Ciencia y Deporte

Volume 8 issue 2; 2023

Universidad de Camagüey "Ignacio Agramonte Loynaz"

Ciencia y Deporte
ISSN 2223-1773, RNPS: 2276
Vol. 8. No. 2, May-August, 2023 p-4309

Artículo original

DOI: https://doi.org/10.34982/2223.1773.2023.V8.No2.002

Respiratory Function of Tennis Players with Spinal Cord Injury

[*La función respiratoria en los tenistas con lesión medular*]

[*Função respiratória em tenistas lesionados na medula espinhal*]

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Received:10/01/2023.
Accepted:20/02/2023.

ABSTRACT

Introduction: Athletes with spinal cord injury experience deterioration or loss of motor and/or sensory function in the cervical, thoracic, lumbar, or sacral areas of the spine, causing a greater or lesser reduction of movement that limits the development of the main and auxiliary muscles involved in breathing. These factors lead to defects in respiratory functions, hampering sports performance.

Aim: To evaluate the respiratory function of national table tennis selection athletes with spinal cord injuries.

Materials and methods: this study relied on theoretical, empirical, and mathematical-statistical methods.

Results: A transversal study done during the general training stage of the two sexes revealed respiratory and cardiovascular parameters, such as forced vital capacity, apnea duration, and heartbeat at rest. The overall cardio-respiratory possibilities of athletes were determined according to the forced vital capacity observed at the end of the test, apnea duration while inhaling, and pulse at rest. The results demonstrated the need for periodical evaluation of the respiratory function of athletes with spinal cord injury, to customize training optimization and enhance sports performance.

Conclusions: The functional tests demonstrated that tennis players with spinal cord injuries were observed to have limited vital pulmonary capacity and apnea issues, especially while inhaling. The paraplegic athletes showed better cardiorespiratory possibilities than the tetraplegic tennis players.

Keywords: Evaluation, respiratory function, spinal cord injury, vital pulmonary capacity, table tennis.

RESUMEN

Introducción: Los atletas con lesión medular presentan deterioro o pérdida de la función motora y/o sensitiva en los segmentos cervical, torácico, lumbar o sacro de la médula espinal, que provoca en menor o mayor grado disminución en la amplitud de los movimientos y limita el desarrollo de los músculos principales y auxiliares de la respiración. Estos factores contribuyen a que existan dificultades en la función respiratoria, situación que va en detrimento del rendimiento deportivo.

Objetivo: Evaluar la función respiratoria de los atletas con lesión medular que integran la selección nacional de tenis de mesa.

Materiales y métodos: En la investigación se emplean métodos de orden teórico, empírico y matemático-estadístico.

Resultados: Se realizó un estudio de corte transversal en la etapa de preparación general, se determinaron en ambos sexos, parámetros respiratorios y cardiovasculares: capacidad vital forzada, tiempo de apnea y frecuencia cardiaca en reposo. A partir de la capacidad vital forzada alcanzada al final de la prueba, del tiempo de apnea en inspiración y el pulso en reposo se determinó las posibilidades generales cardio-respiratoria de los atletas. Los resultados obtenidos, demostraron la necesidad de evaluar periódicamente

la función respiratoria de los atletas con lesión medular para lograr la optimización individual del entrenamiento y mejorar los resultados deportivos.

Conclusiones: Las pruebas funcionales aplicadas demostraron que los tenistas con lesión medular presentan disminución de la capacidad vital pulmonar, dificultades en la apnea principalmente en la inspiración, además se evidenció que los tenistas con paraplejia tienen mejores posibilidades generales cardiorrespiratorias que los tenistas con tetraplejia.

Palabras clave: Evaluación, función respiratoria, lesión medular, capacidad vital pulmonar, tenis de mesa.

SÍNTESE

Introdução: Atletas com lesão medular têm comprometimento ou perda da função motora e/ou sensorial nos segmentos cervical, torácico, lombar ou sacral da medula espinhal, o que causa, em menor ou maior grau, diminuição da amplitude de movimento e limita o desenvolvimento da musculatura principal e auxiliar da respiração. Estes fatores contribuem para dificuldades na função respiratória, uma situação que é prejudicial ao desempenho esportivo.

Objetivo: Avaliar a função respiratória de atletas com lesão medular que são membros da equipe nacional de tênis de mesa.

Materiais e métodos: Métodos teóricos, empíricos e matemáticos-estatísticos foram utilizados na pesquisa.

Resultados: Foi realizado um estudo transversal na fase geral de preparação. Os parâmetros respiratórios e cardiovasculares foram determinados em ambos os sexos: capacidade vital forçada, tempo de apneia e freqüência cardíaca em repouso. A partir da capacidade vital forçada alcançada no final do teste, do tempo de apneia na inspiração e da freqüência de pulso em repouso, foram determinadas as possibilidades cardio-respiratórias gerais dos atletas. Os resultados obtidos demonstraram a necessidade de avaliar periodicamente a função respiratória dos atletas com lesão medular, a fim de obter uma otimização individual do treinamento e melhorar os resultados esportivos.

