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Gender Differences in the Association of Individual and Contextual Exposures with Lung Function in a Rural Canadian Population

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Abstract
Introduction To investigate the association of individual and contextual exposures with lung function by gender in rural-dwelling Canadians.
Methods A cross-sectional mail survey obtained completed questionnaires on exposures from 8263 individuals; a sub-sample of 1609 individuals (762 men, 847 women) additionally participated in clinical lung function testing. The three dependent variables were forced expired volume in one second (FEV_1), forced vital capacity (FVC), and FEV_1/FVC ratio. Independent variables included smoking, waist circumference, body mass index, indoor household exposures (secondhand smoke, dampness, mold, musty odor), occupational exposures (grain dust, pesticides, livestock, farm residence), and socioeconomic status. The primary analysis was multiple linear regression, conducted separately for each outcome. The potential modifying influence of gender was tested in multivariable models using product terms between gender and each independent variable.
Results High-risk waist circumference was related to reduced FVC and FEV_1 for both genders, but the effect was more pronounced in men. Greater pack-years smoking was associated with lower lung function values. Exposure to household smoke was related to reduced FEV_1, and exposure to livestock, with increased FEV_1. Lower income adequacy was associated with reduced FVC and FEV_1.
Conclusion High-risk waist circumference was more strongly associated with reduced lung function in men than women. Longitudinal research combined with rigorous exposure assessment is needed to clarify how sex and gender interact to impact lung function in rural populations.

Keywords Sex · Gender · Lung function · Rural

The Saskatchewan Rural Health Study Team are listed in "Acknowledgments."

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Introduction

Lung function is an established predictor of respiratory and non-respiratory morbidity and mortality [1, 2]. Lung function in adulthood may be compromised by numerous individual and contextual factors across the life span, including low birth weight [3], smoking [4], secondhand smoke exposure [5], central adiposity [6], and lower socioeconomic status (SES) [7]. Occupational exposures to grain dust [8, 9] and cotton dust [10], most often occurring in rural environments, are also associated with reduced lung function.

Lung function is also influenced by sex (biological attributes) and gender (social and economic attributes)

[11, 12]. Regarding gender, societal sanctions concerning appropriate behavior for women and men determine, in part, how and where one's time is spent. For example, segregation in the labor force results in the differential exposure of women and men to occupational risk factors [13]. In Canada in 2011, 72.5 % of registered farm operators were men [14]; farmers are exposed routinely to a variety of dusts, chemicals, gases, and fumes which increase their risk for acquiring respiratory health problems [15]. Conversely, although male-dominated, women's involvement in farm work, and thus exposure, has been marginalized in research with farming populations [16, 17]. Regarding the influence of sex, given the same exposure, women and men may be differentially vulnerable as a result of sex-linked biological differences. For example, some research suggests women's lung function may be more adversely affected by smoking than men's [18], which may be due, in part, to sex differences in airway size [11].

Much of the research on determinants of lung function in rural settings has focused on men employed in male-dominated industries; few studies have examined lung function in general populations of rural-dwellers and in relation to gender.[1] To address these gaps, the present study uses baseline data from a recent cohort study examining the determinants of respiratory health of farming and non-farming communities in Saskatchewan Canada [20]. One research question guided this investigation: do associations between individual/contextual exposures and lung function vary by gender among rural-dwelling Canadians?

Methods

Participants

The data source for this study was the Saskatchewan Rural Health Study (SRHS), a prospective cohort study being conducted in two phases, baseline and follow-up. The detailed methodology for the study has been published previously [20]. In brief, purposeful samples of 48 of the 297 rural municipalities and 16 of the 145 towns in southern Saskatchewan were selected to participate in the baseline study. A sample of 9 RMs was randomly generated from four geographical areas: southeast, southwest, northeast, northwest. The local councils for 32 of the 36 RMs and 15 of the 16 towns agreed to participate on behalf of their residents and supplied mailing addresses. Dillman's method was used to recruit study participants aged 18 and older [21]. In total, 8261 individuals from 4624 households in the selected RMs and towns participated in the baseline survey. Information on primary respiratory health outcomes and contextual and individual factors was collected through self-administered mailed questionnaires. The final question on the questionnaire was: "Would you be willing to be contacted about having breathing and/or allergy tests at a nearby location?" Those who responded "Yes" to this question were invited to participate in the clinical assessment component that is reported here. Of the 3209 respondents who expressed a willingness to participate in the clinical assessment, pulmonary function testing was conducted on 762 men and 847 women.

