

# FUNCTIONAL CAPACITY IN ADOLESCENT IDIOPATHIC SCOLIOSIS DURING THE POSTOPERATIVE PERIOD

CAPACIDADE FUNCIONAL NA ESCOLIOSE IDIOPÁTICA DO ADOLESCENTE NO PERÍODO PÓS-OPERATÓRIO

CAPACIDAD FUNCIONAL EN LA ESCOLIOSIS IDIOPÁTICA DEL ADOLESCENTE EN EL PERÍODO POSTOPERATORIO



ORIGINAL ARTICLE  
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## ABSTRACT

**Introduction:** Patients with Adolescent Idiopathic Scoliosis (AIS) show reduced exercise capacity during the Incremental Shuttle Walk Test (ISWT). However, we not know how patients behave in the late postoperative (LPO) period. **Objective:** The aim of this study was to evaluate the ISWT distance (ISWTD) and physiological responses during ISWT in AIS patients during the LPO period. **Methods:** We included 22 patients with AIS in the LPO period (SG) and 21 adolescents in the Control Group (CG). We assessed pulmonary function (FVC and FEV<sub>1</sub>). During ISWT, a gas analyzer was used to assess peak oxygen (VO<sub>2</sub>) and submaximal relations: Oxygen Uptake Efficiency Slope (OUES) and the breathing pattern ( $\Delta V T / \Delta \ln V E$ ). **Results:** Significantly lower values were observed in SG: VO<sub>2</sub> ( $22 \pm 5$  vs.  $27 \pm 4$ ), ISWTD ( $567 \pm 94$  vs.  $604 \pm 86$ ), FVC ( $2.70 \pm 0.47$  vs.  $3.33 \pm 0.52$ ) and FEV<sub>1</sub> ( $2.41 \pm 0.46$  vs.  $2.84 \pm 0.52$ ). There were significant correlations between ISWTD and VO<sub>2</sub>/Kg ( $r = 0.80$ ); between OUES and  $\Delta V T / \Delta \ln V E$  ( $r = 0.65$ ); and between the main thoracic curve with VO<sub>2</sub>/Kg ( $r = -0.61$ ). **Conclusion:** AIS patients in the LPO period have significantly reduced exercise capacity associated with reduced lung function, residual spinal curve and cardiovascular deconditioning. **Level of Evidence III; Prognostic Studies - Investigation of the effect of characteristic of a patient on the outcome of the disease.**

**Keywords:** Adolescents; Exercise testing; Oxygen consumption; Physical fitness.

## RESUMO

**Introdução:** Pacientes com escoliose idiopática do adolescente (EIA) têm capacidade de exercício reduzida durante o Incremental Shuttle Walk Test (ISWT). No entanto, não sabemos como os pacientes se comportam no período pós-operatório tardio (POT). **Objetivo:** O objetivo deste estudo foi avaliar a distância do ISWT (ISWTD) e as respostas fisiológicas durante o teste em pacientes com EIA no período POT. **Métodos:** Foram incluídos 22 pacientes com EIA no período POT (GCI) e 21 adolescentes no Grupo Controle (GCo). Avaliamos a função pulmonar (CVF e VEF1). Durante o ISWT, foi utilizado um analisador de gases para avaliar o pico de oxigênio (VO<sub>2</sub>) e as relações submáximas: eficiência da captação de oxigênio (OUES) e o padrão de respiração ( $\Delta V C / \Delta \ln V E$ ). **Resultados:** Valores significativos mais baixos foram observados no GCI: VO<sub>2</sub> ( $22 \pm 5$  vs.  $27 \pm 4$ ), ISWTD ( $567 \pm 94$  vs.  $604 \pm 86$ ), CVF ( $2,70 \pm 0,47$  vs.  $3,33 \pm 0,52$ ) e VEF1 ( $2,41 \pm 0,46$  vs.  $2,84 \pm 0,52$ ). Houve correlações significativas entre ISWTD e VO<sub>2</sub>/Kg ( $r = 0,80$ ); entre OUES e  $\Delta V C / \Delta \ln V E$  ( $r = 0,65$ ) e entre a curva torácica principal com VO<sub>2</sub>/Kg ( $r = -0,61$ ). **Conclusão:** Os pacientes com EIA no período POT tiveram redução significativa da capacidade de exercício associada à função pulmonar reduzida, curva residual na coluna vertebral e descondicionamento cardiovascular. **Nível de Evidência III; Estudos Prognósticos - Investigação do efeito de característica de um paciente sobre o desfecho da doença.**

