ANA LUIZA DE CASTRO LOPES

MOVIMENTAÇÃO RESPIRATÓRIA TORACOABDOMINAL DE CICLISTAS: EM REPOUSO E DURANTE UMA SIMULAÇÃO DE UM CONTRA RELÓGIO DE 20-KM

Dissertação apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Educação Física, para obtenção do título de Magister Scientiae.

Orientador: Paulo Roberto dos Santos Amorim

Coorientadora: Amanda Piaia Silvatti

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Aos meus pais,
Ataides Clementino Lopes e Emília Castro Lopes,
Pelo amor incondicional....

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RESUMO

LOPES, Ana Luiza de Castro, M.Sc., Universidade Federal de Viçosa, julho de 2019. **Movimentação respiratória toracoabdominal de ciclistas: em repouso e durante uma simulação de um contra relógio de 20-km.** Orientador: Paulo Roberto dos Santos Amorim. Coorientadora: Amanda Piaia Silvatti.

A proposta da presente dissertação foi investigar a movimentação toracoabdominal de ciclistas. Para atingir este objetivo, primeiramente, nós investigamos como o treinamento de ciclismo pode influenciar o padrão da movimentação respiratória de ciclistas em uma postura sentada. Depois disso, para prover uma compreensiva avaliação das mudanças induzidas pelo exercício neste comportamento mecânico, nós avaliamos um ecológico contra relógio de 20-km. A estrutura desta dissertação inclui um capítulo de introdução, que inclui uma breve revisão de literatura sobre os temas abordados, bem como a relevância desta pesquisa e seus objetivos. Nos capítulo seguintes, a investigação será conduzida da seguinte forma: o primeiro artigo, intitulado “Padrão da movimentação respiratória toracoabdominal de ciclistas de estrada na postura sentada” objetivou investigar quais mudanças o treinamento em ciclismo de estrada pode induzir no padrão da movimentação respiratória toracoabdominal durante manobras respiratórias na postura sentada em ciclistas de estrada da categoria master. O segundo artigo, intitulado “Padrão da movimentação respiratória toracoabdominal de ciclistas de estrada durante uma simulação de contra relógio de 20-km” investigou o padrão da movimentação respiratória toracoabdominal de ciclistas de estrada da categoria master durante uma simulação de contra relógio de 20-km. Ao final, uma conclusão geral aborda os principais resultados e futuros trabalhos. Como considerações gerais, os principais achados da presente dissertação foram que durante as manobras respiratórias na postura sentada os ciclistas de estrada apresentaram uma alta coordenação da movimentação toracoabdominal e, comparado com o grupo controle, eles apresentaram uma maior contribuição do tórax inferior e um maior deslocamento do abdômen. Esses achados podem estar relacionados ao padrão desenvolvido quando os ciclistas estão pedalando em sua própria bicicleta, uma vez que, durante um simulado de contra relógio de 20-km, o compartimento abdominal teve o maior percentual de contribuição inspiratório e o tórax superior teve o menor percentual de contribuição inspiratório. Além disso, apesar de apresentarem coeficiente de correlação moderado, as mudanças na amplitude de deslocamento do tórax superior (ST) e do abdômen (AB) afetou sua coordenação pareada, portanto, a coordenação entre

ST×AB foi a mais afetada pelo contra relógio. Por fim, o representativo percentual de contribuição inspiratório do tórax inferior pode estar associado à postura que os participantes foram submetidos durante o exercício. Como foi destacado pelos nossos estudos anteriores durante manobras respiratórias na postura sentada, o tórax inferior tem uma importante atuação no padrão da movimentação respiratória toracoabdominal de ciclistas.

Palavras-chave: Mecânica Respiratória. Volume Respiratório. Ciclismo de estrada.

ABSTRACT

LOPES, Ana Luiza de Castro, M.Sc., Universidade Federal de Viçosa, July, 2019. **Cyclists thoracoabdominal breathing motion: at rest and during a simulated 20-km time-trial.** Advisor: Paulo Roberto dos Santos Amorim. Co-advisor: Amanda Piaia Silvatti.

The purpose of this work was to investigate the thoracoabdominal breathing of cyclists. To reach this aim, firstly, we investigate how cycling training influences their breathing motion pattern at sitting posture. After that, to provide a comprehensive evaluation of exercise-induced changes in this mechanical behavior we evaluate an ecological 20-km time trial. The structure of this work includes an introductory chapter, which includes a brief literature review on the topics being addressed, as well as the relevance of this research and its objectives. In the proceeding chapters, the investigations conducted are presented as follows: the first paper, entitled "Thoracoabdominal breathing motion pattern of master road cyclists at sitting posture" aimed to investigate which changes road cycling training can induce on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes. The second paper, entitled "Thoracoabdominal breathing motion pattern of master road cyclists during a simulated 20-km time trial" investigate the thoracoabdominal breathing motion pattern of master road cyclists during a simulated 20-km time trial. Finally, the general conclusion with highlights and future directions are addressed. As general considerations, the key finds of the present work were that breathing maneuvers at sitting posture road cyclists presented a high coordinate thoracoabdominal movement and, compared to a control group they had a higher inspiratory percentage of contribution of the inferior thorax and a higher enrolment of the abdomen. These findings could be related to the pattern developed while they pedal in their own bike since, during a simulated 20-km time trial, the abdominal compartment has the greatest inspiratory percentage of contribution and the superior thorax has the lowest inspiratory percentage of contribution. In addition, although they presented moderate correlation coefficient, the change in the range of enrolment of the ST and AB affected their pair coordination, so these compartment pairs (ST×AB) was the most affected by the time trial. Finally, the representative inspiratory percentage of contribution of IT could be associated with the posture that the participants were submitted during the test. As highlighted by our previous findings during breathing maneuvers at sitting posture, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists.

Keywords: Breathing mechanics. Respiratory volumes. Road cycling.

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GLOSSARY OF TERMS AND ABBREVIATIONS

CG = Control group

CyG = Cyclists group

ST = Superior Thorax

IT = Inferior Thorax

AB = Abdomen

ST×IT = Superior Thorax versus Inferior Thorax

ST×AB = Superior Thorax versus Abdomen

IT×AB = Inferior Thorax versus Abdomen

QB = Quiet breathing

VC = Vital capacity

FEV_1 = Forced expiratory volume in one second

FVC = Forced vital capacity

TV^i = Inspiratory Tidal Volume

3D = Tridimensional

SD = Standard deviation

TT_{20km} = 20 kilometers time trial

5km = 5 kilometers

10km = 10 kilometers

15km = 15 kilometers

20km = 20 kilometers

ST×IT = Superior Thorax versus Inferior Thora

ST×AB = Superior Thorax versus Abdomen

IT×AB = Inferior Thorax versus Abdomen

SUMÁRIO

GENERAL INTRODUCTION

Work Structure

The structure of this work includes an introductory chapter, a brief literature review on the topics being addressed, as well as the relevance of this research and its objectives. In the preceding chapters, the investigations conducted are presented as follows:

The first paper, entitled "Thoracoabdominal breathing motion of master road cyclists at sitting posture" aimed to investigate which changes road cycling training can induce on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes.

The second paper, entitled "Thoracoabdominal breathing motion of master road cyclists during a simulated 20-km time trial" to investigate the effects of the simulated 20-km time trial on thoracoabdominal breathing motion pattern of master road cyclists.

Finally, the general conclusion with highlights and future directions are addressed.

Literature Review

Pulmonary system

The pulmonary system is responsible to maintain homeostasis of arterial blood gases, ensuring an adequate supply of O_2 and facilitate the removal of CO_2 (Shephard e Astrand, 2008). It is composed of four main parts: (1) pulmonary ventilation, the process in which a volume of gas is added to, or removed from the lungs; (2) gas exchange, the process in the lungs by which blood is recharged with O_2 and dumps its waste CO_2; (3) transport of O_2 and CO_2, between the tissues and the lungs; (4) regulation of ventilation, the process by which bodily needs and translated into more rapid slower ventilation.

Gas is a fluid that obeys the same general principles of other fluids: it flows from a region of high pressure to a region of low pressure. Thus, pressure and volume have an inverse relation: it is the basic principle of pulmonary ventilation. Exchange of air between the atmosphere and the alveoli can be influenced by the mechanical properties and interaction between the lung, chest wall and muscles.

The lungs and chest wall interact to produce the pressures that drive ventilation. Breathing motion involves the mechanical characteristics of the ventilatory dynamics that are generally conducted according to the volume-pressure relationship (Grimby et al., 1976). Volume-pressure loops during relaxation allow investigating the pressure attributable to the specific respiratory muscle (Konno e Mead, 1968; Ward et al., 1992).

Chest wall movements

Konno e Mead (1967) defined the chest wall as all parts of the body outside the lung with share changes in the volume of the lungs and are coexistent. The changes in lung volume were recorded by plot x-y axis coordinates of the thoracic dimensions. Enrolments of the lung are transmitted to the chest wall and vice versa. The lung and the chest wall are in series; therefore, lung volume variations can be estimated by chest wall variation.

Antero-posterior diameter and cross-sectional area of thoracic and abdominal compartments

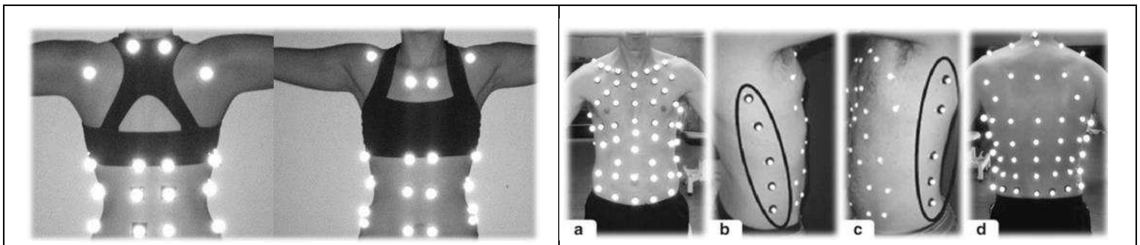
Inductance plethysmography and magnetometers were used to measure the chest wall sections (Konno e Mead, 1967). However, changes in anteroposterior and cross-sectional area of thoracic and abdominal compartments are not linear to volume (Romagnoli et al., 2008).

This framework provided great insights to understand how the ventilatory pump acts on respiratory structures (Macklem, 2004; Massaroni, Carraro, et al., 2017). Given the complexity of the respiratory system, technological advances have permitted further insights and improvements in the mechanics of breathing by chest wall modeling. Thoracoabdominal model based on motion analysis was developed from 3D coordinates of markers fixed on the trunk making possible to estimate the trunk volume.

Thoracoabdominal models

From different geometrical approaches were developed models that used 30 markers (Loula, 2005); 32 markers (Ferrigno et al., 1994) after, 86 markers (Cala et al., 1996) and finally, to 89 markers (Aliverti et al., 2001). The last one is considered the most reliable model to measure the tidal volume, gold standard model to measure the trunk volume. A refinement to the original model successfully improves the accurate reconstruction of the trunk, as during breathing maneuvers at rest as during exercise when compared to the gold standard resource of lung volume measurements, the spirometer (Layton et al. 2013). However, spirometry could alter the natural breath frequency, tidal volume, dead space ventilation and breath awareness which may alter the breathing pattern.

However, considering that the high number of markers could lead to a long time to place the markers on the trunk, massive post-processing, and, also, affect the reproducibility of measurements, Massaroni et al. (2018a) compared 32 markers model (reduced - left) and 89 markers model (full - right). They found that both models had a strong correlation of tidal volume, however, the reduced model underestimated the data. Regard to thoracoabdominal breathing motion pattern variables, the reduced model was adequate to distinguish it.



reduced (32 markers)

full (89 markers)

FIGURE 1: Markers' position of 32 markers model (personal collection) and 89 markers model (Massaroni, 2018b).

The reduced thoracoabdominal models divide the trunk into three compartments: superior thorax, from 2nd rib to xiphoid process; inferior thorax, from this line to the 10th rib; and abdomen, from this line to transverse of the abdomen. Each compartment appears to move as a unit but between them however, there are considerable independence of motion (Konno e Mead, 1967). Therefore, any volume changes in the contents of the diaphragm must be equal and opposite to the volume swept by the abdominal compartment (Aliverti, 2008).

At rest and during exercise, there are two completely different patterns of muscular recruitment. During quiet breathing, the pressuring acting in each compartment is similar, the inspiratory rib cage muscles and diaphragm contracts expand the thoracic cavity and the content of the abdominal cavity shift caudally decreasing intrapulmonary pressure and allowing the gas exchange. Therefore, during rest the diaphragm act as a pressure generator, while, during exercise, the diaphragm behaves essentially as a flow generator because of its shortening ability being greater than that of the inspiratory muscle rib cage (Aliverti et al., 1997).

Applicability to analyze the thoracoabdominal motion

Based on this method, a lot of studies have been developed in different fields as patients with chronic obstructive pulmonary disease (Aliverti et al., 2004; Cavalcanti et al., 2014), patients with Duchenne muscular dystrophy (Romei et al., 2012; Lomauro et al., 2014), with participants of different training activities during breathing maneuvers at sitting posture (Silvatti et al., 2012; Rodrigues et al., 2017; Lopes et al. 2018, Campos et al. 2019), at different postures (Aliverti et al., 2001; Lee et al., 2010), during exercise (Vogiatzis et al., 2005; Romagnoli et al., 2006; Guenette et al., 2007; Layton et al., 2011; Layton et al., 2013; Massaroni et al., 2016; Lopes et al. 2019), during exercise-induced diaphragmatic fatigue (Vogiatzis et al., 2008), during exercise with externally imposed expiratory flow-limitation (Iandelli et al., 2002).

During exercise, the assessment of the chest wall allows the understanding of the relationship between respiratory compartments and suggest the action of respiratory muscles. Furthermore, the 3D kinematic analysis is an important resource at this situation since don't require mouthpiece or nose clip that could induce to abnormal breathing pattern (Aliverti et al., 2002). Therefore, investigations using this methodology are emerging and some knowledge regarding the breathing pattern in some sports is required. Layton et al. (2011), analyzed the thoracoabdominal breathing motion pattern of cyclists, triathletes and untrained men. They described an equal contribution of the superior thorax and the abdominal compartment during rest in a completely sitting upright cycle ergometer. However, recently, enrolling only road cyclists, preliminary studies found a different breathing pattern during breathing maneuvers at sitting posture and during a simulated 20-km time trial in a normal bike posture (Lopes et al. 2018; Lopes et al. 2019).

Since these works showed that cyclists could develop a particularly thoracoabdominal breathing pattern we hypothesize that the thoracoabdominal breathing motion pattern could be affected by the cycling training breathing maneuvers at rest, as found with participants of different training activities at sitting posture (Silvatti et al., 2012; Rodrigues et al., 2017; Lopes et al. 2018, Campos et al. 2019). Based on that, we developed the first study in Vitória-Brazil as a result of the cooperation of the Universidade Federal do Espírito Santo (UFES), where we enrolled master road cyclists.

In order to understand the influences on the pattern that we found in the first study, the second study also with UFES cooperation was developed. It should be noted that some studies investigated breathing mechanics during exercise, however, they analyzed using the model is composed of 89 markers (Cala et al., 1996). Lots of markers made unfeasible the data acquisition in some postures as cycling in a cycle ergometer at a natural posture. As a solution, some researchers resort to subjects sit completely upright with arms in the scapular plane while pedaling (Layton et al., 2011; Layton et al., 2013; Massaroni et al., 2016). This position besides being unnatural also difficult to be maintained and, consequently, the participant could not reach our maximum exhaustion. In addition, the postural changes impact the distribution between compartments of the chest wall (Aliverti et al., 2001; Lee et al., 2010; Romei et al., 2010) and the optimized position adopted by cyclists could affect the ventilatory demands (Charlton et al., 2017) and power output (Mcconnell, 2011). Due to the importance to understand the mechanics of breathing, the present study opted for a feasible reduced chest wall model (Ferrigno et al., 1994).

