



Association between physical activity in daily life and pulmonary function in adult smokers

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ABSTRACT

Objective: To determine whether the level of physical activity in daily life (PADL) is associated with pulmonary function in adult smokers. **Methods:** We selected 62 adult smokers from among the participants of an epidemiological study conducted in the city of Santos, Brazil. The subjects underwent forced spirometry for pulmonary function assessment. The level of PADL was assessed by the International Physical Activity Questionnaire and triaxial accelerometry, the device being used for seven days. The minimum level of PADL, in terms of quantity and intensity, was defined as 150 min/week of moderate to vigorous physical activity. Correlations between the studied variables were tested with Pearson's or Spearman's correlation coefficient, depending on the distribution of the variables. We used linear multiple regression in order to analyze the influence of PADL on the spirometric variables. The level of significance was set at 5%. **Results:** Evaluating all predictors, corrected for confounding factors, and using pulmonary function data as outcome variables, we found no significant associations between physical inactivity, as determined by accelerometry, and spirometric indices. The values for FVC were lower among the participants with arterial hypertension, and FEV₁/FVC ratios were lower among those with diabetes mellitus. Obese participants and those with dyslipidemia presented with lower values for FVC and FEV₁. **Conclusions:** Our results suggest that there is no consistent association between physical inactivity and pulmonary function in adult smokers. Smoking history should be given special attention in COPD prevention strategies, as should cardiovascular and metabolic comorbidities.

Keywords: Smoking; Respiratory function tests; Motor activity; Accelerometry.

INTRODUCTION

Smoking is a major public health problem worldwide. In the 20th century, tobacco use killed 100 million people worldwide. Smoking accounts for 5.4 million deaths per year worldwide, and it is estimated that it will account for more than 8.0 million deaths per year in 2030. Approximately 80% of these deaths will occur in developing countries, and smoking is currently the leading cause of preventable death worldwide.⁽¹⁾

The impact of tobacco use on health is well known, tobacco use accounting for 90% of all cases of lung cancer, 75% of all cases of chronic bronchitis, and 25% of all cases of ischemic heart disease.⁽²⁾ Individuals who smoke more than 20 cigarettes per day are significantly different from nonsmokers in terms of their FEV₁.⁽³⁾ This is due to the fact that smoking causes acute lung changes, including changes in airflow resistance, cough, and airway irritation.⁽⁴⁾

Lung function decline is less pronounced in smokers who engage in moderate- to high-intensity physical

activity.⁽⁵⁾ Studies have shown that regular physical activity is effective in preventing chronic diseases such as cardiovascular disease, diabetes, cancer, hypertension, obesity, depression, and osteoporosis. It has been suggested that there is a significant association between physical activity and health status, increased physical fitness resulting in additional health benefits.⁽⁶⁾ Other studies have shown that endurance training in nonsmokers results in adaptations of the cardiorespiratory and neuromuscular systems that increase the supply of oxygen to the mitochondria, thus contributing to maintaining physical fitness.^(7,8) It has been suggested that smoking reduces cardiorespiratory fitness and lung function.^(9,10) In addition, significant differences have been found between physically active and physically inactive smokers regarding fatigue immediately after the six-minute walk test and during the recovery period, at two minutes after the test.⁽¹¹⁾

Regular physical exercise can counter the negative effects of smoking through an anti-inflammatory and antioxidant mechanism. Physical activity and smoking

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interact antagonistically: inflammatory markers that are produced in the lung and are related to a decline in cardiorespiratory fitness are suppressed by physical exercise.⁽⁵⁾

Physical activity can be assessed by a variety of methods, including direct observation, questionnaires, self-report diaries, and motion sensors, such as pedometers and accelerometers.⁽¹²⁾ Objective assessment is performed by motion sensors, which are instruments that are used in order to detect body motion and determine the level of physical activity in daily life (PADL) over a period of time. Accelerometers are real-time motion capture sensors that are sensitive to acceleration.⁽¹³⁾

Few studies have examined the preventive effect of physical activity on the lung function of smokers, the level of PADL having been determined on the basis of self-reports, face-to-face interviews, or physical activity questionnaires. Using pedometers, Furlanetto et al.⁽¹¹⁾ found that the mean number of daily steps was significantly lower in adult smokers than in adult controls, the former also having lower physical capacity, worse lung function, and greater sensation of fatigue. However, there is a lack of studies in which the level of PADL in smokers is more accurately determined with the use of triaxial accelerometers.