Measures

Dependent Variables

Mobile clinics were set up in participating towns, and research nurses trained in spirometry and allergy assessment telephoned each household of consenting participants to arrange a time and a place (usually no greater than 60 km from their residence) for clinical assessment. The protocol used to obtain pulmonary function measurements is described elsewhere [20]. Lung function measures of interest in this investigation were (1) forced expired volume in one second (FEV_1), (2) forced vital capacity (FVC), and (3) FEV_1/FVC ratio. Of the 1609 participants that underwent lung function testing, 738 men and 827 women met American Thoracic Society spirometry testing standards [22].

Independent Variables

Individual factors of primary interest were body mass index (BMI), waist circumference, and personal smoking. BMI was calculated by dividing respondents' measured weight in kg by height in m^2 to form three groupings: normal (<25 kg/m^2), overweight (25–30 kg/m^2), and obese (>30 kg/m^2). Measured waist circumference was categorized as low risk or high risk based on sex-specific cut-off points (men ≥102 cm = high risk; women ≥88 cm = high risk) established by Health Canada [23]. Pack-years was calculated to quantify cigarette smoking exposure, based on self-reported duration and amount of cigarette consumption and grouped into the following categories: never smoker <0–10, >10–25, and >25 years.

Contextual factors included those related to the household environment, occupation, and socioeconomic circumstances. Three indoor household exposures were assessed. Dampness was measured with the question: "During the past 12 months, has there been water or

[1] For brevity sake, we use the term gender throughout the rest of the paper; however, we recognize that the effects of sex and gender on human health are complexly interwoven throughout the life course [19].

dampness in your home from broken pipes, leaks, heavy rain, or floods?" (yes/no). Mold was assessed with the question: "Does your home (including basement) frequently have a mildew odor or musty smell?" (yes/no). Household smoking (yes/no) was measured with the question: "Do any of the people who live in your house use any of the following tobacco products in the home?" with options: "cigarettes," "cigars," or "pipes." Occupational exposures were assessed with the question: "Have you ever been exposed to any of the following in the work place…" (yes/no): grain dust, livestock, insecticides, herbicides, fungicides; responses to the latter three exposures were collapsed to create a pesticide exposure (yes/no) variable. Location of residence (farm/non-farm) was based on answers to the question "Where is your home located?" with the options of "farm," "in town," or "acreage"; town and acreage responses were combined to create a non-farm category. Farm/non-farm residence was considered an occupation-related exposure in this study in recognition of the fact that the farming workplace often overlaps with family residence in rural Saskatchewan. SES was measured by household income adequacy (low, middle, high), a derived variable based on total household income and the number of people living in the household [24].

Statistical Analysis

Thirteen households had two participants each; to avoid accounting for within-subject household clustering at the analysis stage, we randomly excluded 13 individuals (five men and eight women) from the analysis. This exclusion, which resulted in a sample size of 819 women and 733 men, allowed for the use of classical linear regression techniques to examine associations between exposure variables and lung function measures. Following descriptive analyses, multiple linear regression analyses were conducted separately for each lung function measure. In the first step, individual exposures were entered as a group, followed by contextual exposures in step 2. In step 3, two-way interactions between gender and exposure variables were assessed. Final multivariable models included statistically significant variables ($p \leq 0.05$), adjusted for age and height. For statistically significant interaction terms, predicted probabilities based on the final multiple regression models were depicted graphically. Statistical analysis was completed using IBM SPSS version 20 [IBM Corp., NY, USA].

Results

The frequency distribution of study variables, by gender, is given in Table 1. A higher percentage of men than women were in the older age categories, with no differences observed for marital status. A greater proportion of men than women smoked and were in the overweight/obese BMI categories, although no difference was observed for waist circumference. Regarding contextual factors, no gender differences emerged for indoor household exposures. A higher proportion of men than women reported occupational exposure to grain dust, livestock, pesticides, and living on a farm. Women and men reported similar levels of income adequacy.