OBJECTIVES

General

We aimed to investigate the thoracoabdominal breathing motion pattern of cyclists during breathing maneuvers at sitting posture, as quiet breathing and vital capacity; and during a simulated 20-km time trial

Specific

1. To investigate which changes road cycling training can induce on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes.
2. To investigate the thoracoabdominal breathing motion pattern of master road cyclists during a simulated 20-km time trial.

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PAPER 1

THORACOABDOMINAL BREATHING MOTION OF MASTER ROAD CYCLISTS AT SITTING POSTURE

ABSTRACT

Introduction: Since cycling training requires greater aerobic capacity and development in the respiratory muscle dynamics is expected, we could hypothesize a changing in the breathing mechanics patterns in a daily used position as, the sitting posture. **Objective:** The present study aimed to investigate which changes road cycling training can induce on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes. **Methods:** Ten male cyclists (CyG) and ten male physically active subjects (CG) participated in this study. To assess the spirometry pulmonary function data, they performed the forced vital capacity maneuver. To assess the thoracoabdominal breathing motion pattern, 11 optoelectronic cameras (360 Hz) fixed around the subjects and 32 retro-reflective markers positioned on the subjects' trunk were used to obtain their 3D coordinates, allowing divide the trunk into three compartments (Superior Thorax, Inferior Thorax, and Abdomen). The cyclists executed two breathing maneuvers, quiet breathing (QB) and vital capacity (VC), at sitting posture. In order to evaluate the thoracoabdominal motion pattern, we calculated the inspiratory tidal volume, the inspiratory percentage of contribution, the coefficient of variation (ST, IT, AB) and the correlation coefficient pairs (ST×IT, ST×AB, and IT×AB). **Results:** No significant differences were found in the spirometry pulmonary results and in the inspiratory thoracoabdominal volume between the groups. However, in VC, the inspiratory percentage of contribution of the TI was significantly higher in the CyG than the CG. Nevertheless, for the coefficient of variation values, the AB was significantly higher in the CyG in both maneuvers. High values of the correlation coefficient pairs were found in both groups and no significant difference between the compartments and groups were found. **Conclusion:** Since no differences between the pulmonary capacity and inspiratory thoracoabdominal volume between the groups were found our study suggests that there is a breathing mechanical adaptation. The higher contribution of the inferior thorax and the higher enrolment of the abdomen found in this study could be triggered by road cycling training.

Keywords: Breathing mechanics, respiratory volumes, road cycling

INTRODUCTION

Endurance sport requires greater aerobic capacity, respiratory muscle efficiency, and improvement of oxygen delivery and utilization (Joyner e Coyle, 2008; Power et al., 2012). The training stimulus, as an approach to potentialize these needs, develop the respiratory muscle dynamics (Mcconnell, 2011); improve the breathing pattern (Lucía et al., 1999; Verges et al., 2008; Jesús et al., 2018) and, consequently, can enhance performance (Holm et al., 2004).

The pulmonary capacity is usually evaluated using a spirometer device that provides physiological information about it. However, in the last decades, the 3D kinematic analysis allows a new approach to investigation. This methodology evaluates the enrolment and coordination of the rib cage and abdomen mechanics (Konno e Mead, 1967, Massaroni et al., 2017). That discloses the thoracoabdominal breathing motion pattern making possible to suggest the mechanisms underlying dynamic pressures and muscles actions in many situations (Aliverti et al., 2002).

In the literature, it is already reported in many contexts, such as with participants of different training activities during breathing maneuvers at sitting posture, intensity of exercise, age, gender, and body position (Estenne et al., 1985; Aliverti et al., 1997; Aliverti et al., 2001; Vogiatzis et al., 2005; Lee et al., 2010). At sitting posture, some authors described that training activities can generate a specific breathing pattern. Proof of this, swimming athletes (Silvatti et al., 2012), ballet dancers (Rodrigues et al., 2019), yoga practitioners (Barros et al., 2003) and, mat Pilates training (Campos et al., 2019) developed higher coordination between the trunk compartments an uniqueness relative contribution between then compared to non-trained group.

Relate to cyclists' athletes, Layton et al. 2011 described an equal contribution of the superior thorax and the abdominal compartment during rest in a completely sitting upright cycle ergometer. Notwithstanding is important to highlight that their sample was composed by cyclist, triathletes and untrained men. In our preliminary results, composed only by road cyclists, however, with a small sample size, we found a different behavior, with a higher contribution of the abdominal compartment (Lopes et al. 2018).

Because training activities could lead to the formation of a specific breathing pattern at sitting posture, the present study aimed to investigate the influence of road cycling training on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes.

METHODS

Sample

Participated in this study subjects with more than 35 years (master athletes) and health and non-smokers subjects were selected. They were divided into two experimental groups: control and cyclists. The control group (CG) was composed of ten male active subjects (enrolled in different recreational sports all-encompassing more than 150 minutes per week of practice), without any cycling training. Cyclists group (CyG) were composed of ten male cyclists with at least five years of competitive experience in road cycling. Subjects characteristics are shown in Table 1. This study was approved by the Universidade Federal de Viçosa Ethics Committee (# 59773616.0.0000.5153).

Pulmonary function test

A spirometer (Micro-medical Ltd, Rochester, Kent, England) was used to evaluate the pulmonary function. The participants performed 3 maneuvers of the forced vital capacity (FVC), that consisted of the volume delivered during a forced expiration starting from full inspiration at sitting posture. As a result, we obtained the FVC which is the greatest total amount of air expired; and the forced expiratory volume in one second (FEV_1), which is the volume delivered in the first second of an FVC maneuver (Miller et al., 2005). These data were expressed as the mean of the three maneuvers and as percentages of predicted values according to Rufino et al. (2017).

3D Kinematic capture of breathing pattern

The coordinates of the markers were acquired with eleven OptiTrack Prime 17W cameras at the sampling rate of 360 Hz, positioned around the subjects. Thirty-two retro-reflective markers were placed on the trunk of the subjects. The markers followed a grid using anatomical references (Ferrigno et al., 1994) that allows to divide the trunk into three compartments: Superior Thorax (ST) influenced by the action of neck and parasternal muscles; Inferior Thorax (IT) mainly reflecting the action of diaphragm, and Abdomen (AB) mainly reflecting the action of diaphragm and abdominal muscles (Figure 1).

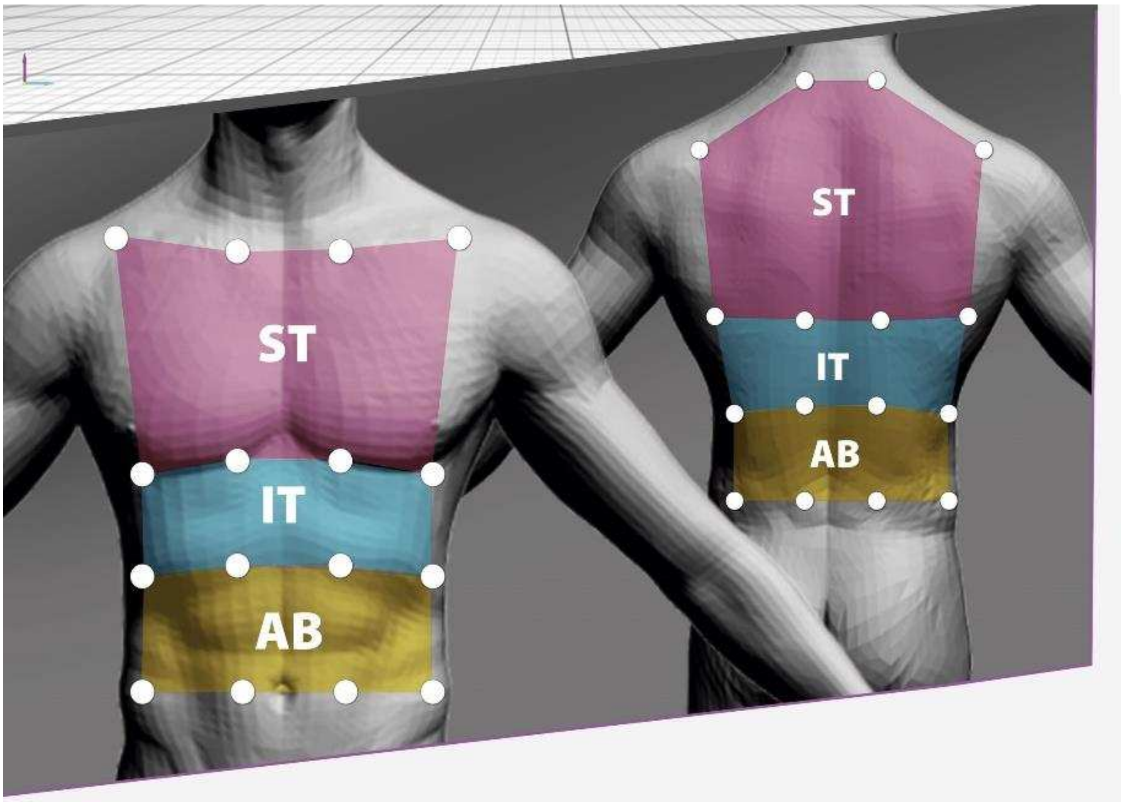

FIGURE 1: Markers' position and trunk compartmental division according to Ferrigno et al., 1994.

Participants sat on a chair without back support with shoulder abduction, forearms leaned on a rigid support, 90º of knee flexion and feet on the ground. We acquired two quiet breathing (QB) trials (30 seconds, each). Then, they performed two trials of five cycles of vital capacity (VC) that was characterized by five cycles of maximum inspiration followed by maximum forced expiration and a verbal stimulus was used to incentive the subjects to perform this maneuver.

Data Analysis

From the reconstructed and smoothed (Butterworth, cutoff 10 Hz) 3D coordinates of the markers, the compartmental volumes were calculated using a volumetric convex hull method in the software Visual 3D (C-Motion Inc, USA). The compartmental volume was expressed as a function of the time, divided in breathing cycles (minimum to a minimum) and used for calculated all variables. In order to evaluate the thoracoabdominal motion pattern, we calculated the mean of the followed variables considering the n breathing cycles collected in the tasks resulting in only one value per participant:

1) Inspiratory thoracoabdominal volume (TV^i): to estimate the total inspiratory volume of the thorax, we calculated the sum of each compartmental inspiratory

thoracoabdominal volume as the volume difference between the beginning and the end of inspiration by each compartment, Eq. 1:

$$TV^{\mathrm{i}} = \frac{1}{n}\sum_{i=1}^{n}(ST^{\mathrm{i}} + TI^{\mathrm{i}} + AB^{\mathrm{i}}) \qquad (1)$$

2) Inspiratory percentage of contribution: to evaluate the inspiratory contribution of each compartment, we calculated the inspiratory percentage of contribution (%C) as expressed in Eq.2,

$$\begin{cases} \%ST = \frac{1}{n}\sum_{i=1}^{n}\%(ST^{i}/TV^{\mathrm{i}}) \\ \%IT = \frac{1}{n}\sum_{i=1}^{n}\%(TI^{i}/TV^{\mathrm{i}}) \\ \%AB = \frac{1}{n}\sum_{i=1}^{n}\%(AB^{i}/TV^{\mathrm{i}}) \end{cases} \qquad (2)$$

3) Coefficient of Variation: to evaluate the enrolment volume of the compartment comparing itself, we calculated the value of each compartment: We used the mean and SD of the volume curve as function of the time instead of breathing cycles.

4) Correlation Coefficient: to evaluate the coordination among trunk compartments involved in respiration, we calculated the cross-correlation among the compartmental volumetric time-varying signals of each pairs. Correlation coefficient (r) between each pairs of the cycle as function of the time of the compartments (ST×IT, ST×AB, and IT×AB) was calculated for the whole cycle and during the inspiration phase. Positive correlation values indicate coordinated movements and negative correlation values indicate asynchrony movements.

Statistical Analysis

Descriptive variables were reported as mean and standard deviation (SD). We tested the normality of the data using the Shapiro-Wilk test. Considering that the correlation coefficient and percentage of contribution were not normally distributed, Fisher's z-transformation and arcsine transformation, respectively, was applied to the original data and used in the statistical process. Since the QB e VC are different breathing maneuvers we analyzed it separately.

Independent t-test was used in order to compare the descriptive subjects' characteristics between groups, inspiratory tidal volume, and coefficient of variation (ST, IT, AB separately). Repeated measure ANOVAs with one between factors (groups:

control and cycling) and one within factor (ST, IT, AB; ST×IT, ST×AB, and IT×AB) were used to evaluate the inspiratory percentage of contribution and correlation coefficient, respectively.

Mauchly's test of sphericity was performed and the Huynh-Feldt correction was used to correct for variability in experimental error. If significant F-ratios were detected, a Bonferroni post-hoc comparison was applied to determine where the differences occurred. Statistical significance was set at $\alpha=5\%$ for all analyses. All the statistics were performed using SPSS version 18.0.

RESULTS

Subject characteristics

The descriptive characteristics of each group are shown in Table 1. No significant differences between groups were found in age, height and weight data. All the subjects presented pulmonary function variables within or higher than predicted and no significant differences between groups were found. As expected, the CyG presented significantly higher time per week of training compared to the CG (p<0.001).

TABLE 1. Descriptive subjects' characteristics (mean ±SD)

	Cyclists (n=10)	Control (n=10)
Age (years)	42.7 ± 6.3	41.9 ± 8.7
Height (m)	1.75 ± 0.07	1.7 ± 0.08
Weight (kg)	75.9 ± 7.4	81.4 ± 10.2
Pulmonary function tests		
FEV_1 (l)	3.9 ± 0.6	3.6 ± 0.5
FEV_1 (% predict)	109.7 ± 19.3	105.2 ± 15.8
FVC (l)	4.3 ± 0.8	4.4 ± 0.7
FVC (% predict)	100.3 ± 20.6	104.8 ± 14.8
Training characteristics		
Time per week (h)	11.2 ± 2.1	5.9 ± 2.7*
Experience (years)	19.2 ± 10.9	22.6 ± 14

FEV_1 = Forced expiratory volume in 1 s; FVC = Forced vital capacity.
*Significant difference between CyG and CG using independent t-test ($p < 0.05$).

Inspiratory thoracoabdominal volume

Related to inspiratory thoracoabdominal volume, no significant differences between groups were found in both maneuvers (QB, p=0.35; VC, p=0.24, Fig. 2).

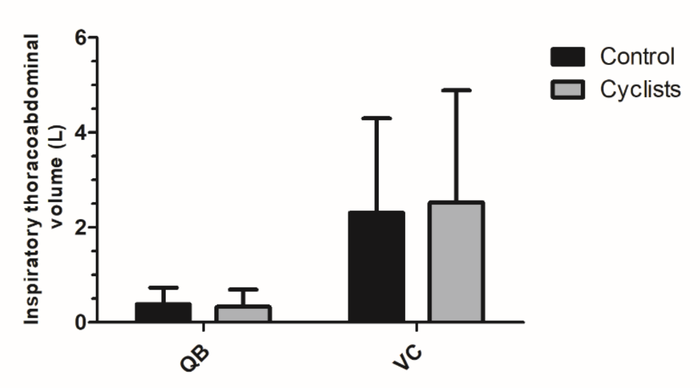

FIGURE 2: The mean values (±SD) of the Inspiratory thoracoabdominal volume during quiet breathing and vital capacity for the control group and cyclists' group; QB: quiet breathing; VC: vital capacity.

