Literature Review

Ventilatory muscle training in tetraplegic patients after traumatic medal injury: integration review

Treinamento muscular ventilatório em pacientes tetraplégicos pós lesão medular traumática: revisão integrativa

Bruno Souza de Matos[1]
Andressa Santana Montino de Melo[2]
Tatiana Maita Alves Conceição[3]

[1]Corresponding author. Centro Universitário Jorge Amado (Salvador). Bahia, Brazil. bruno_souza1801@hotmail.com
[2,3]Centro Universitário Jorge Amado (Salvador). Bahia, Brazil. andressamontinomelo@gmail.com, tatianamaita@bol.com.br

ABSTRACT | INTRODUCTION: Spinal trauma is a disabling clinical condition that can trigger quadriplegia, described as partial or complete paralysis of the trunk, respiratory muscles and limbs, favoring the onset of complications, mainly of a respiratory nature. Therefore, the Physiotherapist can use ventilatory muscle training (TMV) in order to increase the strength and fatigue resistance of the ventilatory muscles, in addition to preventing respiratory complications. **OBJECTIVE:** To describe which devices, protocols and techniques are most used for ventilatory muscle training and the associated effects in quadriplegic individuals after spinal cord trauma. **METHODOLOGY:** A bibliographic survey was carried out between November 2019 and February 2020, in the Medline, LILACS and SciELO databases using the keywords: Breathing Exercises, Spinal Cord Injuries, Quadriplegia and synonyms using the Boolean operators "AND" and " OR ". **RESULTS:** After consulting the databases, 3334 articles were found, 36 were selected for reading the summary, with 23 being excluded for not meeting the selection criteria, leaving 12 articles for the full reading, resulting in the final selection of 12 articles. **CONCLUSION:** It is evidenced that protocols for TMV through linear resistors are the most used quadriplegics. In addition, execution of protocols with linear resistors to inspiration, using intensity around 30-60% of MIP, had significant effects on MIP. However, it was noticed that there are many disagreements regarding the training variables, mainly intensity and number of series proposed. However, it is clear that the use of TMV in quadriplegics presents certain divergences, mainly related to the choice of appropriate techniques and / or devices.

KEYWORDS: Breathing exercises. Spinal cord injuries. Quadriplegia.

RESUMO | INTRODUÇÃO: O Trauma Raquimedular é uma condição clínica incapacitante que pode desencadear a tetraplegia, descrita como paralisia parcial ou completa do tronco, músculos respiratórios e membros, favorecendo o surgimento de complicações, principalmente de caráter respiratório. Diante disso, o Fisioterapeuta pode utilizar treinamento muscular ventilatório(TMV) objetivando aumentar a força e resistência à fadiga dos músculos ventilatórios, além de prevenir complicações respiratórias. **OBJETIVO:** Descrever quais os dispositivos, protocolos e técnicas mais utilizadas para treinamento muscular ventilatório e os efeitos associados em indivíduos tetraplégicos pós trauma raquimedular. **METODOLOGIA:** Foi realizado levantamento bibliográfico entre novembro de 2019 e fevereiro de 2020, nas bases de dados Medline, LILACS e SciELO utilizando as palavras-chave: *Breathing Exercises*, *Spinal Cord Injuries*, Quadriplegia e os sinônimos utilizando os operadores booleanos "AND" e "OR". **RESULTADOS:** Após consulta nas bases de dados, foram encontrados 3334 artigos, 36 foram selecionados para leitura de resumo, sucedendo que 23 foram excluídos por não atender aos critérios de seleção, restando 12 artigos para a leitura integral, resultando na seleção final de 12 artigos. **CONCLUSÃO:** Fica evidenciado que protocolos para TMV através de resistores lineares são os mais utilizados tetraplégicos. Além disso, execução de protocolos com resistores lineares a inspiração, empregando intensidade em torno de 30-60% da PImax, apresentou efeitos significativos em PImax. No entanto, percebeu-se que há muitas discordâncias quanto as variáveis de treinamento, principalmente intensidade e número de séries propostos. Contudo, é notório que a utilização do TMV em tetraplégicos apresenta certas divergências, principalmente relacionado a escolha das técnicas e/ou dispositivos adequados.

PALAVRAS-CHAVE: Exercícios respiratórios. Traumatismos da medula espinal. Quadriplegia.

Submitted 03/08/2020, Accepted 04/27/2020, Published 05/15/2020
J. Physiother. Res., Salvador, 2020 May;10(2):334-345
Doi: 10.17267/2238-2704rpf.v10i2.2809 | ISSN: 2238-2704
Designated editor: Cristiane Dias

How to cite this article: Matos BS, Melo ASM, Conceição TMA. Ventilatory muscle training in tetraplegic patients after traumatic medal injury: integration review. J Physiother Res. 2020;10(2):334-345. doi: 10.17267/2238-2704rpf.v10i2.2809

Introduction

The Spinal Cord Injury (SCI) is considered by the World Health Organization (WHO) as a serious public health problem that occurs due to a traumatic event causing spinal cord injury[1,2]. The worldwide incidence of SCI is 10.5 cases per 100,000 people, resulting in an estimated 768,473 new cases of spinal cord injury annually worldwide[3,4]. The clinical manifestations depend on the extent and location of the injury. This clinical condition is disabling and generates autonomic dysfunctions, partial or total loss of voluntary motor skills and / or sensitivity (tactile, painful, profound), in addition to causing dysfunction of the respiratory muscles[3].

