Inspiratory critical pressure - new methodology for evaluating and training the inspiratory musculature for recreational cyclists: study protocol for a randomized control trial

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Abstract

**Background:** Inspiratory muscle training (IMT) has brought great benefits in terms of improving physical performance in healthy individuals. However, there is no consensus regarding the best training load being in most cases the maximal inspiratory pressure (MIP) is used, mainly the intensity of 60% of MIP. So, the prescription of an IMT protocol that considers respiratory muscle strength and endurance may bring additional benefits to commonly used protocols, since the respiratory muscles that differ from other muscles because of their greater muscular resistance. Thus, IMT using inspiratory critical pressure (PThC) can be an alternative as the calculation of PThC considers these characteristics. Therefore, the aim of this study is to propose a new IMT protocol to determine the best training load for recreational cyclists.

**Methods:** Thirty recreational cyclists (between 20-40 years) will be randomized into the SHAM Group (SG), the PThC Group (PCG) and the 60% of MIP Group (60G), according to age and aerobic functional capacity. All participants will undergo the following evaluations: pulmonary function test (PFT), respiratory muscle strength test (RMS), cardiopulmonary test (CPET), incremental respiratory muscle endurance test (iRME) [maximal sustained respiratory pressure for 1 minute (PThMAX)] and constant load test (CLT) (95%, 100% and 105% of PThMAX) using a linear load inspiratory resistor (PowerBreathe K5). The PThC will be calculated from the inspiratory muscle endurance time (TLIM) and inspiratory loads of each CLT. The IMT will last 11 weeks (3 times/week and 1 hour/session). The session will consist of 5-minute warm-ups (50% of the training load) and 3 sets of 15-minute breaths (100% of the training load), with a 1-minute interval between them. RMS, iRME, CLT and CPET will be performed beforehand, at week 3 and 7 (to adjust the training load) and after training. PFT will be performed before and after training. The data will be analyzed using specific statistical tests (parametric or non-
parametric) according to the data distribution and their respective variances. The $p < 0.05$ will be established.

**Discussions:** It is expected that the results of this study will enable the training performed with PThC to be used by health professionals as a new tool to evaluate and prescribe IMT. **Clinical Trial:** ClinicalTrial.gov, ID Number NCT02984189. Registered on December 6, 2016, [https://clinicaltrials.gov/ct2/show/NCT02984189](https://clinicaltrials.gov/ct2/show/NCT02984189).

**Keywords:** Physical Exercise, Physiotherapy, Physical Performance, Critical Power, Respiratory Muscle

**Background**

Positive results obtained by using inspiratory muscle training (IMT) in active and non-active healthy individuals have transformed this type of intervention into one of the most studied in recent decades(1-3). IMT, which is already used as an integral part of cardiorespiratory rehabilitation in individuals with respiratory muscle weakness(4-6), is currently an alternative to improve the athletic performance of amateur and professional athletes by reducing the sensation of dyspnea in these individuals(7-15).

However, despite the large number of studies that evaluate the efficiency of IMT, there is a gap in the literature related to choosing the best protocol for each population and training objective. Thus, new studies need to be carried out aimed at establishing the best load (intensity), duration and frequency of training for healthy active individuals and to promote central and peripheral adaptations, which can help regulate respiratory muscle activity(16).

Among these parameters, the most studied is the training load, but there is still no consensus as to which the best load is to be used. Thus, studies in the literature have mainly used respiratory muscle strength (RMS) measurement and the percentage of maximal inspiratory pressure (MIP) is the most used for establishing training loads(16,17).
However, as well as RMS, respiratory muscle endurance (RME) should also be considered, which together make up the main characteristics of the respiratory system, and can bring about greater systemic adjustments, leading to an improvement in physical performance as the respiratory muscles stand out from the other muscles due to their great resistance (18).

According to Hajghanbari et al. (3), the loads presented in the studies cited in this review used training intensities between 50% and 80% of MIP. In a review by Janssens et al. (19), the authors concluded that changes in inspiratory muscle strength (IMS) were more significant in training with loads between 60% and 80% of MIP. Thus, most of the studies that show good results in relation to IMT (3, 19) used the 60% of MIP. However, to the best of our knowledge, no new methods have been found in the literature that use the IMS and RME together to determine the training load.

