ISSN 1980-5918
Fisioter. Mov., Curitiba, v. 29, n. 4, p. 821-830, Oct./Dec. 2016
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DOI: http://dx.doi.org/10.1590/1980-5918.029.004.AR02

Use of Powerbreathe® in inspiratory muscle training for athletes: systematic review

A Utilização do Powerbreathe® no treinamento muscular inspiratório por atletas: revisão sistemática

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Abstract

Introduction: Inspiratory muscle training (IMT) has been used as part of athletic training. It is beneficial due to an increase in respiratory capacity, and can be related to the optimization of exercise tolerance. There are a growing number of publications on the subject, however the methodological rigor of these publications is still unknown. **Objective**: To perform a systematic literature review in order to analyze the effects of Powerbreathe® on inspiratory muscle training by athletes. **Methods**: Original scientific studies published in English, from 2000 to 2015, were included. Their typology was classified. The literature search was performed in the Lilacs, Medline, Pubmed, and Scielo databases using the following keywords: inspiratory muscle training, athletes, and Sports medicine (in English), treinamento muscular inspiratório, atleta, medicina esportiva (in Portuguese). Results: Inspiratory muscle training with specific linear resistance has been used in some athletic training, and its results are promising. However, its application is still recent and generally supported by experiments with limited population and which do not properly define the confounding factors for the results. **Conclusion**: The state of the art suggests that IMT is useful as a respiratory therapy supporting the training of athletes for some specific sports. However, there is a scarcity of studies of high methodological quality, thus requiring further experiments on the subject.

Keywords: Breathing Exercises. Respiratory Muscles. Athletes. Sports Medicine. Motor Activity.

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Resumo

Introdução: *O treinamento muscular inspiratório (TMI) vem sendo utilizado como coadjuvante na preparação do atleta. Seu benefício viria no aumento da capacidade respiratória, podendo estar relacionado com a otimização da tolerância ao exercício. É crescente o número de publicações sobre o assunto, contudo o rigor metodológico destas publicações ainda é desconhecido.* ***Objetivo****: Realizar uma revisão sistemática da literatura, a fim de analisar os efeitos do Powerbreathe® no treinamento muscular inspiratório por atletas.* ***Métodos****: Foram incluídos estudos científicos originais, classificados na sua tipologia, no idioma inglês, publicados entre 2000 e 2015. A busca dos artigos foi realizada nas bases de dados: Lilacs; Medline; Pubmed; Scielo, utilizando os seguintes descritores: treinamento muscular inspiratório, atleta, medicina esportiva (em português), inspiratory muscle trainaing, athletes e Sports medicine (em inglês).* ***Resultados****: O treinamento muscular inspiratório com resistor linear específico tem sido utilizado na preparação de algumas modalidades esportivas, seus resultados são promissores. Porém, sua aplicação ainda é recente, e em geral embasada por experimentos com população limitada e sem delimitar adequadamente os fatores de confusão para os resultados encontrados.* ***Conclusão****: O estado da arte sugere que o TMI é útil como terapêutica respiratória coadjuvante à preparação do atleta de algumas modalidades esportivas específicas. Contudo, escassez na literatura de estudos com alta qualidade metodológica, demanda maiores experimentos sobre o tema.*

Palavras-chave*: Exercícios Respiratórios. Músculos Respiratórios. Atletas. Medicina Esportiva. Atividade Física.*

Introduction

High-performance athletic training includes numerous variables, all of which have a significant influence on final performance in the sport (1, 2). Physical training is crucial for optimization of exercise performance, either to gain strength and power, or to prevent musculoskeletal injuries (3, 4). Cardiovascular conditioning focuses on maximizing perfusion capacity, thereby preventing lactic acidosis, which knowingly compromises performance (4, 5). However, a forgotten facet is respiratory training (6, 7). Its benefits are associated with a greater supply of oxygen to the tissues, thereby providing a differentiated physical performance (8 - 16).

The respiratory system and its regulatory centers control the levels of oxygen (O_2) and carbon dioxide (CO_2), which is released at higher levels in bursts of activity or activity sustained for a long period (17 - 19). Recent studies suggest that the inspiratory muscles can interfere in the performance of physical exercise in athletes, precisely because in physically stressful conditions, when the production of free radicals exceeds elimination capacity, a reflex sympathetic reaction of peripheral vasoconstriction would be triggered, leading to early fatigue in skeletal muscles and dramatically reducing performance in this activity. Conditioned muscles, on the other hand, have an increased tolerance, thereby slowing reflex activation (19 - 21).