Immediately after a traumatic spinal cord injury, there is a period of spinal shock, resulting in flaccid paralysis of the muscles below the level of the injury. This paralysis generates imbalance and mechanical disadvantage resulting in less efficient ventilation, increased respiratory work and a tendency to collapse the distal airways and microatelectasis, causing respiratory dysfunctions. These respiratory repercussions are the most common cause of mortality after spinal cord injury[5,6] and are responsible for about 80% of deaths in hospitalized patients with cervical injuries, with pneumonia being responsible for 50% of them[7].

In the multiprofessional scope of respiratory assistance, the physiotherapist can employ a set of procedures and techniques that enable better respiratory rehabilitation. Among them, ventilatory muscle training (VMT) stands out, which aims to improve or redistribute ventilation, increase strength, fatigue resistance and coordination of respiratory muscles, improve coughing capacity and improve the patient's functional capacity for activities of daily life. The indication of respiratory muscle strengthening is assessed by identifying weakness of these muscles[8,9].

The objective of this integrative review was to describe which devices, protocols and techniques are most used for ventilatory muscle training and the associated effects in quadriplegic individuals after spinal cord trauma.

Methodology

This study is an Integrative Review, which is a review method elaborated based on a broader process, as it covers theoretical and empirical literature so that it includes studies with different types of methodological approaches that can be quantitative and / or qualitative[10,11]. To design this article, the electronic databases Scientific Electronic Library (SciELO), Latin American Literature in Health Sciences (LILACS), and PubMed / MEDLINE were consulted. The search was carried out between November 2019 and February 2020.

The keywords Breathing Exercises, Spinal Cord Injuries, Quadriplegia and synonyms were used according to the databases, identified in the Health Sciences Descriptors (HSD) and Medical Subject Headings (MeSH), using the Boolean operators "AND "and" OR "as shown in Chart 1. The selection of articles should conform to the following inclusion criteria: year of publication between 2008 and 2020; to address ventilatory muscle training only in quadriplegic patients after spinal cord injury, regardless of the level affected. In relation to the exclusion criteria: articles that have escaped the theme or that addressed ventilatory muscle training in other groups of patients.

Chart 1. Keywords used in the electronic search plus the Boolean operators "AND" and "OR" and their combination

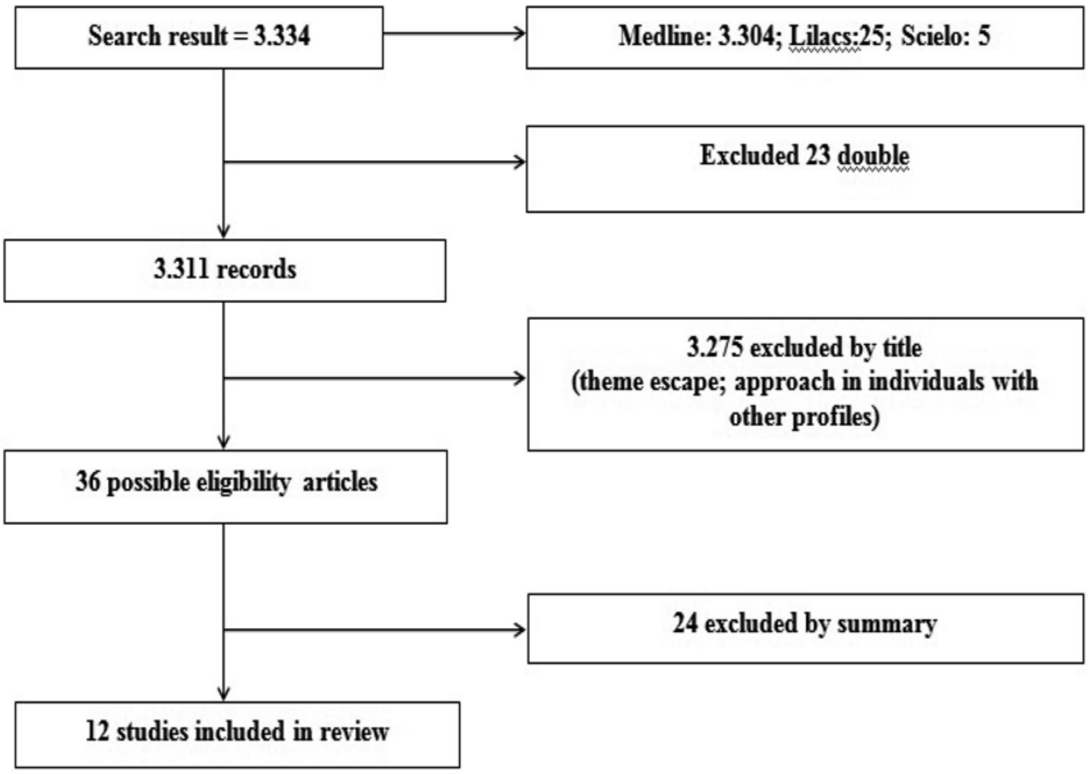
Keywords	Synonym and MeSH
Breathing Exercises	Respiratory Muscle Training
Spinal Cord Injuries	Spinal Cord Trauma
Quadriplegia	Tetraplegia
((((quadriplegia) OR (Tetraplegia)) AND (Spinal Cord Injuries)) AND (Breathing Exercises)) OR (Respiratory Muscle Training)	

In the evidence selection process, the analysis of the titles and abstracts found in the initial search according to the established eligibility criteria. If the title and abstract were not cleaners, the article would be consulted in its entirety. After critically analyzing and evaluating all studies included in the review, the articles were presented in a table highlighting the items: authors, year of publication, study design, number of participants, comparison groups, brief description of the intervention protocol (duration, intensity, frequency and interval between sessions) and summaries of the results found.