**Descritores:** Adolescentes; Testes de exercício físico; Consumo de oxigênio; Aptidão física.

## RESUMEN

**Introducción:** Pacientes con escoliosis idiopática del adolescente (EIA) tienen capacidad de ejercicio reducida durante el Incremental Shuttle Walk Test (ISWT). Sin embargo, no sabemos cómo los pacientes se comportan en el período postoperatorio tardío (POT). **Objetivo:** El objetivo de este estudio fue evaluar la distancia del ISWT (ISWTD) y las respuestas fisiológicas durante la prueba en pacientes con EIA en el período POT. **Métodos:** Se incluyeron 22 pacientes con EIA en el período POT (GQ) y 21 adolescentes en el grupo control (GC). Se evaluó la función pulmonar (CVF y VEF1). Durante el ISWT, se utilizó un analizador de gases para evaluar el pico de oxígeno (VO<sub>2</sub>) y las relaciones submáximas: eficiencia de la captación de oxígeno (OUES) y el patrón respiratorio ( $\Delta V C / \Delta \ln V E$ ). **Resultados:** Se observaron valores significativos más bajos en el GQ: VO<sub>2</sub> ( $22 \pm 5$  vs.  $27 \pm 4$ ), ISWTD ( $567 \pm 94$  vs.  $604 \pm 86$ ), CVF ( $2,70 \pm 0,47$  vs.  $3,33 \pm 0,52$ ) y VEF1 ( $2,41 \pm 0,46$  vs.  $2,84 \pm 0,52$ ). Hubo correlaciones significativas entre ISWTD y VO<sub>2</sub>/Kg ( $r = 0,80$ ), entre OUES y  $\Delta V C / \Delta \ln V E$  ( $r = 0,65$ ) y entre la curva torácica principal con VO<sub>2</sub>/Kg ( $r = -0,61$ ). **Conclusión:** los pacientes con EIA en el período POT tuvieron reducción significativa de la capacidad de ejercicio asociada a la función pulmonar reducida, la curva residual de la columna vertebral y la falta de condicionamiento cardiovascular. **Nivel de evidencia III; Estudios pronósticos - Investigación del efecto de característica de un paciente sobre el desenlace de la enfermedad.**

**Descriptorios:** Adolescentes; Test de esfuerzo físico; Consumo de oxígeno; Aptitud física.



## INTRODUCTION

The adolescent idiopathic scoliosis (AIS) represents 80% of all idiopathic scoliosis, with a higher prevalence in women, affecting especially the age group between 10 and 18 years.<sup>1</sup> Surgical treatment is indicated in spinal curvatures greater than 45°<sup>1</sup> and aims to prevent disease progression and correct deformities<sup>2</sup> that could compromise ventilatory mechanics and exercise capacity.<sup>3</sup>

Individuals with AIS exhibit lower exercise tolerance. This has already been demonstrated with a significant reduction in oxygen consumption ( $\text{VO}_2$ ) in Cardiopulmonary Exercise Testing (CPET).<sup>4-6</sup> Few studies used the Incremental Shuttle Walking Test (ISWT) to evaluate exercise limitation in this population,<sup>3,7,8</sup> but only in patients during the preoperative period. The ISWT is a simple walking test, which shows good reproducibility, no need to use specific ergometer<sup>9,10</sup> and it can be done with good tolerance and safety in children and adolescents.<sup>11</sup> The Incremental Shuttle Walk Distance (ISWD) shows consistent correlation with  $\text{VO}_2$  peak obtained in the CPET.<sup>12</sup>

Based in the literature and in the absence of consensus on exercise tolerance in CPET after surgery,<sup>4</sup> we hypothesized that there is a significant impairment in functional exercise capacity in AIS patients at late postoperative (LPO) period. The aim of this study was to evaluate the ISWD and physiological responses during ISWT in AIS patients at the LPO and to assess the postoperative spinal curvature, respiratory muscle strength, pulmonary function and its correlation with the physiological variables.

## METHODS

This is a cross-sectional study, with AIS patients in the LPO period and healthy individuals. All participants and their legal representatives signed the consent form and free and informed consent. The Ethics Committee approved this study (n° 1349351).

Patients were screened voluntarily during the Orthopedics appointment in a local Hospital. During the screening were collected the angle values of postoperative curvatures using the Cobb method. Proximal thoracic Cobb angle (CobbPT), main thoracic Cobb angle (CobbMT) and lumbar Cobb angle (CobbL) were recorded, also were recorded the number of fixed vertebrae during surgery.