Inspiratory muscle training (IMT) is a therapeutic modality that overcomes resistance against muscles responsible for expanding the rib cage. This effort must be controlled, specific and repeated at regular intervals. Its application has been demonstrated as a viable strategy for optimizing the respiratory capacity (22 - 28), thereby allowing this person to always expand his/her physical tolerance to adverse situations during practice (29 - 36).

Powerbreathe® is one of the existing linear load resistor models on the market, which generates resistance via a spring-loaded system or an electronic valve. The basic difference between this tool and the others is its ability to offer the largest load during the therapy, and to adapt inspiratory resistance to the pressure x lung volume curve (13, 37), which could generate load stabilization along the breath, by providing a feeling of comfort to the patient. Up until now this concept has a physiological basis.

Currently, a growing amount of evidence on the use of IMT associated with various sports has been published (22, 29 - 36). However it is necessary to systematically analyze the methodological rigor of these experiments in order to delimit the real benefit of IMT in athletic training. In addition, knowledge about this therapeutic resource – its indication, dosage and benefits – is still not familiar to most of the scientific community. Thus, the aim of this study is to perform a systematic review of the literature in order to analyze the effects of Powerbreathe® on inspiratory muscle training by athletes.

Methods

This study was a systematic literature review on the use of inspiratory muscle training, using a specific linear resistor by athletes. The study was performed from October of 2013 to March of 2014.

Inclusion criteria

Original scientific studies were included, classified according to their typology as descriptive, experimental or causal-comparative; published between 2000-2015; inspiratory muscle training with Powerbreathe® was a dependent variable in different protocols; athletic training was a dependent variable; various sports were included in their sample; had no athletes using another respiratory therapy in the studies; had a sample characterized by a group combination therapy with sports or an equivalent practice; was clear regarding the samples and the different analyses performed.

Search strategy

Initially these descriptors were established: inspiratory muscle training, athlete, sports medicine, when in the vernacular and in English language, “inspiratory muscle training”, “athletes” and “Sports medicine” (in English), available in Descriptors of Health Sciences (DeCS) and the Medical Subject Headings (MeSH). In order to maximize the search, synonyms were adapted, as well as the related words used in the retrieved papers found previously.

By respecting the operational differences of each database, when possible, we decided to search in the primary fields "Title" or "Keywords" using "or" and "and" as connectors and the term "athletes" as a limitation. The survey was performed in the following databases: Lilacs, Medline, Pubmed, Scielo.

Selection criteria

Developed by the Physiotherapy Evidence Database, the PEDro scale is a tool that quantifies the methodological quality of randomized clinical trials (RCT), or quasi-randomized studies. It has external validity (criterion 1, not considered), internal validity criteria (2 - 9, considered) and if there is sufficient statistical analysis in the results of the experiment, this should be considered (criteria 10 and 11) (38 - 40). Thus, the criteria are classified dichotomously as "satisfied" or "not satisfied", and can have a maximum degree of methodological requirement, reaching a total of ten points.

Although this scale was adopted as a selection tool for this systematic review, considering the inability to blind those responsible for the intervention and the athletes who participated in experiments with IMT, the chosen cutoff point was > 3 (39).

The PEDro scale was also used as a tool for selecting non-experimental studies accepted according to the inclusion criteria. However, these studies needed to meet criteria 1, 10 and 11, at a minimum, to legitimize their potential generalization and interpretation of results (38, 40).

The articles identified in the search strategy were evaluated independently and in a blinded fashion by two researchers (BRVNJ and TBG), strictly observing the inclusion criteria. The article selection was initiated using the key words, followed by the article selection according to the titles, which would focus on inspiratory muscle training in association with sports practice. In the next stage, the abstracts of the preselected articles were read and studies were included that satisfied the inclusion criteria described above.

Finally, due to the established cutoff point for the selection criteria, the most experienced researcher in this particular topic independently analyzed the experiments.

Results

Eight hundred thirty-six articles were found using the descriptors. After reading the titles, 36 articles remained on the use of the selected linear resistor in athletes. After methodological examination, eight articles were selected that met the established inclusion criteria; two were excluded because they had a PEDro score ≤ 3. Six clinical trials were included in this systematic review. Figure 1 shows the flowchart for article selection.