Results

The search in the databases resulted in 3,334 articles (Medline: 3,304; Lilacs: 25; Scielo: 5), resulting in 3,311 records after removing duplicates. Of these, 3,275 articles were excluded by the title because they did not meet the inclusion criteria; 36 were selected for reading the abstract, with 23 being excluded for not meeting the selection criteria, leaving 12 articles for full reading. Of these, it was found that the 12 fulfilled all inclusion criteria, resulting in the final selection of 12 articles, as shown in Figure 1. The studies included contemplated different clinical contexts and covered several types of methodological approaches, from report / case series to randomized clinical trials, as shown in Chart 2.

Figure 1. Research flow diagram



The selected publications presented in their content, the description of the devices used. Among the intervention possibilities found, there were training protocols with linear and nonlinear load resistors, normocapnic hyperpnea, as well as techniques and associated devices. It was noticed that a total of eight articles (66.6%) carried out the intervention protocols, using linear load resistors.

A number of three studies (25%) carried out the intervention protocols, through the association between Threshold IMT® (resistance to inspiration) and Threshold PEP® (resistance to expiration), described in Chart 2. In the studies by Legg Ditterline et al.[12] and Aslan et al.[13], the devices were assembled using a three-way valve system with nozzle, following their respective protocols, while the article by Boswell-Ruys et al.[14] did not provide descriptive reports of the devices used, detailing only the applied protocol. In view of this information, it was found that the application of protocols associating Threshold IMT® and Threshold PEP®, provided increases related to inspiratory (MIP) and expiratory (MEP) muscle strength, as well as vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), the peak expiratory flow (PEF) and, in addition to gains related to improved sleep, reduced orthostatic hypotension and apnea-hypopnea index.

Still with regard to the use of devices with linear load resistors, it was observed that three articles[15,16,17] performed their protocols using only Threshold IMT® (25%) in their researches (Chart 2). Through these publications, an increase in inspiratory muscle strength was noted in both articles and an increase in expiratory muscle strength only in the study by Silveira et al.[15], with no positive effects on endurance.

With regard to the use of PowerBreathe® for VMT, only one study performed a protocol using this device, as described in Chart 2. The authors point out that this relatively recent handheld electronic device provides a variable flow resistive load through an electronically controlled valve. Through this protocol, McDonald and Stiller[18] highlight that a program of high resistance and low repetition of VMT is viable and safe, without causing complications registered before, during or after execution in adults with complete cervical or thoracic spinal cord injury with respiratory function stable, in the acute phase.

The study by Russian et al.[19] carried out concomitant respiratory resistance training using equipment that proposes simultaneous inspiratory and expiratory resistance, commercially described as PowerLung Performer®. This, like that of Boswell et al.[15], was one of the few articles that assessed the effects of VMT on lung function, but specifically on sleep disorders. The post-training results indicated improvements in sleep quality, as well as a reduction in daytime sleepiness, as well as an increase in MIP and MEP(Chart 2).

Still in this context, Roth et al.[20] conducted their research by applying training using a nonlinear load resistor, specifically the Boehringer meter. The authors evaluated the effects of expiratory muscle training using the Boehringer Meter, a device with a small portable plastic tube where individuals breathe out against a manometer. Resistance is given by the fact that it is a closed system, creating resistance to high pressure during exhalation. The results presented show that there was a statistically significant increase in the MEP variable ($p < 0.02$), only in the resistance training group, shown in Chart 2.

Only Van Houtte et al.[21] used the Normocapnic Hyperpnea technique for VMT. This technique consists of a breathing bag connected to a tube and mouthpiece system, with a small hole in the tube where it allows additional inspiratory and expiratory flow. The volume of the bag is about 30 to 40% of the subject's forced vital capacity (FVC). It was observed that Maximum Voluntary Ventilation (MVV), respiratory muscle strength and endurance significantly improved and respiratory complications were reported less frequently in the experimental group compared to the control group, as shown in Chart 2.

Among the studies included, two carried out the proposed training, associating different techniques or devices (Chart 2). Mueller et al.[22] compared the effects of a protocol using three different techniques: Inspiratory muscle training by means of a linear resistor with visual feedback of the achieved resistance, commercially called Respifit S®; Normocapnic hyperpnea through a device by the trade name Spirotiger®, which allows intensive hyperventilation through a new partial breath of ventilated air, supported by visual feedback; In addition to the group that performed incentive spirometry with a device known as Voldyne 5000®.

In their research, Kim et al.[23] performed their protocols through the association of incentive spirometry and abdominal traction maneuver. Regarding incentive spirometry, they claim to be one of the current techniques used to train respiratory muscles. As for the abdominal traction maneuver, they describe that this technique is designed to activate the transverse muscle of the abdomen (muscle involved in forced expiration), being commonly used in lumbar stabilization training programs. To perform the maneuver, a pressure biofeedback unit was used, with the trade name Stabilizer®, inflated to 50 mmHg, placed between the treatment table and the lower abdomen of the individuals in the prone position, subsequently requested to maintain a pressure below 6 -10 mmHg, based on visual feedback from an analog pressure gauge.