The age- and height-adjusted ANOVA results of lung function measures by individual and contextual variables, analyzed separately for women and men, are shown in Table 2. For both women and men, pack-years smoking was inversely related to FEV_1 and FEV_1/FVC. Greater BMI was associated with lower FVC in both genders and lower FEV_1 in men. High-risk waist circumferences was related to lower lung function for all participants with the exception of FEV_1/FVC in men. Exposure to household smoke was related to lower FEV_1 and FEV_1/FVC for both genders. In women only, home dampness was associated with reduced FEV1/FVC. The presence of a mildew/musty odor was related to increased FEV_1 in women, reduced FEV_1 in men, and reduced FEV_1/FVC in women. Exposure to grain dust was associated with reduced FEV_1/FVC ratio in men. Farm/non-farm home location was unrelated to lung function. Lower income adequacy was associated with lower FVC and FEV_1 in both women and men.

Results of the final multivariable models by lung function measure are presented in Table 3. Greater pack-years smoking was associated with reduced lung function. The relationship between waist circumference and FVC and FEV_1 was modified by gender; although high-risk waist circumference was related to reduced lung function for both genders, the effect was more pronounced in men than women (Figs. 1, 2). Exposure to household smoke was associated with reduced FEV_1, and exposure to livestock, with increased FEV_1. Lower income adequacy was related to reduced FVC and FEV_1.

Discussion

This study examined the association of individual and contextual factors with lung function by gender in a general population of rural-dwelling Canadians. Our results showed a stronger detrimental effect of high-risk waist circumference on lung function in men than women. Greater pack-years smoking, exposure to household smoke, lower income adequacy, and grain dust exposure were associated with reduced lung function. Exposure to livestock was associated with increased lung function.

In this study, high-risk waist circumference was related to reduced lung function, whereas BMI showed no

Table 1 Distribution of individual and contextual factors in women ($n = 819$) and men (733)

	Women *n* (%)	Men *n* (%)	*p* level
Individual factors			
Age (years)			
18–45	189 (23.1)	137 (18.7)	
46–55	258 (31.5)	201 (27.4)	
56–65	249 (30.4)	245 (33.4)	
>65	123 (15.0)	150 (20.5)	0.004
Marital status			
Married/living together	725 (88.7)	646 (88.3)	
Widowed, divorced, separated/never married	92 (11.3)	86 (11.7)	0.76
Pack-years smoking			
Never smoker	466 (57.8)	378 (52.8)	
>0 to ≤10 years	182 (22.6)	137 (19.1)	
>10 to ≤25 years	94 (11.7)	115 (16.1)	
> 25 years	64 (7.9)	86 (12.0)	0.001
Body mass index (kg/m^2)			
Normal (0 to <25)	224 (27.3)	89 (12.2)	
Overweight (25–30)	297 (36.3)	340 (46.4)	
Obese (>30)	298 (36.4)	303 (41.4)	<0.0001
Waist circumference (cm)			
High risk (≥102 for men, ≥88 for women)	347 (42.6)	385 (52.8)	
Low risk (<102 for men, <88 for women)	468 (57.4)	344 (47.2)	0.07
Contextual factors			
Household smoking			
Yes	88 (10.8)	81 (11.0)	
No	729 (89.2)	652 (89.0)	0.86
Dampness			
Yes	172 (21.1)	146 (20.0)	
No	645 (78.9)	585 (80.0)	0.60
Mildew odor or musty smell			
Yes	154 (19.2)	129 (18.0)	
No	647 (80.8)	588 (82.0)	0.54
Grain dust			
Yes	463 (56.9)	639 (87.2)	
No	351 (43.1)	94 (12.8)	<0.0001
Livestock			
Yes	351 (43.1)	495 (67.5)	
No	463 (56.9)	238 (32.5)	<0.0001
Pesticides			
Yes	368 (44.9)	572 (78.0)	
No	451 (55.1)	161 (22.0)	<0.0001
Residence location			
Farm	380 (46.5)	378 (51.8)	
Non-farm	437 (53.5)	352 (48.2)	0.04
Income adequacy			
Lowest	116 (16.6)	78 (12.3)	
Middle	233 (33.2)	217 (34.1)	
Highest	352 (50.2)	341 (53.6)	0.08

Table 2 Lung function measurements (mean ± SD) by individual and contextual factors for women ($n = 819$) and men ($n = 733$)