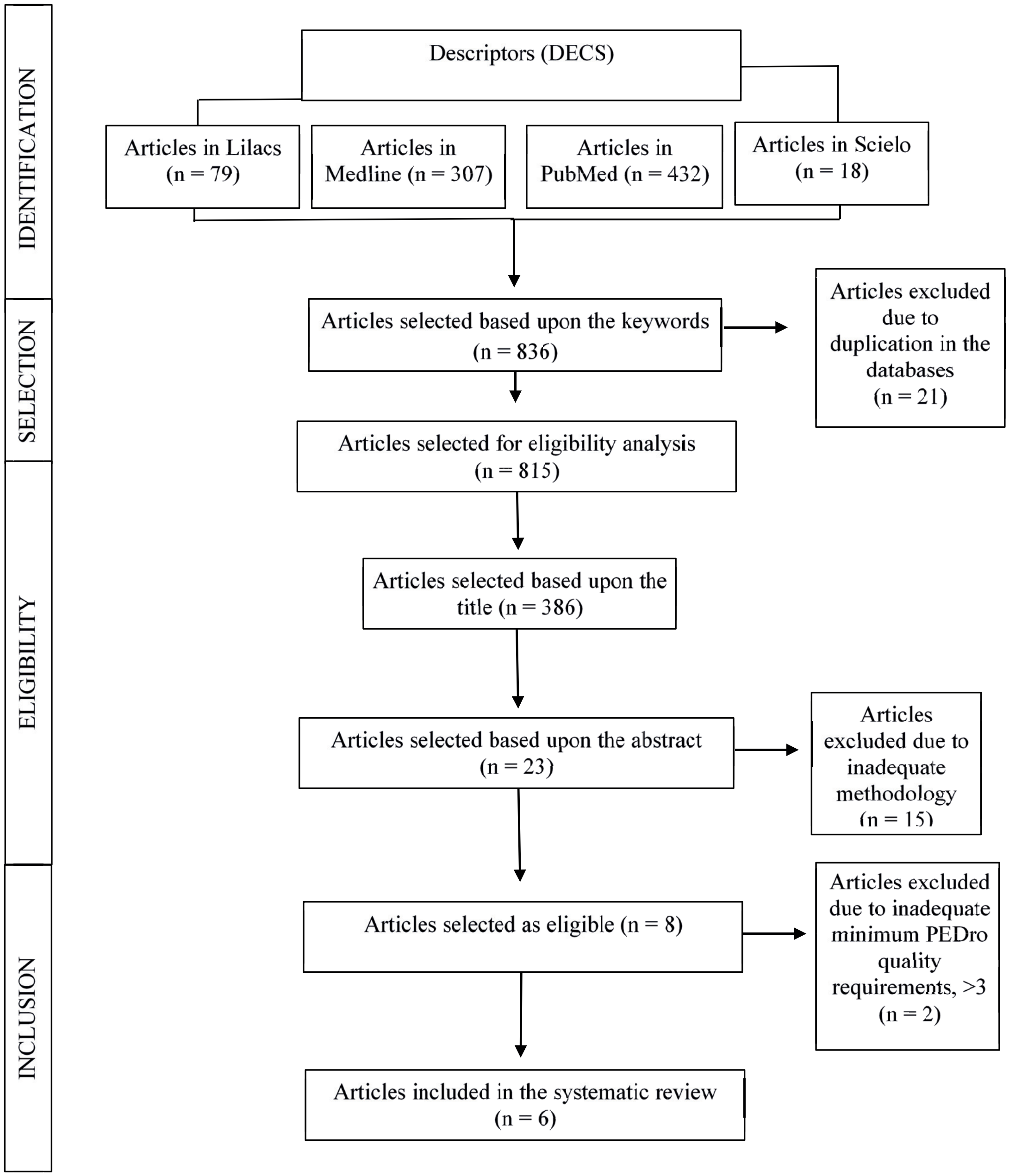

Figure 1 - Flowchart of the article selection steps in the systematic review.

Study characteristics and quality

The evaluation of methodological quality using the PEDro scale had a mean score of 4.5 (4 - 5). Table 1 shows details on the methodological and quality evaluation of the studies. Only one study used a third group with IMT association with expiratory muscle training (EMT) in this review (29), and one article was performed outside the United Kingdom (UK) (36). The low quality identified by the PEDro scale signals to the need for further studies with greater methodological rigor.