Chart 2. Articles that performed Ventilatory Muscle Training in quadriplegic individuals, published between 2008-2019 (to be continued)

Authors/ Year	Study Design	Nº particip ants	Device / Technique used	Objective	Intervention Protocol	Effects found
Legg Ditterline *et al*[12] 2018	Randomized controlled trial.	44 IG=24 CG=20	Threshold IMT® e PEP®	Evaluate the effects of VMT on heart rate variability and baroreflex sensitivity in people with chronic spinal cord injury (SCI)	INT: Not specified; FREQ: a: 5 days/ 4 weeks; Nº SERIES: Only duration time specified (45 minutes); INT. SESSIONS: Not specified;	Significant increase in FVC and FEV 1 ($p < 0.01$); Improved quality of sleep, cough and speech Significant increase in baroreflex sensitivity ($p < 0.05$); Improvement in cardiac and hemodynamic response during the stress test.
Aslan *et al*[13] 2016	Randomized controlled trial.	21 IG= 11 CG=10	Threshold IMT® e PEP®	Investigate the effects of VMT on pulmonary function and autonomic and cardiovascular responses mediated by orthostatic stress in individuals with chronic SCI.	INT: begin 20% da MIP e MEP; FREQ: 5 days/ 4 weeks; Nº SERIES: Description only nº of series (6) - 45 minutes / day; Int. SESSIONS: 3 minutes;	FVC increased significantly after VMT ($p < 0.05$); Significantly reduced the drop in blood pressure ($p < 0.05$)
Boswell-Ruys *et al*[14] 2015	Case study series	3	Threshold IMT® e PEP®	Evaluate the viability and efficacy of VMT to improve pulmonary function and obstructive sleep apnea in patients with cervical SCI.	INT: 30% of MIP and MEP; FREQ: 5 days/ 4 weeks/ 2x day; Nº SERIES: 3 series of 12 repetitions; INT.SESSIONS: Not specified;	Increase in MIP and MEP; CV, FEV1, peak expiratory flow and improved inspiratory capacity; Improved apnea-hypopnea index and Epworth sleepiness scale.
Silveira *et al*[15] 2010	Nonrandomiz ed clinical Trial	8	Threshold IMT®	Determine whether VMT can increase the strength and endurance of inspiratory muscles in patients with quadriplegia.	INT: Begin with 30% of MIP; FREQ: 5 days/ 8 weeks; Nº SERIES: Only the running time is specified (30 minutes / day) INT. SESSIONS: Not specified;	MIP was significantly higher at weeks 4 and 8 in the sitting and supine position and MEP only at the 4th week ($p < 0.05$); After 8 weeks of training, MIP increased 12% in the sitting position and 14% in the supine position ($p < 0.05$); There was no significant improvement in endurance.

Chart 2. Articles that performed Ventilatory Muscle Training in quadriplegic individuals, published between 2008-2019 (continuation)

Authors/ Year	Study Design	Nº particip ants	Device / Technique used	Objective	Intervention Protocol	Effects found
Colman e Beraldo [16] 2010	Quasi-experimental	5	Threshold IMT®	Demonstrate the possible changes in the capacity of respiratory strength in quadriplegics by means of VMT.	INT: 30% of MIP; FREQ: 3 days/ 10 weeks; Nº SERIES: Only the duration (15 minutes) is specified; INT. SESSIONS: Not specified;	Significant increase in MIP (p <0.05); Improvement in the quality of life of the subjects associated with a lower score on the Modified Borg Scale.
Postma *et al*[17] 2014	Randomized controlled trial.	40 IG=20 CG=20	Threshold IMT®	Assess the immediate and long-term effects of VTM in people with SCI.	INT: 60% of MIP; FREQ: 5 days/ 8 weeks; Nº SERIES: 7 series de 2 minutes and 1 minute of breathing without resistance; INT. SESSIONS: Not specified;	Greater improvement in MIP during the intervention period (p <0.02) but with no significant difference in follow-up; MIP improved over a longer period in participants who continued VMT after the intervention period; No differences between groups regarding other measures of respiratory function were found (FVC, PEF, FEV1)
McDonal d e Stiller[18] 2018	Prospective, observational pilot study	7	Power Breathe®	Investigate the feasibility and safety and, to a lesser extent efficacy, of VMT for patients with acute complete cervical or thoracic spinal cord injury (SCI).	INT: 50% of MIP; FREQ: 1x/day – 4 a 5 days/ 4 weeks; Nº SERIES: 3-6 series of 6 repetitions with session time <10 minutes); INT SESSIONS: desired by the participant;	There were no occasions when participants did not meet the pre-session criteria to perform the VMT; just as it did not have to be reduced during the session; No adverse safety results were identified in any of the sessions; MIP increased in four participants and FVC increased in three participants;
Russian *et al*[19] 2011	Case report.	1	Concomitant respiratory resistance – PowerLung Performer®	Describe the effects of 10 weeks of VMT on the quality of sleep of a man with cervical SCI.	INT: Not specified; FREQ: Not specified; Nº SERIES: 3 series of 10 repetitions;3x/day INT. SESSIONS: Not specified.	The number of awakenings, the amount of awakening after sleep onset and the rate of respiratory disturbances during sleep decreased from the pre to the post-test; Less fragmented sleep and better sleep quality;
Roth *et al*[20] 2010	Randomized controlled trial.	29 IG=16 CG=13	Measured Boehringer	Evaluate the effectiveness of expiratory muscle training on lung function in patients with SCI.	INT: Breathe as fast and as hard as possible; FREQ: 2x/day – 5 days/6 weeks; Nº SERIES: 10 repetitions for 3 to 5 minutes; INT. SESSIONS: No break;	There were no differences between the resistance training and simulated training groups for any of the tests, in multivariate analysis (p = 0.22) Only MEP was significantly higher for the resistance training group compared to the simulated group (p <0.002)

Chart 2. Articles that performed Ventilatory Muscle Training in quadriplegic individuals, published between 2008-2019 (conclusion)