Inspiratory Percentage of contribution

No significant differences in the inspiratory percentage of contribution between groups were found in QB ($p>0.05$). Also, both groups presented the same contribution with higher values of AB than ST and IT ($p<0.001$; Fig. 3a).

Related to VC, AB was significantly higher than ST and IT ($p<0.001$) in CG; while IT and AB were significantly higher than ST ($p<0.001$) in CyG. Furthermore, IT in CyG was statistically higher than IT in CG ($p<0.001$; Fig. 3b).

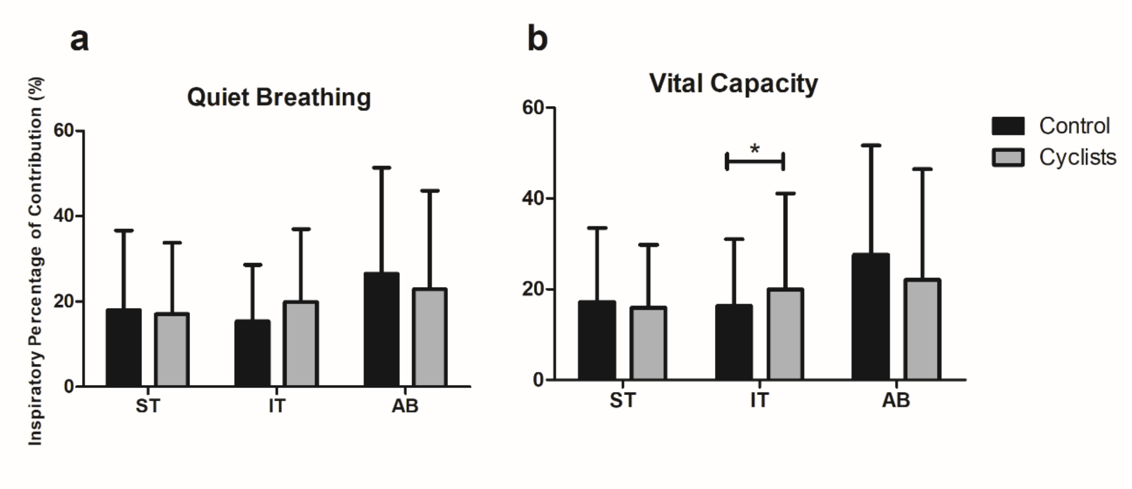

FIGURE 3: The mean (±SD) values of the inspiratory percentage of contribution of each compartment during quiet breathing and vital capacity for the control group and cyclists' group. ST: superior thorax; IT: inferior thorax; AB: abdomen.
*: $p<0.05$ CyG vs. CG

Coefficient of variation

The AB had significantly higher values of the coefficient of variation in the CyG than CG in both maneuvers (QB, p=0.03; VC, p=0.01, Fig. 4). In both maneuvers, no significant differences were found in ST and IT, compared groups (p>0.05).

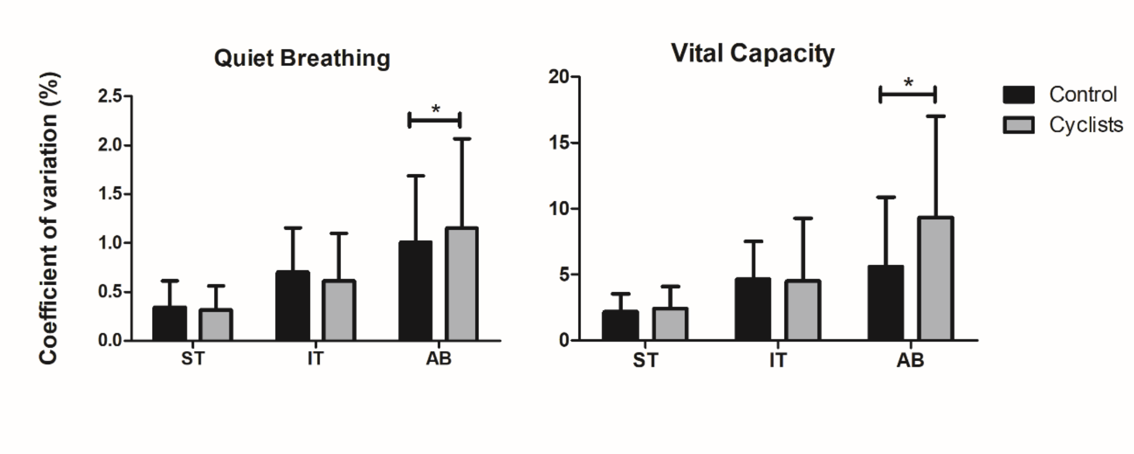

FIGURE 4: The mean (±SD) values of the coefficient of variation of each compartment during quiet breathing and vital capacity for the control group and cyclists' group. ST: superior thorax; IT: inferior thorax; AB: abdomen.
*: p<0.05 CyG vs. CG

Correlation Coefficient

All participants presented strong positive correlation values. No significant difference between the compartment pairs in both cycle analysis (breathing cycle and inspiratory phase) and between groups were found (p>0.05).

TABLE 2. Correlation coefficient results (mean±SD)

	Quiet Breathing		Vital Capacity	
Variables	Control	Cyclist	Control	Cyclist
Correlation coefficient				
ST×IT	0.93±0.04	0.96±0.02	0.95±0.02	0.97±0.02
ST×AB	0.91±0.03	0.93±0.05	0.91±0.04	0.93±0.04
IT×AB	0.90±0,08	0.94±0,05	0.92±0.05	0.94±0.04
Inspiratory correlation coefficient				
ST×IT	0,95±0,02	0.97±0.01	0,95±0.04	0.96±0.02
ST×AB	0,92±0,03	0.95±0,03	0,91±0.05	0.92±0.06
IT×AB	0,93±0,05	0.96±0.02	0,93±0.04	0.93±0.05

ST: superior thorax; IT: inferior thorax; AB: abdomen.

DISCUSSION

This was a cross-sectional study that compared master road cyclists with physically active subjects for describing the influence of road cycling training on the thoracoabdominal breathing motion pattern during breathing maneuvers at sitting posture in master road cycling athletes.

Since both groups presented similar FVC and FEV_1 values and, likewise, inspiratory thoracoabdominal volume of QB and VC, we assume that the differences found in the thoracoabdominal breathing motion pattern could be associated to the cycling training. Related to the age of our sample, is important to point out that the higher pulmonary function values found in the CyC were expected since the mean age of our sample was around 40 years. Despite, the gradual decreases in the respiratory function start from 27 years (Schmidt et al., 1973; Janssens et al., 1999), it becomes more apparent from 50 years and increases around 80 years (Enright et al., 1994; Britto et al., 2009). Consequently, the possible aging-induced changes were not considered in our evaluation, and we could hypothesize that younger cyclists could have higher respiratory functions using the same mechanical, however further studies on this field is required.

The compartmental contribution depends on the pressure and shape compartment (Agostoni et al., 1965), so, the subjects were evaluated in sitting posture, in order to approximate the posture during cycling, and to take into account that sitting posture is a daily position. Despite, there are some trunk representation (Ferrigno et al., 1994; Cala et al., 1996; Aliverti et al., 2001; Loula, 2005) to perform a 3D analysis during breathing to obtain the thoracoabdominal breathing motion pattern, we opted to use the model composed of 32 markers because of the practical assessment of breathing, and facility to capture the markers that allowed to compare with further studies in exercise situations (for example: in a cycling simulation in lab). It is important to highlight that this reduced model underestimates the tidal volume (Aliverti et al., 2001), however, is highly correlated with the golden model to obtain thoracoabdominal pattern variables (Massaroni et al., 2018).

Our major finds were related to VC, when submitted to a more vigorous maneuver, the influence of expiratory abdominal muscles is emphasized, their contraction shifted the diaphragm to a more optimal position. When the expiratory muscles relax during the subsequent inspiration, the diaphragm descends to facilitate lung inflation (Dodd et al., 1984). The fact that exercise training induces an increase in diaphragmatic oxidative capacity (Powers et al., 1992), cyclists could have a greater diaphragm stimulation, since they developed both higher appositional and insertional force (Lee et al., 2010; Troyer e Wilson, 2016), both considered important components of IT compartment. These findings support our results in VC, that the main effect of cycling training on breathing pattern is related to IT. The CyG presented higher IT inspiratory percentage of contribution compared to physically active subjects.

The present study demonstrated that cyclists have a greater enrolment of the abdomen, evaluated by the coefficient of variation. This increased abdominal compartment expansion in cyclists could be associated with improved action of the diaphragm and abdominal muscles (Grimby et al., 1968). Since the abdominal wall strength is an important role in cycling success leading to a greater body stabilization during pedal (Asplund e Ross, 2010). It is consistent with swimmers that presented a similar pattern with an improved expansion of the abdomen in breathing movements, suggesting that the training can improve and increase the abdominal contribution during breathing movements (Silvatti et al., 2012), and also, with mat Pilates practitioners (Campos et al., 2019). But in contrast to a prior study that studied health subjects (trained and untrained) Layton et al. (2011), however, agrees with our preliminary results (Lopes et al. 2018).

Both groups presented high coordination of the compartment pairs in the breathing cycle and the inspiratory phase. This mechanical arrangement could allow an increase in the volume of air mobilization during breathing and, consequently, movement coordination can improve breathing efficiency. It was expected since both groups are physically active corroborating with previous studies (Rodrigues et al., 2019; Silvatti et al., 2012; Barros et al., 2003; Campos et al., 2019).

Since both groups presented similar descriptive characteristics and pulmonary respiratory function, the results could be more associative to cycling training-induced changes. However, our study had some limitation as to the absence of assessment of sedentary group in order to decrease the confounding factors becoming the data more reliable and absence of assessment of age-related groups in order to investigate the influences caused by age. This study pointed out the thoracoabdominal motion pattern at rest, further studies evaluating it during exercise could improve the understanding of its influences and consequences to performance.

CONCLUSION

The key findings of our investigation were the higher contribution of the inferior thorax and higher enrolment of the abdomen, that were the main adaptations of cycling training on breathing pattern of the road cyclists compared with physically active subjects.

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PAPER 2

THORACOABDOMINAL BREATHING MOTION OF MASTER ROAD CYCLISTS DURING A SIMULATED 20-KM TIME TRIAL

ABSTRACT

Introduction: Time trial is a bicycle race in which athletes should sustain high power output and maintain it for a longer time, causing metabolic stress and requiring greater respiratory function, that could change the thoracoabdominal motion pattern. The present study to investigate the effects of the simulated 20-km time trial on thoracoabdominal breathing motion pattern of master road cyclists. **Methods:** Eight male master cyclists (41±5.45 years, 1.75±0.07 m and, 76.1±7.76 kg) with least five years of competitive experience in road cycling participated in this study. To assess their pulmonary function, they were asked to perform the forced vital capacity maneuver in the spirometer. In order to characterize the time trial, the heart rate, the rating of perception of effort and power output (Powermeter) were acquired during the test. The thoracoabdominal breathing motion pattern was evaluated by 11 optoelectronic cameras (360 Hz) fixed around the subjects. This breathing evaluation was performed in the following conditions: (1) in sitting posture during the quiet breathing and vital capacity maneuver and (2) during a simulated 20-km time trial. The model, composed by 32 retro-reflective markers were positioned on the subjects' trunk and split the trunk into three compartments (superior thorax (ST), inferior thorax (IT) and abdomen (AB)). We calculated the inspiratory tidal volume, inspiratory percentage of contribution, (ST, IT, AB) and the correlation coefficient pairs (ST×IT, ST×AB, and IT×AB) in the sitting posture maneuvers and in one minute before achieving the 5km, 10km, 15km and 20km (stages) of the 20-km time trial simulation. **Results:** As expected, they presented similar values of power output and, also, inspiratory tidal volume, highlighting that they maintained the intensity during the test. In addition, the thoracoabdominal volume during all stages of the test was higher than QB and lower than VC. The coefficient of variation and inspiratory percentage of contribution variables presented higher values of AB, than IT and, than ST during all stages of the time trial. ST presented lower inspiratory percentage of contribution, in QB and VC than in all stages of the time trial. Conversely, the AB presented higher values, in QB and VC than in all stages of the time trial. The AB coefficient of variation was significantly higher in VC and during all stages of the time trial compared to the other compartments. Notwithstanding of moderate to strong correlation coefficient pairs values, the pairs ST×IT and IT×AB were significantly higher than the ST×AB in all conditions. **Conclusion:** The abdominal compartment has the greatest inspiratory percentage of contribution to the ventilation. Despite the posture adopted by road cyclists, the superior thorax has a lower capacity to expand and consequently, has a lower inspiratory percentage of contribution comparing with quiet breathing at sitting posture. Consequently, this discrepant range of enrolment between ST and AB affected the coordination between them. Although of moderate to strong correlation coefficient pairs values, the pairs ST×IT and IT×AB were significantly higher than the ST×AB in all conditions. Finally, the representative inspiratory percentage of contribution of IT could be associated with the posture that the participants were submitted. As highlighted by our previous findings during breathing maneuvers at rest, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists.

Keywords: Breathing mechanics, respiratory volumes, time trial

INTRODUCTION

The endurance time trial is a bicycle race in which cyclist complete a predetermined distance as fast as possible. It has been used in a laboratory situation for simulate endurance events and to predict aerobic performance such as VO_2 and lactate threshold (Zavorsky et al., 2007). In an ecological simulation, successful athletes sustain moderate power output at moderate intensity for a longer time (Hawley e Noakes, 1992; Levin et al., 2013). At moderate intensity, highest possible steady-state intensity, are expected gradual increases of ventilation in parallel with alveolar ventilation (Stegmann e Kindermann, 1982) and respiratory function (Fernandez-Garcia et al., 2000; Earnest et al., 2009).

Thoracoabdominal breathing motion pattern provides substantial information about ventilatory mechanics and breathing muscles, helping to assess the relationship between superior thorax, inferior thorax, and abdomen (Konno e Mead, 1967). Breathing muscle actions affect the thoracoabdominal motion pattern given the complex interaction between their respiratory and postural functions and, rhythmical limb activities (Aliverti, 2016; Asplund e Ross, 2010). Celli et al., 1988 reported that different exercises using arm and leg could recruit different breathing muscles and, also, different chest wall kinematics (Romagnoli et al., 2006) were already observed.

The postural stabilization of the breathing muscles provides a central anchoring point from which the limb muscles are able to generate greater levels of power output (Mcconnell, 2011), allowing an efficient pedal and symmetries (Rannama et al., 2016). During exercise in cycling, different thoracoabdominal motion pattern was already found (Layton et al., 2011), however the data acquisition of the higher amount of the 3D markers fixed on the trunk to obtain the thoracoabdominal motion interferes and, the participants seated completely upright. Nevertheless, the literature already reports that the body position influences the chest wall shape and motion distribution between compartments (Lee et al., 2010; Romei et al., 2010). Additionally, the optimized position adopted by cyclists, a greater factor to performance, could increase the oxygen consumption, breathing frequency and, minute ventilation (Fintelman et al., 2016; Charlton et al., 2017).