Table 1 - Stratification of IMT studies in the athlete through the PEDro Scale.PEDro (Physiotherapy Evidence Database), available from http://www.pedro.fhs.usyd.edu.au (38 - 40) (To be continued)

Author	Study design	Locality	Program	PEDro scale
Volianitis et al. (30)	Randomized clinical trial	Wolverhampton, UK	IMT with Powerbreathe® + Rowing training	04/10
Romer et al. (31)	Randomized clinical trial	Brunel, UK	IMT with Powerbreathe® + Cycle ergometer training	05/10

Table 1 - Stratification of IMT studies in the athlete through the PEDro Scale.PEDro (Physiotherapy Evidence Database), available from http://www.pedro.fhs.usyd.edu.au (38 - 40)

Romer and McConnell (32)	Randomized clinical trial	Brunel, UK	IMT with Powerbreathe® + Cycle ergometer training	05/10
Griffiths and McConnell (29)	Randomized clinical trial	Brunel, UK	EMT vs IMT / EMT + Rowing ergometer training	05/10
Johnson et al. (35)	Randomized clinical trial	Nottingham, UK	IMT with Powerbreathe® + Cycle ergometer training	04/10
Kilding et al. (36)	Randomized clinical trial	Auckland, New Zealand	IMT with Powerbreathe® + Swimming Training	04/10

Eligibility and randomization were implemented in all studies; however, only three of them clearly stipulated how randomization was performed. The therapists were not blinded in any article. Table 2 expresses the intervention protocols applied in each study, as well as the IMT program duration. This table also demonstrates that biking was the sport in 50% of studies, followed by rowing (33.3%), and swimming (16.6% of the studies).

Table 2 - Inspiratory muscle training protocols (TMI) and association with the sport. IMT = Respiratory Muscle Training; MIP = maximal inspiratory pressure

(To be continued)

Author (year)	Sport	Sample	Application protocol	Training time
Volianitis et al. (30)	Rowing	14	Load 50% of MIP, 30 repetitions, 2 times a day.	11 weeks
Romer et al. (31)	Cycling	16	Load 50% of MIP, 30 repetitions, 2 times a day.	06 weeks
Romer and McConnell (32)	Cycling	16	Load 50% of MIP, 30 repetitions, 2 times a day.	06 weeks
Griffiths and McConnell (29)	Rowing	17	Load 50% of MIP, 30 repetitions, 2 times a day.	04 weeks

Table 2 - Inspiratory muscle training protocols (TMI) and association with the sport. IMT = Respiratory Muscle Training; MIP = maximal inspiratory pressure

(Conclusion)

Author (year)	Sport	Sample	Application protocol	Training time
Johnson et al. (35)	Cycling	18	Load 50% of MIP, 30 repetitions, 2 times a day.	06 weeks
Kilding et al. (36)	Swimming	16	Load 50% of MIP, 30 repetitions, 2 times a day.	06 weeks

Characteristics of the population included in the studies

The studies used a population of young adults, with a mean age of 22.9 ± 2.8 years. There was gender balance in the studies; three studies included only male athletes, two included male athletes, and Kilding et al. (36) included athletes of both genders.

Inspiratory muscle training intervention program

The included articles had a standardized frequency of IMT. All studies used an inspiratory load of approximately 50% of maximal inspiratory pressure (MIP), one series of 30 breaths, repeated twice daily. At the same time, this uniformity did not extend to the time taken to perform the IMT protocols, with a period ranging from four to 11 weeks of training. Four studies, equivalent to 66.6% of the articles, adopted six weeks of IMT associated with sports training.

Measured outcomes

The article search addressing association of concomitant sports training to an IMT protocol suggests benefits to lung capacity, mainly expressed by the improvement of MIP, present in 62.5% of the articles. In addition, referred gains of associated training included reduced perceived exertion during sports practice, measured by the Borg scale. One study (31) found a statistically significant increase in the maximum volume of oxygen ($MaxVO_2$). The improved sports performance in regard to timed activity can also be related to the combination of therapeutic modalities (Table 3).

