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Original article

Does inspiratory flow resistance modify the intensity of a pilates session?

A resistência do fluxo inspiratório modifica a intensidade de uma sessão de pilates?

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ABSTRACT | INTRODUCTION: The evidence on the improvement of functional capacity using the Pilates Method is not conclusive. One possibility to improve the effect of a Pilates session on the cardiorespiratory capacity of its practitioners is to use the inspiratory flow resistance (IFR) concomitantly. This effect can be visualized by determining the glycemic threshold (GT), a technique used as an exercise intensity marker. **OBJECTIVE:** To test the hypothesis that the use of IFR in a Pilates session anticipates GT. **METHODS:** Cross-sectional crossover study. A total of 26 individuals of both genders were evaluated, 10 of whom were male, healthy, and aged between 20 and 40 years. The volunteers were randomized to two protocols: Protocol IFR - Eleven movements of the Pilates method with IFR using 20% of the maximum inspiratory pressure, and Protocol no IFR (NIFR) - Eleven movements of the Pilates method without IFR. The two protocols were performed on the same day, one in the morning and the other in the afternoon, according to randomization by simple random draw. At rest and at the end of each movement, capillary blood collections were performed to measure blood glucose and construct the glycemic curve. GT was determined at the smallest point on the curve. **RESULTS:** The GT was anticipated in the protocol that used IFR; that is, in the protocol with IFR, the GT was visualized in the sixth exercise, while in the NIFR protocol, the GT was visualized in the ninth exercise (p<0.05). **CONCLUSION:** IFR anticipated GT, which suggests that IFR increases the intensity of a Pilates session. This suggests the hypothesis that IFR can provide additional medium and long-term benefits to Pilates method practitioners.

KEYWORDS: Exercise Movement Techniques. Anaerobic Threshold. Breathing Exercises. Pilates Training

RESUMO | INTRODUÇÃO: As evidências sobre a melhora da capacidade funcional utilizando o Método Pilates não são contundentes. Uma possibilidade de melhorar o efeito de uma sessão de Pilates sobre a capacidade cardiorrespiratória de seus praticantes é utilizar a resistência de fluxo inspiratório (RFI) de forma concomitante. Esse efeito pode ser visualizado através da determinação do limiar glicêmico (LG), técnica utilizada como marcador de intensidade do exercício. **OBJETIVO:** Testar a hipótese de que a utilização de RFI em uma sessão de pilates antecipa o LG. **MÉTODOS:** Estudo crossover de corte transversal. Foram avaliados 26 indivíduos de ambos os sexos, sendo 10 do sexo masculino, sadios e com idade entre 20 e 40 anos. Os voluntários foram randomizados para dois protocolos: Protocolo RFI – 11 movimentos do Método Pilates com RFI utilizando 20% da pressão inspiratória máxima; e Protocolo sem RFI (SRFI) – 11 movimentos do Método Pilates sem RFI. Os dois protocolos foram realizados no mesmo dia, sendo um pela manhã e outro à tarde, conforme randomização feita por sorteio aleatório simples. No repouso e ao final de cada movimento coletas de sangue capilar foram realizadas para dosagem da glicemia e construção da curva glicêmica. O LG foi determinado no menor ponto da curva. **RESULTADOS:** O LG foi antecipado no protocolo que utilizou RFI, ou seja, no protocolo com RFI o LG foi visualizado no sexto exercício, enquanto no protocolo SRFI o LG foi visualizado no nono exercício (p<0,05). **CONCLUSÃO:** A RFI antecipou o LG, o que sugere que a RFI aumenta a intensidade de uma sessão de pilates. Isso aventa a hipótese de que a RFI pode proporcionar a médio e longo prazo benefícios adicionais aos praticantes do Método Pilates.

PALAVRAS-CHAVE: Técnicas de Exercício e de Movimento. Limiar Anaeróbio. Exercícios Respiratórios. Método Pilates.