Therefore, considering that the body position plays an important role in the chest wall shape and motion the present study aimed to investigate the effects of the simulated 20-km time trial on thoracoabdominal breathing motion pattern of master road cyclists.

In order to allow the acquisition of the simulated 20-km time trial in normal position, in their own bicycle, a reduced model was used.

METHODS

Subjects

Eight male cyclists were selected to participate in our study. They were healthy, non-smokers and have at least five years of competitive experience in road cycling. The characteristics of the subjects were shown in Table 1. This study was approved by the Universidade Federal de Viçosa Ethics Committee (# 59773616.0.0000.5153).

TABLE 1. Mean (±SD) of age, height, weight, time of training per week and years of experience.

	Cyclists (n=8)
Age (years)	41±5.45
Height (m)	1.75±0.07
Weight (kg)	76.1±7.76
Training per week (h)	11.25±2.31
Experience (years)	16.75±9.2

m: meters; kg: kilograms; h: hours

General protocol

Upon arrival at the laboratory, subjects underwent the following procedures: (1) pulmonary function test; (2) quiet breathing (QB); (2) a vital capacity (VC); and (3) warm-up and after TT_{20km} in which the only 4 stages (5 km, 10km, 15km and 20km, Fig. 2) were then analyzed.

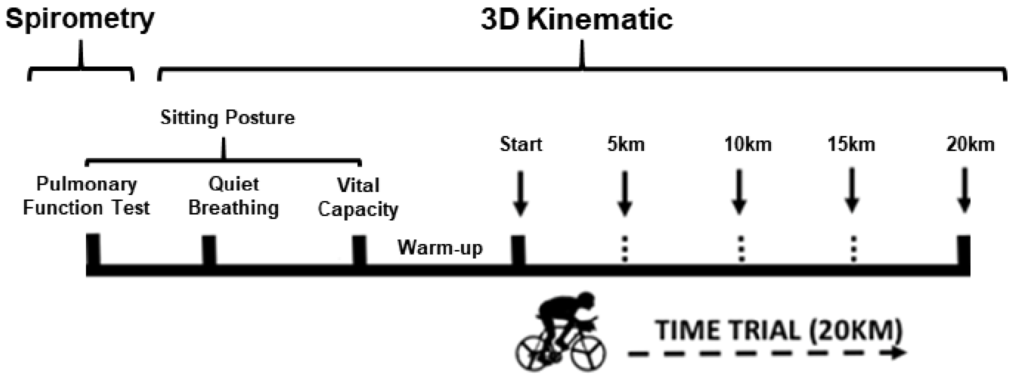


FIGURE 1: Schematic procedures of data collection.

Pulmonary function test

In order to evaluate the pulmonary function, we used a spirometer (Micro-medical Ltd, Rochester, Kent, England). The participants performed 3 maneuvers of the forced vital capacity (FVC), that consisted of the volume delivered during a forced expiration starting from a full inspiration in sitting posture.

Power Output of the 20-km time trial

The original wheel was substituted to wheel with Powermeter (PowerTap, Saris, Madison, USA) accoupled in order to acquire the power output during TT_{20km}. The TT_{20km} protocol consisted of: (1) 10-min warm-up and (2) 20-km time trial. The participants received verbal encouragement stimulus when they were nearly to achieve a distance of 5km, 10km, 15km and at the end of the test.

Heart rate and Rating of perceived exertion of the 20-km time trial

Heart rate and Rating of perceived exertion (RPE) were acquired in the following distances – 5km, 10 km, 15 km, and 20 km (figure 1). Heart rate was measured using Polar Fitness tracker chest strap and the data acquisition was done with HRV® software. The RPE was measured using Borg’s CR-10 scale (1–10), where 1 corresponding to ‘no exertion’ and 10 correspondings to ‘extreme/maximal exertion’. The participants received standardized instructions for each measure using this scale prior to an exercise session.

3D Kinematic

For the tridimensional kinematic analysis (3D), eleven OptiTrack Prime 17W cameras (360Hz) were positioned around the subjects, approximately 3 m from the participant in order to capture the chest wall motion as shown in figure 2. Thirty-two retro-reflective markers were placed on their trunk, which was divided into three compartments: superior thorax (ST), inferior thorax (IT) and abdomen (AB) (Ferrigno et al., 1994). We acquired the breathing maneuvers in sitting posture and the TT_{20km}.

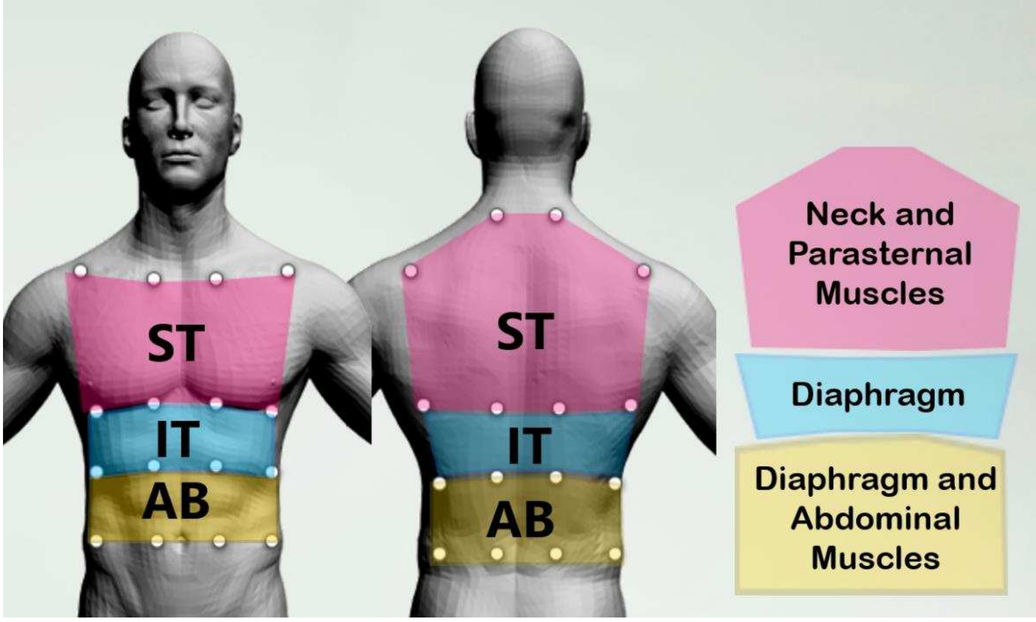


FIGURE 2: Markers' position and trunk compartmental division according to Ferrigno et al., 1994.

Breathing maneuvers

Participants sat on a chair without back support with shoulder abduction, forearms leaned on a rigid support, 90° of knee flexion and feet on the ground (Fig. 3A). We acquired two quiet breathing (QB) trials of thirty seconds. Then, they performed two trials of five cycles of vital capacity (VC) that was characterized by five cycles of maximum inspiration followed by maximum forced expiration with a verbal stimulus.

20-km time trial

The cyclists performed a self-paced time trial (TT_{20km}) in laboratory conditions (Fig. 3B), in the less time possible, using their own bicycle coupled on cycle trainer (Computrainer ProLab 3D, Racermate Inc, Seattle, WA, USA). They were oriented to maintain their hands at brake hoods enabling trunk markers' tracking. The flat course was configured in the Computrainer 3D software. Automatic control of the constant workload mode was set to weight (bicycle + cyclist). The kinematic data of the makers fixed on the subject's trunk were acquired one minute before each step in 5, 10, 15 and 20 kilometers of the TT_{20km}.

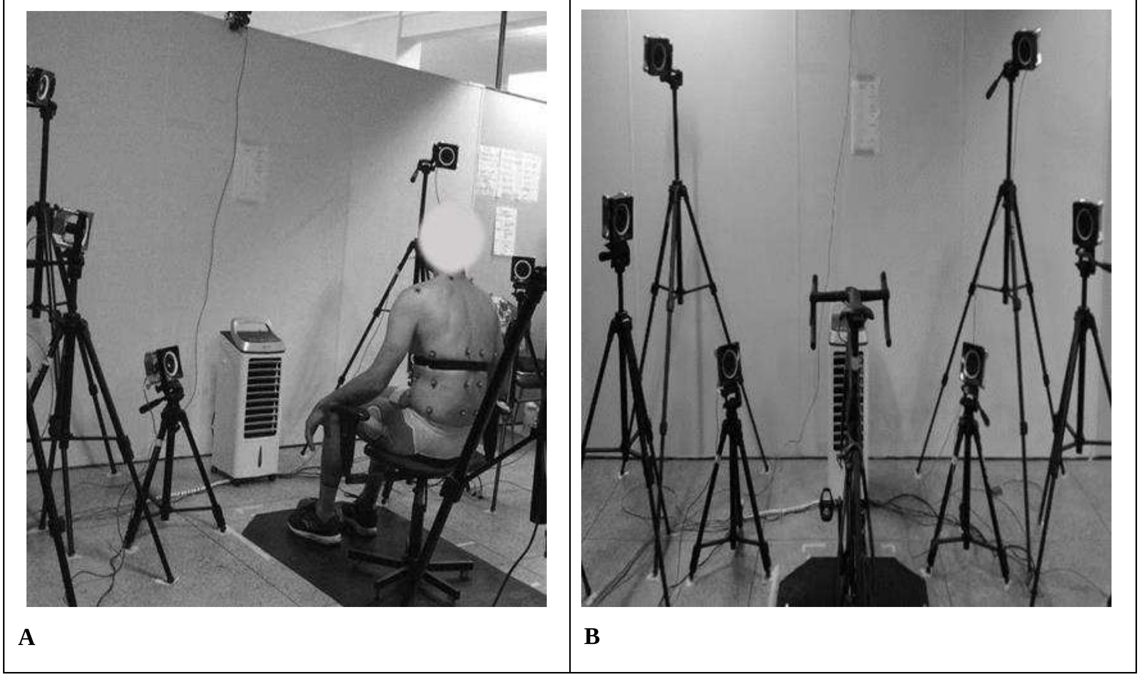


FIGURE 3: Set up of the Optitrack cameras for 3D kinematic analysis for breathing maneuvers in sitting posture (A) and during a TT_{20km} (B).

Data and Statistical Analysis

Pulmonary function test

The data of the FVC, which is the greatest total amount of air expired; and the forced expiratory volume in one second (FEV_1), which is the volume delivered in the first second of an FVC maneuver (Miller et al., 2005) were obtained by the spirometer. The FVC and FEV_1were expressed as the mean of the all maneuvers and as percentages of predicted values according to Rufino et al. (2017).

Power Output of the 20-km time trial

The power output variables were reported as mean and SD. Test duration and power output of each subject were normalized by percentile (0-100%) of total time and mean of power output, respectively. We tested the normality of the data using the Shapiro-Wilk test. Then, in order to analyze the power output, we used repeated measure ANOVAs with one within factor (time: 0-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-100% of the TT_{20km}).

HR and RPE of the 20-km time trial

The HR and RPE variables were reported as mean and standard deviation (SD). In order to characterize the test performed, they were acquired at the following stages: 5km, 10km, 15km, and 20km. We tested the normality of the data using the Shapiro-Wilk test. In order to analyze the HR and RPE, we used repeated measure ANOVA with one within factor (time: QB, VC, 5, 10, 15, 20 kilometers).

3D Kinematic

From the reconstructed and smoothed (Butterworth, cutoff 10 Hz) 3D coordinates of the markers, the compartmental volumes were calculated using a volumetric convex hull method in the software Visual 3D (C-Motion Inc, USA). The compartmental volume was expressed as a function of the time, divided in breathing cycles (minimum to a minimum) and used for calculated all variables. In order to evaluate the thoracoabdominal motion pattern, we calculated the mean of the followed variables considering the n breathing cycles collected in the tasks resulting in only one value per participant:

1) Thoracoabdominal volume (TV^{i}): to estimate the total inspiratory volume of the thorax, we calculated the sum of each compartmental thoracoabdominal volumeas the volume difference between the beginning and the end of inspiration by each compartment, Eq. 1:

$$TV^{\mathrm{i}} = \frac{1}{n}\sum_{i=1}^{n}(ST^{\mathrm{i}} + TI^{\mathrm{i}} + AB^{\mathrm{i}}) \tag{1}$$

2) Inspiratory percentage of contribution: to evaluate the inspiratory contribution of each compartment, we calculated the inspiratory percentage of contribution (%C) as expressed in Eq.2,

$$\begin{cases} \%ST = \frac{1}{n}\sum_{i=1}^{n}\%(ST^{i}/TV^{\mathrm{i}}) \\ \%IT = \frac{1}{n}\sum_{i=1}^{n}\%(TI^{i}/TV^{\mathrm{i}}) \\ \%AB = \frac{1}{n}\sum_{i=1}^{n}\%(AB^{i}/TV^{\mathrm{i}}) \end{cases} \tag{2}$$

3) Coefficient of Variation: to evaluate the enrolment volume of the compartment comparing itself, we calculated the value of each compartment: We used the mean and SD of the volume curve as function of the time instead of breathing cycles.

4) Correlation Coefficient: to evaluate the coordination among trunk compartments involved in respiration, we calculated the cross-correlation among the

compartmental volumetric time-varying signals were calculated in pairs. The correlation coefficient (r) between each pairs of the cycle as function of the time of the compartments (ST×IT, ST×AB, and IT×AB) was calculated for the whole cycle and during the inspiration phase. Positive correlation values indicate coordinated movements and negative correlation values indicate asynchrony movements.

We tested the normality of the data using the Shapiro-Wilk test. Considering that only the correlation coefficients were not normally distributed, Fisher's z-transformation was applied to the original data and used in the statistical process.

In order to analyze the inspiratory tidal volume, we used repeated measure ANOVA with one within factor (time: QB, VC, 5, 10, 15, 20 kilometers). In order to analyze the inspiratory percentage of contribution and correlation coefficient, we used the Repeated measure ANOVA with two within factor (compartments: ST, IT, AB; ST×IT, ST×AB, and IT×AB and time: QB, VC, 5, 10, 15, 20 kilometers), respectively. In order to analyze the coefficient of variation, we used repeated measure ANOVA with one between subject factors (compartments: ST, IT, AB) and one within factor (time: QB, VC, 5, 10, 15, 20 kilometers).

Mauchly's test of sphericity was performed and the Huynh-Feldt correction was used to correct for variability in experimental error. If significant F-ratios were detected, a Bonferroni post-hoc comparison was applied to determine where the differences occurred. Statistical significance was set at α=5% for all analyses. All the statistics were performed using SPSS version 18.0.

RESULTS

Pulmonary Function

Pulmonary function tests and TT_{20km} characteristics results are shown in table 2 and table 3, respectively.

TABLE 2. Mean (±SD) values of the pulmonary function tests.

	Cyclists (n=8)
FEV_1 (l)	4.2±0.4
FEV_1 (% predict)	115.7±13.8
FVC (l)	4.6±0.5
FVC (% predict)	106.3±14.8

Definitions of abbreviations: FEV_1, Forced expiratory volume in 1 s; FVC, Forced vital capacity.

Time trial characteristics

We evaluated the pacing profile from power output data dividing the test into ten steps, one each 10% of the total time duration (Figure 4). All the participants showed a U strategy, with higher values in the beginning and end of the test, however no significant change between each time percentile (p>0.05).

