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Respiratory muscle strength and aerobic performance of wheelchair basketball players

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Abstract—The respiratory system has been described as a limiting factor in the performance of athletes. Therefore, the objective of this study was to evaluate the relationship between the respiratory muscle strength (RMS) and aerobic performance of wheelchair basketball players (WCBPs). We evaluated 19 male WCBPs who were divided into two groups: trunk control group (TCG) and without trunk control group (WTCG). All participants underwent a pulmonary function test, evaluation of maximal inspiratory (MIP) and expiratory (MEP) pressures, and an aerobic performance test. The MIP of both groups and the MEP values of TCG exceeded the predicted values for age and gender. No differences were observed in the MIP and aerobic performance between the groups although a difference was observed in the MEP values. Positive correlations were observed between MIP/MEP and the aerobic performance for both groups. These results suggested that the overall RMS of this group of WCBPs fell within or above the predicted values. Hence, the study concluded that RMS can positively influence the aerobic performance of WCBP.

Keywords: respiratory muscles, adapted physical activity, athletic performance, breathing tests

Introduction

Respiratory muscle strength is an important variable for evaluating the respiratory health of people with disabilities, especially in subjects who have some form of muscle dysfunction generating trunk instability. Apart from being related to postural control, trunk muscles are responsible for the rib cage motion and the pressure difference that ensures proper air flow in and out of the lungs during the breathing process. A dysfunction in this process could predispose the subject to develop some pulmonary diseases such as atelectasis and pneumonia[1]. In view of the respiratory alterations and their aggravation resulting from a sedentary lifestyle, participation in physical activity and sports has been encouraged as a means of health promotion among people with disabilities[2].

Meanwhile, the respiratory system has also been described as a limiting factor in the aerobic performance of highly-trained athletes. These limitations are related to increased respiratory work, exercise-induced arterial hypoxemia, respiratory muscle fatigue, and dyspnea[3]. The increase in respiratory rate, tidal volume, and minute volume; particularly in sustained exercises that exceed 85% of the maximal oxygen uptake (VO_2 max)—generates a greater metabolic demand on the inspiratory muscles, especially in the diaphragm, and can lead to muscle fatigue in some cases[4].

The increase in the inspiratory muscle work during physical exercises also generates a greater activation of metaboreflex. The major activation of this reflex leads to specific adaptations in the blood flow circulation, which cause the redirection of peripheral blood flow from the limbs to the diaphragm and other inspiratory muscles[5]. Therefore, the exacerbation of this mechanism could decline the exercise performance of well-trained subjects[6,7].

In search of strategies to improve aerobic performance, specific inspiratory muscle training programs have been developed, the aims of which are to postpone or prevent inspiratory muscle fatigue and reduce the blood flow redirection from the limb muscles[8]. However, divergent results have been found with regards the effectiveness of this strategy of training among wheelchair athletes[9-11].

Thus far, only one study has reported the behavior of respiratory muscle strength (inspiratory and expiratory) in wheelchair basketball players (WCBPs)[12]. However, this study only reported the respiratory muscle strength of paraplegic athletes without assessing subjects with other types of disabilities.

Thus, considering the importance of respiratory muscle strength to the exercise performance of athletes and the relevance of evaluating the respiratory health of people with disabilities, the aims of this study are to (1) evaluate the respiratory muscle strength and the aerobic performance of WCBPs and (2) compare the obtained values of inspiratory muscle strength (IMS) and expiratory muscle strength (EMS) with the predicted values by equation. Moreover, the respective relationships between IMS and EMS and the aerobic performances of these subjects are also assessed.

Methods

Study design

This is a clinical trial with an observational and cross-sectional design.

Participants

Thirty-one male WCBPs were considered for participation, of which 19 were eventually selected. Inclusion criteria were as follows: male and training for WCB for more than one year. Exclusion criteria included smoking and/or the presence of cardiovascular, respiratory, motor or cognitive alterations that make it impossible to perform the research procedures.

WCB training sessions took place three to five times per week for 3–5 h each and included physical training and coaching on techniques and tactics. The training involved stretching and resistance exercises as well as cardiovascular resistance; the WCB resistance training focused on the arm, shoulder, and trunk musculature.

Apart from physical training, the athletes were involved in technical and tactical training specific to WCB. Approximately 60% of the sessions were dedicated to practice games and tactical positioning, while 40% of the sessions focused on specific activities, such as shooting, passing, and obstacle courses.