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1. Introduction

Inspiratory muscle training (IMT) is a technique widely used to treat patients with respiratory and cardiovascular diseases.[1,2] One of the ways used for IMT in clinical practice is through inspiratory flow resistance (IFR) concomitantly with other exercises. Chronically, its use increases functional capacity and improves ventilatory function, which directly impacts gains in quality of life.[2] Likewise, the Pilates method is widely used by physiotherapy and physical education professionals to improve flexibility and muscular strength, with these benefits being widely proven in scientific literature.[3,4] However, the evidence on improving functional capacity using the Pilates method is not overwhelming and presents controversial results.[5]

One possibility to improve the effect of a Pilates session on the functional capacity and ventilatory function of its practitioners is to use IFR concomitantly. Alvarenga et al.[6] carried out a study in which they associated Pilates sessions with the use of IMT; however, although they identified an increase in maximum inspiratory pressure (MIP), no improvement in functional capacity was observed. Therefore, the question arises whether or not the addition of IFR to a Pilates session promotes sufficient overload on the cardiorespiratory and metabolic system to impact functional capacity.

One of the ways to visualize this cardiorespiratory and metabolic overload is by determining the glycemic threshold (GT).[7] This is a minimally invasive technique capable of determining the anaerobic threshold and which can be used as a marker of cyclic or resistance exercise intensity.[8] The literature on the determination and use of LG is extensive, although, as far as we know, it has not yet been applied in a Pilates session. Therefore, in this study, we determined the objective of testing the hypothesis that the use of IFR in a Pilates session anticipates the glycemic threshold. In this way, it is possible to infer whether cardiorespiratory and metabolic overload is increased when combining a Pilates session with IFR.

2. Method

2.1. Design

This is a cross-sectional crossover study.

2.2. Eligibility criteria and sample characteristics

Individuals of both sexes, aged between 20 and 40 years, healthy, active, and with at least one year of experience in the Pilates method were included. Individuals who had cardiovascular changes due to a potential decrease in cardiorespiratory fitness and musculoskeletal or pulmonary disorders that compromised ventilatory mechanics were excluded.

2.3. Data collect

Initially, a standard questionnaire was applied, and a physical examination was carried out with the aim of collecting clinical, anthropometric, and sociodemographic data on the sample's age and sex. The physical examination consisted of measuring blood pressure using the Premium® brand adult tensiometer, resting blood glucose using the G-Tech free® (expressed in mg/dL), partial oxygen saturation (SpO2) using the G-Tech® Portable Pulse Oximeter model Oled Graph, and MIP assessment measured by POWERbreathe® K5.

Height was measured using a Sanny® stadiometer, performed with the subjects barefoot and their buttocks and shoulders supported on a vertical backrest. Total body mass was measured using a Filizola® digital scale with a maximum capacity of 150 kg, measured by the Instituto Nacional de Metrologia, Qualidade e Tecnologia - Inmetro (National Institute of Metrology, Quality and Technology), with its own certificate, specifying a margin of error of approximately 100 g. The Body Mass Index (BMI) was calculated using mass and height measurements according to the Quetelet equation: mass (kg)/height^2 (m). The BMI cutoff point adopted was recommended by the V Brazilian Guideline on Dyslipidemias and Prevention of Atherosclerosis of the Department of Atherosclerosis of the Brazilian Society of Cardiology[9], that is, eutrophic (BMI 18.5-24.9 kg/m^2).