Based on this, it was proposed in our group's previous research to determine the critical respiratory pressure (PThC) of apparently healthy young and middle-aged men during RME (20). This new methodology to determine the training load was based on the concept of critical power (CP) defined as the limit work (W_{LIM}) where an exercise can be maintained for a long period of time (T_{LIM}) without any signs of fatigue (21, 22) or as the intensity where the aerobic and anaerobic pathways are recruited together (23).

The determination of PThC is performed by the total work (abscissa) graph for the total time to exhaustion (coordinate), from multiple intensities of exercise to fatigue. Once this is done, a linear regression of the points is performed to identify the curvature constant (W') and the PThC is determined as the point at which the line intersects the abscissa.

This work-time relationship is defined by a hyperbolic function, in which the slope represents the aerobic function and the intercept in y (W'), the anaerobic working capacity, that is, the maximal workload that can be performed using stored energy in the
active muscle (adenosine triphosphate, phosphocreatine, glycogen and myoglobin-bound oxygen)(24,25). In addition, it should be noted that both RMS and RME are used to determine it; the latter by evaluating PTh_{MAX}, which represents the maximal workload that the individual can sustain for at least 1 minute(26–29).

Thus, it was observed that the percentage of PThC is similar to other values of CP found in the literature; where PThC and the percentage of PTh_{MAX} were influenced by age(20). This suggests that the concept of PThC can be applied as a new IMT tool, as this method considers the characteristics of the respiratory musculature, i.e., RMS and RME together(20).

In addition, during the proposition of a new training load, the results of this new methodology need to be compared with the other loads found in the literature to clarify what the best training intensity is for a given population and to define the responses generated by this training in the main systems involved: cardiovascular, respiratory and metabolic systems.

IMT using PThC can bring additional benefits, such as increased oxygen uptake (VO_{2PEAK}), generated by using a moderate to high intensity load that can be performed over a long period of time(23) due to improving the efficiency of respiratory, cardiovascular and musculoskeletal systems and which will contribute to improved physical performance. In addition, a longer delayed mechanism of inspiratory muscle metaboreflex has been pointed out as one of the main factors responsible for the benefits of IMT in healthy individuals(3,19).

Methods

Aim

The aim of this study is to propose a new methodology to determine the IMT load for
recreational cyclists, which promotes better results for physical performance and for cardiovascular, respiratory and metabolic responses compared to traditional methodologies.

**Classification of the study**

This is an experimental, longitudinal, randomized, controlled and double-blind study. The research participants and the researcher, who will perform the statistical analysis (PRS), will be blinded. The methodological design was based on the SPIRIT(30).

**Subjects**

GPower software 3.1.3 was used to calculate the sample size required for this study. To determine the sample size, the mean effect size value \([f = 0.25, \text{ according to COHEN}(31)]\) was used for the two-way mixed ANOVA test, values of 0.05 for the type I probability error \((\alpha)\), of 0.80 for the type II probability error (power or \(\beta\)). Therefore, in order to ensure these pre-established conditions, at least 30 subjects should participate in this study. Thirty recreational male cyclists, aged between 20 and 40 years, will be evaluated. They will be randomly divided into three groups: SG, PCG and 60G. The groups will be formed by the randomization of the paired individuals with the same aerobic functional classification(32) and age group (subdivided into decades), using R software 3.0.2 to allocate the subjects.

