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ORIGINAL ARTICLE

Evaluation of dose–response relationship between smoking load and cardiopulmonary fitness in adult smokers: A cross-sectional study

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Abstract
Objective: To evaluate the dose–response relationship between smoking load and cardiopulmonary fitness, as measured with cardiopulmonary exercise testing (CPET), in adult smokers free of respiratory diseases.
Methods: After a complete clinical evaluation and spirometry, 95 adult smokers (35 men and 60 women) underwent CPET on a treadmill.
Results: The physiological responses during CPET showed lower cardiorespiratory fitness levels, regardless of smoking load, with a peak V'_{O_2} lower than 100% of the expected value and a lower maximum heart rate. We observed a significant moderate negative correlation between smoking load and peak V'_{O_2}. The smoking load also presented a significant negative correlation with maximum heart rate($r = -0.36$; $p < 0.05$), lactate threshold($r = -0.45$; $p < 0.05$), and peak ventilation($r = -0.43$; $p < 0.05$). However, a dose–response relationship between smoking load quartiles and cardiopulmonary fitness was not found comparing quartiles of smoking loads after adjustment for age, sex and cardiovascular risk.
Conclusion: There appears to be no dose–response relationship between SL and cardiopulmonary fitness in adult smokers with preserved pulmonary function, after adjusting the analysis for age and cardiovascular risk. Our results suggest that smoking cessation might be useful as the primary strategy to prevent cardiopulmonary fitness decline in smokers, regardless of smoking load. Thus, even a very low dose of tobacco use must be avoided in preventive strategies focusing on becoming people more physically active and fit.

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Introduction

Tobacco use continues to be the leading global cause of preventable deaths.[1] Smoking affects health among young smokers without established chronic disease.[2] Smoking increases the risk of developing respiratory and cardiovascular diseases, and it is responsible for causing many types of cancer, even in non-smokers exposed to second-hand tobacco smoke (SHS). When smoking, a person inhales an average of 2500 toxic substances leading to symptoms such as increased mucus production, airway inflammation, infections, and decreased muscular function.[3]

Smoking is associated not only with lower physical activity, but also with impaired cardiorespiratory fitness and heart rate variability.[4] The best way to determine cardiorespiratory fitness is through cardiopulmonary exercise testing (CPET). One of the variables used to determine the functional cardiorespiratory capacity is the measurement of the pulmonary oxygen uptake (V'_{O_2}) at peak exercise intensity.

Smoking load (SL), expressed in pack-years, is widely used as a simple way to quantify current tobacco use. An SL greater than 15 pack-years should have detailed screening for respiratory diseases, such as chronic obstructive pulmonary disease (COPD).[5] Lung cancer screening is recommended for individuals with an SL greater than 30 pack-years.[6] However, the health effects of lower SL are not fully understood. Although there is detailed knowledge of the negative effects of smoking, there are few studies on the dose−response relationship of SL and cardiorespiratory fitness. The objective of this study was to evaluate the dose−response relationship between SL and cardiopulmonary fitness through CEPT in adult smokers with preserved pulmonary function.

Methods

In this cross-sectional study, 95 adult smokers (35 men and 60 women) underwent CPET on a treadmill, after a complete clinical evaluation and spirometry. Participants were selected from the EPIMOV Study (Epidemiology and Human Movement Study). Briefly, the EPIMOV Study, is a cohort study with the main objective of investigating the longitudinal association between sedentary behavior and physical inactivity with the occurrence of hypokinetic diseases, especially cardiorespiratory diseases. The volunteers were recruited through dissemination in social networks, folders displayed in the universities of the region, local magazines and newspapers. Inclusion criteria for this study were male or female aged between 18 and 90 years and being free from self-reported physician-diagnosed cardiac or pulmonary disease. Exclusion criteria were orthopedic problems, recent respiratory infections, unstable or stable angina in the last four weeks, recent myocardial infarction, angioplasty or cardiac surgery in the last three months and spirometric abnormalities. We have excluded participants considering impaired functional vital capacity (FVC < 80% predicted) and/or low relationship between forced expiratory volume in the 1st second and FCV (FEV1/FVC ratio $\leq$ 0.7 in absolute value).[7–9] In order to calculate the predicted spirometric variables, Brazilian reference values[10] were used. The participants were informed about the possible risks and discomforts of the procedures proposed in the present study and signed a consent form. The Ethics Committee for Research in Humans of the local university approved this study by the 186.796 protocol.

Clinical evaluation

The height and weight of the subjects were measured and the body mass index (BMI) was calculated. Personal and demographic data were collected (e.g., sex, age, education, home address). In addition, participants answered the physical activity readiness questionnaire (PAR-Q) in order to evaluate some possible contraindication for CPET[11]; questions about respiratory disorders based on the American Thoracic Society (ATS) questionnaire[12] to investigate pollutants exposition, history of asthma and smoking status; and cardiovascular disease (CVD) risk stratification was performed according to the American College of Sports Medicine (ACSM).[13] We investigated the presence of self-reported major risk factors for CVD, including age (male $\geq$ 45 years; female $\geq$ 55 years); family history of premature coronary heart disease (CHD) (definite myocardial infarction before 55 years old in father or 65 years old in mother or other first-degree relative); systemic arterial hypertension; diabetes; dyslipidemia and current cigarette smoking.

Spirometry

The forced vital capacity (FVC) was determined using a calibrated spirometer (Quark PTF; COSMED, Pavonadi Albano, Italy), following the criteria of the American Thoracic Society (ATS).[14] The forced expiratory volume in 1-s (FEV_1) was measured, and then the FEV_1/FVC ratio was calculated. All spirometric values were measured in absolute and percentage of normal values by using reference values for the Brazilian population.[10]

Cardiopulmonary exercise testing

All participants were informed about the preparatory procedures prior to CPET. Several recommendations were standardized, such as not smoking on the assessment day, not performing intense exercise on test day and avoiding coffee, tea or on test day. CPET was done on a treadmill (ATL, Inbrasport, Curitiba, Brasil) by using a ramp protocol. Pulmonary oxygen uptake (V'_{O_2}), carbon dioxide output (V'_{CO_2}) and minute ventilation (VE) were recorded using a computerized system for cardiopulmonary exercise testing, periodically calibrated following the manufacturer's recommendations (Quark PTF; COSMED, Pavona di Albano, Italy). Heart rate was monitored during CPET with a 12-lead EKG (C12x; COSMED, Pavona di Albano, Italy). The V'_{O_2} equivalent to the lactate threshold was obtained through a gas exchange technique, visually inspecting the V_{CO_2}/V'_{O_2} slope inflection point (v-slope) and by using the oxygen (VE/V'_{O_2}) and carbon dioxide (VE/V'_{CO_2}) ventilatory equivalents.[15] The data were averaged every 15-s. The average of the last 15 s at the end of the test, immediately before the recovery phase, was considered the peak V'_{O_2}. Subjects with less