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To assess MIP, the volunteer was placed in a sitting position, with the spine erect, then instructed to perform a slow exhalation maneuver followed by a quick and forced inspiration with the nose occluded by a nasal clip. The maneuver was repeated three times until the highest value found was identified, and the last maneuver could not present the highest MIP value. When this occurred, a new maneuver was requested until the last attempt was not the highest value obtained, which avoids the learning effect of the test.[10]

2.4. Randomization for protocols

After collecting clinical and anthropometric data, volunteers were randomly selected to carry out the protocols. The IFR protocol consisted of performing 11 Pilates method movements associated with an IFR of 20% of MIP, and the protocol no inspiratory flow resistance (NIFR) consisted of performing only the same 11 Pilates method movements. The two protocols were carried out on the same day, one in the morning and the other in the afternoon. The randomization of which protocol each volunteer would undergo first was done by simple random drawing. For this, two balls were used inside a bag: the black ball corresponding to the IFR protocol and the blue ball corresponding to the NIFR protocol.

2.5. Pilates session exercise protocol

Eleven movements of the Pilates method were made in the IFR and NIFR protocol, all original and performed in an identical way. Each movement had two sets of 10 repetitions with a 30-second break between each set and a 2-minute break between one exercise and another. The movements chosen were: 1 - Single Leg Stretch; 2 - Double Leg Stretch; 3 - Roll Up; 4 - Shoulder Bridge; 5 - Side Bend; 6 - Foot Work (v position, arches, heels, tendon stretch); 7 - T (long box); 8 - Down Stretch; 9 - Reverse Chest Expansion - Arm Circles; 10 - Short Spine Massage; 11 - Short Box Series: Flat Back. The duration of each protocol was 50 minutes per volunteer.

2.6. Blood collections to determine the glycemic curve

Blood collections were performed by puncture in one of the digital pulps after asepsis with alcohol (70%), using lancets and disposable procedure gloves. Blood glucose values were obtained by applying blood to a test strip attached to the G-Tech free® glucose monitor (expressed in mg/dL), obtaining the result immediately after contact with the blood on the lancet.

At the end of each exercise, capillary blood glucose levels were measured, and this was repeated until the end of the test. The glycemic threshold was determined through visual inspection at the lowest value of the glycemic curve constructed in the test, according to what Simões et al.[7] proposed.

2.7. Study variables

For primary data analysis, the GT variable was used (Table 2); this is the movement in which GT was achieved in the respective protocols. As a secondary analysis, the behavior of glycemia is illustrated in Figure 1; these are glycemic averages during movements in the IFR and NIFR protocols.

2.8. Ethical consideration

This study was submitted and approved by the Ethics and Research Committee of Faculdade Adventista da Bahia with CAAE: 44262321.1.0000.0042. All participants received information about the study and signed an informed consent form (ICF), at which time the risks and benefits that the research could generate were explained according to National Health Council resolution 466/12.

2.9. Sample sufficiency calculation and statistical analysis

Initially, a sample size calculation was carried out using the WinPep version 11.65 program, adopting a confidence level of 95%, an acceptable error of 9% using a standard deviation of 8.00 for both protocols, referring to the glycemia value in women in the Pilates exercise[11], totaling 26 participants.

The D'Agostino normality test (k-samples) was performed to choose measures of central tendency and dispersion. Mean and standard deviation were used in parametric variables, and median with interquartile ranges in non-parametric variables. Categorical variables were presented as numbers and/or percentages. Comparisons of fasting blood glucose and GT in both groups were made using the paired two-way Student t test. For statistical analysis, the GraphPad Prism version 8.0.1 program was used.

3. Results

They were 26 individuals were evaluated, 10 of whom were male. Table 1 presents the clinical and anthropometric characteristics of the sample.

Table 1. Anthropometric and clinical characteristics of the sample (n= 26)

Variables	Mean±SD
MIP (cmH2O)	129±24.2
Age (years)	27±4.6
BMI (km/m2)	23±2.8

MIP: Maximum Inspiratory Pressure; BMI: Body Mass Index.
Source: the authors (2023).

Table 2 presents the basal or pre-exercise glycemia and the movement in which GT was reached in both Pilates session protocols. We highlight that there was no significant difference between the pre-exercise glycemia of both protocols ($p=0.68$); on the other hand, we saw that there was a significant difference in the movement in which the GT was reached between the NIFR protocol and with IFR ($p <0.01$).