The criteria used to select the participants will be: male subjects aged 20 to 40 years old, apparently healthy, who have been practicing cycling for at least 6 consecutive months and at least 150 minutes/week [classified as active by the AMERICAN COLLEGE OF SPORTS MEDICINE(33)], non-smokers, non-alcoholics, or users of illicit drugs or medication that may interfere with the results of the research. In addition, participants will not be able to present abnormalities in the cardiovascular, respiratory, orthopedic or neurological systems, nor of other systems that make the proposed tests impossible. The exclusion
criteria of the study is as follows: participants with electrocardiogram (ECG) changes [ischemia, overload, severe arrhythmias (such as ventricular tachycardia) and conduction disorders], both at rest and during the clinical exercise test, obese [body mass index (BMI) >30 kg/m²], diabetics, hypertensive, participants with alterations in laboratory tests, participants with respiratory muscle weakness [MIP<60% predicted(34)], former smokers with at least 1 year of interruption, those who are illiterate and/or who do not have a sufficient level of understanding to understand the routine of the protocols, as well as participants who have performed some type of IMT over the last 12 months.

The participants will be recruited by electronic and printed media, as well as contacts with subjects that are part of the database from the Laboratory of Cardiovascular Physiotherapy (LFCV) at the Federal University of São Carlos (UFSCar). After identifying the eligible participants, they will be invited to participate in the study and after they have accepted, they will carry out all the evaluations described below, as well as the type of training to which they are allocated.

**Study planning**

The present study will be conducted in accordance with the Helsinki Declaration. This study was approved by the Human Research Ethics Committee at the Federal University of São Carlos (UFSCar) (nº 1.558.731). All subjects signed an informed consent form.

The experimental tests and procedures will be performed at the LFCV at the Nucleus of Research in Physical Exercise (NUPEF) at the Department of Physical Therapy (DFisio) and the clinical ergometric tests at the Physiotherapy in Cardiology Department of the Health School Unit (USE), both located at UFSCar, São Carlos campus. The blood tests will be performed at the Laboratory of Clinical Analysis at UNIMED (a cooperative medical system) in São Carlos (UNILAB).

Environmental conditions will be controlled, and participants will be instructed according
to Persequini et al. (35). The tests will always be performed in the afternoon, considering the influence of the circadian cycle on the evaluation results.

On the day of the tests, previously to applying the experimental protocols, the conditions related to the participants’ state of health will be observed. Moreover, prior to the tests, participants will be familiarized with the equipment, respiratory maneuvers and the subjective perception of effort scale - BORG/CR10 (36) in order to reduce participants’ anxiety and prevent the effect of the learning process from affecting the search results.

**Clinical evaluation and characterization of the sample**

Before performing the experimental protocols, the participants will be submitted to the following evaluations: anamnesis and physical examination, conventional 12-lead ECG, treadmill clinical exercise test, both performed in the presence of a cardiologist, assisted by a physiotherapist. The aim of these tests will be the clinical and cardiovascular evaluation of the participants.

To characterize the participants and verify their health status, the following evaluations will be performed before the experimental protocol: body composition evaluation by Dual-energy X-ray Absorptiometry (DXA) (Discovery DXA System, Hologic, USA), nutritional assessment and blood tests (lipid profile, total cholesterol, High density lipoproteins (HDL), Low density lipoproteins (LDL), urea, creatinine, fasting glucose, uric acid, insulin resistance, C-reactive protein and glycated hemoglobin to check their health status.

**Experimental Protocol**

The experimental protocol will take place over thirteen weeks, as shown in Figure 1. In the first, fifth, ninth and thirteenth weeks, the participants will be submitted to the following evaluations: CPET, RMS, iRME and constant load test (CLT). The pulmonary function test (PFT) will be performed only in the first and thirteenth weeks of the study. The IMT will be carried out for 11 weeks. It is emphasized that during the reevaluation
weeks, the participants will continue doing the training.

The aim of the re-evaluations, which will be carried out in the fifth and ninth weeks of training, is to readjust the training loads, as well as follow the responses to the IMT.