Table 3 - Benefits of Inspiratory muscle training (IMT) with Powerbreathe® in association with sports training

Author	Study design	Population	Intervention	Results
Volianitis et al. (30)	Randomized clinical trial	14 athletes	IMT group: 30 repetitions, twice daily, load of 50% MIP; Placebo group: 60 breaths once daily, load of 15% MIP.	IMT group increased respiratory muscle strength to 44 ± 25 cm H_2O (45.3 ± 29.7%) compared with only 6 ± 11cm H_2O (5.3 ± 9.8%) in the placebo group ($P < 0.05$, between groups). The distance walked in the 6-minute maximum effort test was 3.5 ± 1.2% compared to 1.6 ± 1.0% in the placebo group ($p < 0.05$). The 5000m time decreased to 36 ± 9s in the intervention group compared to only 11 ± 8s in the placebo group ($P < 0.05$). The group resistance was improved from a deficit in IMP of 11.2 ± 4.3% to only 3.0 ± 1.6% ($p < 0.05$), before and after intervention.
Romer et al. (31)	Randomized clinical trial	16 athletes	IMT group: 30 repetitions, twice daily for six weeks, load of 50% MIP; Placebo group: 60 cycles once daily load of 25% MIP for six weeks	An improvement of respiratory function, with significant increase in MIP (28 ± 7%), $MaxVO_2$ (17 ± 4%), Max W (49 ± 16%) in the intervention group ($p < 0.01$), a reduction of 8±1.2% in lactate values, without statistical significance. A reduction in the perception of respiratory and peripheral effort in the IMT group compared to the placebo (Borg: 16 ± 4% and 18 ± 4%, $P < 0.01$), respectively
Romer and McConnell (32)	Randomized clinical trial	16 athletes	IMT group: 30 repetitions, twice a day for six weeks, load of 50% MIP; Placebo group: Load of 25% MIP for six weeks	Improvement in the inspiratory muscle function in IMT group ($p \leq 0.05$); improvement in the simulated clock test to 20 and 40 km (66 ± 30" and 115 ± 38" faster, respectively, $p = 0.025$ and 0.009).
Griffiths and McConnell (29)	Randomized clinical trial	17 athletes	IMT group (four weeks): 30 repetitions, twice daily for four weeks, load of 50% MIP; IMT/EMT group: individual training of IMT or EMT for four weeks, the following two weeks combining IMT/EMT: 30 repetitions, twice daily, load of 50% IMT/EMT;	IMT group had an increase of 26% in MIP ($P < 0.001$) and an improvement in performance during ergometric rowing exercise for six minutes of 16.2 meters ($p = 0.02$). IMT/EMT group showed no statistically significant gain for the variables of interest.
Johnson et al. (35)	Clinical trial	18 athletes	IMT group: 30 repetitions, twice daily for six weeks, load of 50% MIP; Placebo group: 30 repetitions, twice daily for six weeks, no load;	The MIP increased by 17.1 ± 12.2% for the IMT group ($p < 0.01$) and was accompanied by a reduction of 2.66 ± 2.51% of the time taken to go 25km ($p < 0$ 05), and there were no changes compared to group placebo. There was an improvement in physical endurance during cycling in the IMT group (18.3 ± 15.1%, $p < 0.05$).
Kilding et al. (36)	Clinical trial	16 athletes	IMT group: 30 repetitions, twice daily for six weeks, load of 50% MIP; Placebo group: 60 breaths daily, load of 15% MIP for six weeks	A substantial reduction in swimming times in 100m (1.7 ± 1.4%, $p < 0.05$), 200m (1.5 ± 1.0%, $p = 0.02$), and 400m showed no significance, with a change of 0.6 ± 1.2% ($p = 0.363$).

Note: HR = Heart rate; IMT= Respiratory muscle training; MIP: Maximum inspiratory pressure; MEP: Maximum expiratory pressure; $PETCO_2$ = pressure of end-tidal carbon dioxide; EMT= Expiratory muscle training; TV= Tidal volume; VFC = Vital functional capacity.

Discussion

The use of IMT using a specific linear resistor showed benefits for respiratory capacity. In addition, the reviewed studies suggested that the association between IMT and specific athletic physical training could improve physical performance, when compared to a control group.

The exposure of inspiratory muscles to a training program with controlled and individualized load, repeated regularly, provides gain in sarcomeres, increasing muscle volume and its ability to generate strength. This information is still empirical, based on muscle physiology. However, in line with this reasoning, this review with athletes submitted to IMT led to an improvement in MIP compared to the placebo group, with a gain of between 17 - 28% in the baseline studies. The heterogeneity between the time taken for the training protocol is a plausible explanation for this variability in the final MIP.

The IMT protocol was useful when comparing the training of athletes in different sports. Swimming, rowing and cycling were the sports that were associated with respiratory training. In these experiments, there was a strong association between the associated program and the improvement in physical performance during the test against the clock. It should be noted that all six studies had small populations, with less than 20 athletes, which is insufficient to rule out possible confounding factors. Studies were found that used IMT with soccer, running and tennis amateurs (22, 34). However, they did not include the aim of this review.