There is evidence that a higher level of PADL reduces smoking-related complications. However, there is a need for further clarification of the association between the level of PADL and lung function in smokers. If this association is found to be consistent, preventive strategies can be devised. Longitudinal studies of the role that a higher level of objectively measured PADL has in preventing lung function decline in smokers could contribute to preventing smoking-related complications, which consume a significant proportion of health care resources in Brazil and the world.⁽¹⁴⁾

We hypothesized that smokers who have a higher level of PADL (more accurately determined by triaxial accelerometry) have relatively preserved lung function, regardless of their smoking history. Confirmation of our hypothesis would support the need for strategies to increase the level of PADL in smokers in order to reduce the damage caused by smoking. Therefore, we sought to determine whether the level of PADL, as determined by triaxial accelerometry, was associated with lung function in adult smokers.

METHODS

This was a cross-sectional study involving a convenience sample of adult smokers selected from among the participants of a study conducted in the Federal University of São Paulo Laboratory of Epidemiology and Human Movement, located in the city of Santos, Brazil. The study included 62 adult smokers who were 20 years of age or older and had no cardiac, respiratory, or metabolic diseases limiting their exercise capacity. In brief, this was a population-based epidemiological study whose primary objective was to determine

the association of sedentary behavior and physical inactivity with the development of chronic diseases. The exclusion criteria were as follows: a spirometric diagnosis of COPD; problems indicating inability to perform PADL adequately; being a smoker with a smoking history of fewer than 1.5 pack-years or more than 50 pack-years; and being a former smoker.⁽¹⁵⁾

The following demographic variables were analyzed: age; gender; race; place of birth; level of education; and socioeconomic status. After being selected for inclusion, all participants were informed of the procedures, discomfort, and risks associated with the present study and gave written informed consent. The study project was approved by the Federal University of São Paulo Human Research Ethics Committee (Protocol no. 186.796).

Initial clinical evaluation included history taking for previous health problems and use of medications. The risk of cardiovascular events was determined on the basis of the following risk factors: age; family history; smoking history; hypertension; dyslipidemia or hypercholesterolemia; diabetes or hyperglycemia; obesity; and sedentary lifestyle.

Smoking status was determined by self-report, and smoking history was calculated by multiplying the duration of smoking in years by the number of cigarettes smoked per day and dividing the result by 20 (the number of cigarettes in one pack). Individuals who reported current smoking and having smoked 100 or more cigarettes in their lifetime at the time of the study were defined as smokers.⁽¹⁵⁾

After anthropometric measurements, including weight, height, and BMI calculation, all participants were evaluated as described below.

Lung function was assessed by forced spirometry (Quark PFT; Cosmed, Rome, Italy). FEV₁, FVC, FEV₁/FVC, and PEF were determined in accordance with the American Thoracic Society criteria.⁽¹⁶⁾ Spirometric indices were expressed as absolute values and as a percentage of reference values.⁽¹⁷⁾

The level of PADL was determined by the International Physical Activity Questionnaire (IPAQ), which assesses total energy expenditure in metabolic equivalent task-minutes per week (MET-min/wk) and time spent in daily physical activity. PADL was classified as vigorous, moderate, or light, measured in MET-min/wk, and divided into four domains: work; transport; household chores; and recreation and leisure. The total IPAQ score is calculated by summing the individual domain scores. The IPAQ-long form was used, consisting of 27 questions regarding physical activity. The participants were instructed to answer the questions on the basis of the week prior to the administration of the IPAQ.⁽¹⁸⁾ The level of PADL was also assessed with a widely used triaxial accelerometer (GT3X ActiGraph; MTI, Pensacola, FL, USA).⁽¹⁹⁻²²⁾ A triaxial accelerometer measures the duration and intensity of physical activity. The participants were instructed to wear the device on an elastic belt placed on their dominant hip and left