**Respiratory muscle strength tests (RMS)**

The evaluation of RMS will be performed with the volunteers at rest in the sitting position, using a digital manovacuometer (MVD-300, Globalmed, Porto Alegre, Brazil) and a nasal clip, according to the Brazilian Guidelines for measuring maximum static respiratory pressures(37). This measure will always be carried out by the same appraiser. MIP will be determined after maximal inspiratory effort, from the residual volume. The maximal expiratory pressure (MEP) will be determined after maximal expiratory effort, from total lung capacity. These maneuvers will be performed against a tube with an occluded distal end and a 2 mm-hole mouthpiece(37) will be used. The values of the maximal respiratory pressures will be those observed in the first second after the peak of pressure(37). At least three maneuvers will be performed, with a 30s interval between each maneuver(38), obtaining the highest reproducible values (difference <10%) found in at least three maneuvers and considering the maximal respiratory pressure value the highest value. Normal values will be based on the regression equation proposed by Neder et al.(39) for the Brazilian population. Respiratory muscle weakness, static pressure values <60% of those predicted, will be considered(34).

**Cardiopulmonary Test (CPET)**

The CPET will be used to assess the aerobic power of the participants [peak oxygen uptake (VO₂\text{PEAK})](40), to determine the gas exchange threshold (GET) by the ventilatory method(41), the respiratory compensation point (RCP)(40) and inspiratory muscle metaboreflex(42).

A ramp type protocol will be performed on an electromagnetic braking cycle ergometer
(CORIVAL V3, Lode BV, The Netherlands) and will consist of a 6-minute rest, 3-minute free-load warm up and a gradual increase in load until the exercise is stopped, followed by 6 min active recovery and 1 min passive recovery. The power increment will be calculated for each participant according to the values established by the formula described by Wasserman et al.(43) and adapted according to the evaluator's experience, preventing the increment from being underestimated.

Participants will be instructed to maintain a cadence between 60 and 70 rpm throughout the protocol and the test will last from 8 to 12 minutes(43). Three independent evaluators will determine the GET and the RCP. The highest value of VO₂ obtained in the last 30 seconds of the CPET will be considered the VO₂ peak(40). In addition, the following variables will be evaluated in the GET and peak effort: VO₂, carbon dioxide production (VCO₂), pulmonary ventilation (VE), oxygen uptake efficiency slope (OUES) and minute ventilation-carbon dioxide production slope (VE/VCO₂ slope)(40,44).

The activation of the inspiratory muscle metaboreflex will be evaluated by analyzing the behavior of the variables: oxyhemoglobin (O₂Hb), deoxyhemoglobin (HHb) and total hemoglobin (tHb) obtained by Near Infrared Spectroscopy (NIRS) and the cardiovascular data, heart rate (HR) and mean arterial pressure (MAP), obtained by a bioamplifier for ECG signals (BioAmp FE132) and a Finometer (Finapres Medical Systems, The Netherlands), respectively, at the intensities of 50% to 100% of the VO₂ peak, subdivided into 10% intervals. In addition, the activation point of the inspiratory muscle metaboreflex will be considered the moment at which the nonlinear HR and MAP, as well as oxygenation decrease for the vastus lateralis (VL) and increase for the external intercostal (EI), i.e. redirection of blood flow from the peripheral musculature to the respiratory muscles(6).

**Pulmonary function test (PFT)**
This examination will be performed according to the international standard(45) and will consist of tests of slow and forced vital capacity (SVC and FVC) and maximum voluntary ventilation (MVV). The test will be performed using a flow module coupled with a system of ventilatory and metabolic measurements (ULTIMA MedGraphics - St. Paul, Minnesota, USA). The variables analyzed will be: FVC, relationship between VEF1 and CVF (VEF1/CVF), IC, expiratory reserve volume (ERV) and MVV. The predicted values will be calculated according to Pereira(46).

**Protocol for the determination of inspiratory critical pressure (PTHc)**

An incremental protocol with a load of 50 to 100% MIP (Figure 2) will be performed and 10% of MIP will be added every 3 min. The participant will receive a verbal stimulus to maintain the respiratory rate (RR) in 12 breaths/minute and the test may continue until he/she reaches 100% of MIP. In this case, if the participant can generate an air flow capable of triggering the equipment more than once in this load, the MIP measurement will be redone and the test repeated. The following will be considered: failure to maintain the stipulated load at 12 breaths/minute for at least 1 minute, failure to maintain respiratory effort indicated by the volunteer (BORG / CR10≥7)(36) and the participant requesting interruption. The highest percentage of MIP that the volunteer is able to maintain for at least 1 min (PTHcMAX) will be stipulated as the RME measurement(26–28,47).