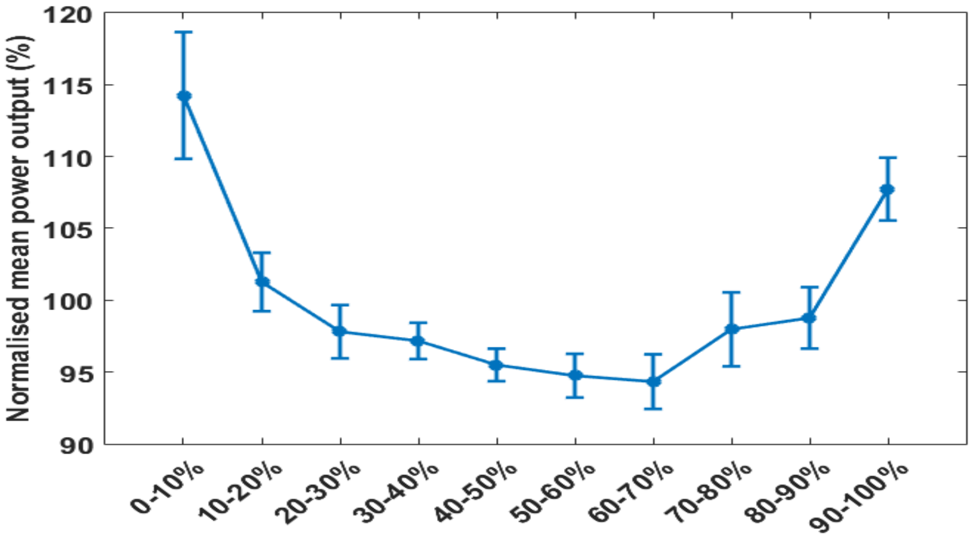
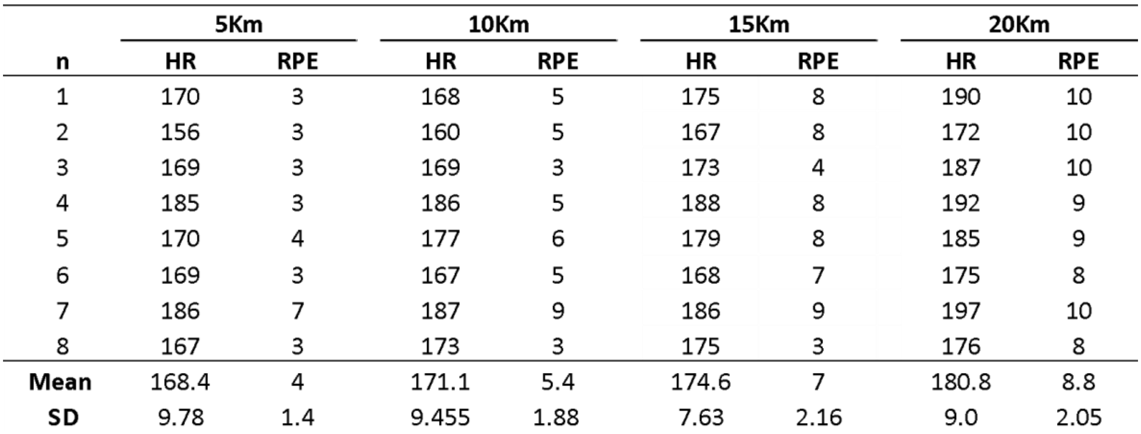


Figure 4: The mean of power output during: 0-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60%, 60-70%, 70-80%, 80-90%, 90-100% of the TT_{20km}.

As expected, no significant differences in HR were found (p=0.08), and RPE at 15km was higher than 5km; and, 20km higher than 15km and 5km (Table 3; p<0.001).

TABLE 3. Mean (±SD) values of the descriptive 20-km time trial characteristics



	5Km		10Km		15Km		20Km	
n	**HR**	**RPE**	**HR**	**RPE**	**HR**	**RPE**	**HR**	**RPE**
1	170	3	168	5	175	8	190	10
2	156	3	160	5	167	8	172	10
3	169	3	169	3	173	4	187	10
4	185	3	186	5	188	8	192	9
5	170	4	177	6	179	8	185	9
6	169	3	167	5	168	7	175	8
7	186	7	187	9	186	9	197	10
8	167	3	173	3	175	3	176	8
Mean	168.4	4	171.1	5.4	174.6	7	180.8	8.8
SD	9.78	1.4	9.455	1.88	7.63	2.16	9.0	2.05

Period related to 5km(0-5km), 10km(5-10km), 15km(10-15km) and 20-km(15-20km). Definitions of abbreviations: HR, Heart rate; RPE, Rating of perceived exertion using Borg's scale.

Kinematic data

The rest maneuvers, QB and VC, were used to investigate the influence of the exercise compared to a rest position.

Thoracoabdominal volume

Related to inspiratory tidal volume, all stages of time trial had significantly higher values than QB and lower values than VC ($p<0.001$). No significant difference was found in the comparison of the total tidal volume between the stages of time trial (Fig. 5).

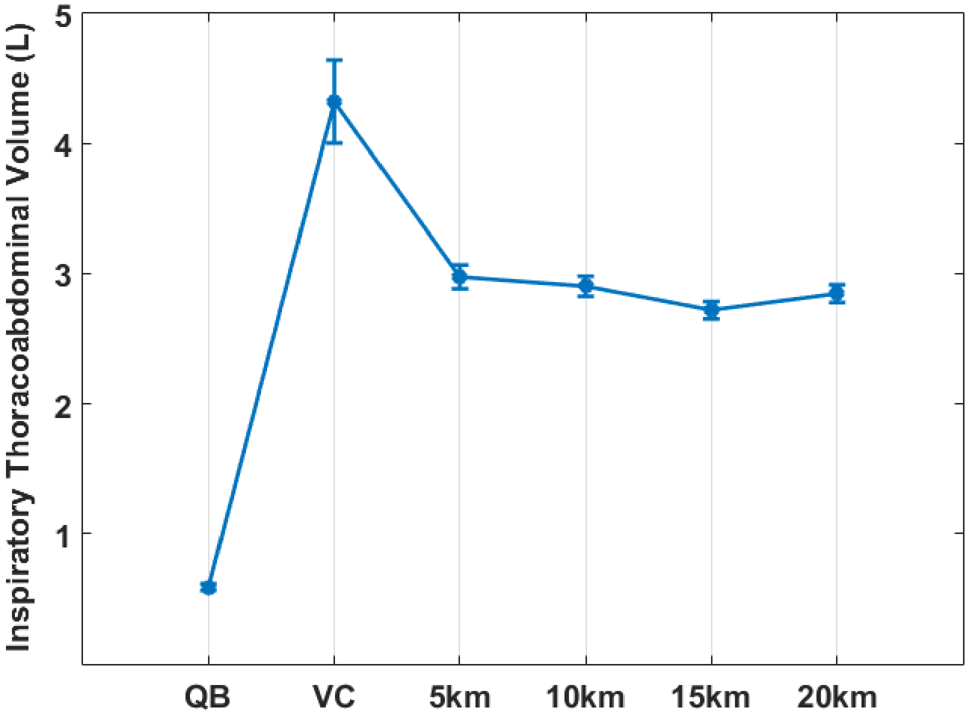


Figure 5: The mean (±SEM) of thoracoabdominal volumeof ST, IT and AB during breathing maneuvers on sitting posture (QB and VC) and TT_{20km} (5, 10, 15 e 20 kilometers).

Coefficient of variation

In QB, ST presented lower coefficient of variation than IT and AB ($p<0.05$). In, VC and during all stages of the time trial, the compartments were significantly different between them (AB> IT>ST; $p<0.05$; Fig. 6).

The ST and AB values were significantly lower at QB than all other conditions (VC, 5km, 10 km, 15 km and 20 km of time trial; $p<0.05$). The values of IT in QB presented the same behavior of the other compartments, however, the VC was significantly higher than the 4 stages of the time trial, in which no difference between them was found.

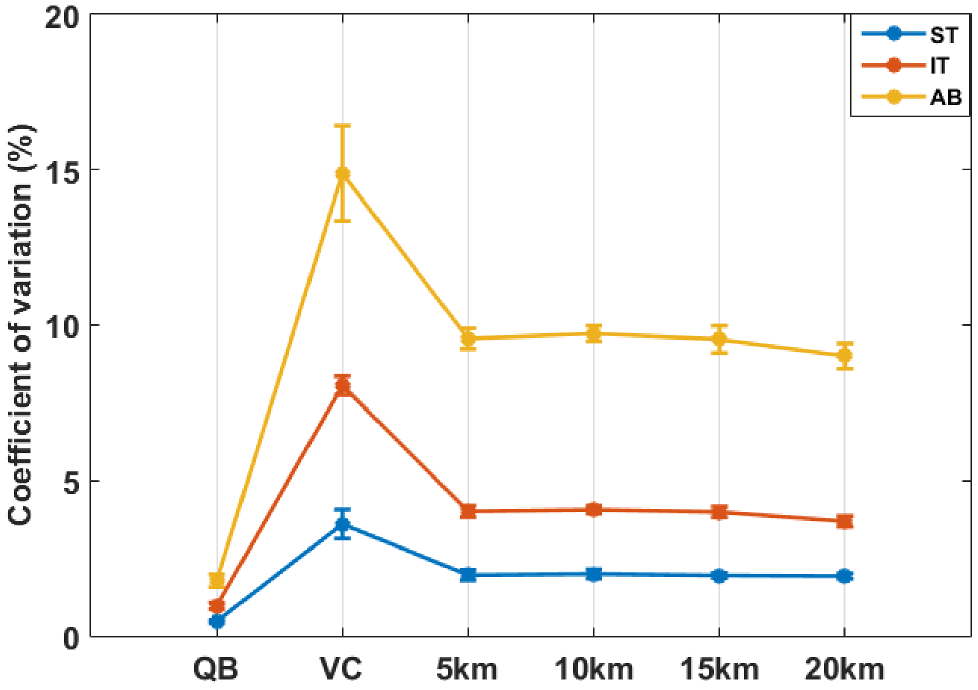


Figure 6: The mean (±SEM) of the coefficient of variation of ST(%ST), IT (%IT) and AB (%AB) on the total volume during breathing maneuvers on sitting posture (QB and VC) and time trial (5, 10, 15 e 20 kilometers)

Inspiratory percentage of contribution

ST presented significantly higher contribution at sitting posture (QB and VC) than in all stages of time trial ($p<0.05$). Conversely, AB presented significantly lower contribution at sitting posture than in all stages of time trial ($p<0.05$). Instead, IT contribution not changed from sitting posture to time trial ($p>0.05$, Fig. 7).

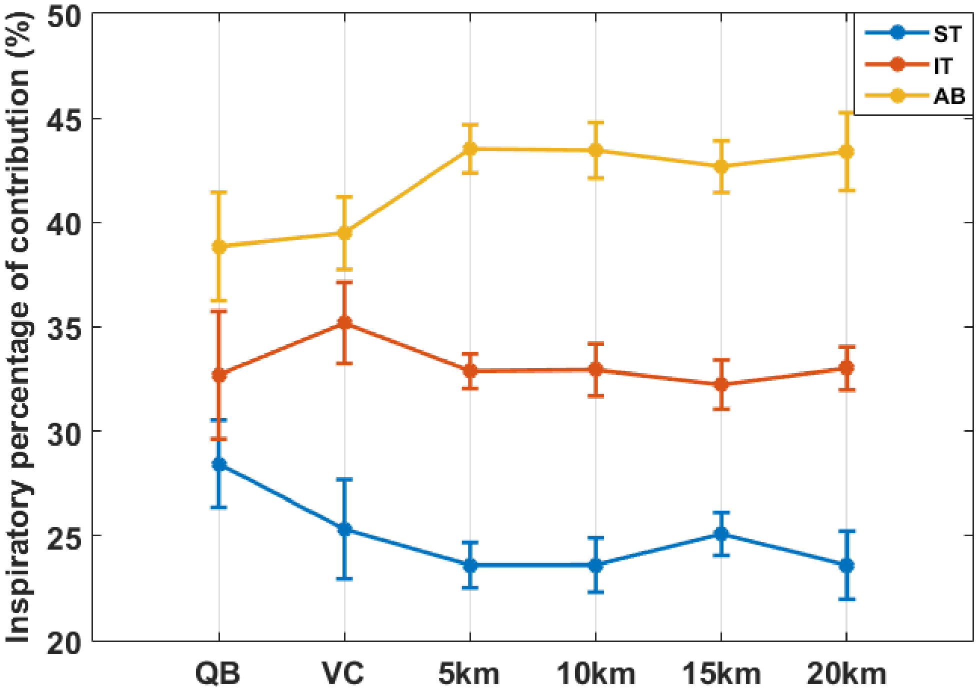


Figure 7: The mean (±SEM) of the inspiratory percentage of contribution of ST(%ST), IT (%IT) and AB (%AB) on the total volume during breathing maneuvers on sitting posture (QB and VC) and TT20km (5, 10, 15 e 20 kilometers).

Correlation coefficient

Figure 8 shows the correlation coefficient of all conditions. All compartment pairs presented from moderate to strong correlation values, although only at sitting posture the coefficients were higher than 0.9. We found statistical differences between compartmental pairs, which ST×AB presented lower values than ST×IT and IT×AB ($p<0.05$).

No statistically differences were found between the breathing maneuvers at sitting posture (QB and VC). ST×IT values were statistically higher at sitting posture than 4 stages of the time trial, in which 5km values were statistically higher than 20km. ST×AB values were statistically higher at QB than 4 stages of time trial; VC values were statistically higher than 20km; 10km values were statistically higher than 15km. IT×AB values were statistically higher at sitting posture than 4 stages of time trial ($p<0.05$).

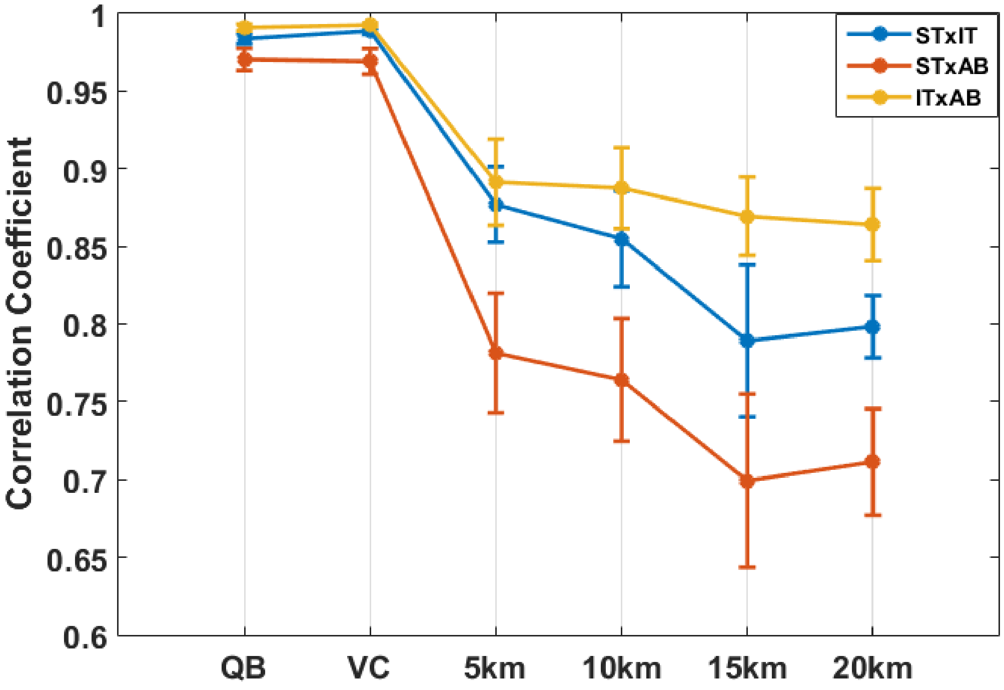


Figure 8: The mean (±SEM) of correlation coefficient of ST×IT, ST×AB, and IT×AB during breathing maneuvers on sitting posture (QB and VC) and time trial (5, 10, 15 e 20 kilometers)

DISCUSSION

This study was designed to investigate the thoracoabdominal breathing motion pattern of master road cyclists during a simulated 20-km time trial. An ecological methodology was used to understand the thoracoabdominal pattern of the road cyclists when they are in their own bicycle performing a time trial. Our previous investigations highlighted a specific thoracoabdominal breathing motion pattern of the cyclists at rest, this was a forward step aimed to understand it during pedal (Lopes et al. 2018)

The cyclists were able to maintain a steady power output, heart rate, and inspiratory thoracoabdominal volume during the time trial, although increases in the rating of perceived effort in the final stages. This fact, highlighting that they were able to use a sustainable strategy over the test and conducted the test relatively fast yet comfortable pace without achieving fatigue. The constant shape of the time trial could suggest a usual aerobic time trial. In addition, during the test, the thoracoabdominal volumewas higher than QB and lower than VC, emphasizing that their maximum breathing capacity could not have been used.