The participants were divided into two groups according to functional classification score, as suggested by the International Wheelchair Basketball Federation (IWBF): without trunk control group (WTCG, N = 12, functional classification from 1.0 to 2.5) and with trunk control group (TCG, N = 07, functional classification from 3.0 to 4.5) (Figure 1). The IWBF functional classification for group division was chosen because this process also indirectly evaluated some respiratory muscle functions. Some of these muscles also acted as postural muscles (e.g., sternocleidomastoid, trapezius [upper fibers], pectoralis minor, serratus anterior and posterior superior, and rib lifters muscles). The characteristics of the participants and the etiologies of their respective disabilities are described in Table 1.

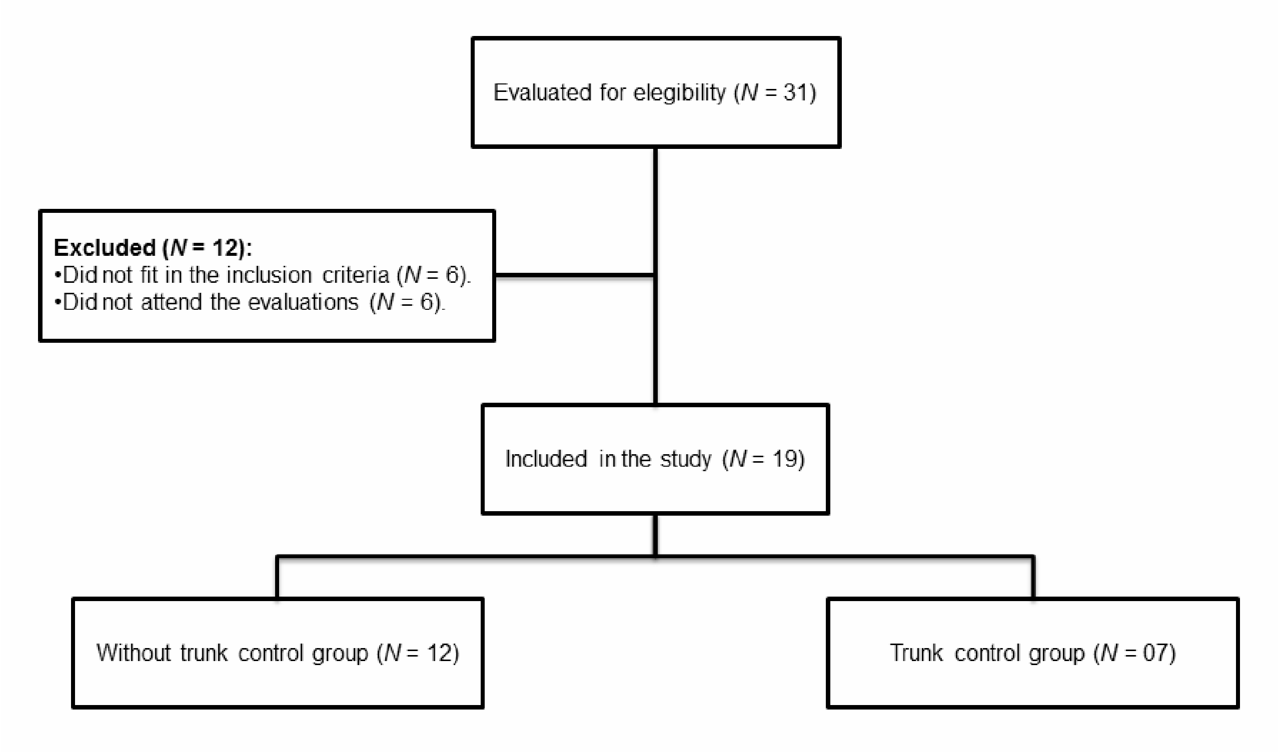

Figure 1. Flowchart presenting sample loss in the study.

Table 1. Characteristics of the subjects.