After determining the PThcMAX, individuals will carry out incursions against a constant load, without the RR being controlled in order to identify the total time tolerated in each load (TcLIM). Individuals will be exposed to three different resistances (95%, 100% and 105% PThcMAX) with a 15-minute interval between them. The order of resistances will be determined by a draw without the individual knowing which order he will be in. After obtaining the TcLIM of each load, a pressure graph will be plotted by time and the PThc will...
be determined by using a linear regression between the variables (23).

**Monitoring the experimental protocol**

The equipment described below will be used to monitor the participants in the evaluations of the CPET and iRME.

**Metabolic and respiratory variables**

The ventilatory and metabolic variables will be collected, breath by breath, through a system of expired gas measurements (ULTIMA MedGraphics - St. Paul, Minnesota, USA) and processed through specific software (Breeze Suite 7.1, MedGraphics - St. Paul, Minnesota, USA). In addition, the BORG CR10 scale (36) will be used to assess the subjective perception of the exercise performed by the participant.

**Cardiovascular variables**

The acquisition of the ECG and BP signals to evaluate the cardiovascular responses will be performed at a sampling frequency of 1.000 Hz. The ECG signals will be captured by means of the CMS lead. The HR will be recorded and stored beat-to-beat. Electrocardiographic signals will be captured and processed via an interface between a bioamplifier for ECG signals (BioAmp FE132, ADInstruments, Australia) and a biological signal acquisition system (Power Lab 8/35, ADInstruments, Australia) and a microcomputer (Intel I5).

On the other hand, pulse pressure will be captured using Finometer Pro® (Finapres Medical Systems, The Netherlands), which allows non-invasive measurements of pulse arterial pressure (FinAP), beat-to-beat, obtained by positioning a cuff in the third phalanx of the third finger of the left hand. The equipment will be calibrated according to the manufacturer's instructions. In addition to pulse arterial pressure (AP), the values of cardiac output (CO), stroke volume (SV) and total peripheral vascular resistance (PVR), derived from the AP curves and analyzed in the Beat Scope® Easy software (Finapress...
Medical Systems, The Netherlands) will be evaluated.

**Metabolic evaluation by NIRS**

The EI and VL muscle oxygenation variables will be measured by the NIRS (Oxymon Mk III, Artinis Medical Systems, The Netherlands). Two optodes will be used, which will be positioned as described below: IE = eighth left intercostal space in the anterior axillary line; VL = 12 to 15 cm of the knee joint, lateral line between the greater trochanter of the femur and the patella.(48).

The sampling rate of the device will be set at 250 Hz. Inter-ops distance will be 35 mm for the EI and 40 for the VL.(48). The differential path-length factor (DPF) will be 4 for the EI muscles and 3.83 for the VL. The calibration will be redone for each subject and the data will be continuously captured during the CPET and the iRME. For each muscle, the change in tissue oxygenation and local blood volume will be estimated by changes in $O_2$Hb, HHb and tHb, calculated automatically by the software of the equipment by the formula ($tHb = O_2Hb + HHb$).

**Inspiratory muscle training (IMT)**

**Training Description**

The training will last for 11 weeks, with a weekly frequency of 3 sessions and each session will last one hour each. Each session will consist of a 5-minute warm-up, where each volunteer will perform a constant loading protocol with 50% of their training load. The training protocol will consist of 3 sets of 15 minutes of breaths, with a 1-minute interval between them (**Figure 3**).

The loads that will be used in the training will be: for the PCG the value of the PThC, for the 60G, the resistance will be 60% of MIP and for the SG, the training will be carried out with a resistance of 6 cmH₂O. All groups will perform IMT using the Linear Load
Respiratory (PowerBreathe inspiratory muscle trainer, Ironman K5, HaB Ltd, UK).
The volunteers will be instructed to maintain diaphragmatic breathing and RR of 12
breaths/minute for the entire duration of the training protocol, and the RR will be
controlled by using a recorded verbal command, ensuring that all participants receive the
same stimulus. During the 11 weeks of training, volunteers will be instructed not to
change their activities and physical training or food intake.