Authors/ Year	Study Design	Nº particip ants	Device / Technique used	Objective	Intervention Protocol	Effects found
Van Houtte *et al*[21] 2008	Randomized controlled trial.	14	Normocapnic Hyperpnoea	Investigate the effects of VMT with normocapnic hyperpnea on lung function, respiratory muscle strength and endurance and on the incidence of respiratory symptoms.	INT: CG= 15% of MVV / IG=30% e 40% da MVV; FREQ: 30 min/days – 4 days/ 8 weeks; Nº SERIES: CG=15 a 25 breaths/min; IG=30 e 45 cycles/min. INT. SESSIONS: Not specified.	Significant differences were obtained for FVC (p = 0.021), MVV (p = 0.054), MIP (p = 0.011) and MEP (p = 0.0473); MEP did not improve after 4 weeks of training (p= 0.093); There were significant differences in the RRT duration between the groups after 4 (p = 0.009) and 8 weeks of training (p = 0.003), as well as after follow-up (p = 0.002).
Mueller *et al*[22] 2013	Randomized controlled trial.	24	*Respifit S*®	Compare the effects of inspiratory resistance training and normocapnic hyperpnea versus incentive spirometry (placebo) on respiratory function, voice, chest mobility and quality of life in individuals with quadriplegia.	VMTG= *Respifit S*; HG= *Spirotiger*; PG= espirometria INT: VMTG= >80% MIP; HG= 40-50% MVV; PG= 16x of RV for TLC; FREQ: 4 days/ 8 weeks – 10 minutes; Nº SERIES: Not specified. INT. entre SESSIONS: no break.	Significant effect on MIP in VMTG versus placebo (p = 0.016) and VMTG versus GH (p = 0.012); They did not have a significant effect on the other parameters of respiratory function, voice measurements, subjective breathing parameters, chest mobility or quality of life.
Kim *et al*[23] 2017	Randomized controlled trial.	37 VMTG=12 IG=13 CG=12	Incentive spirometry combined with the abdominal drawing-in maneuver	Investigate the effects of VMT combined with abdominal traction on lung function in patients with chronic spinal cord injury.	INT: Not specified FREQ: 3 days/ 8 weeks; Nº SERIES: IG: 5 series de 10 repetitions + abdominal drawing-in maneuver/ CG: 5 series of 10 repetitions with spirometry; INT. SESSIONS: 1 minute;	Significant increase in FVC and FEV1 before and after the intervention in both groups (p <0.01); The post-hoc tests revealed that the FVC and FEV1 of the subjects in the VMTG were significantly different from those in the isolated VMT (p <0.01) and CG (p<0.001) group, and those in the isolated VMT group were significantly different from those in the CG (p <0.01);

Doi: 10.17267/2238-2704rpf.v10i2.2809 | ISSN: 2238-2704

Discussion

This Integrative Review identified that there are several protocols for VMT in quadriplegics after spinal cord injury, using different methods in isolation or in association. Considering the evidence from studies carried out, the literature reports that, in general, the intensity recommended for VMT in other specific groups must be the highest supported by the patient and that it is between 50 to 70% of MIP. Regarding the training frequency, it is proposed to be performed twice a day for seven days a week, linked to a set of five sets and six repetitions, totaling 30 inspirations per session, with an interval of 60 seconds between each set[8,9,24].

Among the articles eligible for this review, which describe VMT protocols with a focus on inspiratory muscles using linear load resistors, only the study by McDonald and Stiller[18] used the intensity referring to 50% of the MIP and with progression of this load up to 90% of MIP. However, there is disagreement regarding the frequency, number of repetitions and duration of the interval, being smaller than proposed[8,24]. Mueller et al.[22] used a protocol that made an initial use of 80% of MIP, but it also pointed out differences in the other variables, mainly in reducing training time. All other authors applied the protocols with an intensity between 20 and 30% of MIP. Only the work by Boswell-Ruys et al.[14] was performed with the proposed frequency of 2 times a day, but only for 5 days a week.

Regarding the parameters of number of sets / repetitions and interval between sets, it was observed that the vast majority did not report and / or made clear about these aspects. In addition, no description of evidence-based protocols was found in the literature, in order to compare it with what was proposed by the authors for training expiratory muscles with linear load (Threshold PEP®) or not (Boehringer's Meter), as well as for incentive spirometry and associated maneuvers. As for Normocapnic Hyperpnea, the protocols found in the literature suggest application at least three times a week, with an average duration of three months[25]. Van Houtte et al.[21] performed protocols similar to the one recommended, diverging only in the duration less than three months. However, this technique seems to be limiting when its objective is VMT[26].

Although other scientific evidence points to the intensity of VMT between 50-70%, Boswell-Ruys et al.[15], Silveira et al.[16] and Colman et al.[17], carried out protocols that differ from the proposed[8,9,24], using an initial intensity around 30% of the MIP and showed that the VMT through a linear load resistor is effective for increasing respiratory muscle strength, obtaining significant gains mainly in MIP. Colman et al.[16], point out that one of the members of the study achieved one of the lowest responses, due to a lower number of attendance than the others, suggesting a possible influence on the responses regarding the intervention period, which can even be compared to the study of Silveira et al.[15], where they obtained significant responses with longer training time. Another important aspect to be highlighted in this study is related to the early intervention in which two research participants evolved considerably, as was seen in the articles by McDonald and Stiller[18] and Mueller et al.[22] and in which there was a positive influence in the studied groups, supporting the understanding that the shorter the injury time, the greater the capacity to increasing MIP[27].