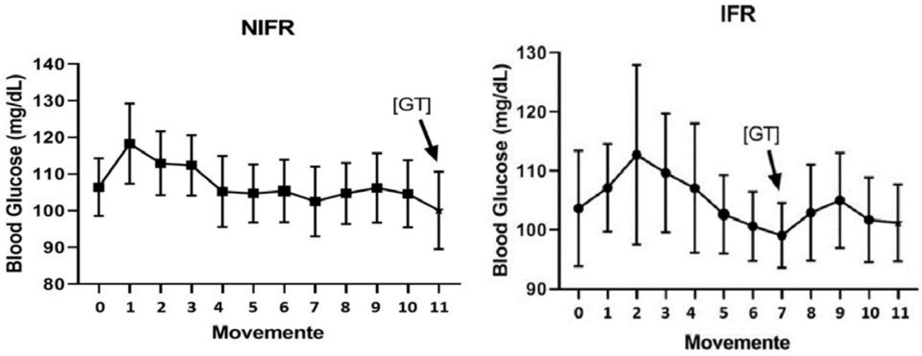
Table 2. Pre-exercise blood glucose and glucose threshold in protocols with and without inspiratory flow resistance

Variables	NIFR	CI 95%	IFR	CI 95%	Valor de p*
Resting blood glucose (mm/dL)@	106±13	98-114	103±7	93-113	0.68
Glycemic Threshold#	8.7±2.6	7-10	5,7±3.0	3-7	<0.01

IFR: Inspiratory Flow Resistance; NIFR: No Inspiratory Flow Resistance; @It does not refer to fasting blood glucose, but the blood glucose that preceded the collection protocol; #Movement in which the glycemic threshold was reached; *paired bidirectional Student t-test.
Source: the authors (2023).

Figure 1 shows the linear distribution of the glycemic curve in the NIFR and IFR protocols, which are expressed through the glycemic averages during the performance of Pilates movements. It is observed that the use of the IFR anticipated the GT.

Figure 1. Behavior (mean±95%CI) of blood glucose during the Pilates session No Inspiratory Flow Resistance (NIFR) and Inspiratory Flow Resistance (IFR)



[GT]: Glycemic Threshold
Source: the authors (2023).

4. Discussion

In this study, we investigated whether the use of IFR in a Pilates session anticipates GT. Our results show that IFR was responsible for anticipating GT, which leads to an increase in effort intensity during the Pilates session.

There are two mechanisms that can explain this result. Possibly, the main physiological mechanism that justifies this finding is the increase in diaphragmatic and accessory inspiration muscle recruitment with the use of IFR. The increase in inspiratory load is responsible for greater electromyographic activity of the muscles of the lower thoracic cage[12], mainly due to the recruitment of type IIa and IIx strength and power muscle fibers of the diaphragm.[13] These fibers, which are mainly glycolytic, increase energy demand and generate disturbances in local and systemic metabolic homeostasis through a decrease in blood glucose.[14]

The second mechanism is the activation of the metaboreflex.[15] As previously stated, IFR is responsible for increased inspiratory muscle activity, which results in greater energy demand from glycolytic diaphragmatic fibers. As a result of the increase in anaerobic glycolytic metabolism, there is greater generation of H+ ions. These ions stimulate type III and IV afferent nerve pathways, responsible for activating the diaphragmatic metaboreflex and sympathetic nervous activity.[15,16]

The diaphragmatic metaboreflex promotes arterial vasoconstriction of the appendicular skeletal muscles, vasodilation in the diaphragmatic muscles, and increased heart rate and cardiac output.[16] This mechanism is carried out in order to supply the increase in diaphragmatic metabolic activity, which on a functional hierarchical scale is primary in comparison to the function of the adjacent skeletal muscles.[15]