in place for seven days. A valid day was defined as at least 12 h of accelerometer use. All participants were instructed to remove the device before engaging in water-based activities, such as bathing and swimming, and at bedtime. Only the data from the participants who used the accelerometer for at least four valid days were analyzed.⁽¹⁹⁾ On the basis of its intensity, physical activity was classified as follows: physical inactivity or light physical activity, fewer than 3.00 MET-min/wk; moderate physical activity, 3.00-5.99 MET-min/wk; hard physical activity, 6.00-8.99 MET-min/wk; and very hard physical activity, ≥ 9.00 MET-min/wk.⁽²³⁾ The minimum level of PADL, in terms of quantity and intensity, was defined as 150 min/week of moderate to vigorous physical activity.⁽²⁴⁾ The participants who were unable to achieve that level of PADL were considered to be physically inactive.

In the present study, statistical analysis was performed with the IBM SPSS Statistics software package, version 23 (IBM Corporation, Armonk, NY, USA). The Kolmogorov-Smirnov test was used in order to determine the normality of continuous variables. Data are presented as mean \pm standard deviation or as median (interquartile range).

The study sample size was calculated on the basis of the number of independent variables of interest for inclusion in the multiple regression model. Outcome variables in the regression models included percent predicted FEV₁ and FVC. The models were adjusted for age, gender, weight, height, and six other variables. Smoking history was considered to be the main predictor. Possible predictors were initially evaluated in categories. Demographic and anthropometric characteristics were taken into consideration, as were cardiovascular risk factors. After the bivariate analysis, the variables that were found to be significantly associated with the spirometric indices were included in the multiple regression model, as follows: age; gender; presence of hypertension; presence of diabetes mellitus; IPAQ household chores domain score; daily energy expenditure in kcal; and physical inactivity.

The Student's t-test or the Mann-Whitney test was used in order to compare the spirometric indices between males and females according to the presence of comorbidities, such as hypertension, diabetes mellitus, dyslipidemia, obesity, and physical inactivity.

Correlations between the studied variables were tested with Pearson's or Spearman's correlation coefficient, depending on the distribution of the variables. The level of significance was set at 5%.

RESULTS

Among the 62 volunteers in the study sample, obese individuals and females predominated (Table 1). There were significant differences between males and females regarding smoking history, weight, and BMI.

Table 2 shows the correlations between PADL and lung function, FVC having been found to correlate significantly with the IPAQ household chores domain score, energy

expenditure in kcal/day, and hard physical activity in h ($p < 0.05$ for all). The aforementioned variables were also found to correlate significantly with FEV₁. The household chores domain scores were the only IPAQ domain scores that correlated significantly with lung function. PEF was found to correlate significantly with the IPAQ household chores domain score, light physical activity, and hard physical activity. Table 3 shows the bivariate association between lung function data and cardiovascular risk factors. FVC was found to be reduced in the participants with arterial hypertension, and the FEV₁/FVC ratio was found to be reduced in those with diabetes mellitus. Obese participants and those with dyslipidemia were found to have reduced FVC and FEV₁. No significant associations were found between physical inactivity, as determined by accelerometry, and spirometric indices.

Evaluating all predictors, corrected for confounding factors, and using lung function data (FVC and FEV₁, both in % of predicted) as outcome variables, we found that the variables that remained in the model as predictors of lung function were smoking history and the presence of diabetes, as predictors of FVC, and smoking history and the presence of arterial hypertension, as predictors of FEV₁ (Table 4).

DISCUSSION

The present study investigated the association between the level of PADL and lung function in adult smokers without respiratory disease. The level of PADL was directly assessed by triaxial accelerometry over the course of seven days. To our knowledge, there is little information regarding the use of triaxial accelerometry for determining the level of PADL. After adjustment for the main confounding factors, no association was found between an adequate level of PADL and better lung function.