Mueller et al.[22] applied a protocol with an intensity of 80% of MIP, pointing out significant effects on this variable and claiming that there is a strong relationship between MIP and coughing capacity. Park et al.[28] show that if the pre-cough volume is insufficient due to inspiratory muscle weakness, the capacity for coughing decreases. In addition, greater inspiratory muscle strength increases diaphragmatic tension during inspiration and, consequently, provides greater elastic recoil during expiration and, therefore, increases the peak expiratory flow (PEF), directly proportional to the coughing capacity[29]. However, Postma et al.[17], who used 60% intensity of MIP with a longer training time, show that IMT did not promote significant changes in the short, medium and long term, in PEF and peak cough flow (PCF), even showing an increase in MIP, which can be justified by the variability of injury levels as well as the time of spinal cord injury.

Roth and collaborators[20] were the only ones who exclusively evaluated the effectiveness of expiratory muscle training, but there were no reports of proposed protocols for this purpose in the literature. However, employing a subjective intensity (breathing faster and stronger), it was noted that only the results corresponding to MEP were significantly higher in the experimental group, however, it is not surprising that significant gains were obtained only at MEP, once the training was directed to the expiratory musculature. This finding brings a reflection on the specificity of the training, one of the bases of the VMT[8]. With these results it is suggested that a specific protocol for training expiratory muscles may have the effect of increasing the strength of and the effectiveness of the cough, promoting decreased retention of secretions in the airways and, thus, reducing the occurrence of pneumonia and other causes of respiratory morbidity[30].

Another principle of VMT is the reversibility of muscle atrophy, which supports the idea that when training is interrupted (detraining), the body is readjusted according to decreased physiological demand, and beneficial adaptations can be lost[8]. Postma et al.[17], followed the participants after the end of the training, in order to record the permanence or not of the gains. In this context, they point to a significant positive effect on MIP only in the short term. Perhaps for long-term purposes, it is necessary to maintain training, as described by Weiner et al.[31] in people with Chronic Obstructive Pulmonary Disease (COPD).

Still addressing about the aspects related to lung function, it was noted that the clinical trial by Kim et al.[23] was the only one to use a ventilatory muscle training protocol associating incentive spirometry to the abdominal traction drawing maneuver in patients with spinal cord injury . However, no study has yet been carried out to assess the effects of an integrated protocol with both techniques on quadriplegics, despite this, the study points to an improvement in lung function by increasing the pressure of the abdominal muscles. Even though it is not considered a measure of lung function, the authors believe that the abdominal muscles contribute not only to the stabilization of the spine and posture, but also with regard to pulmonary mechanics, however, MIP e MEP were not evaluated before and after intervention, these parameters being important to affirm and quantify gains in muscle performance[32].

The article by Van Houtte et al.[21] was the only one that reported VMT using the normocapnic hyperpnea technique in isolation. The literature recommends that training using this technique is not the first intervention option for VMT, as it is believed that this type of training would increase the risk of muscle fatigue[26]. However, no reports of fatigue were observed during or after implementation of the protocol. In addition, it was observed that there was no significant increase in MEP, which differs from that found by Roth et al.[21] through a specific protocol for expiratory muscles.

Regarding the effects of TMV on sleep-related parameters, Russian et al.[19] point to positive changes after the protocol was performed. However, the participant did not have some predictors of sleep-disordered breathing, such as overweight, thick neck and sleeping position in the supine position, therefore, a low respiratory disturbance index is expected[33,34]. It was also noted that the individual performed breathing exercises not specified in the study, however, even when associated with VMT, MIP did not point out significant changes, perhaps justified by the use of a device without reports found in the literature for use in this audience.

Boswell-Ruys et al.[14], explored variables similar to those of Russian et al.[19] in items related to sleep disorders, specifically Obstructive Sleep Apnea (OSA), but it is known that the problems inherent to sleep are very common in the evaluated population, although some of these problems are probably related to the high incidence of central sleep apnea, which is much more prevalent in this audience compared to OSA[35]. The authors believe that positive effects of VMT on sleep-related items may be related to the fact that this intervention favors the training of the upper airway dilator muscles, however, these muscles are not directly affected in spinal cord injured people[36]. Nevertheless, it can be deduced that these TMV protocols[14,19] are a possible alternative to treat OSA and other sleep disorders, based on the low rate of adherence to the use of CPAP (continuous positive airway pressure) in these individuals, since this is the most used tool for this clinical profile[35].

Regarding the impact of the VMT protocols on hemodynamic issues, Aslan et al.[13] and Legg Ditterline et al.[12], had similar objectives and presented the effects of VMT on the regulation of blood pressure (BP) as well as on orthostatic hypotension (OH) and baroreflex sensitivity. The effects pointed out by the authors are linked to the hypothesis that BP fluctuations during the VMT session can improve and / or increase the elasticity of baroreceptors[13]. However, this hypothesis differs from the proposal by Frisbie, where he states that postural transfers (bench press for sitting) generate fluctuations in BP and greater respiratory effort, thus increasing the venous return to the chest, also favoring the increase in cardiac output, a variable that is of great value for the stimulation of baroreceptors and, thus, responding to fluctuations in blood pressure in a more physiological way[37].

The heterogeneity of the study designs, as well as the applied protocols, is consistent with the findings of Sheel et al.[38] and Tamplin and Berlowitz[39], which may be explained by the great challenge of providing health care to this population, as that the most varied individuals can be affected by this condition, in addition to the divergence of injury levels, resulting in the impossibility of generalization the results.