Discussing more specifically the behavior of the glycemic curve in the two protocols, we can infer a pertinent point. Normally, blood glucose increases slightly at the beginning of physical exercise and reduces throughout its duration until it reaches the lowest value, which corresponds to the GT point.[7,8] After this point, as exercise continues, especially in incremental load protocols, blood glucose values rise again, as observed in Figure 1 in the IFR protocol and as already reported in previous studies by other groups.[7,8] This behavior of the glycemic curve occurs due to the activation of hormonal mechanisms that regulate glycemia. Again, during exercise, insulin production decreases and glucagon production increases, which explains the initial rise behavior. In Figure 1, we can see that in both protocols, this initial phase was identified. After this phase, as exercise continues, muscular energy demand consumes excess glycemia, especially by activating glucose uptake mechanisms by skeletal muscles, independent of insulin[17], which promotes a phase of decline of the curve to its lowest point value, in which the GT is determined.

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As exercise continues, especially incremental exercise, another hormonal mechanism regulating blood glucose comes into activity: the production of cortisol. This is a hormone that accelerates gluconeogenic activity by providing extra energy in the form of glucose. This again favors the balance of blood glucose elevation, composing the last phase of the glycemic curve that we can call the "second phase of rise". When analyzing Figure 1, it is observed that the NIFR graph does not present this second phase, as observed in the IFR graph. This indicates that most of the individuals probably did not reach the anaerobic threshold during the session without IFR, which leads to the hypothesis that, in this session the work was mostly of low intensity. It is worth mentioning that the GT corresponds to the anaerobic threshold[7] and that below this threshold, the exercise is essentially of low intensity.[7,8]

In line with what was discussed previously, we know that the main benefits of a Pilates program are increased strength and flexibility.[3,4] However, it is difficult to say that Pilates exercises alone increase cardiovascular fitness.[5] Some observational studies point to this improvement after 6 to 8 weeks of training, but this evidence cannot attribute causality, mainly because they associate the Pilates program with aerobic activities.[18,19] Therefore, the present work raises the hypothesis that the use of IFR by increasing effort intensity, through the physiological mechanisms initially explained in this discussion, can generate improvements in functional capacity and other benefits associated with the use of IFR. However, it is important to point out that only longitudinal clinical trials that present functional capacity as an outcome can test this hypothesis.

In short, the results presented here converge towards the idea that associating RFI with a Pilates session can contribute to gains that are conventionally not achieved with Pilates alone, such as in functional capacity and decreased blood pressure.[20] The fact that the IFR anticipates the GT, increasing the intensity of effort during the session, suggests that possibly in the medium and long term the use of the IFR may reduce the metaboreflex, which may also trigger an improvement in functional capacity. However, the certainty that this will happen will only be demonstrated by carrying out randomized clinical trials that evaluate the cause-effect relationship of IFR associated with a Pilates session.

5. Conclusion

Inspiratory flow resistance anticipated glycemic threshold and increased the intensity of effort in a Pilates session. This suggests the possibility of obtaining clinical and functional advantages when combining inspiratory flow resistance with a Pilates session.

Authors' contributions

Petto J participated in the conception of the research question, the methodological design, the collection and interpretation of data, the interpretation of results, and the writing of the scientific article. Oliveira AM worked on data collection and interpretation and writing of the scientific article. Sacramento MS and Souza PES participated in the methodological design, statistical analysis of research data, and interpretation of the results of the scientific article. Cerqueira DGLES contributed to the design of the research question, data collection and interpretation. Moreira PHS worked on collecting and writing the scientific article. Silva WS participated in the conception of the research question, interpretation of the results, and writing of the scientific article. All authors reviewed and approved the final version and are in agreement with its publication.

Conflicts of interest

No financial, legal, or political conflicts involving third parties (government, private corporations and foundations, etc.) have been declared for any aspect of the submitted work (including, but not limited to, grants and financing, advisory board participation, study design, preparation manuscript, statistical analysis, etc.).

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