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Original Article

Artigo Original

Muscular Behavior during Inspiratory Training in Patients with a Complete Cervical Spinal Cord Injury: Pilot Study

Comportamento muscular durante treino inspiratório em pacientes com lesão medular cervical completa: estudo piloto

Tomás Santibáñez-Arellano[§1,2] MS; María José Schacht[1;] Matías Soto[1]; Diego Robles[1]; Eduardo Vega[1]; Alejandro Troncoso[1]; Joel Álvarez-Ruf[1] MS

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Abstract

Introduction: There is a huge variety of inspiratory muscle training protocols in patients with complete cervical spinal cord injury. None of them provide information about muscle behavior and its relationship with effort and fatigue sensation perceived by the subject.

Objective: Analyze the relationship between the behavior of the Median Frequency (MF) and the Root Mean Square (RMS) of diaphragm (DPH) and sternocleidomastoid (ECOM) muscles and Subjective Fatigue Sensation (SFS) during an inspiratory muscle training session using a threshold valve in patients with CCSCI.

Methods: Electromyographic activity of the DPH and ECOM during a fifteen minutes training session using a threshold valve with a Maximum Inspiratory Pressure (MIP) of 30% was recorded. Median Frequency average and the Root Mean Square of DPH and ECOM was calculated. SFS was recorded every minute. The correlation between variables was determined by Spearman *rho*.

Results: The correlation between SFS and MF of the DPH was 0.22. The correlation between SFS and MF of the ECOM was 0.36. The correlation between SF and RMS_INDEX was -0.09.

Conclusion: There is no correlation between the variables studied. The RMS_INDEX is presented as a useful tool to describe the muscle behavior during training with threshold valve.

Keywords: electromyography, inspiratory muscle training, complete cervical spinal cord injury.

Resumo

Introdução: Existe uma grande variedade de protocolos de treinos inspiratórios em pacientes com lesão medular cervical completa. Nenhum deles passa informação a respeito do comportamento muscular nem sua relação com a sensação de esforço e fadiga percebida pelo sujeito.

Keypoints

- RMS_INDEX is usefull to describe the muscular pattern durin inspiratory muscle training.

- There's a slight increase in median frequency in DPH and ECOM, rejecting fatigue.

- A significant correlation does not exist between the studied variables.

Pontos-Chave Destaque

- RMS_INDEX é útil para descrever o padrão muscular durin treinamento muscular inspiratório.

- Há um ligeiro aumento na frequência mediana em DPH e ECOM, rejeitando fadiga.

-A correlação significativa não existe entre as variáveis estudadas.

[§] Corresponding Author: Tomás Santibáñez-Arellano – e-mail: tsantibanez@udd.cl
Affiliations: [1]Universidad del Desarrollo, Santiago, Chile, [2]Hospital San José, Santiago, Chile

Objetivo: Analisar a relação entre o comportamento da FM e raiz media quadrática (RMS) de diafragma (DPH) e esternocleidomastóideo (ECOM) e a SSF durante uma sessão de treino de musculatura inspiratória com válvula umbral em pacientes com LMCC.

Métodos: Foi registrada a atividade eletromiográfica do diafragma e o esternocleidomastoideo durante quinze minutos de treino com válvula umbral a 30% de PIM. Foi calculada a frequência média e a raiz quadrada média do DPH e ECOM. Foi registrada a SSF a cada minuto. Foi determinada a correlação entre as variáveis mediante *rho* de Spearman.

Resultados: A correlação entre SSF e FM de DPH foi 0.22. A correlação entre SSF e FM de ECOM foi 0.36. A correlação entre SSF e RMS_INDEX foi -0.09.

Conclusão: Não existe correlação entre as variáveis estudadas. O RMS_INDEX é apresentado como uma ferramenta útil para descrever o comportamento muscular durante um treino com a válvula umbral.

Palavras-chave: eletromiografía, treino muscular inspiratório, lesão medular cervical completa.

Muscular Behavior during Inspiratory Training in Patients with a Complete Cervical Spinal Cord Injury: Pilot Study

Introduction

The literature describes the participation of various muscles during the ventilatory cycle highlighting the diaphragm (DPH) and scalene muscles as the prime movers with the sternocleidomastoid (ECOM) considered as ancillary musculature. Moreover, it is noted that the intercostal muscles play a stabilizing role of the rib cage and that the abdominal muscle contains the viscera favoring the mechanical advantage of the diaphragm (1–4). Complete cervical spinal cord injury (CCSCI) generates an inactivity of the muscles related to one lower level of the spinal cord injury forcing the ECOM, initially considered as an accessory to assume a leading role in ventilation. Added to this, the DPH would not be able to use the abdominal stabilization, becoming a detriment to the normal lung function.