		WTCG	TCG	p value
N		12	7	
Age (years)	**Mean**	31.67	30.00	0.64
	SD	8.15	6.06	
Body mass (kg)	**Mean**	65.41	68.99	0.64
	SD	16.16	14.90	
Height (m)*	**Mean**	1.59	1.55	0.90
	SD	0.17	0.24	
Time of disability (years)	**Mean**	17.23	22.67	0.31
	SD	10.14	11.69	
Training experience (years)	**Mean**	5.14	7.91	0.21
	SD	4.67	4.74	
Training volume (hours/week)	**Mean**	23.50	18.00	0.45
	SD	10.32	11.22	
IWBF basketball classification		1.0 – 2.5	3.0 – 4.5	
Etiology of physical disabilities				
SCI (T4–L5)		7	1	
Spina bifida		2	1	
Polio		1	1	
Congenital malformation		1	2	
Unilateral amputation		0	2	
Arthrogryposis multiplex		1	0	

Note. WTCG = without trunk control group; TCG = with trunk control group; IWBF = International Wheelchair Basketball Federation; SCI = spinal cord injury; (T4–L5) = level of SCI; p value = comparison between WTCG vs. TCG; * non-parametric data. (Data presented as mean and standard deviation [SD]).

All participants were informed about the study's relevance and procedures. After agreeing to participate, they were asked to sign an informed consent form. This study was approved by the research Ethics Committee of the involved institution (protocol number 57/13).

Procedures

All subjects underwent a 48-hour period of rest (without training) prior to the evaluation protocol. An interview was conducted to collect data about the volunteers' health and to verify their eligibility. After this interview, the evaluation protocol was carried out on two consecutive days. On the first day, the respiratory variables were evaluated with a pulmonary function test and maximal respiratory pressure measurements (inspiratory and expiratory). On the second day, (24 h after the first evaluation procedures) we assessed the participants' aerobic performance by using the 12-minute aerobic test for wheelchair users.

Pulmonary function test

The pulmonary function tests were carried out with a spirometer (Easy one, ndd Medizintechnik AG, Zurich, Switzerland) according to the American Thoracic Society (ATS) guidelines for technique, acceptability, and reproducibility[13]. The device was calibrated before each test according to the manufacturer's instructions. Spirometric variables were recorded and expressed in body temperature and pressure as well as saturated conditions.

The measurement protocol was as follows. First, we carefully described the procedures to them, after which the subjects rested for 10 min. The examination then began with the subjects seated upright (90º hip flexion angle) in their own wheelchair with their heads in neutral position and wearing a nose clip to avoid air leakage through the nostrils. The mouthpiece was correctly placed over each subject's mouth to avoid air leakage.

The force vital capacity (FVC) maneuver was carried out. For this maneuver, the subjects were instructed to maximally inspire and then exhale completely with maximum effort. The participants were verbally encouraged to exhale forcibly until the end of the maneuver. Expiration was interrupted after 6 s.

Each maneuver was carried out until three acceptable and two reproducible curves were obtained without exceeding eight attempts. During the maneuvers, real-time graphics of the curves were shown to them, indicating whether they met the acceptance criteria proposed by the ATS[13].

The tests were superimposed automatically in the equipment, which made it easier to verify their reproducibility. Thus, after the acceptance criteria were fulfilled, the curves were classified according to reproducibility, with the maximal differences for FVC and FEV_1 in the two best curves (i.e., 5% or 150 mL) being considered for analysis. Tests that exceeded these limits were excluded. The curves were analyzed by using two evaluators, and those considered technically inappropriate were excluded from the analysis. After the acceptability and reproducibility criteria were met, the highest values of the studied variables were recorded.

The absolute values were obtained based on spirometric tests and the percentages of the predicted values for age and gender of both groups for FVC and the volume exhaled during the first second of a forced expiratory maneuver (FEV_1). Based on the equations for healthy subjects, which were developed by previous study for use as guidelines in pulmonary function tests, equations were used to predict normal values so as to verify the presence of ventilator dysfunctions and thus characterize the population[14].

Respiratory muscle strength

The respiratory muscle strength values were obtained by measuring maximal inspiratory and expiratory pressures (MIP and MEP) with an analog manometer (Ger-ar®, São Paulo, Brazil) scaled in cmH_2O with an operational limit of $\pm$ 300 cmH_2O.

MIP and MEP were measured from residual volume (RV) and total lung capacity (TLC), respectively. Each subject was asked to sit in an erect position (90º hip flexion). A nose clip was used to prevent air leakage through the nostrils; a rigid plastic mouthpiece that was connected to the manometer was also used. The entire protocol was conducted in the presence of a trained evaluator. At least five maximal maneuvers were performed, of which three had to be acceptable and reproducible (difference of less than 10%); a one-minute rest interval was given between each maneuver. The inspiratory and expiratory efforts had to be sustained for at least one second, and the highest values obtained were recorded for subsequent analysis[15]. The maximal predicted respiratory pressures were calculated in absolute values and percentages for each volunteer using equations[15].