Every day, before and after the training protocol, the AP will be checked, and the health
status of the volunteers will be observed while the HR will be monitored, recorded and
stored during all training sessions by a Polar 800CX (Kempele, Finland).

In addition, during the training period, the participants will be asked to complete a
physical activity schedule to monitor the activities performed by each individual during
the research participation and complete a food survey that will be analyzed later by a
nutritionist, thus avoiding these factors interfering with training responses. The weekly
training volume and the end, which will be controlled over 11 weeks, will be ensured for
all participants throughout this study who do not complete the 3 weekly training sessions
and/or the 18 total training sessions, or participants who change their physical activities,
their eating habits, or those who begin to use any supplement or medication continuously
will be excluded during the survey.

**Statistical analysis**

All statistical analyses will be processed using the SPSS Statistics software 17.0. The level
of significance will be set at p < 0.05. Data with normal distribution will be presented
according to the mean±standard deviation; and those with non-normal distribution,
according to median (interquartile range).

The Shapiro-Wilk test will be used for data analysis normality testing and the Levene test
for the homogeneity evaluation. A descriptive analysis of the three groups evaluated and
then the paired t-test will be performed on the following data: age, anthropometric evaluation, body composition densitometric analysis and blood test results.

To analyze the comparison between the three groups, considering the following factors: group and training time, in the variables of the PFT (FVC, FEV1/FVC, IC, ERV and MVV), RMS (MIP and MEP), CPET (VO₂peak, OUES and VE/VCO₂slope), cardiovascular variables (HR, CO, SAP, SV, total PVR) and metabolic variables (O₂Hb, HHb, tHb and VO₂peak), the two-way mixed ANOVA test of data is parametric and if they are non-parametric, mathematical transformations will be performed in order to normalize the data.

**Expected results**

Among the scientific contributions from this project, the main one refers to adopting a new evaluation methodology (PThC) and prescription of IMT. It is expected that PCG will obtain better results than 60G and SG, such as obtaining a higher increase in workload (Watts) and peak oxygen uptake (VO₂PEAK) in the CPET; higher MIP and iRME; decreased sensation of dyspnea and the sensation of peripheral fatigue, evaluated by the perception index to the physical effort of BORG and delay in the activation of the inspiratory muscle metaborreflex both during the CPET and in the iRME.

Thus, it is expected that: using IMT based on this new approach can increase the benefits derived from traditional methodology (IMT based on 60% of MIP); it can provide subsidies on the best understanding of the physiological responses from applying it; and this new methodological approach can be used by health professionals as a new tool to evaluate and prescribe IMT, bringing more satisfactory results and greater physiological impact.

**Discussion**

Most systematic reviews (1,3,19) that study the effects of IMT emphasize the need for studies that perform a controlled and randomized experimental design, following the
guidelines of the CONSORT(49), as well as establishing training parameters that seek to achieve the best results for the population studied.

However, adapting this type of training to meet these guidelines becomes extremely complicated because of the need for this therapy to be used in a laboratory. Several experiments, also presented in these reviews(1,3,19), perform the training on average 5 times a day, or often with more than one session on the same day. Therefore, for the results of this research to be discussed considering the studies already published in the literature, we used the determination of the average training volume(50) of these studies, because this is an important parameter for determining training effectiveness, mainly resistance. Moreover, we divided the total time into 3 training days per week, the number of days also indicated by the ACSM(33), as the ideal time for performing physical activities, thus totaling 45 min of IMT on each day of training.

Contributions to the area

This study will be important for Physiotherapists, Physical Educators and other health professionals who work with physical exercise and training, as knowledge concerning the cardiovascular, respiratory and metabolic responses generated by IMT in recreational cyclists, using PthC and 60% of MIP, will enable these professionals to prescribe an IMT in a more suitable way for healthy active individuals. It will also help to encourage new studies that aim to promote greater gains for this population.

It is hoped that the results of this study will enable training performed with PthC to be used by health professionals as a new tool for assessing and prescribing IMT.