As expected, smoking history was a predictor of worse FVC and FEV₁, even after having been adjusted for confounding factors. Studies have shown that smoking history is the main predictor of reduced FEV₁ in smokers with a normal FEV₁/FVC ratio.⁽²⁵⁾ Smoking is also associated with dysregulation of gene expression in the small airway epithelium and accelerates the aging of the airways, as well as being the principal factor responsible for progressive lung function decline.⁽²⁶⁾

Lallukka et al.⁽²⁷⁾ conducted a cohort study and concluded that smoking and physical inactivity are associated with disability retirement and that even hard physical activity is not sufficient to eliminate the adverse effects that smoking has on health. Elderly smokers have reduced exercise capacity when compared with elderly never-smokers, and tobacco exposure is associated with reduced quality of life regardless of the level of physical activity.⁽²⁸⁾ Smoking is associated with evidence of mild obstruction and accelerates lung function decline in adolescents. Female adolescents are possibly more vulnerable to the effects of smoking on lung function than are male adolescents.⁽²⁹⁾ We believe

Table 1. General characteristics of the sample (N = 62).^a

Variable	Males (n = 20)	Females (n = 42)
Age, years	47 ± 14	53 ± 8
Smoking history, pack-years	12.7 (3.2-20.0)*	22.5 (11.7-40.0)
Weight, kg	80.2 ± 12.3*	74.6 ± 19.9
Height, cm	1.71 ± 0.07*	1.57 ± 0.07
BMI, kg/m ²	27.4 ± 4.5*	29.8 ± 7.07
Risk factors, n (%)		
Hypertension	4 (20)	13 (31)
Obesity	5 (25)	20 (47)
Diabetes	2 (10)	10 (23)
Dyslipidemia	5 (25)	18 (42)
Physical inactivity	7 (35)	14 (33)

^aData presented as mean ± SD or median (interquartile range), except where otherwise indicated. *p < 0.05.

Table 2. Statistical correlations between lung function and physical activity in daily life.

Lung function	Physical activity in daily life						
	IPAQ-HC ^a	EE, kcal/day	WST, h	WLPA, h	WMPA, h	WVPA, h	WVPA, h
FVC, L	0.432*	0.320*	0.182	0.203	0.104	0.375*	0.034
FEV ₁ , L	0.400*	0.330*	0.218	0.186	0.103	0.346*	0.036
FEV ₁ /FVC	0.110	0.064	0.205	0.064	0.023	0.071	0.018
FEV ₁ /FVC, % predicted	0.057	0.046	0.241	0.059	0.012	0.084	0.001
PEF, L/min	0.451*	0.191	0.246	0.264*	0.052	0.392*	0.008

IPAQ-HC: International Physical Activity Questionnaire household chores domain score; EE: energy expenditure; WST: weekly sedentary time; WLPA: weekly light physical activity; WMPA: weekly moderate physical activity; WVPA: weekly vigorous physical activity; and WVPA: weekly very vigorous physical activity. ^aEnergy expenditure measured in metabolic equivalent task-minutes per week. *p < 0.05.

Table 3. Relationship between lung function data and cardiovascular risk factors.

Risk factors		Lung function data				
		FVC, L	FVC, % predicted	FEV ₁ , L	FEV ₁ , % predicted	FEV ₁ /FVC, % predicted
Arterial hypertension	Yes	2.81 ± 0.62*	86 ± 14	2.22 ± 0.53	84 ± 16	78 ± 6
	No	3.72 ± 0.10*	94 ± 12	2.88 ± 0.89	95 ± 12	82 ± 5
Diabetes mellitus	Yes	2.74 ± 0.85	83 ± 10	2.29 ± 0.69	86 ± 10	84 ± 2*
	No	3.47 ± 1.03	94 ± 12	2.80 ± 0.87	94 ± 15	80 ± 6*
Dyslipidemia	Yes	2.98 ± 0.67*	92 ± 12	2.44 ± 0.52*	93 ± 13	82 ± 5
	No	3.53 ± 1.16*	92 ± 13	2.85 ± 0.98*	92 ± 15	80 ± 6
Obesity	Yes	2.94 ± 0.59*	88 ± 11	2.41 ± 0.52*	89 ± 14	81 ± 6
	No	3.58 ± 1.19*	95 ± 13	2.90 ± 0.99*	94 ± 14	80 ± 5
Physical inactivity	Yes	3.27 ± 1.11	92 ± 15	2.62 ± 0.97	91 ± 18	79 ± 6
	No	3.35 ± 1.00	92 ± 12	2.74 ± 0.81	93 ± 12	82 ± 5