Aerobic performance test

To evaluate each participant's aerobic performance, the 12-minute test for wheelchair users was conducted in a covered multisport court. A rectangle measuring 25 × 15 meters (m) was marked on the court. A total of 12 cones were placed on the rectangular space: four cones were placed at each corner and the remaining eight cones were spaced every 2 m, forming a rectangle with a perimeter of 75.32 m. Figure 2 shows the test area.

Figure 2. Test area for the 12-minute aerobic test.

The participants' resting cardiopulmonary variables were checked before conducting the test. Blood pressure (BP) was measured with the auscultation method, heart rate (HR) with a Polar RS800CX® heart rate monitor (Polar Electro Co.Ltda. Kempele, Oulu, Finland), and peripheral oxygen saturation (SpO_2) with pulse oximetry (Solmedica MD300C1 oximeter, Beijing Choice Eletronic Tech. Co., Ltd.). Subjective perception of effort was measured by using the Borg scale (CR-10).

After completing these procedures, the test was initiated, during which the participants were instructed to follow the marked track, turn strategically to maintain velocity, and cover the greatest distance possible within 12 min. The test began and ended with a beep, and standardized verbal encouragement was given each minute by the same evaluator (e.g., "2 min have passed and you are doing very well, keep it up").

At the end of the test, in addition to calculating the total distance covered, the previously mentioned cardiopulmonary variables were measured again. The estimated VO_2 max reached was then calculated according to a previous method[16].

Statistical analysis

The statistical procedures were carried out using Bioestat v.5.0. The Shapiro-Wilk test was conducted to analyze the normality of the data distribution. Student's t-test was used for parametric data, and the Mann-Whitney test was used to compare non-parametric data.

To measure the effect size, Cohen's d was calculated by using the Effect Size Generator 2.3 software (Swinburne University of Technology, Center for Neuropsychology, Melbourne, Australia). The threshold values for effect size statistics were 0.2, 0.5, and 0.8 for small, medium, and large effect sizes, respectively[17].

Pearson's linear correlation coefficient was used to analyze the relationship between variables. All results were described as means and standard deviation, and the significance level adopted for all analyses was 5%.

Results

Table 2 presents the relative and absolute values of the spirometric variables. Neither of the groups presented restrictive or obstructive pulmonary disease. In both groups, values that were over 80% of the predicted were found for all variables. A small effect size was found for small to FEV_1/FVC; medium to FVC (L), FEV_1 (L), and FEV_1 (%); and large to FVC (%) comparisons.

Table 3 shows the obtained and predicted MIP and MEP values. It is noteworthy that both groups showed MIP values above the predicted ones, both with large effect size. Regarding

MEP, the values obtained in the TCG were significantly higher than the predicted values, with large effect size. Meanwhile, the WTCG presented no significant difference for this variable and showed medium effect size for this comparison.

Table 2. Absolute and relative values obtained from the pulmonary function test.

		WTCG	TCG	Difference (%)	p value	Effect size
FVC (L)	**Mean**	3.95	4.52	12.61	0.27	0.56
	SD	1.10	0.92			
FVC (%)	**Mean**	96.25	130.71	26.36	0.07	0.82
	SD	24.36	52.75			
FEV_1 (L)	**Mean**	3.26	3.68	11.41	0.30	0.54
	SD	0.91	0.63			
FEV_1 (%)	**Mean**	93.42	121.86	23.34	0.19	0.78
	SD	18.51	48.24			
FEV_1/FVC	**Mean**	0.84	0.82	2.38	0.47	0.30
	SD	0.08	0.05			

Note. WTCG = without trunk control group; TCG = with trunk control group; p value = comparison between WTCG vs. TCG; FVC = forced vital capacity; FEV_1 = forced expired volume after 1 second. (Data presented as mean and standard deviation [SD]).

Table 3. Comparison between obtained and predicted values of maximal inspiratory and expiratory pressures in both groups.

	Group		Obtained (cmH_2O)	Predicted (cmH_2O)	Difference (%)	p value (Obtained vs. Predicted)
MIP	**WTCG**	**Mean**	157.50	129.97	17.48	0.04
		SD	40.82	6.52		
	TCG	**Mean**	180.00	131.30	27.06	0.04
		SD	49.75	4.84		
MEP	**WTCG**	**Mean**	166.25	139.35	16.18	0.19
		SD	66.34	6.60		
	TCG	**Mean**	237.14	141.00	40.54	0.002
		SD	50.57	4.90		

Note. MIP = maximal inspiratory pressure. MEP = maximal expiratory pressure. WTCG = without trunk control group. TCG = with trunk control group. P value = comparison between Obtained vs. Predicted values of MIP and MEP. (Data presented as mean and standard deviation [SD]).