Conclusões: Os testes funcionais aplicados mostraram que os tenistas com lesão

medular diminuíram a capacidade vital pulmonar, dificuldades na apneia, principalmente na inspiração, e também foi demonstrado que os tenistas com paraplegia têm melhores possibilidades cardiorrespiratórias gerais do que os tenistas com tetraplegia.

Palavras-chave: Avaliação, função respiratória, lesão da medula espinhal, capacidade pulmonar vital, tênis de mesa.

INTRODUCTION

The excellent results achieved by the Cuban table tennis players with spinal cord injury (SCI) in the Pan-American and Paralympic Games in recent years evidenced the fulfillment of high work demands, resulting from the joint efforts of several specialties to enhance physical, technical-tactical, psychological, and functional development.

Because of the deterioration or loss of motor and/or sensory function in the cervical, thoracic, lumbar, or sacral areas of the spine, (Brizuela, G.*et al.*, 2016), the athletes who suffer from this injury experience a reduction in the extension of movements that limit the development of the main and auxiliary muscles of breathing. Hence, the respiratory function must be evaluated to customize the best possible training.

The search for published information about this issue revealed that in Cuba and internationally, there has been little research on the evaluation of the respiratory function of athletes with SCI due to the particular characteristics of each type of limitation, resulting in studies with few and varied specimens. Some of the authors can be cited: Sainz *et al.* (2015), and Núñez *et al.* (2020), whose papers aimed to evaluate physical and physiological indicators, particularly the cardiovascular capacity as a physiological parameter to be evaluated. Though these authors did not evaluate the respiratory function, they are referents for this study.

Moreover, the requirements of table tennis for SCI athletes are almost the same as those for conventional athletes. To comply with these requirements, the players should have

proper physical endurance associated with the O_2 requirements by the skeletal and cardiac muscles during the exercise. This scenario was appropriate to do an evaluation study of the respiratory function of the national table tennis selection athletes with spinal cord injury (SCI).

MATERIALS AND METHODS

The methods and techniques used in this research are listed below.

Three athletes from the Paralympic national selection of table tennis, on wheelchairs, were selected for a transversal study during the general training stage. The team is made of a woman belonging to class 3 due to a spinal cord injury in the lumbar area, and two men in class 1 with cervical-thoracic injuries. The respiratory parameters, such as forced vital capacity (ml), apnea duration while inhaling and exhaling (sec) were determined in the two sexes.

The functional tests to evaluate the respiratory system were voluntary apnea while inhaling and exhaling, spirometry, and the spirometric curve, using a digital spirometer (FCS 10000).

The cardiac frequency (beat/min) at rest was determined as well. The overall cardio-respiratory possibilities of athletes were determined according to the forced vital capacity observed at the end of the test. The Skibinski index was determined for the apnea duration and the pulse at rest.

This index evaluates the overall cardiorespiratory possibilities, using Equation 1:

$$\frac{\frac{\text{Vital cap.(ml)}}{100}\text{x apnoea duration (sec)}}{\text{pulse at rest (beat/min.)}} \quad (1)$$

The vital pulmonary capacity was determined using the digital spirometer (FCS 10000). The results of spirometry were collected following to the existing methodology, which

states that the mean value of vital capacity is 3500 ml for women, whereas it is 4000 ml for men.

Methodological procedure for the spirometry:

- To inform the athlete clearly and precisely about the test.
- To place the athlete in a seated position on their wheelchair in front of the spirometer.
- To place the nozzle in the mouth and close the nostrils using clips (check for any air leak).

Ask the athlete to:

- Inhale deeply.
- Exhale to the top, with quick and strong blows, all the possible air through the nozzle.
- Breathe normally.

A total of five repetitions will be necessary for the spirometric curve, to comply with the methodology, at 10-15 sec. intervals. The outcome will be favorable whenever the initial values remain steady; if they drop, the result will be incorrect.

Voluntary apnea duration was evaluated (sec), considering the time the athlete is in a normal state of maximum inhaling and exhaling. The average values for women varied between 50-60 sec., and 70-80 for the men during inhaling; whereas they were 30 (sec.) and 40 (sec), respectively during exhaling.

RESULTS AND DISCUSSION

The results of spirometry showed that the three SCI athletes suffered a decline in vital pulmonary capacity, with no values near the set averages. It can be explained by the dysfunction of the respiratory muscles associated with the degree and location of the neurological injury and the duration of the injury, all of them over 15 years.

The spirometric curve was unfavorable for one athlete; rather than climbing progressively or remaining steady, the values dropped, which may have been caused, regardless of the injury, by the smoking habits of the individual that threaten his respiratory system. The other two athletes showed a gradual increase with the takes. Hence, despite having a limited vital capacity, the subjects were evaluated as favorable.