Under this condition, our results showed that ST presented a lower inspiratory percentage of contribution during time trial than in sitting posture. Decreases of ST could be related to a reduced capacity to expand the thorax when cyclists are attached on the bike (Mcconnell, 2011). Conversely, AB presented a higher inspiratory percentage of contribution during time trial than in sitting posture. Indeed, previous studies have shown that since lower levels of exercise the abdominal muscles were recruited, and also, they presented higher magnitude than rib cage muscles (Aliverti et al., 1997). These findings corroborate with previous studies that found that an increase of end-expiratory tidal volume was resulted by activation of the expiratory abdominal muscles during exercise (Aliverti et al., 1997; Aliverti, 2016).

Our finds showed a higher inspiratory percentage of contribution of the IT than ST during a time trial in contrast to previous studies that evaluated health subjects in a sitting posture with arms abduction during pedal exercise (Aliverti et al., 1997; Iandelli et al., 2002; Vogiatzis et al., 2005). So, the representative inspiratory percentage of contribution of IT could be associated with the posture that the participants were submitted. As highlighted by our previous findings during breathing maneuvers at rest, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists. Considering that the intraabdominal pressure regulation could contributes to spinal and pelvic floor stabilization (Hodges et al., 2007; Kocjan et al., 2017), respiratory function and power output (Hodges e Gandevia, 2000; Kolar et al., 2013; Kocjan et al., 2017) we could suggest that the IT was an important actuation on thoracoabdominal breathing motion pattern of cyclists.

Each compartment appears to move as a unit between itself, with considerable independence of motion (Konno e Mead, 1967). The enrolment volume of the compartment comparing itself was expressed by the coefficient of variation. Our findings showed that AB presented higher coefficient of variation during VC and time trial compared to other compartments, in agreement with its higher percentage of contribution. It was expected once the abdominal compartment, the most compliant compartment, could reach levels below the functional residual capacity, achieving higher levels of expansion (Aliverti et al., 1997).

Consequently, this discrepant range of enrolment between ST and AB affected the coordination between them. Although they presented moderate correlation coefficient values during the time trial, ST×AB presented lower values during rest and time trial than ST×IT and IT×AB. Other factors contribute to the lower coordination between ST and AB as a small mechanical linkage between ST and AB (Deschamps et al., 1988). It is caused by the strategy to minimize the elastic work of moving chest wall and the fact of the inspiratory reserve volume is proportionately greater in the rib cage and the expiratory reserve volume is proportionately greater in the abdominal compartment (Aliverti et al., 1997). This arrangement has important significance for the mechanics of breathing during exercise preventing paradoxical motion of any compartment of the chest wall (Aliverti, 2008).

These results tried to linkage breathing, posture, and exercise, allowing leads to a new step for the breathing and cycling knowledge. Since Romer et al. (2002) found improvements in time duration and power output performance during a 20-km time trial when cyclists were submitted to inspiratory muscle training, further studies could investigate the influence (1) of respiratory muscles strength on thoracoabdominal breathing motion pattern e their association with performance; (2) of the trunk flexion angle on the thoracoabdominal motion pattern; (3) of different exercise intensities on the thoracoabdominal breathing motion pattern; and (4) of age-related effects.

However, our study had some limitations. The model developed by Ferrigno et al. (1994) as verified by Massaroni et al. (2018), has an inherent underestimation of the inspiratory tidal volume, therefore, we used this variable only to compare all conditions rather than evaluate the ventilatory ratio. Besides that, we evaluate a small sample size composed by eight master cyclists at the age about 40 years, and they were amateurs that participate of national race level and we did not have physiological information about their performance level.

CONCLUSION

To our knowledge, this is the first study comparing the thoracoabdominal breathing motion pattern of road cyclists at sitting posture and during a time trial coupled in their own bicycle. The abdominal compartment has the greatest inspiratory percentage of contribution for the ventilation. Despite the posture adopted by road cyclists, the superior thorax has a lower capacity to expand and consequently, has a lower inspiratory percentage of contribution comparing with quiet breathing at sitting posture. Consequently, this discrepant range of enrolment between ST and AB affected the coordination between them. Although of moderate to strong correlation coefficient pairs values, the pairs ST×IT and IT×AB were significantly higher than the ST×AB in all conditions. Finally, the representative inspiratory percentage of contribution of IT could be associate to the posture that the participants were submitted. As highlighted by our previous findings during breathing maneuvers at rest, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists.

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GENERAL CONCLUSION

In the first study, we described which changes cycling training can induce on the thoracoabdominal breathing motion pattern during quiet breathing and vital capacity at a sitting posture in master road cycling athletes. As results, an adaptation on the thoracoabdominal motion pattern the road cyclists were found compared with physically active subjects; with the higher contribution of the inferior thorax and the higher enrolment of the abdomen found in this study could be triggered by the road cycling training.

Therefore, we investigated the thoracoabdominal breathing motion pattern of master road cyclists during a simulated 20-km time trial. The cyclists were able to maintain a steady power output, heart rate, and thoracoabdominal volumeduring the time trial, although increases in the rating of perceived effort in the final stages. This fact, highlighting that they were able to use a sustainable strategy over the test and conducted the test relatively fast yet comfortable pace without achieving fatigue. The abdominal compartment has the greatest inspiratory percentage of contribution to the ventilation. Despite the posture adopted by road cyclists, the superior thorax has a lower capacity to expand and consequently, has a lower inspiratory percentage of contribution. Consequently, this discrepant range of enrolment between ST and AB affected the coordination between them. Although of moderate to strong correlation coefficient pairs values, the pairs ST×IT and IT×AB were significantly higher than the ST×AB in all conditions. Finally, the representative inspiratory percentage of contribution of IT could be associated with the posture that the participants were submitted. As highlighted by our previous findings during breathing maneuvers at rest, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists.

At this point, some questions still were unknown as concerned with posture and intensity. Firstly, our sample was composed of participants at the age of about 40 years, that had high years of experiences. Although, they were amateurs that participate in the national race level and we did not have physiological information about their performance level. Second, there was a lack of information about the physiological exercise intensity during the 20-km time trial. Finally, the literature researches during cycling exercise were developed with subjects sit completely upright with arms in the scapular plane while pedaling. Even though they analyzed in incremental exercise, our results were substantially different.

As general considerations, the key finds of the present work were that breathing maneuvers at sitting posture road cyclists presented a high coordinate thoracoabdominal movement and, compared to a control group they had a higher inspiratory percentage of contribution of the inferior thorax and a higher enrolment of the abdomen. These findings could be related to the pattern developed while they pedal in their own bike since, during a simulated 20-km time trial, the abdominal compartment has the greatest inspiratory percentage of contribution and the superior thorax has the lowest inspiratory percentage of contribution. In addition, although they presented moderate correlation coefficient, the change in the range of enrolment of the ST and AB affected their pair coordination, so these compartment pairs (ST×AB) was the most affected by the time trial. Finally, the representative inspiratory percentage of contribution of IT could be associated with the posture that the participants were submitted during the test. As highlighted by our previous findings during breathing maneuvers at sitting posture, IT had an important actuation in thoracoabdominal breathing motion pattern of road cyclists.

Further studies should be developed to improve the knowledge underlying the thoracoabdominal breathing motion pattern of cyclists. Some questions should be solved as (1) how different degrees of trunk flexion; (2) different intensities of exercise affect the thoracoabdominal breathing pattern; (3) factors that influence the individual responses; (4) the linkage between the thoracoabdominal breathing motion pattern and 3D kinematics of upper limbs, lower limbs, trunk and, power output. Finally, (5) the magnitude of the influence at each mechanical variable to performance.

ANEXO I - Termo de Consentimento Livre e Esclarecido

UNIVERSIDADE FEDERAL DE VIÇOSA

UNIVERSIDADE FEDERAL DO ESPÍRITO SANTO

LABORATÓRIO DE ANÁLISES BIOMECÂNICAS

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Você está sendo convidado(a) como voluntário(a) a participar da pesquisa "ANÁLISE CINEMÁTICA TRIDIMENSIONAL DO PADRÃO RESPIRATÓRIO DE CICLISTAS DE ESTRADA NA SIMULAÇÃO DE UMA PROVA DE CONTRARRELÓGIO INDIVIDUAL". O objetivo é compreender a mecânica respiratória de ciclistas de estrada em repouso e sob exercício durante uma prova de contrarrelógio individual. O motivo que nos leva a estudar é trazer maior esclarecimento sobre a influência do padrão mecânico respiratório na performance do ciclista.

Para esta pesquisa adotaremos os seguintes procedimentos: anamnese, onde serão feitas perguntas acerca do treinamento, histórico de lesões, queixa de dores, competições; análise cinemática tridimensional da simulação de uma prova de contrarrelógio individual e sentado em repouso e realizando manobras de inspiração e expiração; análise sanguínea antes e após o contrarrelógio individual.

Os riscos envolvidos na pesquisa são mínimos, com relação à análise cinemática eles consistem em constrangimento devido à exposição do corpo com uso somente de uma bermuda de compressão diante dos pesquisadores ou desconforto à palpação para detecção dos pontos anatômicos, porém garantimos que as avaliações serão feitas em uma sala reservada para minimizar o constrangimento e que, a palpação será realizada com profissionalismo e da forma menos invasiva possível. Para evitar tonturas ou mal-estar durante o teste um profissional estará ao lado orientando para que ele ocorra com cautela e seja interrompido a qualquer momento.

A pesquisa contribuirá para maior compreensão dos fatores relacionados à performance. Para participar deste estudo você não terá nenhum gasto e nem receberá qualquer vantagem financeira. Apesar disso, caso sejam identificados e comprovados danos provenientes desta pesquisa, lhe é assegurado o direito à indenização. Você tem garantida plena liberdade de recusar-se a participar ou retirar seu consentimento, em qualquer fase da pesquisa, sem necessidade de comunicado prévio. A sua participação é voluntária e a recusa em participar não acarretará qualquer penalidade ou modificação na forma em que você é atendido(a) pelo pesquisador.

Os resultados da pesquisa estarão à sua disposição quando finalizada. Seu nome ou o material que indique sua participação não serão liberados sem a sua permissão. Este termo de consentimento encontra-se impresso em duas vias originais, sendo que uma será arquivada pelo pesquisador responsável, no Laboratório de Biomecânica (LAB) e a outra lhe será fornecida. Os dados e instrumentos utilizados na pesquisa ficarão arquivados com o pesquisador responsável por um período de 5 (cinco) anos após o término da pesquisa, depois serão destruídos. Os pesquisadores tratarão a sua identidade com padrões profissionais de sigilo e confidencialidade, atendendo à legislação brasileira, em especial, à Resolução 466/2012 do Conselho Nacional de Saúde, e utilizarão as informações somente para fins acadêmicos e científicos.

Eu,____,
contato___________________, fui informado(a) dos objetivos da pesquisa "ANÁLISE CINEMÁTICA TRIDIMENSIONAL DO PADRÃO RESPIRATÓRIO DE CICLISTAS DE ESTRADA NA SIMULAÇÃO DE UMA PROVA DE CONTRARRELÓGIO INDIVIDUAL" de maneira clara e detalhada, e esclareci minhas dúvidas. Sei que a qualquer momento poderei solicitar novas informações e modificar minha decisão de participar se assim o desejar. Declaro que concordo em participar. Recebi uma via original deste termo de consentimento livre e esclarecido e me foi dada a oportunidade de ler e esclarecer minhas dúvidas.

Vitória, ______ de dezembro de 2017.

____

Assinatura do Participante

____

Amanda Piaia Silvatti

Telefone de contato: (31) 3899-4386

E-mail: amandasilvatti@ufv.br

____

Richard Diego Leite

Telefone de contato: (27) 98169-2382

E-mail: rdleite@gmail.com

Equipe de Trabalho:

Ana Luiza de Castro Lopes

Telefone de contato: (32) 98454-9074

E-mail: analuiza.castrolopes@gmail.com

Em caso de discordância ou irregularidades sob o aspecto ético desta pesquisa, você poderá consultar:

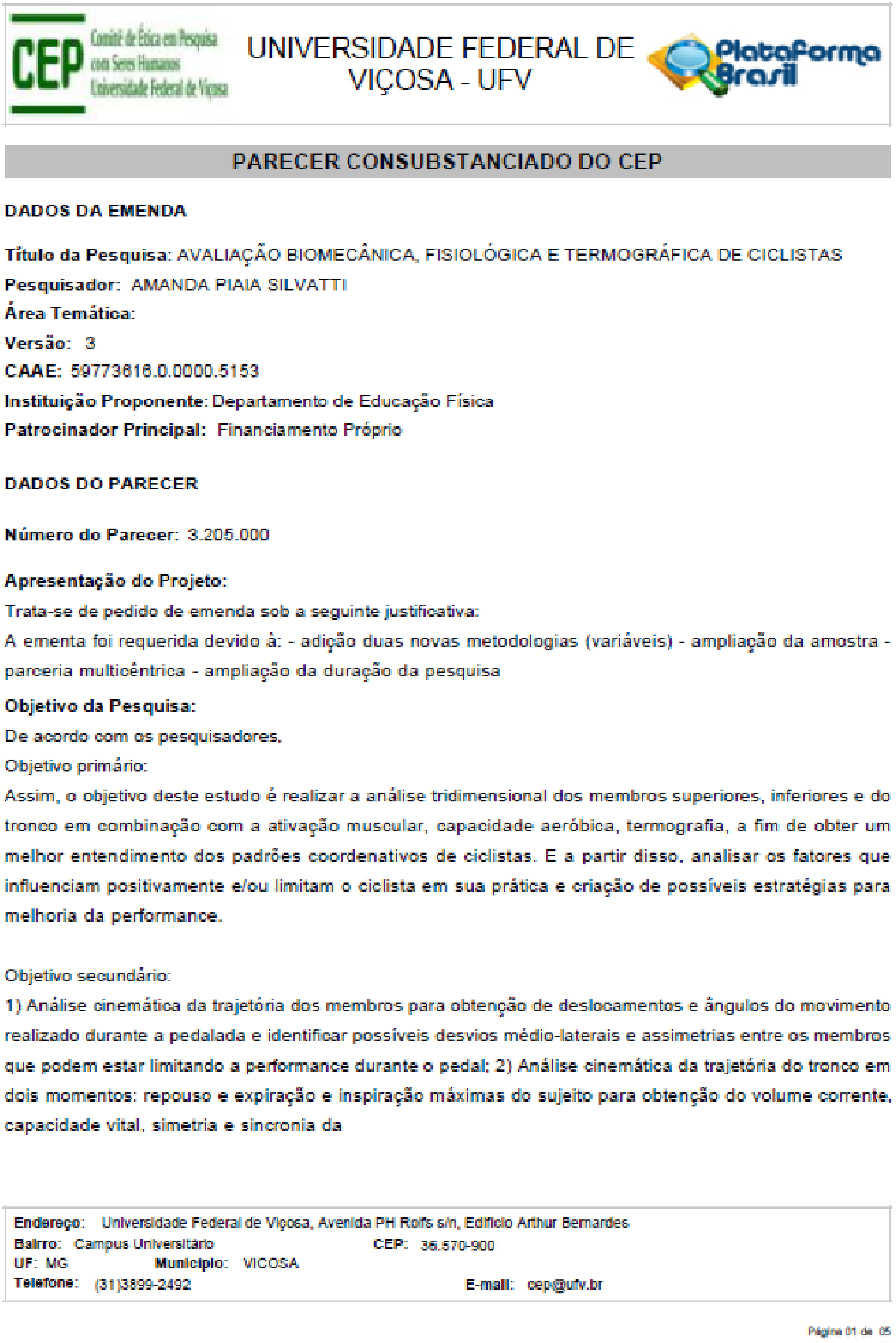
CEP/UFV – Comitê de Ética em Pesquisa com Seres Humanos - Universidade Federal de Viçosa