Table 4 presents the comparisons of obtained values for maximal respiratory pressure and the variables of the aerobic performance test. Significant difference was found only between MEP values, which had a large effect size. The other variables showed small (MIP; Δ Diastolic blood pressure; Final SpO_2), medium (Δ Systolic blood pressure and Final Borg scale), and large effect sizes (Δ Heart rate and VO_2 max).

Table 4. Comparison of respiratory pressure obtained values and of the 12-minute aerobic test result between the two groups.

		WTCG	TCG	Difference (%)	p value	Effect size
Obtained MIP (cmH_2O)	**Mean**	157.50	180.00	12.50	0.30	0.49
	SD	40.82	49.75			
Obtained MEP (cmH_2O)	**Mean**	166.25	237.14	29.89	0.03	1.20
	SD	66.34	50.57			
Distance covered (m)	**Mean**	2055.81	2275.55	9.66	0.09	0.88
	SD	261.91	238.69			
Δ Heart rate	**Mean**	102.33	88.71	13.31	0.08	0.84
	SD	13.24	18.58			
Δ SBP (mmHg)*	**Mean**	30.00	39.29	23.64	0.42	0.52
	SD	12.06	22.07			
Δ DBP (mmHg)	**Mean**	- 9.17	- 6.43	29.88	0.73	0.17
	SD	18.81	11.80			
Final SpO_2 (%)*	**Mean**	97.75	97.86	0.11	0.87	0.18
	SD	0.75	0.38			
Final Borg scale (0–10)*	**Mean**	8.83	9.43	6.36	0.22	0.65
	SD	1.03	0.79			
VO_2 max (ml/kg/min)	**Mean**	26.94	31.00	13.10	0.09	0.88
	SD	4.83	4.40			

Note. MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; WTCG = without trunk control group; TCG = with trunk control group; Δ Heart rate = variation in the heart rate values before and after the exercise test; Δ SBP = variation in the systolic blood pressure values before and after the exercise test; Δ DBP = variation in the diastolic blood pressure values before and after the exercise test; SpO2 = peripheral oxygen saturation at the end of the test; VO_2 m_{ax} = maximal oxygen uptake; p value = comparison between WTCG vs. TCG; * non-parametric data. (Data presented as mean and standard deviation [SD]).

Regarding the correlations between distance covered in the aerobic performance test and the maximal respiratory pressures, the WTCG showed positive correlations for both MIP ($r = 0.60$; $R^2 = 0.36$; $p = 0.04$) and MEP ($r = 0.35$; $R^2 = 0.12$; $p = 0.36$). At the same time, the TCG showed positive correlations for MIP ($r = 0.71$; $R^2 = 0.50$; $p = 0.07$) and MEP ($r = 0.51$; $R^2 = 0.26$; $p = 0.24$). These data are presented in Figure 3.