IMT can cause muscle fatigue, both at the expense of performance (physiological fatigue) or tired feeling perceived by the individual (psychological fatigue). Psychological fatigue can be measured with the Borg scale and can allow an appropriate programming exercise or a therapeutic plan (5). Borg Scale is often used to determine the sense of effort related by an individual when subjected to do a task with a certain degree of intensity. Values in between 13 to 15 describe a change from an aerobic phase to an anaerobic phase during exercise and allow comparing their pre and post training values to quantify the evolution of a subject (6–8).

As for the evaluation of muscle function, electromyography (EMG) is considered as a tool used to determine the decrease of action potentials generated in the muscle, which can be interpreted as the fatigue associated for a period of time (9). Inspiratory musculature responds to dynamic contractions, and to this condition studies indicate that the decrease of the MF of the EMG signal can be considered as a useful tool in identifying muscle fatigue or the occurrence of a trend related to this (10).

Training in patients with CCSCI has not been described at all, this is because the data available has not been sufficient to conclude about the effects or changes in inspiratory muscle, quality of life, exercise tolerance or decreased dyspnea (11). This is due to small samples of the studies and the variety of existing protocols depending on the type of device in question (3). Although reports of beneficial results on lung function and quality of life (12,13), the design of the protocols implemented is not based on physiological foundations.

In the reviewed literature there is no study that physiologically justifies the use of the protocols described in patients with CCSCI, therefore inquiry on the inspiratory muscle behavior using EMG during a training session to determine the activity of respiratory muscles associated to the use of a threshold device considering the subjective sensation of effort to establish relationships with EMG's findings would be useful information for the clinic. Using these tools to identify muscle fatigue associated with training can develop an appropriate protocol for patients with spinal cord injury with loads and time of training justified for such pathological condition.

Thus, the main objective is to analyze the relationship between the behavior of the MF and root mean square (RMS) of DPH and ECOM and SFS during an inspiratory muscle training session using a threshold valve in patients with CCSCI. It is hypothesized that muscle activity will increase in conjunction with the SFS during training and that the MF will decrease, indicating muscle fatigue.

Methods

A pilot study of an observational nature and transversal cut has been performed. Data was collected at the home of each participant. We use surface electromyography (Delsys Bagnoli®) to collect EMG data, a threshold IMT valve (Phillips Respironics®) for inspiratory muscular training and a visual Borg scale was used to determine the SFS. Three subjects with complete cervical spinal cord injury (C4-C5, C5-C6 and C6-C7), one female and two males aged 27-53 years signed a consent for participating.

Protocol

Maxim inspiratory pressure (MIP) was evaluated over three trials and the highest value was obtained. A training session was conducted for a period of 15 minutes with a load of 30% of the MIP. Every minute the SFS was recorded. DPH and ECOM EMG were registered. The signals obtained were processed in the MATLAB® software. In the first instance, the signal DPH was filtered through independent component analysis (ICA) and then the signals from each participant, both DPH and ECOM, were processed with different Butterworth filters because the signals were obtained under different noise situations. Data was reinterpreted several times with the objective to temporarily evaluate muscle behavior and SFS of each participant. Once filtered, the signals, the RMS and MF of each burst per muscle was calculated throughout the training. The bursts were visually identified and in that interval the MF and RMS were measured. For calculating MF, a mobile windowing was performed on each burst's window with a width of 128 points. Finally the median of the MF of all windows of each burst was calculated. A RMS was calculated for each burst.

The results are presented as medians of each variable, for each burst, between the three participants. An index of activation between DPH and ECOM (rms_index = rmsDPH / rmsECOM) was generated. This index reflects the relationship between the RMS of the DPH and ECOM during training with the purpose of determine the activation pattern throughout the training. The correlation (Spearman rho: ρ) between the SFS and muscle behavior of DPH and ECOM is analyzed in terms of RMS and MF.

Results

DPH presented a MF = 56.94 Hz, for ECOM the MF was 100.17 Hz. The median of rms_index was 0.05. In Figure 1 it can be seen the progression of the SFS and muscle behavior of the ECOM and DPH in terms of median discharge frequency with a trend line presented.

Table 1 shows the correlation between the variables studied. Low levels of association were obtained between all variables (SSF_DPH ρ= 0.23; SSF_ECOM ρ = 0.36; SSF_RMS_INDEX ρ = -0.09).