	FVC (L/s)		FEV_1 (L/s)		FEV_1/FVC	
	Women	Men	Women	Men	Women	Men
Individual factors						
Pack-years smoking						
Never smoker	3.45 ± 0.60	4.83 ± 0.83	2.73 ± 0.51#	3.74 ± 0.72#	0.79 ± 0.05#	0.77 ± 0.07#
>0 to ≤10 years	3.51 ± 0.67	4.77 ± 0.80	2.75 ± 0.56	3.64 ± 0.64	0.78 ± 0.06	0.76 ± 0.06
>10 to ≤25 years	3.35 ± 0.62	4.55 ± 0.80	2.56 ± 0.51	3.38 ± 0.71	0.76 ± 0.06	0.74 ± 0.08
> 25 years	3.14 ± 0.51	4.51 ± 0.76	2.29 ± 0.43	3.28 ± 0.58	0.73 ± 0.07	0.73 ± 0.07
Body mass index (kg/m^2)						
Normal (0 to <25)	3.59 ± 0.63**	4.90 ± 0.81#	2.81 ± 0.53	3.75 ± 0.72#	0.78 ± 0.06	0.76 ± 0.07
Overweight (25–30)	3.45 ± 0.61	4.83 ± 0.78	2.69 ± 0.53	3.66 ± 0.68	0.78 ± 0.06	0.76 ± 0.07
Obese (>30)	3.28 ± 0.58	4.56 ± 0.85	2.57 ± 0.50	3.47 ± 0.75	0.78 ± 0.06	0.76 ± 0.07
Abdominal Girth (cm)						
High risk (≥102 for men; ≥88 for women)	3.32 ± 0.60#	4.57 ± 0.82#	2.60 ± 0.51**	3.47 ± 0.72#	0.78 ± 0.06*	0.76 ± 0.07
Low risk (<102 for men; <88 for women)	3.57 ± 0.62	4.90 ± 0.79	2.79 ± 0.53	3.74 ± 0.69	0.78 ± 0.06	0.76 ± 0.07
Contextual factors						
Household smoking						
Yes	3.38 ± 0.61	4.71 ± 0.84	2.59 ± 0.53**	3.43 ± 0.69#	0.76 ± 0.07#	0.73 ± 0.08#
No	3.44 ± 0.62	4.73 ± 0.82	2.69 ± 0.52	3.62 ± 0.72	0.78 ± 0.06	0.76 ± 0.07
Dampness						
Yes	3.56 ± 0.65	4.78 ± 0.85	2.76 ± 0.54	3.65 ± 0.76	0.78 ± 0.07*	0.76 ± 0.07
No	3.39 ± 0.61	4.71 ± 0.82	2.66 ± 0.52	3.58 ± 0.71	0.78 ± 0.06	0.76 ± 0.07
Mildew odor or musty smell						
Yes	3.47 ± 0.61	4.64 ± 0.81	2.70 ± 0.52*	3.52 ± 0.74*	0.78 ± 0.08*	0.75 ± 0.07
No	3.42 ± 0.62	4.74 ± 0.83	2.68 ± 0.53	3.61 ± 0.71	0.78 ± 0.05	0.76 ± 0.07
Grain dust						
Yes	3.40 ± 0.62	4.73 ± 0.81	2.66 ± 0.53	3.59 ± 0.72	0.78 ± 0.06	0.76 ± 0.07*
No	3.48 ± 0.62	4.68 ± 0.89	2.72 ± 0.51	3.63 ± 0.74	0.78 ± 0.06	0.77 ± 0.07
Livestock						
Yes	3.37 ± 0.61	4.73 ± 0.81	2.63 ± 0.51	3.59 ± 0.71	0.78 ± 0.06	0.76 ± 0.07
No	3.48 ± 0.63	4.71 ± 0.86	2.72 ± 0.53	3.60 ± 0.74	0.78 ± 0.06	0.76 ± 0.08
Pesticides						
Yes	3.50 ± 0.64	4.74 ± 0.88	2.75 ± 0.54	3.64 ± 0.75	0.78 ± 0.06	0.71 ± 0.07
No	3.34 ± 0.59	4.72 ± 0.81	2.60 ± 0.50	3.58 ± 0.71	0.77 ± 0.05	0.76 ± 0.07
Residence location						
Farm	3.47 ± 0.61	4.73 ± 0.81	2.71 ± 0.52	3.59 ± 0.70	0.78 ± 0.06	0.76 ± 0.07
Non-farm	3.40 ± 0.62	4.72 ± 0.84	2.65 ± 0.53	3.60 ± 0.73	0.78 ± 0.06	0.76 ± 0.07
Income adequacy						
Lowest	3.28 ± 0.65**	4.49 ± 0.95*	2.56 ± 0.55**	3.42 ± 0.81*	0.78 ± 0.06	0.76 ± 0.08
Middle	3.40 ± 0.60	4.67 ± 0.79	2.62 ± 0.50	3.52 ± 0.69	0.77 ± 0.07	0.75 ± 0.07
Highest	3.55 ± 0.62	4.85 ± 0.78	2.80 ± 0.52	3.72 ± 0.69	0.79 ± 0.05	0.77 ± 0.07