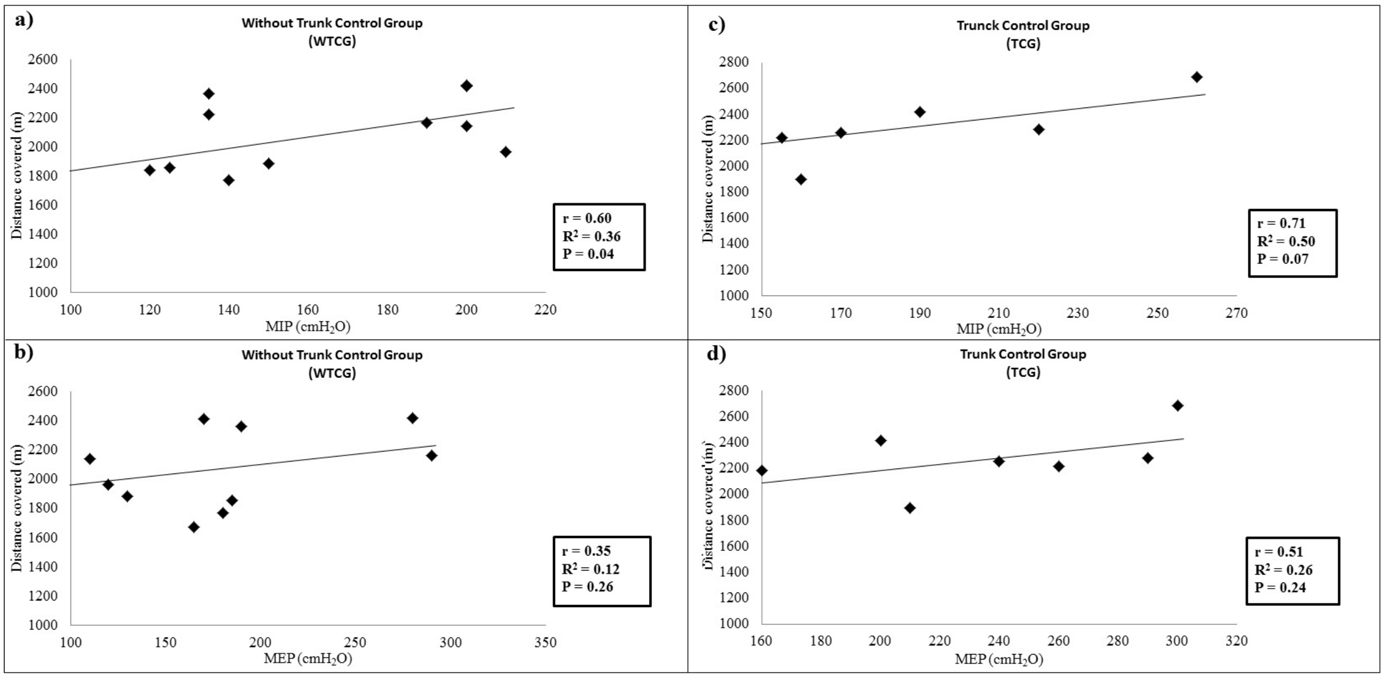

Figure 3. Correlations between the distances covered in the aerobic performance test and the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP).

a) Correlation between the distances covered and MIP in the WTCG; b) Correlation between the distances covered and MEP in the WTCG; c) Correlation between the distances covered and MIP in the TCG; d) Correlation between the distances covered and MEP in the TCG.

Discussion

The pulmonary function test revealed that both groups did not present ventilatory disorders. Several authors have indicated the relevance of spinal cord injury (SCI) in decreased pulmonary function resulting from alterations in the mechanics of respiratory muscles[1,12,18,19]. In addition, evidence showed a decline in the pulmonary function of subjects with SCI, which they attributed to higher body mass index, lower inspiratory muscle strength, and declined levels of physical fitness[20]. In another study, it was demonstrated values of 2.67 ± 0.83 and 3.10 ± 1.10 L for FVC at the baseline of intervention and control groups of sedentary subjects with SCI, respectively; they also reported FEV_1 values of 2.11 ± 0.68 and 2.18 ± 0.75 L for these two groups[21]. In the present study, we found values that exceeded those reported in the abovementioned studies.

Regarding Paralympic athletes without SCI, only a single study has reported the pulmonary function of these subjects at the baseline[22]. It was found values of 4.74 ± 0.77 L for FVC and 4.10 ± 0.68 L for FEV_1 at the baseline of a group of highly trained subjects from the Swiss Paralympic team with single-limb amputation or blindness. These values are almost similar to the variables reported in the present study. However, caution must be taken when comparing these data, because in the present study, we investigated subjects who trained in just one specific sport modality whereas Osthoff[22] did not specify the sports modality of their volunteers.

These findings suggest that the WCB regular training could preserve the pulmonary function of the present study's subjects. Indeed, WCBPs make ample use of the upper limb and trunk muscles both for wheelchair propulsion and for throwing the ball during the matches[23-25]. Some of these muscles involved in the stabilization, positioning, and execution of upper limb; trunk movements also act as the accessory muscles facilitating the inspiratory and expiratory processes. Therefore, the training of these muscles during the WCB practice may have helped prevent alterations in respiratory mechanics and, consequently, in the pulmonary function of these subjects, especially in those who had SCI.

In the present study, the level of the participants' SCI fell between T4 and L5. According to the literature, this should indicate a reduced functioning of the intercostal muscles, which have innervations originating in the spinal roots from T1 to T11[1]. According to De Troyer[26], alterations in intercostal muscle function may lead to decreased IMS and consequent decreases in thoracic expansibility. However, in the current study, the obtained MIP values were higher than the predicted values, and similar values were obtained in both groups.