The athletes treated with IMT with a linear load device had a minimized variability of heart rate (HR), respiratory rate (RR) and feeling of dyspnea, as reported by the Borg scale (20, 31). These findings suggest that this treatment could improve tolerance during sports practice. Romer et al. (31), in studies with cyclists, improved $MaxVO_2$ following an associated program for six weeks, as compared to a placebo.

Sheel et al. (19), in 2001, reported that inspiratory muscle fatigue activated a sympathetic reflex reaction of peripheral vasoconstriction, which would precipitate limb muscle fatigue during physical activity. This condition was known as metaboreflex. McConnell and Lomax (21), in a clinical trial using different IMT protocols associating lower limb (LL) exercises, observed early lower limb fatigue in the group exposed to severe respiratory muscle overload (greater than 70% of MIP). After the TMI protocol, the duration of fatigue with LL physical activity significantly increased.

All six studies included in this systematic review performed intervention protocols with thirty breaths under inspiratory resistance, equivalent to 56% of the MIP, repeated twice, seven days a week. This standardization facilitates comparison between studies and enables the adoption of this protocol in future studies.

Volianitis et al. (30) found an improvement in the six-minute all-out effort test with a rowing ergometer, in a study with rowers. The IMT program associated with ergometry found an improvement of 3.5 ± 1.2% in the distance covered in kilometers in the intervention group, compared with a 1.6 ± 1.0% gain in the placebo group, $p < 0.05$. The study by Griffiths and McConnell (29), using the same submaximal testing to assess gain between IMT and IMT/EMT groups, found that the IMT group had a mean improvement of 16.2 m in the final distance in kilometers, with $p = 0.02$. The benefit was not evidenced for the IMT/EMT group. The alternating between IMT and EMT, associated with the small sample per group, are the main factors that could explain the lack of gain in the IMT/EMT group.

Of the six studies selected for this systematic review, five were performed in the UK, the place in which Powerbreathe® was created. Only the study by Kilding et al. (36) was performed in New Zealand. This observation could support the small propagation of scientific knowledge about the benefits of IMT for athletes. With regard to the choice of this linear resistor device for this population, it should be noted that the initial MIP of the population under study was 103 ± 7cmH2O. This magnitude, considered high compared to the mean of the general population, would impair the use of other resistors available on the market, since in most cases they have maximum inspiratory load lower than what is therapeutic for this MIP.

With regard to the stratification with the PEDro scale, low methodological rigor was observed, with mean scores between 4 and 5. The similarity between the methods used probably is related to the fact that most of the studies were performed by the same group. Future studies are needed with larger populations that seek to blind investigators and athletes about the performed intervention. Of the eight studies selected as eligible for the review, two were excluded because they had a PEDro score ≤ 3. This criterion aimed to ensure the quality of evidence analyzed in this review.

Table 3 shows benefits of IMT using linear resistor for athletes. Kilding et al. (36) found a reduced swim time for 100m ($p = 0.05$) and 200m ($p = 0.032$) after IMT. Volianitis et al. (30), in studies with rowers, found an improvement in the 500m rowing time (reduction of 36' 69" in the IMT group *versus* a reduction of 11' 8" in the placebo group, with $p < 0.05$). Romer et al., in a study with cyclists, also evidenced an improved duration of 20km and 40km time-trials ($p = 0.025$ and 0.0009, respectively). This evidence is encouraging, and explains the need for further studies with larger populations and other sports. Only then will there be consensus for a recommendation to include IMT using a linear resistor in athletic training programs.

Conclusion

This systematic review has shown that the association between IMT and sports training favors the increase in MIP of athletes, but there is also a relationship with the improved performance in timed tests. The identified studies had a low methodological rigor, with small populations, and without the elimination of possible confounding factors. The IMT practice can be used in athletic training. However, it is necessary to eliminate gaps regarding the duration of the protocol, the sports for which it is beneficial, and studies that blind the population exposed to the intervention, thereby enabling elimination of psychological factors associated with the best final performance.

The state of the art suggests that IMT is useful as an associated therapeutic resource in training for some specific sports. However, further studies with larger populations are necessary, which delineate the confounding factors and utilize greater methodological rigor.

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Received in 11/29/2014
Recebido em 29/11/2014

Approved in 11/09/2015
Aprovado em 09/11/2015