*p < 0.05.

Table 4. Multivariate regression results with the main predictors of lung function.^a

Outcome	Predictors	Coefficient	Standard error	p	ΔR	R ²
FVC, % predicted	Smoking history	-0.218	0.065	0.001	0.110	0.246
	Diabetes mellitus	-12.266	3.763	0.002	0.136	
FEV ₁ , % predicted	Smoking history	-0.202	0.074	0.009	0.135	0.225
	Arterial hypertension	-9.883	3.781	0.011	0.090	

^aModel adjusted for age, gender, weight, height, hypertension, diabetes, physical inactivity (determined by triaxial accelerometry), and International Physical Activity Questionnaire score.

that the benefits of PADL were not enough to make up for the damage caused by smoking.

We observed a crucial association between the presence of diabetes mellitus and lung function in our participants. Our results are in agreement with

those of previous studies.^(30,31) Lung volume changes reducing lung compliance and DLCO have been described in patients with diabetes. This is probably due to a reduction in pulmonary capillary blood volume as a result of diabetes mellitus. Impaired lung function in

individuals with diabetes suggests that the lung is a “target organ” in diabetes mellitus.⁽³²⁾ Systematic reviews have examined lung function in patients with diabetes mellitus. Reduced FEV₁ and FVC have been found to be associated with type 1 diabetes and type 2 diabetes.⁽³³⁾ Our results suggest that this association remains significant even in smokers with varying history of smoking. Therefore, diabetes mellitus should be considered a major risk factor for lung function decline and, eventually, COPD. According to the aforementioned studies, moderate to high levels of regular physical activity are associated with reduced lung function decline and reduced risk of COPD in smokers.^(5,34) This difference can be attributed to the methods used in order to determine the level of PADL. In the present study, we used triaxial accelerometry, which precisely measures the amount and intensity of PADL. The aforementioned studies involved the use of questionnaires. Despite the size of those studies, the major limitation of questionnaires is that they overestimate the level of PADL. Triaxial motion sensors can overcome some of the limitations of self-report instruments, are not affected by random and systematic errors introduced by interviewees and interviewers, and provide valid and reliable estimates of basic features such as the frequency, duration, and intensity of physical activity, as well as the pattern of physical activity.⁽³⁵⁾ An accurate assessment of physical activity is extremely important when the relationship between exposure to physical activity and a range

of health outcomes (e.g., cardiovascular disease, hypertension, and obesity) is examined.⁽³⁶⁾ In addition, self-reported physical activity is highly susceptible to inaccuracy because self-report instruments depend on the ability of individuals to recall and report their physical activity.⁽²³⁾ Our results suggest the need for longitudinal epidemiological studies to investigate the association between lung function and PADL, the latter being more accurately assessed by motion sensors.

The major limitation of the present study is its convenience sample, which can explain the predominance of females and the difference in smoking history between males and females. However, the sample size was sufficient to adjust the regression models to the main confounders of clinical interest.

Our results suggest that there is no association between physical inactivity and lung function in adult smokers, as well as reinforcing the importance of smoking cessation and preventing comorbidities such as diabetes mellitus and arterial hypertension in order to prevent lung function decline and COPD. Therefore, health professionals should focus on health promotion instructions and strategies, as well as on preventing comorbidities in smokers and the general population.

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