The Skibinski index showed better overall cardiovascular possibilities in athlete No. 1 than in athletes No 2 and 3, according to the scale presented by Roig (2010). Athlete No. 1 belongs to functional classification No 3, due to a spinal cord injury in the lumbar and thoracic areas, with paraplegia not affecting his arms. Besides, his heart frequency was higher than that of the other athletes. Athletes No 2 and 3 belong to the functional classification No 1, with a spinal cord injury in the cervical area, both are tetraplegic and though their heart frequency was within the normal values, was lower than that of the paraplegic athlete.

An assessment of the voluntary apnea duration revealed that the three athletes had negative values, none came close to the reference values for a normal population. the difficulties were even greater in paraplegic athletes, especially during inhaling in apnea.

These tests corroborated the existence of alterations in the respiratory function in SCI athletes, which varies depending on the location of the injury (Table 1).

Table 1. *- Functional tests for the respiratory system*

	Respiratory system

	Tests		
Athlete No. 1 (female), Class No. 3	Spirometry	2075 ml	Unfavorable
	Spirometric curve	1210 ml 1825 ml 2027ml	Favorable
	Skibinski index	11.6	Average
	Apnea duration	Inhaling	Exhaling
		44.68 seg	26.39 seg
Athlete No. 2 (male), Class No. 1	Spirometry	2240 ml	Unfavorable
	Spirometric curve	1625 ml 2240 ml 2027ml	Unfavorable
	Skibinski index	10.7	Unfavorable
	Apnea duration	Inhaling	Exhaling
		34.90 seg	21.19 seg
Athlete No. 3 (male), Class No. 1	Spirometry	2627 ml	Unfavorable
	Spirometric curve	1760 ml 2245 ml 2027ml	Favorable
	Apnea duration	Inhaling	Exhaling
		16	36

The pulmonary respiratory function requires the utilization of muscles located in different areas of the body, from the neck to the abdomen. Depending on the level of SCI, the respiratory function may be harmed to different degrees. Meanwhile, in people with a low SCI (lumbar or sacral areas), the respiratory parameters are relatively normal, not affecting the control of any respiratory muscle (Martínez & López, 2014) in individuals with a high SCI (high dorsal or cervical), the respiratory function is considerably reduced (Winslow & Rozovsky, 2003), causing a total absence of the respiratory mechanics. Under a full SCI, above C3, it compels the use of an external breathing device. Between these extreme constraints, the level (and degree of damage) of SCI will determine the respiratory muscles the individual will be able to use for pulmonary ventilation Brizuela, *et al.* (2016).

Research done by Haisma *et al.* (2006), and Slater & Meade, (2004) demonstrated the difference between the aerobic power measured in individuals with high and low SCI. The paraplegic subjects showed as much as twice the VO 2MAX values (maximum oxygen consumption or aerobic power) that of the tetraplegic subjects. The same occurs in face of partial SCI, the reduction of the respiratory muscle mass leads to changes in the cardiovascular response.

Considering that the diseases of the respiratory system and their complications have a significant repercussion on the health of individuals with SCI, their prevention and search for better respiratory functions should be targeted by any rehabilitation and sports training progra. Brizuela, *et al.* (2016).

In that sense, several authors like Bhambhani, (2002); Slater and Meade, (2004); Price & Campbell, (1999); Bar-On &Nene, (1990) cited by Brizuela, *et al.* (2016), highlighted the enormous difference between SCI individuals who play this sport regularly, and those who do not. The former have shown greater aerobic power and other indexes related to the capacity of enduring a sustained effort.

At the same time, authors like Brizuela *et al.* (2010); Jacobs & Nash, (2004); Spooren *et al.* (2009); Le Foll-de Moro *et al.* 2005; Van Houtte *et al.* (2006); Roth *et al.* (2010) cited by Martínez & López, (2014) emphasized the beneficial effects of physical exercise on the respiratory parameters of SCI individuals, at different levels, and recommend water training.

However, despite the well-known relevance of exercise and sports to enhancing the respiratory function of SCI athletes, studies that evaluated the pulmonary capacity of these athletes are few. The ventilatory volume of these athletes is said to be mainly reduced for those with a severe SCI that blocks the need for high oxygen intake, thus leading to a higher respiratory frequency, reducing the efficiency, and increasing the energy used for physical activity.

CONCLUSIONS

The results of the tests conducted evidenced the need for evaluating the respiratory function of SCI athletes that belong to the national table tennis selection, based on the alterations caused by the injury, and the relevance of periodic assessment of the system to enhance sports-training based on the individual characteristics of each player.

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Conflict of interest statement:

The authors declare no conflicts of interests.

Author contribution statement:

The authors have taken part in the redaction of the manuscript and analysis of the documents.