Edifício Arthur Bernardes, piso inferior
Av. PH Rolfs, s/n – Campus Universitário

Cep: 36570-900 Viçosa/MG

Telefone: (31)3899-2492

ANEXO 2 – Aprovação do Comitê de Ética de Pesquisa em Seres Humanos



CEP Comitê de Ética em Pesquisa com Seres Humanos Universidade Federal de Viçosa

UNIVERSIDADE FEDERAL DE VIÇOSA - UFV

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DA EMENDA

Título da Pesquisa: AVALIAÇÃO BIOMECÂNICA, FISIOLÓGICA E TERMOGRÁFICA DE CICLISTAS
Pesquisador: AMANDA PIAIA SILVATTI
Área Temática:
Versão: 3
CAAE: 59773616.0.0000.5153
Instituição Proponente: Departamento de Educação Física
Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.205.000

Apresentação do Projeto:

Trata-se de pedido de emenda sob a seguinte justificativa:

A ementa foi requerida devido à: - adição duas novas metodologias (variáveis) - ampliação da amostra - parceria multicêntrica - ampliação da duração da pesquisa

Objetivo da Pesquisa:

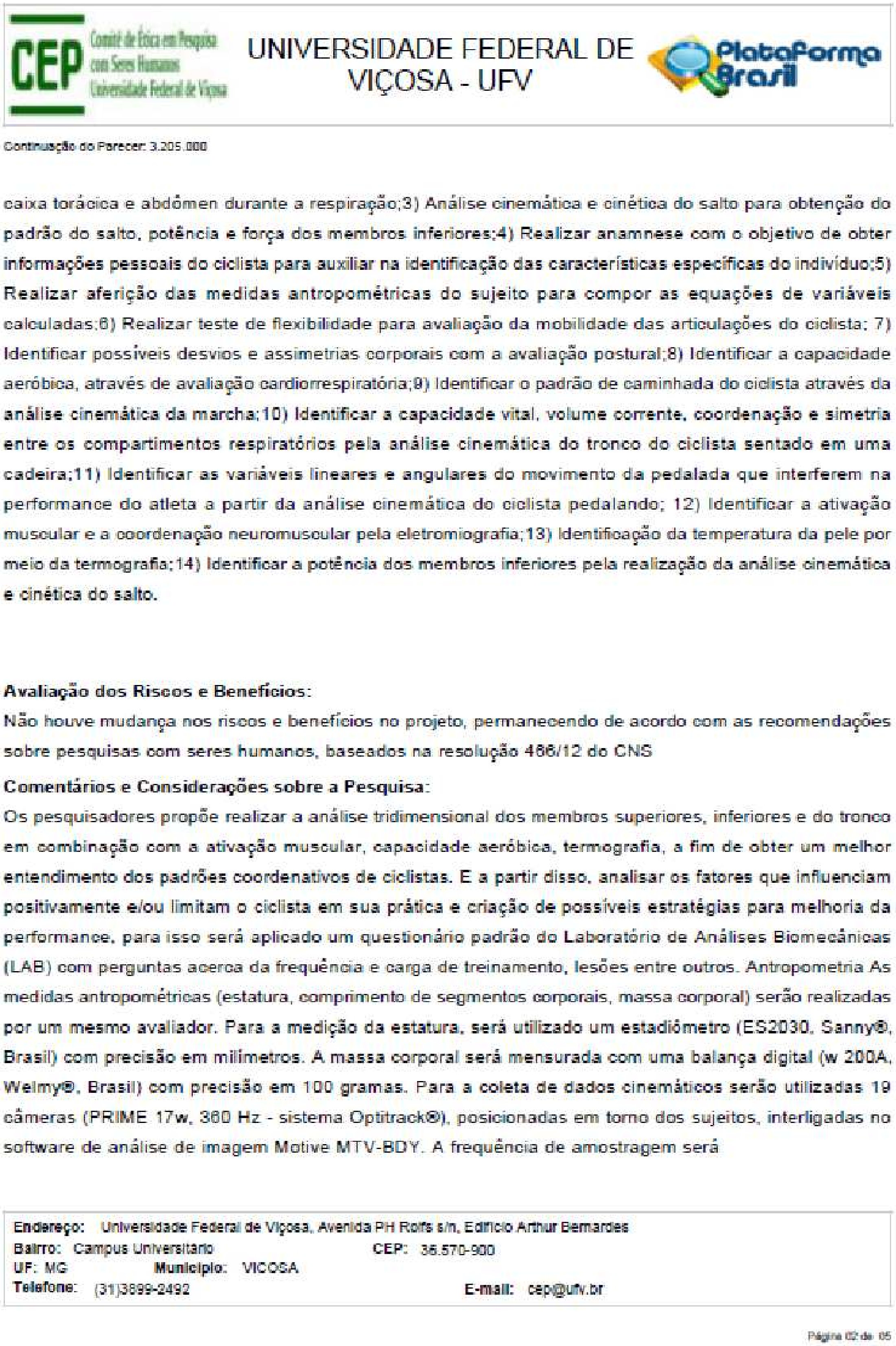
De acordo com os pesquisadores,

Objetivo primário:

Assim, o objetivo deste estudo é realizar a análise tridimensional dos membros superiores, inferiores e do tronco em combinação com a ativação muscular, capacidade aeróbica, termografia, a fim de obter um melhor entendimento dos padrões coordenativos de ciclistas. E a partir disso, analisar os fatores que influenciam positivamente e/ou limitam o ciclista em sua prática e criação de possíveis estratégias para melhoria da performance.

Objetivo secundário:

1) Análise cinemática da trajetória dos membros para obtenção de deslocamentos e ângulos do movimento realizado durante a pedalada e identificar possíveis desvios médio-laterais e assimetrias entre os membros que podem estar limitando a performance durante o pedal; 2) Análise cinemática da trajetória do tronco em dois momentos: repouso e expiração e inspiração máximas do sujeito para obtenção do volume corrente, capacidade vital, simetria e sincronia da



Continuação do Parecer: 3.205.000

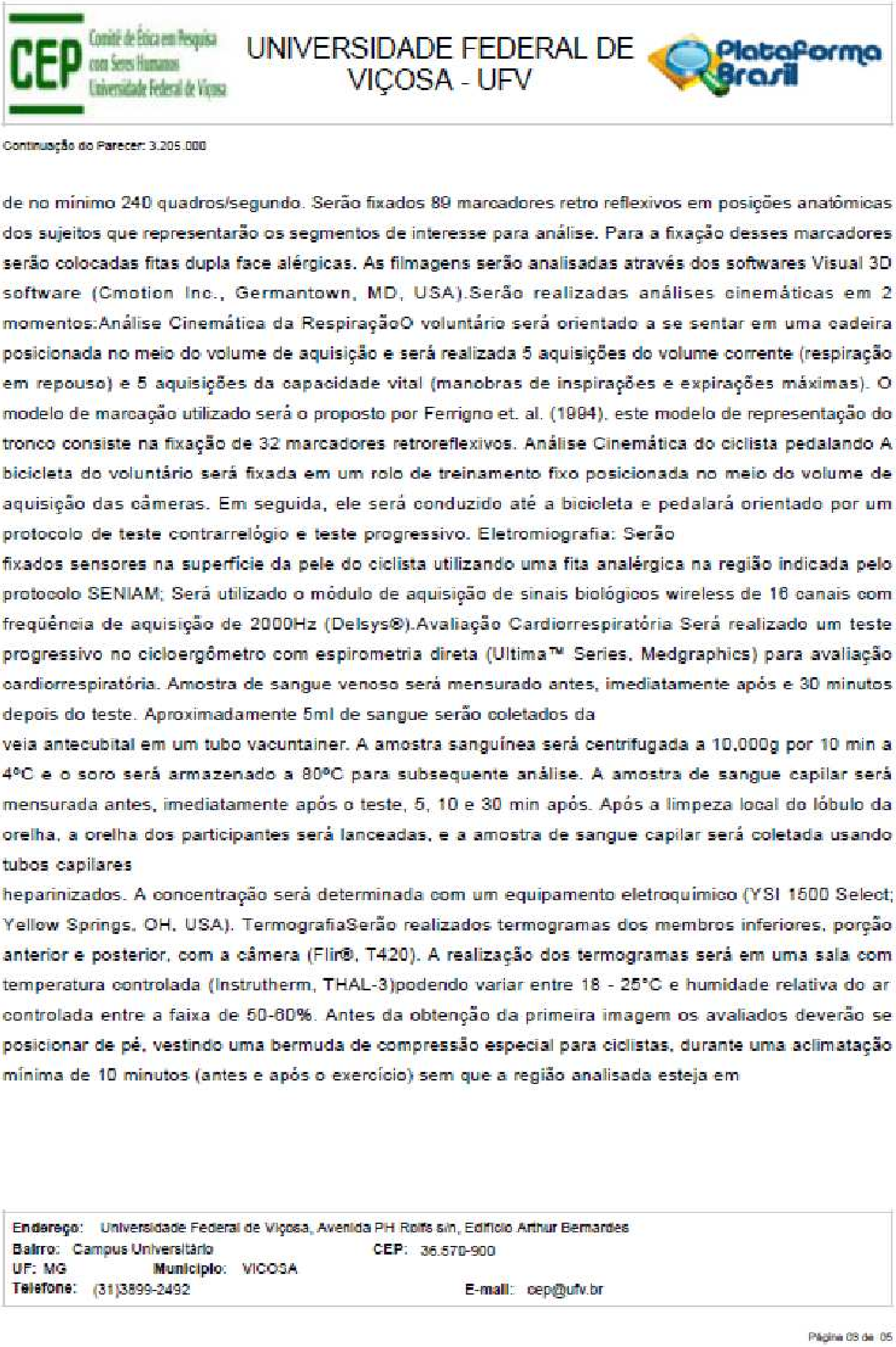
caixa torácica e abdômen durante a respiração;3) Análise cinemática e cinética do salto para obtenção do padrão do salto, potência e força dos membros inferiores;4) Realizar anamnese com o objetivo de obter informações pessoais do ciclista para auxiliar na identificação das características específicas do indivíduo;5) Realizar aferição das medidas antropométricas do sujeito para compor as equações de variáveis calculadas;6) Realizar teste de flexibilidade para avaliação da mobilidade das articulações do ciclista; 7) Identificar possíveis desvios e assimetrias corporais com a avaliação postural;8) Identificar a capacidade aeróbica, através de avaliação cardiorrespiratória;9) Identificar o padrão de caminhada do ciclista através da análise cinemática da marcha;10) Identificar a capacidade vital, volume corrente, coordenação e simetria entre os compartimentos respiratórios pela análise cinemática do tronco do ciclista sentado em uma cadeira;11) Identificar as variáveis lineares e angulares do movimento da pedalada que interferem na performance do atleta a partir da análise cinemática do ciclista pedalando; 12) Identificar a ativação muscular e a coordenação neuromuscular pela eletromiografia;13) Identificação da temperatura da pele por meio da termografia;14) Identificar a potência dos membros inferiores pela realização da análise cinemática e cinética do salto.

Avaliação dos Riscos e Benefícios:

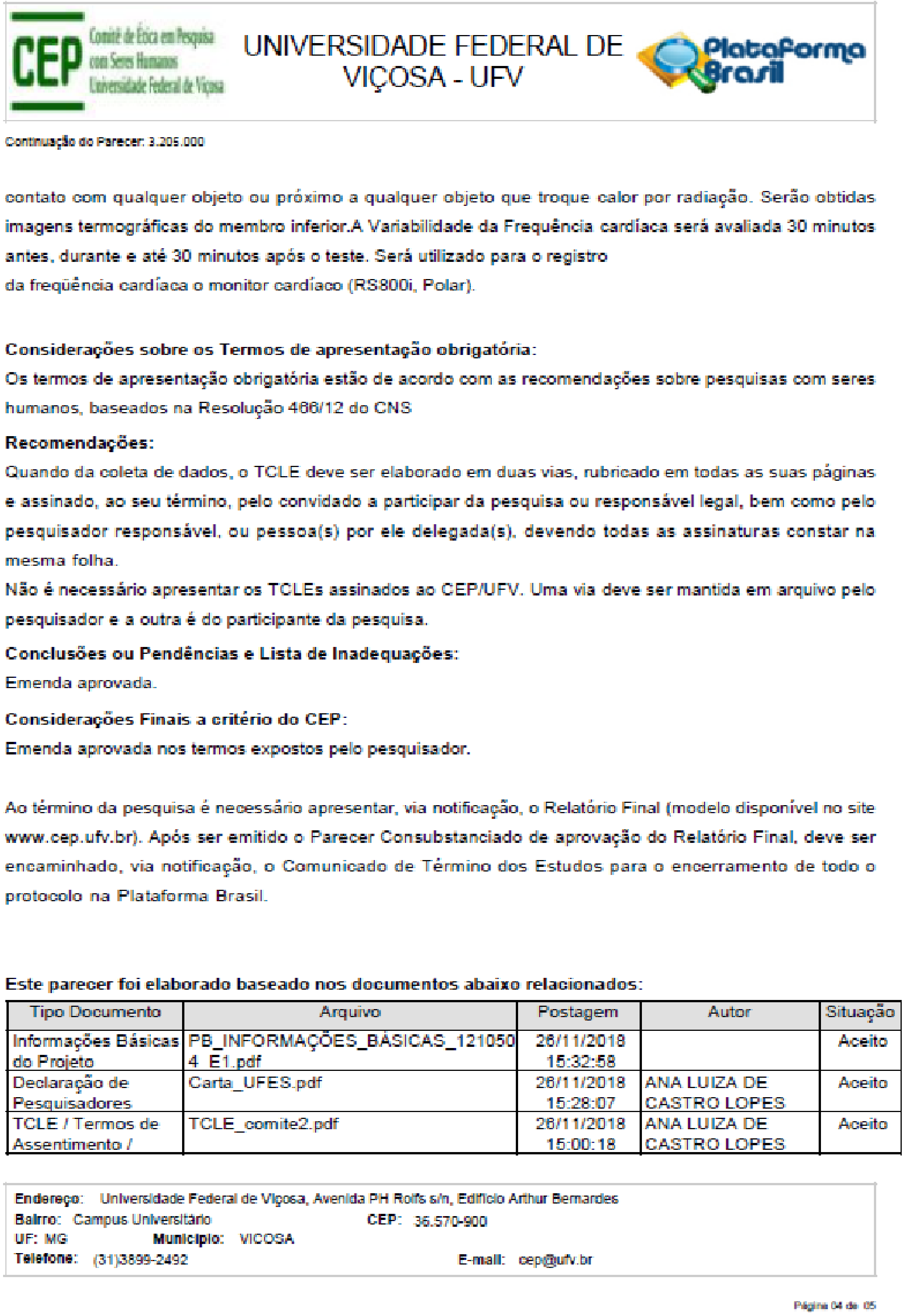
Não houve mudança nos riscos e benefícios no projeto, permanecendo de acordo com as recomendações sobre pesquisas com seres humanos, baseados na resolução 466/12 do CNS