Final considerations

Given this analysis, it is evident that protocols for VMT, through linear resistors, are the most used in individuals with quadriplegia, since they are also the most addressed in other audiences. In addition, it is concluded that the execution of protocols with linear resistors to inspiration, employing intensity around 30-60% of MIP, showed significant effects on MIP. However, it was noticed that there are many disagreements regarding the training variables, mainly intensity and number of series proposed. However, it is notorious that the use of VMT in quadriplegics presents certain divergences, especially with regard to the choice of appropriate techniques and / or devices, since some studies have discussed VMT using methods that have never been used in this population.

Author contributions

Matos BS, Melo ASM participated in the conception, design, search for research data, interpretation of results and writing of the scientific article. Conceição TMA participated in the conception, design, interpretation of results and writing of the scientific article.

Competing interests

No financial, legal or political competing interests with third parties (government, commercial, private foundation, etc.) were disclosed for any aspect of the submitted work (including but not limited to grants, data monitoring board, study design, manuscript preparation, statistical analysis, etc.).

References

1. Eckert MJ, Martin MJ. Trauma: Spinal Cord Injury. Surg Clin North Am. 2017;97(5):1031-1045. doi: 10.1016/j.suc.2017.06.008

2. World Health Organization. Spinal cord injury. [Internet]. 2013. [acesso em 2020 abr. 17]. Disponível em: https://www.who.int/news-room/fact-sheets/detail/spinal-cord-injury.

3. Kirshblum SC, Burns SP, Biering-Sorensen F, Donovan W, Graves DE, Jha A et al.. International standards for neurological classification of spinal cord injury (Revised 2011). J Spinal Cord Med. 2011;34(6):535-546. doi: 10.1179/204577211X13207446293695

4. Brunozi AE, Silva AC, Gonçalves LF, Veronezi RJB. Qualidade de Vida na Lesão Medular Traumática. Rev Neurocienc. 2011;19(1):139-144.

5. Kumar R, Lim J, Mekary RA, Rattani A, Dewan MC, Sharif SY et al. Traumatic spinal injury: global epidemiology and worldwide. World Neurosurg. 2018;113:345-363. doi: 10.1016/j.wneu.2018.02.033

6. França ISX, Coura AS, Sousa FS, Almeida PC, Pagliuca LMF. Qualidade De Vida Em Pacientes Com Lesão Medular. Rev Gaúcha Enferm. 2013;34(1):155-163. doi: 10.1590/S1983-14472013000100020

7. Berlowitz DJ, Wadsworth B, Ross J. Respiratory problems and management in people with spinal cord injury. Breath. 2016;12(4):328-340. doi: 10.1183/20734735.012616

8. Capó-Juan MA. El paciente con lesión medular en fase crónica. Revisión del tratamiento fisioterápico. FisioGlía. 2016;3(1):5-12.

9. Nepomuceno Junior BRV, Gomes-Neto M. Treinamento Muscular Inspiratório no ambiente hospitalar: protocolo para um ensaio clínico randomizado. Revista Pesq. 2016;6(2):158-166. doi: 10.17267/2238-2704rpf.v6i2.896

10. Nepomuceno Junior BRV, Barreto MS, Almeida NC, Guerreiro CF, Xavier-Souza E, Neto MG. Safety and efficacy of inspiratory muscle training for preventing adverse outcomes in patients at risk of prolonged hospitalisation. Trials. 2017;18(1):626. doi: 10.1186/s13063-017-2372-y

11. Botelho LLR, Cunha CCA, Macedo M. O método da revisão integrativa nos estudos organizacionais. Gestão E Sociedade. 2011;5(11):121-136. doi: 10.21171/ges.v5i11.1220

12. Legg Ditterline BE, Aslan SC, Randall DC, Harkema SJ, Castillo C, Ovechkin AV. Effects of Respiratory Training on Heart Rate Variability and Baroreflex Sensitivity in Individuals with Chronic Spinal Cord Injury. Arch Phys Med Rehabil. 2018;99(3):423-432. doi: 10.1016/j.apmr.2017.06.033

13. Aslan SC, Randall DC, Krassioukov AV, Phillips A, Ovechkin AV. Respiratory Training Improves Blood Pressure Regulation in Individuals With Chronic Spinal Cord Injury. Arch Phys Med Rehabil. 2016;97(6):964-73. doi: 10.1016/j.apmr.2015.11.018

14. Boswell-Ruys CL, Lewis CRH, Gandevia SC, Butler JE. Respiratory muscle training may improve respiratory function and obstructive sleep apnoea in people with cervical spinal cord injury. Spinal Cord Ser Cases. 2015;1:15010. doi: 10.1038/scsandc.2015.10

15. Silveira JM, Gastaldi AC, Boaventura CM, Souza HC. Treinamento de músculos inspiratórios em pacientes com quadriplegia. J Bras Pneumol. 2010; 36(3):313-319. doi: 10.1590/S1806-37132010000300008

16. Colman ML, Beraldo PC. Estudo das variações de pressão inspiratória máxima em tetraplégicos, tratados por meio de incentivador respiratório, em regime ambulatorial. Fisioter Mov. 2010;23(3):439-449. doi: 10.1590/S0103-51502010000300011

17. Postma K, Haisma JA, Hopman MT, Bergen MP, Stam HJ, Bussmann JB. Resistive Inspiratory Muscle Training in People With Spinal Cord Injury During Inpatient Rehabilitation: A Randomized Controlled Trial. Phys Ther. 2014;94(12):1709-19. doi: 10.2522/ptj.20140079

18. McDonald T, Stiller K. Inspiratory muscle training is feasible and safe for patients with acute spinal cord injury. J Spinal Cord Med. 2019;42(2):220-227. doi: 10.1080/10790268.2018.1432307