Abbreviations

**IMT**: inspiratory muscle training; **MEP**: maximal expiratory pressure; **MIP**: maximal inspiratory pressure; **PthC**: inspiratory critical pressure; **60G**: 60% of maximal inspiratory pressure group; **SG**: Sham group; **PCG**: inspiratory critical pressure group; **PFT**: 
pulmonary function test; **RMS:** respiratory muscle strength test; **CPET:** cardiopulmonary test; **iRME:** incremental respiratory muscle endurance test; **PTh\textsubscript{MAX}:** maximal sustained respiratory pressure for 1 minute; **CLT:** constant load test; **T\textsubscript{LIM}:** inspiratory muscle endurance time; **RME:** respiratory muscle endurance; **CP:** critical power; **W\textsubscript{LIM}:** defined as the maximal workload; **W':** constant of curvature; **VO\textsubscript{2PEAK}:** peak oxygen uptake; **ECG:** electrocardiogram; **BMI:** body mass index; **LFCV:** Laboratory of Cardiovascular Physiotherapy; **UFSCar:** Federal University of São Carlos; **NUPEF:** Nucleus of Research in Physical Exercise; **DFisio:** Department of Physical Therapy; **USE:** Health School Unit; **UNILAB:** Laboratory of Clinical Analysis at UNIMED; **DXA:** Dual-energy X-ray Absorptiometry; **HDL:** High density lipoproteins; **LDL:** Low density lipoproteins; **GET:** gas exchange threshold; **RCP:** respiratory compensation point; **BOGR/CR10:** subjective perception of effort scale; **VCO\textsubscript{2}:** carbon dioxide production; **VE:** pulmonary ventilation; **OUES:** oxygen uptake efficiency slope; **VE/VCO\textsubscript{2} slope:** minute ventilation-carbon dioxide production slope; **O\textsubscript{2}Hb:** oxyhemoglobin; **HHb:** deoxyhemoglobin; **tHb:** total hemoglobin; **NIRS:** Near Infrared Spectroscopy; **HR:** heart rate; **MAP:** mean arterial pressure; **VL:** vastus lateralis; **EI:** external intercostal; **SVC:** slow vital capacity; **FVC:** forced vital capacity; **MVV:** maximum voluntary ventilation; **VEF1/CVF:** relationship between VEF1 and CVF; **IC:** inspiratory capacity; **ERV:** expiratory reserve volume.

**Declarations**

**TRIAL STATUS**

**Status:** Patient recruitment is currently underway.

**Date recruitment began:** May, 2017.

**Date of final recruitment:** Dezember, 2019.

**Ethics approval and consent to participate**
All ethical aspects were considered. The present study will be conducted in accordance with the Helsinki Declaration. This study was approved by the Human Research Ethics Committee at the Federal University of São Carlos (UFSCar) (nº 1.558.731). All subjects signed an informed consent form and registered in the Clinical Trials (NCT02984189).

**Consent for publication**

Not applicable.

**Availability of data and material**

Not applicable.

**Competing interests**

Not applicable.

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**Authors' contributions**

PRS, VM and AMC created the idea. PRS, VM, JCMM, EFS and RMA designed the study, and CCD structured the nutritional part. PRS, VM, JCMM, EFS and RMA developed the inspiratory muscle training methodology. AMC guided and coordinated the work. PRS wrote the study and did the literature survey. Everyone read and reviewed the final version.

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Figures
Template of recommended Interventional Trials (SPIRIT) schedule. PCG: inspiratory critical pressure group. 60G: 60% of maximal inspiratory pressure group. SG: Sham group. RMS: Respiratory muscle strength test. CPET: Cardiopulmonary test. PFT: Pulmonary function test. iRME: Incremental respiratory muscle endurance test. CLT: Constant load test.
Figure 2

Representation of incremental muscle endurance test protocol. MIP = maximal inspiratory pressure. Min = minute. REC = recovery.
Figure 3

Schematization of inspiratory muscle training protocol. MIP = maximal inspiratory pressure. min = minute. WU = warm-up.

Supplementary Files

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