Comentários e Considerações sobre a Pesquisa:

Os pesquisadores propõe realizar a análise tridimensional dos membros superiores, inferiores e do tronco em combinação com a ativação muscular, capacidade aeróbica, termografia, a fim de obter um melhor entendimento dos padrões coordenativos de ciclistas. E a partir disso, analisar os fatores que influenciam positivamente e/ou limitam o ciclista em sua prática e criação de possíveis estratégias para melhoria da performance, para isso será aplicado um questionário padrão do Laboratório de Análises Biomecânicas (LAB) com perguntas acerca da frequência e carga de treinamento, lesões entre outros. Antropometria As medidas antropométricas (estatura, comprimento de segmentos corporais, massa corporal) serão realizadas por um mesmo avaliador. Para a medição da estatura, será utilizado um estadiômetro (ES2030, Sanny®, Brasil) com precisão em milímetros. A massa corporal será mensurada com uma balança digital (w 200A, Welmy®, Brasil) com precisão em 100 gramas. Para a coleta de dados cinemáticos serão utilizadas 19 câmeras (PRIME 17w, 360 Hz - sistema Optitrack®), posicionadas em torno dos sujeitos, interligadas no software de análise de imagem Motive MTV-BDY. A frequência de amostragem será



de no mínimo 240 quadros/segundo. Serão fixados 89 marcadores retro reflexivos em posições anatômicas dos sujeitos que representarão os segmentos de interesse para análise. Para a fixação desses marcadores serão colocadas fitas dupla face alérgicas. As filmagens serão analisadas através dos softwares Visual 3D software (Cmotion Inc., Germantown, MD, USA).Serão realizadas análises cinemáticas em 2 momentos:Análise Cinemática da RespiraçãoO voluntário será orientado a se sentar em uma cadeira posicionada no meio do volume de aquisição e será realizada 5 aquisições do volume corrente (respiração em repouso) e 5 aquisições da capacidade vital (manobras de inspirações e expirações máximas). O modelo de marcação utilizado será o proposto por Ferrigno et. al. (1994), este modelo de representação do tronco consiste na fixação de 32 marcadores retroreflexivos. Análise Cinemática do ciclista pedalando A bicicleta do voluntário será fixada em um rolo de treinamento fixo posicionada no meio do volume de aquisição das câmeras. Em seguida, ele será conduzido até a bicicleta e pedalará orientado por um protocolo de teste contrarrelógio e teste progressivo. Eletromiografia: Serão
fixados sensores na superfície da pele do ciclista utilizando uma fita analérgica na região indicada pelo protocolo SENIAM; Será utilizado o módulo de aquisição de sinais biológicos wireless de 16 canais com freqüência de aquisição de 2000Hz (Delsys®).Avaliação Cardiorrespiratória Será realizado um teste progressivo no cicloergômetro com espirometria direta (Ultima™ Series, Medgraphics) para avaliação cardiorrespiratória. Amostra de sangue venoso será mensurado antes, imediatamente após e 30 minutos depois do teste. Aproximadamente 5ml de sangue serão coletados da
veia antecubital em um tubo vacuntainer. A amostra sanguínea será centrifugada a 10.000g por 10 min a 4ºC e o soro será armazenado a 80ºC para subsequente análise. A amostra de sangue capilar será mensurada antes, imediatamente após o teste, 5, 10 e 30 min após. Após a limpeza local do lóbulo da orelha, a orelha dos participantes será lanceadas, e a amostra de sangue capilar será coletada usando tubos capilares
heparinizados. A concentração será determinada com um equipamento eletroquímico (YSI 1500 Select; Yellow Springs, OH, USA). TermografiaSerão realizados termogramas dos membros inferiores, porção anterior e posterior, com a câmera (Flir®, T420). A realização dos termogramas será em uma sala com temperatura controlada (Instrutherm, THAL-3)podendo variar entre 18 - 25°C e humidade relativa do ar controlada entre a faixa de 50-60%. Antes da obtenção da primeira imagem os avaliados deverão se posicionar de pé, vestindo uma bermuda de compressão especial para ciclistas, durante uma aclimatação mínima de 10 minutos (antes e após o exercício) sem que a região analisada esteja em



contato com qualquer objeto ou próximo a qualquer objeto que troque calor por radiação. Serão obtidas imagens termográficas do membro inferior.A Variabilidade da Frequência cardíaca será avaliada 30 minutos antes, durante e até 30 minutos após o teste. Será utilizado para o registro
da freqüência cardíaca o monitor cardíaco (RS800i, Polar).

Considerações sobre os Termos de apresentação obrigatória:

Os termos de apresentação obrigatória estão de acordo com as recomendações sobre pesquisas com seres humanos, baseados na Resolução 466/12 do CNS

Recomendações:

Quando da coleta de dados, o TCLE deve ser elaborado em duas vias, rubricado em todas as suas páginas e assinado, ao seu término, pelo convidado a participar da pesquisa ou responsável legal, bem como pelo pesquisador responsável, ou pessoa(s) por ele delegada(s), devendo todas as assinaturas constar na mesma folha.

Não é necessário apresentar os TCLEs assinados ao CEP/UFV. Uma via deve ser mantida em arquivo pelo pesquisador e a outra é do participante da pesquisa.

Conclusões ou Pendências e Lista de Inadequações:

Emenda aprovada.

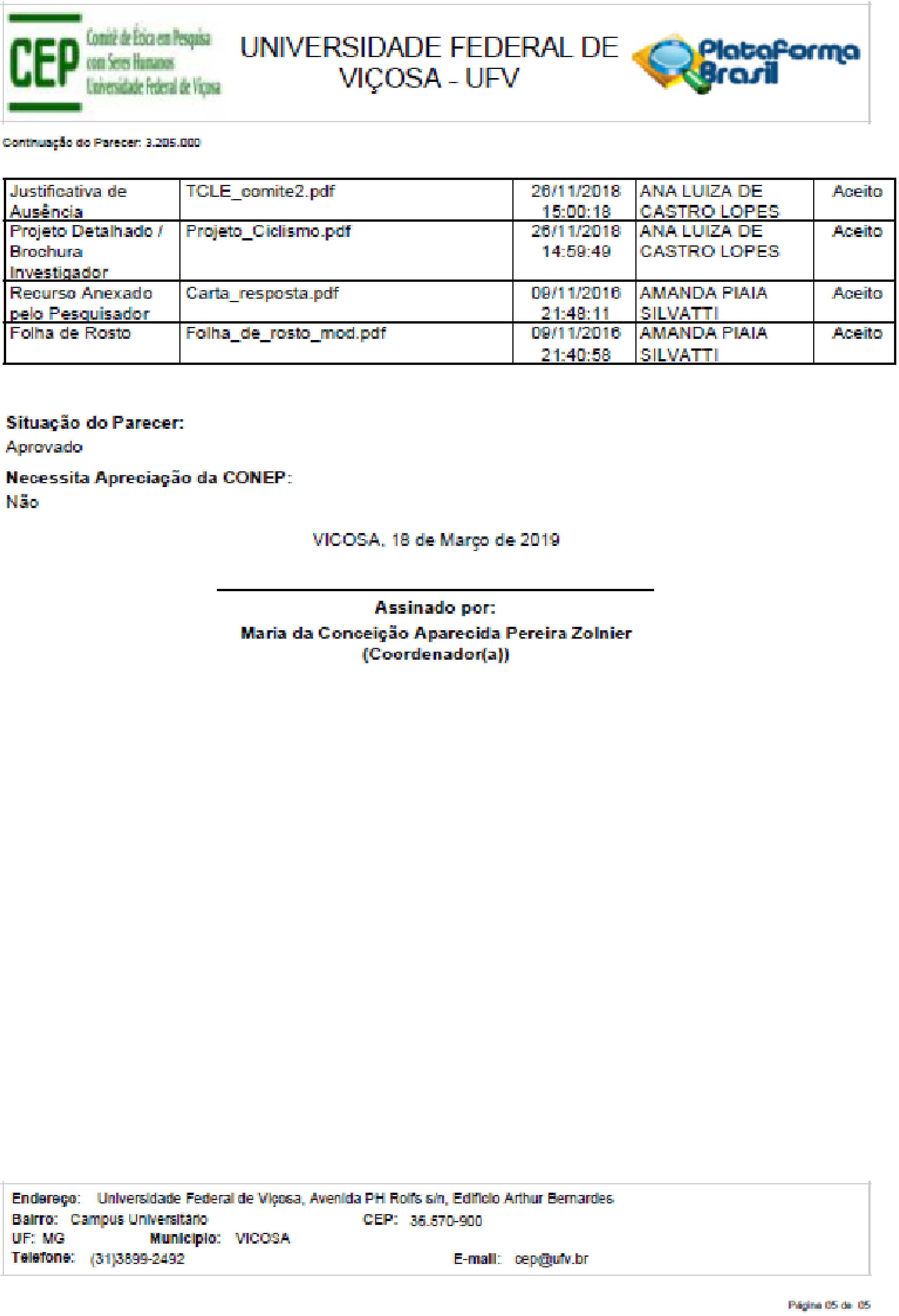
Considerações Finais a critério do CEP:

Emenda aprovada nos termos expostos pelo pesquisador.

Ao término da pesquisa é necessário apresentar, via notificação, o Relatório Final (modelo disponível no site www.cep.ufv.br). Após ser emitido o Parecer Consubstanciado de aprovação do Relatório Final, deve ser encaminhado, via notificação, o Comunicado de Término dos Estudos para o encerramento de todo o protocolo na Plataforma Brasil.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_1210504_E1.pdf	26/11/2018 15:32:58		Aceito
Declaração de Pesquisadores	Carta_UFES.pdf	26/11/2018 15:28:07	ANA LUIZA DE CASTRO LOPES	Aceito
TCLE / Termos de Assentimento /	TCLE_comite2.pdf	26/11/2018 15:00:18	ANA LUIZA DE CASTRO LOPES	Aceito



Continuação do Parecer: 3.205.000

Justificativa de Ausência	TCLE_comite2.pdf	26/11/2018 15:00:18	ANA LUIZA DE CASTRO LOPES	Aceito
Projeto Detalhado / Brochura Investigador	Projeto_Ciclismo.pdf	26/11/2018 14:59:49	ANA LUIZA DE CASTRO LOPES	Aceito
Recurso Anexado pelo Pesquisador	Carta_resposta.pdf	09/11/2016 21:48:11	AMANDA PIAIA SILVATTI	Aceito
Folha de Rosto	Folha_de_rosto_mod.pdf	09/11/2016 21:40:58	AMANDA PIAIA SILVATTI	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

VICOSA, 18 de Março de 2019

Assinado por:
Maria da Conceição Aparecida Pereira Zolnier
(Coordenador(a))

ANEXO 3 – Tabela de produção científica durante o mestrado

Participação em eventos

Participação como congressista no XVII Congresso Brasileiro de Biomecânica e I Encontro Latino Americano de Biomecânica e VIII Simpósio em Neuromecânica Aplicada. Porto Alegre, RS. 2017.

Participação como congressista no XI Congresso Brasileiro de Atividade Física e Saúde. Florianópolis, SC. 2017.

Participação como congressista no 23rd annual congress of the European College of Sports Science. Irlanda. 2018.

Participação como congressista no XVIII Congresso Brasileiro de Biomecânica. Manaus, AM. 2019

Cursos ou palestras ministrados

Palestra “Efeitos do ciclismo na mecânica respiratória”. I Simpósio Internacional em Análises Biomecânicas e Fisiológicas da Atividade Física e do Esporte. Departamento de Esportes da Escola de Educação Física, Fisioterapia e Terapia Ocupacional da UFMG. 2018.

Palestra “Efeitos do ciclismo na mecânica respiratória”. I Simpósio Internacional em Análises Biomecânicas e Fisiológicas da Atividade Física e do Esporte. União de Ensino Superior de Viçosa. 2018.

PRODUÇÃO BIBLIOGRÁFICA

Resumos em anais de congressos

BERNARDINA, G; **LOPES, A**; SILVATTI, A; CALDAS, L; RODRIGUES, I; SOARES, N; DUARTE, T. Efeitos de um treinamento multicomponente nas variáveis lineares da marcha de mulheres da terceira idade. In: XI Congresso Brasileiro de Atividade Física e Saúde. Florianópolis, SC. 2017.

LOPES, A; CARNEIRO-JUNIOR, M; SILVATTI, A; FREITAS, J; CALDAS, L; FREITAS, G; GOMES, G; SANTOS, F. Relação entre a participação em um programa de atividade física sistematizada com a atividade física habitual e aptidão física funcional de idosas da cidade de Viçosa-MG. 2017. In: XI Congresso Brasileiro de Atividade Física e Saúde. Florianópolis, SC. 2017.

LOPES, A; CARNEIRO-JUNIOR, M; SILVATTI, A; FREITAS, J; CALDAS, L; MOREIRA, A; LOPES, E; SANTOS, F. Efeitos da prática regular de atividade física sistematizada na atividade física habitual, aptidão física funcional, composição corporal e Qualidade de vida de idosas da cidade de Viçosa-MG. 2017. In: Simpósio de Integração Acadêmica, Viçosa, 2017.

SILVATTI, A; RODRIGUES, I; BERNARDINA, G; **LOPES, A**; MASSARONI, C; CHIAPETA, A; PEREIRA, E; BARONI, G; CERVERI, P. Effect of a respiratory training in the thoracoabdominal motion pattern of dancers. In: 23rd annual Congress of the ECSS. Dublin, Irlanda, 2018.

LOPES, A; BERNARDINA, G; RODRIGUES, I; MASSARONI, C; SILVESTRI, S; CERVERI, P; LEITE, R; AMORIM, P; SILVATTI, A. Thoracoabdominal motion pattern at rest of road cyclists: preliminary results. In: 23rd annual Congress of the ECSS. Dublin, Irlanda, 2018.

LOPES, A; AMORIM, P; RODRIGUES, I; MASSARONI, C; SILVATTI, A. Thoracoabdominal breathing motion pattern during time trial of master road cyclists. In: XVIII Congresso Brasileiro de Biomecânica. Manaus, 2019.

Resumo da produção durante o mestrado

Prêmios	00
Participação em Eventos	04
Cursos ou Palestras Ministrados	02
Resumos em Anais de Congressos	06
Artigos completos publicados em periódicos	00
Artigos submetidos à periódicos científicos	00