Discussion

The results are controversial in terms of the points made in the research hypothesis, in relation to the increase of the MF during training in both DPH and ECOM. The trend lines show that the MF increases in both muscles, however, it is the decrease in MF which is associated with muscle fatigue (10). In this case expected conditions were not observed. The outcome highlights the highest level of frequency activation of the ECOM over the DPH during training which may be related to increased demand in terms of muscle strength associated with their recruitment of muscle fibers. These trends don't evidence fatigue in any way.

The proposed index pretends to analyze the contributions of each muscle to ventilation

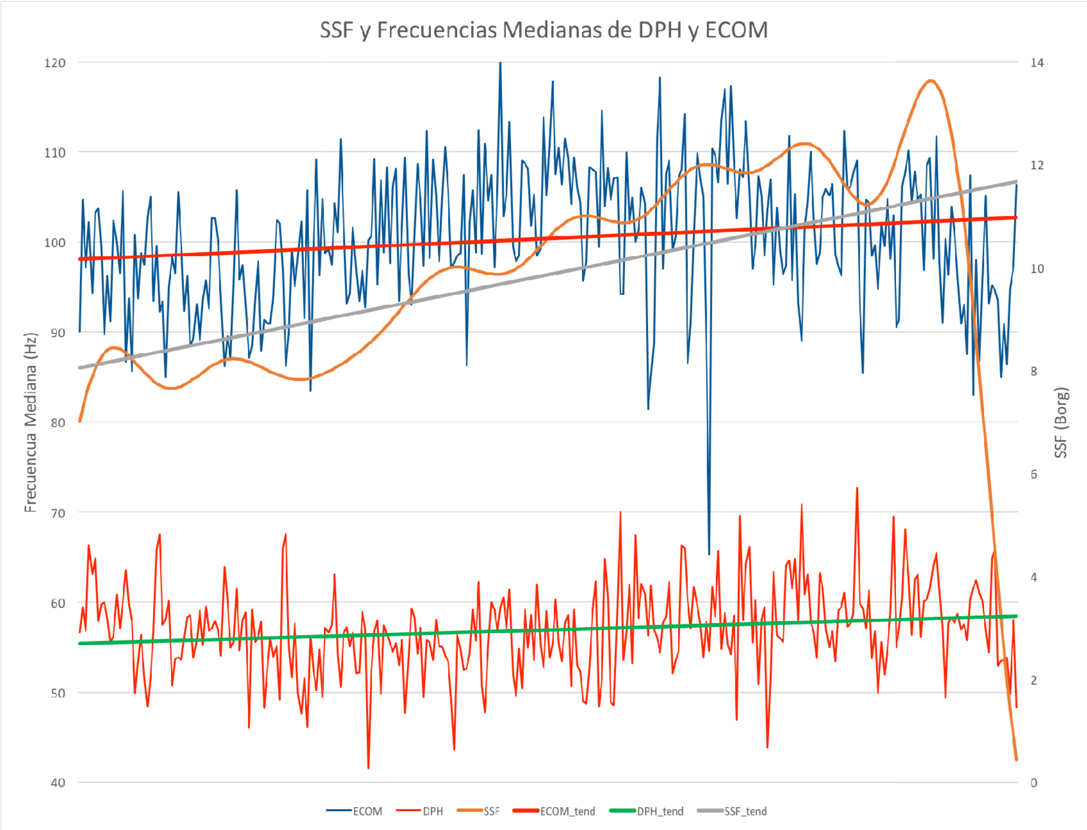

Figure 1 – SFS, MF of DPH and ECOM with trendline. SSF_tend = trendline SSF. ECOM_tend = trendline ECOM. DPH_tend = DPH trendline