Statistical tests evaluated associations between individual/contextual factors and each lung function measurement within gender and adjusted for age and height

* $p \le 0.05$; ** $p < 0.01$; # $p < 0.001$

significant association. Research has shown that obesity, particularly abdominal adiposity, may result in restricted breathing, potentially causing reductions in FEV_1 and FVC [6, 25]. Waist circumference, compared to overall weight or BMI, may be a more reliable indicator of abdominal obesity [26]. The results of several studies also suggest that the relationship between central adiposity and lung function may be more pronounced in men [25, 27, 28], possibly

Table 3 Estimates of regression coefficients and standard errors ($\hat{\beta}(s.e(\hat{\beta}))$) from multiple linear regression models investigating the association of individual and contextual factors with FVC, FEV_1, and FEV_1/FVC ratio

	FVC (L/s)	FEV_1 (L/s)	FEV_1/FVC
Gender			
Men	0.75 (0.05)$^{\#}$	0.60 (0.04)$^{\#}$	−0.001 (0.004)
Women	Ref.	Ref.	Ref.
Pack-years smoking			
>25 years	−0.09 (0.05)*	−0.19 (0.04)$^{\#}$	−0.03 (0.01)$^{\#}$
>10 to ≤25 years	−0.01 (0.04)	−0.09 (0.03)**	−0.02 (0.02)$^{\#}$
>0 to ≤10 years	0.05 (0.03)	0.00 (0.03)	−0.01 (0.004)*
Never smoker	Ref.	Ref.	Ref.
Waist circumference (cm)			
High risk (≥102 for men, ≥88 for women)	−0.12 (0.04)**	−0.05 (0.03)	N/A
Low risk (<102 for men, <88 for women)	Ref.	Ref.	
Household smoking			
Yes	N/A	−0.11 (0.04)**	−0.02 (0.01)**
No		Ref.	Ref.
Grain dust			
Yes	N/A	−0.06 (0.03)*	N/A
No			
Livestock			
Yes	N/A	0.52 (0.03)*	N/A
No			
Income adequacy			
Lowest	−0.13 (0.04)**	−0.11 (0.03)$^{\#}$	−0.001 (0.01)
Middle	−0.01 (0.03)	−0.04 (0.02)	−0.01 (0.003)*
Highest	Ref.	Ref.	Ref.
Gender X waist circumference	−0.18 (0.05)**	−0.16 (0.04)$^{\#}$	N/A

Models adjusted for all variables listed in table columns in addition to age and height

N/A not in the model

* $p \leq 0.05$; ** $p < 0.01$; # $p < 0.001$

due to sex-linked differences in the distribution of body fat [11]. Consistent with these findings, although greater waist circumference was associated with reduced FEV_1 and FVC for both women and men in our study, the effects were stronger in men.

Smoking is a well-established risk factor for impaired lung function [4, 29]. Some [18, 30] but not all [31, 32] studies suggest that smoking may be more detrimental to lung function in women than men. Women's smaller airway size has been postulated as one potential explanation, though sex differences in hormones, immunology, and genetics have also been hypothesized [11]. The results of this study however, indicated a similar, negative association of smoking with lung function in both women and men.

