratio (FEV_1/FVC) and Forced Expiratory Flaw during the middle half of the forced vital capacity (FEF25-75) of Males and Females by Age and Height (a-d); and Age and BMI (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, FEV_1 and $FEF_{25\text{-}75}$ outcome values versus females. Furthermore, from equation (1) it follows that $ABSI = Abdominal\ Girth * Weight^{\frac{-2}{3}} * Height^{\frac{-5}{6}}$ and, 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 FEV_1 (both genders), Figure 1c and Figure 1k for FEV_1/FVC (females) and, Figure 1d and Figure 1l for FEF_{25-75} (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 FEF_{25-75}. In addition, its negative association with FVC and FEV_1 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 FEV_1 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 R^2 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 R^2 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.

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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.

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