The literature features few studies on the effects of wheelchair sports training on respiratory muscle strength. Furthermore, the majority of these studies evaluated only subjects with SCI. Goosey-Tolfrey[9] found lower MIP and MEP values at the baseline in their study (MIP = 75.4 ± 33.3 cmH_2O and MEP = 69.4 ± 21.0 cmH_2O for the intervention group; MIP = 74.5 ± 27.3 cmH_2O and MEP = 60.4 ± 18.3 cmH_2O for the control group) when they analyzed competitive WCBPs with SCI, post-polio, or spina bifida. However, recently, it was reported obtained values of MIP similar to those predicted by equation in tetraplegics who trained in wheelchair rugby (MIP = 113.7 ± 35.5) and paraplegics who trained in WCB (MIP = 112.2 ± 23.3)[12]. In that same study, however, the subjects showed MEP values that were lower than the predicted ones (MEP = 73.7 ± 20.7 cmH_2O for the wheelchair rugby athletes group [tetraplegics]; MEP = 105.6 ± 34.3 cmH_2O for the WBC group [paraplegics]).

Regarding the respiratory muscle strength, several authors investigated its comportment in able-bodied trained subjects and showed values that are below those reported in the present study. One study found values of 129.1 ± 16.5 cmH_2O for the MIP at the baseline when they studied the effects of inspiratory muscle training in 17 competitive male rowers[27]. More recently, it was reported baseline values of 115 ± 26 and 117 ± 30 cmH_2O for the MIP of the experimental and control group, respectively, in 16 club-level competitive swimmers[28].

The findings of the present study are in agreement with those described by Moreno[12] and could also be attributed to the previously described training of the accessory muscles during the WCB practice. Moreover, some of scapular girdle muscles act in upper limb movement and stabilization and serve as accessory muscles in the forced inspiration process[23-25,29]. The constant utilization of these muscles during the WCB training may have resulted in adaptations in their functions and morphologies, which culminated in a greater capacity to generate force.

Regarding MEP behavior, the obtained values were higher than the predicted values only in the TCG. This group's obtained values were higher than those of the WTCG. The natural process of expiration does not require muscular activity and only requires a difference between the pulmonary and external pressures. However, during forced expiration, muscles located in the thoracic (pectoralis major) and trunk (abdominals) regions actively assist the increase of expiratory flow and the deflation of the lungs[30,31]. Maintaining abdominal muscle functionality is linked with preserving trunk control. The maintenance of trunk control is one of the most important behaviors in the IWBF functional classification. Greater trunk stabilization and angular movements (flexion, extension, lateralization, and rotation) generate greater functional classification scores[32]. Therefore, we suggest that the TCG had better trunk control and stabilization owing to their higher functional classification scores. For this reason, this group's MEP values exceeded the predicted ones and were even higher than the WTCG values. This may be attributed to the fact that the TCG had better abdominal muscle function and strength. It should be noted that the obtained WTCG MEP values were not lower than the predicted values, even though 7 of the 12 volunteers in this group had SCI between T4 and L5, suggesting the possible functional impairment of the abdominal muscles. These finding may also be attributed to the regular training of WCBPs, as previously suggested by Moreno[12].

Additionally, similarities in distance covered and VO_2 max were observed in the aerobic test results of the two groups. Leicht,[33] detected a mean VO_2peak of 24.5 mL/kg/min for a group of disabled athletes with high SCI (quadriplegics), 34.9 mL/kg/min for a group of disabled athletes with low SCI (paraplegics), and 42 mL/kg/min in a group of disabled athletes with no SCI and greater trunk control. These findings indicate that a smaller group of muscles utilized during exercise generates lower oxygen uptake, considering that the VO_2 max value takes into account the supply, transportation, and the muscular capacity to extract the oxygen.

Our findings agree with other results presented in the literature. Franklin[16] observed a VO_2 max of 22 mL/kg^{-1}/min^{-1} in a heterogeneous group of 30 wheelchair users (25 paraplegics, two with polio, and three amputees) who practiced sports regularly. The distance covered by these individuals in the 12-minute aerobic test ranged from 0.64 to 1.79 miles (1029.68 to 2880.73 meters). Using a multi-stage test, Vanderthommen[34] evaluated the aerobic physical performance of a heterogeneous group of wheelchair users who practiced sports and found a VO_2peak of 25.3 mL/kg/min. used an adaptation for wheelchair users of the multistage Léger and Boucher test and found a VO_2peak of 2.05 l/min^{-1}.