19. Russian C, Litchke L, Hudson J. Concurrent respiratory resistance training and changes in respiratory muscle strength and sleep in an individual with spinal cord injury: case report. J Spinal Cord Med. 2011;34(2):251-4. doi: 10.1179/107902611x12972448729602

20. Roth EJ, Stenson KW, Powley S, Oken J, Primack S, Nussbaum SB et al. Expiratory muscle training in spinal cord injury: a randomized controlled trial. Arch Phys Med Rehabil. 2010;91(6):857-61. doi: 10.1016/j.apmr.2010.02.012

21. Van Houtte S, Vanlandewijck Y, Kiekens C, Spengler CM, Gosselink R. Patients with acute spinal cord injury benefit from normocapnic hyperpnoea training. J Rehabil Med. 2008;40(2):119-25. doi: 10.2340/16501977-0140

22. Mueller G, Hopman MT, Perret C. Comparison of respiratory muscle training methods in individuals with motor and sensory complete tetraplegia: a randomized controlled trial. J Rehabil Med. 2013;45(3):248-53. doi: 10.2340/16501977-1097

23. Kim CY, Lee JS, Kim HD, Lee DJ. Short-term effects of respiratory muscle training combined with the abdominal drawing-in maneuver on the decreased pulmonary function of individuals with chronic spinal cord injury: A pilot randomized controlled trial. J Spinal Cord Med. 2017;40(1):17-25. doi: 10.1080/10790268.2016.1198576

24. Bissett B, Leditschke IA, Green M. Specific inspiratory muscle training is safe in selected patients who are ventilator-dependent: a case series. Intensive Crit Care Nurs. 2012; 28(2):98-104. doi: 10.1016/j.iccn.2012.01.003

25. Silva DSP. Reabilitação respiratória nas pessoas com lesão medular traumática cervical [dissertação]. Coimbra, Portugal: Escola Superior de Enfermagem de Coimbra;2013.

26. Noda JL, Sonoda LT, Sangean M, Fávero FM, Fontes SV, Oliveira ASB. O efeito do treinamento muscular respiratório na miastenia grave: revisão da literatura. Rev Neurocienc. 2009;17(1):37-45. doi: 10.34024/rnc.2009.v17.8602

27. Liaw MY, Lin MC, Cheng PT, Wong MK, Tang FT. Resistive inspiratory muscle training: its effectiveness in patients with acute complete cervical cord injury. Arch Phys Med Rehabil. 2000; 81(6):752-756. doi: 10.1016/s0003-9993(00)90106-0

28. Park JH, Kang SW, Lee SC, Choi WA, Kim DH. How respiratory muscle strength correlates with cough capacity in patients with respiratory muscle weakness. Yonsei Med J. 2010;51(3):392-7. doi: 10.3349/ymj.2010.51.3.392

29. Kang SW, Kang YS, Sohn HS, Park JH, Moon JH. Respiratory muscle strength and cough capacity in patients with Duchenne muscular dystrophy. Yonsei Med J. 2006;47(2):184-90. doi: 10.3349/ymj.2006.47.2.184

30. Estenne M, Troyer A. Cough in tetraplegic subjects: an active process. Ann Intern Med. 1990;112(1):22-28. doi: 10.7326/0003-4819-112-1-22

31. Weiner P, Magadle R, Beckerman M, Weiner M, Berar-Yanay N. Maintenance of inspiratory muscle training in COPD patients: one year follow-up. Eur Respir J. 2004;23(1):61-5. doi: 10.1183/09031936.03.00059503

32. Caruso P, Albuquerque ALP, Santana PV, Cardenas LZ, Ferreira JG, Prina E et al. Métodos de diagnóstico para avaliar a força muscular inspiratória e expiratória. J Bras Pneumol. 2015;41(2):110-123. doi: 10.1590/S1806-37132015000004474

33. Schafer H, Pauleit D, Sudhop T, Gouni-Berthold I, Ewig S, Berthold HK. Body fat distribution, serum leptin, and cardiovascular risk factors in men with obstructive sleep apnea. Chest. 2002; 122(3):829-39. doi: 10.1378/chest.122.3.829

34. Davies RJ, Ali NJ, Stradling JR. Neck circumference and other clinical features in the diagnosis of the obstructive sleep apnea syndrome. Thorax. 1992;47(2):101-5. doi: 10.1136/thx.47.2.101

35. Chiodo AE, Sitrin RG, Bauman KA. Sleep disordered breathing in spinal cord injury: A systematic review. J Spinal Cord Med. 2016;39(4):374-382. doi: 10.1080/10790268.2015.1126449

36. Guimarães KC, Drager LF, Genta PR, Marcondes BF, Lorenzi-Filho G. Effects of oropharyngeal exercises on patients with moderate obstructive sleep apnea syndrome. Am J Respir Crit Care Med. 2009;179(10):962-966. doi: 10.1164/rccm.200806-981OC

37. Frisbie JH. Correction of orthostatic hypotension by respiratory effort. Spinal Cord. 2010;48(5):434-435. doi: 10.1038/sc.2009.148

38. Sheel AW, Reid WD, Townson AF, Ayas NT, Konnyu KJ. Effects of exercise training and inspiratory muscle training in spinal cord injury. J Spinal Cord Med. 2008; 31(5): 500-8. doi: 10.1080/10790268.2008.11753645

39. Tamplin J, Berlowitz DJ. A systematic review and meta-analysis of the effects of respiratory muscle training on pulmonary function in tetraplegia. Spinal Cord. 2014 Mar; 52(3):175-80. doi: 10.1038/sc.2013.162c