We found that exposure to household smoke was also associated with reduced lung function. Secondhand smoke comprises many of the same hazardous agents that are inhaled by smokers themselves. Although household secondhand smoke has been associated with reduced FEV_1 in several studies, findings have not always been consistent and when present, effect sizes have been small [5, 33]. Although some very limited evidence suggests that passive smoke exposure may be more strongly related to impaired lung function in women [34], we found no evidence of a gender effect.

No association between indicators of mold/musty odor and lung function emerged in our multivariable analysis. A systematic review of respiratory health effects of dampness concluded that although such exposures appear to be associated with an increased risk of respiratory symptoms and asthma, the evidence regarding reduced lung function was inconclusive [35]. Only a limited amount of research has examined gender differences in the health effects of mold/dampness; that being said, however, the results of several studies have shown, in contrast to our results, stronger associations between indicators of damp housing and reduced lung function [36, 37] and respiratory symptoms [38] in women than men. Longitudinal designs combined with enhanced exposure measurement are needed to clarify such relationships in future research.

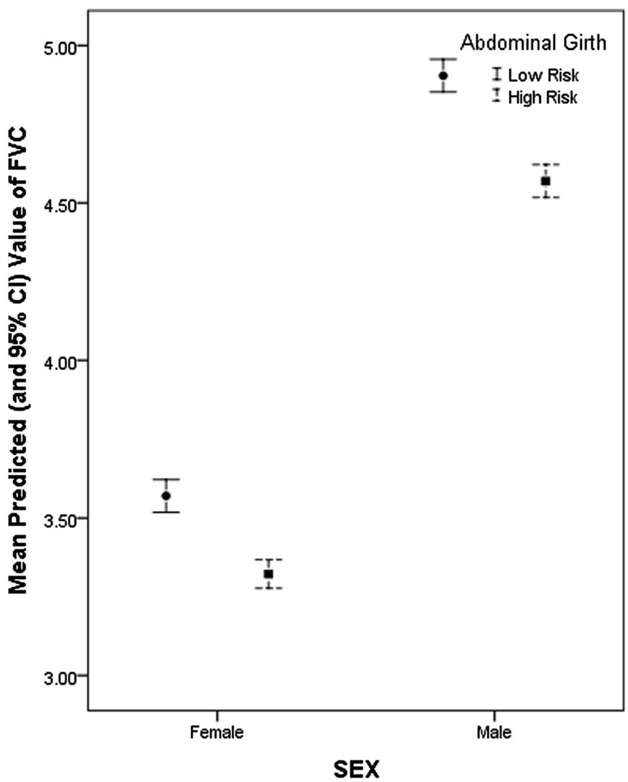

Fig. 1 Mean predicted values of FVC stratified by waist circumference and gender

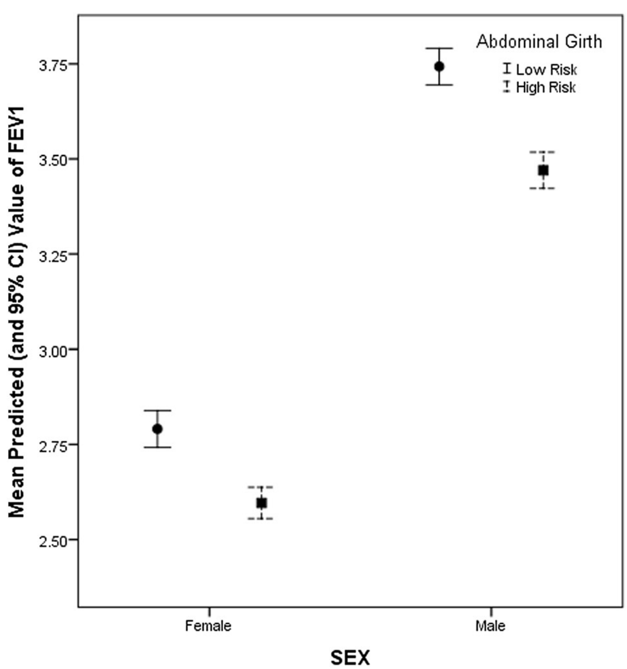

Fig. 2 Mean predicted values of FEV_1 stratified by waist circumference and gender