The literature has suggested that SCI type (partial or complete) and level can lead to reductions in the muscle mass that are activated during exercise and to alterations in the activation of the autonomous nervous system. In turn, these culminate in decreased aerobic capacity, with lower levels being observed in individuals with high SCI (quadriplegics) than in subjects with lower SCI (paraplegics)[33]. However, no differences in aerobic performance between the groups were observed in the present study. This finding may be due to the fact that the TCG had fewer participants (n = 7) than the WTCG.

The relationships found in both groups between MIP and distance covered in the aerobic performance test showed a positive and strong correlation, in which 36% and 50% of aerobic performance test results were influenced by IMS in the WTCG and TCG, respectively. The overloads imposed on inspiratory muscles during an intense exercise activity can limit the aerobic performance of highly trained athletes as well as healthy non-athletes[7,8,36]. Thus, the positive relationships founded between IMS and distance covered in the aerobic performance test may be related to the lower activation of the metaboreflex induced by the work of the inspiratory muscles. Considering that stronger muscles have a lower oxygen demand, the volunteers who presented better inspiratory muscle performances probably had lower oxygen demands from these muscles during the test, which led to lower amounts of required local blood flow. This mechanism may have optimized the blood flow distribution to the active muscles of the trunk and upper limbs, which in turn, reduced the pH imbalance caused by the exercise. This, in turn, led to decreased muscle fatigue and sensation of dyspnea, which culminated in better results on the aerobic test.

MEP was also positively correlated with distance covered in the aerobic performance test for both groups with a moderate strength. Moreover, it is important to note that 26% and 24% of the WTCG and TCG aerobic performance test results, respectively, were influenced by EMS. For wheelchair users, apart from abdominal muscles being use in the forced expiratory process[30] these muscles are also associated with greater efficiency in wheelchair propulsion[37,38]. Thus, the relationship found between EMS and aerobic performance may have been due to the greater activation of the abdominal muscles and better trunk control, which probably led to higher MEP values and better mechanical efficiency in wheelchair propulsion.

We did not find in the literature other studies that correlated IMS and/or EMS with the aerobic performance of wheelchair athletes. Thus, comparing our results with those of previous studies must be done with caution. Some others limitations were found and should be mentioned. The heterogeneity of the volunteers and the small sample size, particularly in the TCG, could have influenced the results. First, we have to take into account the difficulty of finding the specific population being studied study (WBCPs). Nevertheless, the inclusion and exclusion criteria were rigorously followed to minimize possible bias, and all eligible volunteers participated in the study were included. We propose that future studies try to have a higher number of participants and divide the volunteers according the respective etiologies of their disabilities.

We also have to highlight the fact that the equations used to obtain the predicted values for the respiratory variables were developed for individuals without disabilities, and that no similar equations could be found, which can be adapted for people with physical disabilities. Furthermore, evaluating the metabolic variables and the redirection of blood flow during the aerobic performance test could have better clarified the findings of this study.

The choice of the aerobic performance test could also be questioned. An ergospirometry test is often considered the gold standard test in evaluating the athlete's aerobic performance. However, owing to the lack of necessary equipment to perform this test, the field test was chosen because of the daily practice of the athletes and because of their specificity with the sport modality that was studied. We must also consider that the equation used to obtain the VO_2 max values took into account the distance covered by the athlete in this test. Moreover, the correlations analysis was also based on the distance covered because this variable can significantly predict physical capacity in field tests.

The lack of a reproducibility evaluation of the aerobic performance test can also be described as a limitation of the present study. The repetition of the test procedures by the subjects generated better results because of the learning effect. Unfortunately, because of the hard training routine of the athletes, we could not accomplish the second test to avoid this learning bias.

In conclusion, neither of the studied groups presented pulmonary alterations of restrictive or obstructive origin, and the inspiratory and expiratory muscle strengths were within or above the values predicted for age and gender. There were no significant differences in the inspiratory muscle strength or aerobic performance between the groups; however, the expiratory muscle strength of the TCG was greater than that of the WTCG, which could be attributed to greater trunk control and use of abdominal muscles in the former.

In addition, there were positive correlations between the maximal respiratory pressures and the distance covered in the aerobic performance test for both groups. These findings demonstrate that respiratory muscle strength is related to the aerobic performance of these WCBPs.

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