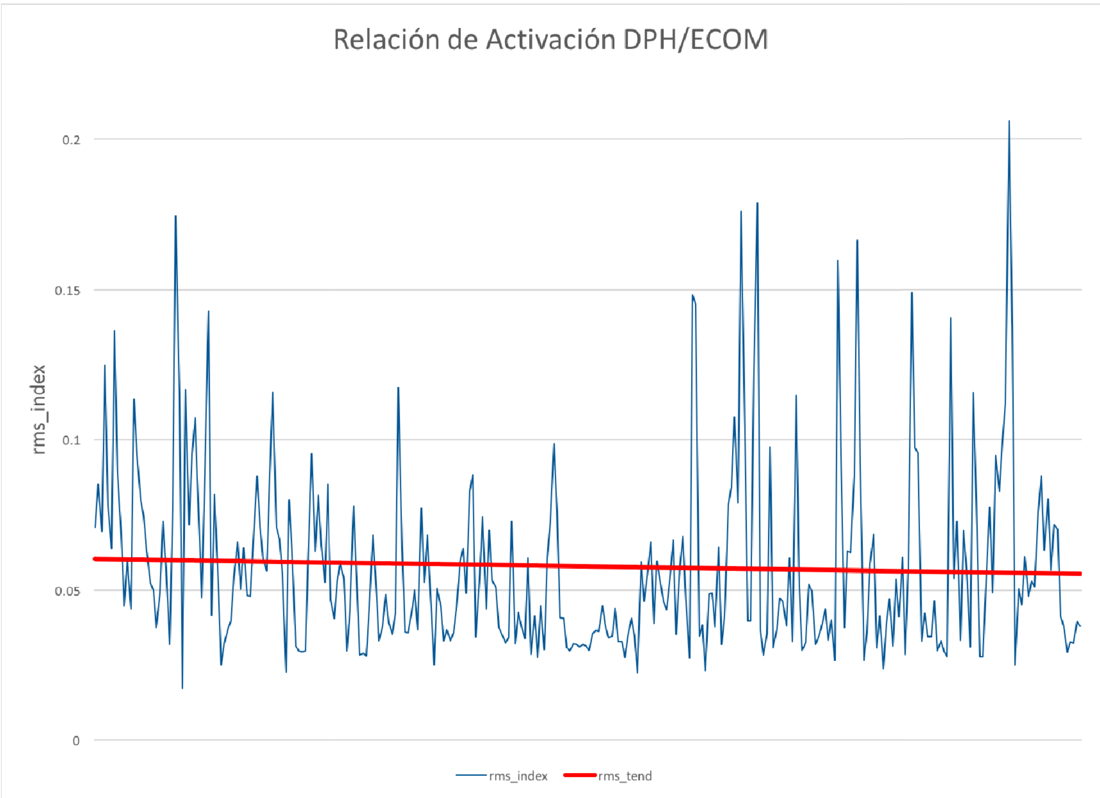

Figure 2 – presents the rms_index and its trend line. Rms_tend = trendline rms_index

Table 1 – Values of correlation analyzed using ρ Spearman between the studied variables. The title should be informative about the content

	DPH	ECOM	RMS_INDEX
SSF	0.22	0.36	-0.09

during training. Depending on the value, if it is > 1 it means that the RMS is greater in ECOM than DPH, which may reflect the strategy used by subjects to ventilate during resistance training. It is noted that the trend line has a negative slope which could be given by an increase in RMS of the ECOM or a decrease in the activity of the DPH; however, it reflects a change in the muscle strategy during the course of the training. The same analysis is possible to do through normalized RMS with the purpose of evaluating changes during training.

It is likely that a workout at 30% of the MIP does not generate enough demand to show fatigue within 15 minutes training, however it is interesting to ask whether the aim really is to make training at the anaerobic threshold. In this sense many questions such as what is the energy pathway that we want to give priority to this type of muscle or if the load is to be modified for an increase strength or endurance of inspiratory muscle. Nowadays there are some studies that use 50% to 75% of PIM (14) to train inspiratory muscles or use maximal minute ventilation to set intensity at 50% to 70% to do the same (15). Those results show that many settings of inspiratory muscle training can produce a positive effect in exercise performance or functional status.

ECOM is a ventilation muscle classified as an accessory that means it is only used during high force requirements, in this sense the percentage of muscle fibers are oriented more to power and strength development than muscular endurance. For this reason it is interesting that the results observed in the rms_index decrease.

Strong points and limitations of the study

The studio has certain limitations in respect of the different possible analyzes against the approach of the variables. On one hand it is possible to normalize both MF as the RMS and resize the window to define the MF. Moreover it is possible to perform an automatic detection of the burst, however, the study provides important information about the behavior of the MF during training with the threshold valve and the activation index is proposed as a useful tool to evaluate the inspiratory musculature behavior.

Conclusion

Given the small sample size used is not possible to consider the results as conclusive. For the sample analyzed there would be no significant correlation between muscle activity of DPH, ECOM and rms_index with the SFS during a session of inspiratory muscle training. The rms_index it is proposed as a useful tool in describing the muscular inspiratory behavior during a muscular training with a threshold valve. The need to continue investigations of the effects of training in inspiratory muscle of people with CCSCI using a threshold valve arises.

Conflict of interests

There is no conflict of interest in this study.

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