Occupational exposure to grain dust was associated with reduced FEV_1 and FEV_1/FVC ratio in this study. Consistent with our findings, a number of cross-sectional and longitudinal studies have shown associations between exposure to grain dust and reduced lung function [8, 9, 39, 40]. The vast majority of these studies were restricted to male samples; the many challenges to studying the effects of sex and gender in occupational health research have been well articulated in the literature, particularly in highly sex-segregated occupations [41–43]. However, the findings of several recent meta-analyses suggest that the effect of organic dust (including grain dust) on impaired lung function [44] and development of chronic respiratory symptoms [45] may be more pronounced in men than women. Recent longitudinal research with cotton workers in China have reported greater FEV_1 impairment in male than female exposed workers [46] and among those retired from the cotton industry, more limited lung function recovery [47]. Although sex-linked differences in response to endotoxin exposure have been proposed as one possibility to explain these findings, uncontrolled differences in exposure between women and men occupying the same job cannot be ruled out as an alternative explanation, nor can the possibility of residual confounding due to smoking [48]. In our study, although the gender/grain dust interaction was not statistically significant, the higher prevalence of grain dust exposure in men than women may indicate exposed men as the main driver of the observed associations.

An unexpected result in this study, and in contrast to previous research [49–51], was the positive association between exposure to livestock and lung function. Some research suggests that exposure to farm animals early in life may be associated with reduced asthma risk [52, 53] and increased lung function in adulthood [54]. We examined whether the relationship between livestock exposure and lung function was modified by having had lived on a farm during the first year of life, but the interaction was not statistically significant (data not shown). Alternatively, it is possible that participants who developed respiratory impairment due to livestock exposure migrated from the study area at an earlier time. Some evidence suggests that current livestock farmers, particularly those involved in pig production, have reduced lung function compared to those who leave the industry [55]. The lack of detail in our exposure measure, along with the cross-sectional design, prevents a more nuanced exploration of the reasons that might explain this positive association.

Consistent with previous research [7], lower SES was associated with reduced FEV_1 and FVC in this rural sample. Associations remained even after adjusting for several factors hypothesized as contributing to SES inequities in lung function, such as smoking and exposure to household smoke [7, 56]. Other potentially mediating factors not assessed in this study include diet, physical inactivity, low birth weight, and childhood SES [57–59].

Study Strengths and Limitations

This investigation has several strengths, including the use of objective measures of lung function, conducted using a standardized protocol. Our relatively large sample size allowed us to examine a broad array of individual and contextual factors potentially associated with lung function and to test for potential interactions with gender. Gender has not often been positioned as a variable of importance in research examining determinants of lung function, particularly in rural settings.

However, limitations in measurement and study design are also present, serving to temper firm conclusions regarding associations between individual/contextual exposures and lung function, both within and between women and men. Most of the exposure variables were based on self-report, increasing the likelihood of misclassification. Previous research suggests moderate correlations between self-report and more objective measures of exposures such as smoking [60], secondhand smoke [61], and household dampness/mold [62], with estimates of the validity of self-reported occupational exposures more variable [63]. The underestimation of exposures independently of respiratory health status would likely result in an attenuation of study effects. The potential for non-differential misclassification was further exacerbated by the lack of detail in our exposure assessment, particularly information on frequency, intensity, and duration. We also lacked information on exposures likely of more relevance to the lung health of women, such as the use of household cleaning products, as well as potentially hazardous agents more often encountered in women-dominated occupations, such as clerical work and health care [64].

The cross-sectional design limits our ability to infer causal relationships between exposures and lung function. The study participants in this investigation were a volunteer sub-sample of a larger study sample. When compared to the overall sample, our clinic participants were younger, more highly educated, and more likely to be a non-smoker and to live on a farm. Although selection bias is a possibility, the focus of our study on estimating exposure-outcome associations, rather than on estimating prevalence, may mitigate this concern [65]. Just over 97 % of the sample indicated being of Caucasian origin thus preventing us from examining ethnicity as a potential correlate of lung function in this rural sample.

Conclusion

High-risk waist circumference was more strongly associated with reduced lung function in men than women. Longitudinal research combined with rigorous exposure assessment is needed to clarify how sex and gender interact to impact lung function in rural populations and in turn inform the development of programs and policies aimed at protecting lung health.

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Compliance with Ethical Standards

Conflicts of Interest None.

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