Female patients diagnosed with AIS in LPO period of arthrodesis with posterior approach were included in the scoliosis group (SG). It was considered LPO the minimum of 18 and maximum of 36 months after surgery. Were excluded from this study those patients with a previous or current history of heart, lung or neuromuscular diseases and patients who for some reason failed to perform the evaluations proposed. Physically active patients were also excluded.<sup>13</sup>

The control group (CG) was matched to the SG. Exclusion criteria were the same described for SG, but were also excluded those individuals with spinal deformity or other important postural changes assessed by the Adams test and postural assessment.<sup>14</sup>

The anthropometric data was assessed, for weight measurement was used a scale with 0.1 kg precision and for height was used a stadiometer to the nearest 0.5 cm. Body mass index (BMI) was calculated ( $\text{weight (kg)} / \text{height}^2 (\text{m})$ ).

### Respiratory Assessment

Spirometry was performed with a portable spirometer (microQuarck; Cosmed, Pavanadi Albano, Italy) according to BSTA recommendations.<sup>15</sup> Forced vital capacity (FVC), forced expiratory volume in the first second ( $\text{FEV}_1$ ) and the  $\text{FEV}_1/\text{FVC}$  ratio in absolute and percentage of predicted values for the Brazilian population<sup>16</sup> were considered.

### Incremental Shuttle Walk Test (ISWT)

The ISWT was performed according to the recommendations.<sup>9</sup>

Heart rate, oxygen saturation, blood pressure and perceived dyspnea and fatigue of the lower limbs (Borg scale) were assessed before and immediately after ISWT. Two tests were conducted with 30 min intervals between them. The walked distance (ISWD) of the second test was considered for the analysis.

During the second ISWT expired gasses were collected and analyzed in portable equipment with telemetry module (K4b2, Cosmed, Pavanadi Albano, Italy). It was used a facial mask with minimal dead space (50 mL). The gas analyzer was accommodated to the trunk of the participants allowing free movement without discomfort. Calibrations were performed following the manufacturer's recommendations.

Oxygen uptake ( $\text{VO}_2$ ),  $\text{VCO}_2$ , tidal volume (VT), respiratory rate (RR), heart rate (HR), and other variables obtained by calculations based on these variables were recorded breath by breath. The ventilatory reserve (VR) was analyzed and represented by the difference between maximum voluntary ventilation and minute ventilation (MVV-VE). Data were filtered every 15 seconds for analysis and all measurements were obtained at the test peak. Additionally, based on the baseline linear regression value (intercept) and the rate of change (slope), the following submaximal relations were determined:  $\Delta\text{HR}/\Delta\text{VO}_2$ ,  $\Delta\text{VE}/\Delta\text{VCO}_2$  and  $\Delta\text{VT}/\Delta\text{VE}$  linearized (ie,  $\Delta\text{VT}/\Delta\ln\text{VE}$ ). These relations were obtained by linear regressions and respectively represent the cardiovascular and respiratory efficiency and breathing pattern during the test. An additional variable was used during the incremental test to check oxygen uptake efficiency slope (OUES), expressed as the ratio  $\Delta\text{VO}_2/\Delta\log\text{VE}$ .

### Statistical analysis

The sample size was calculated taking into consideration the minimum clinically significant differences in peak  $\text{VO}_2$  during ISWT. In a previous study with healthy participant, peak  $\text{VO}_2$  during ISWT presented a standard deviation of 609 mL/min, with a reduction of 605 mL/min representing the lower limit of normal.<sup>17</sup> We, therefore, considered the reduction of more than 605 mL/min as clinically significant for peak  $\text{VO}_2$  related to ISWT. With the standardized effect size around one, probability alpha error at 0.05 and beta of 0.20, we obtained the number of at least 16 participants in each research group.

Data were analyzed descriptively and are presented according to the distribution of the studied variables. The normality of variables was investigated by Shapiro-Wilk test. To compare the means or medians of variables between groups we used the unpaired T-test or Mann-Whitney test. The correlations were assessed by Pearson or Spearman coefficients and linear regressions were performed. The probability of alpha error was set at 5% for all analyzes.

## RESULTS

We evaluated 56 participants, four patients were excluded from SG for not completing all assessments proposed and nine were excluded from CG because they have postural abnormalities detected on screening. The final sample consisted of 43 individuals, of which 22 (51.16%) were allocated to SG. AIS patients had on average  $24 \pm 9$  months of postoperative and the number of fixed vertebrae was  $8.7^{11}$ . No significant differences were observed between groups regarding anthropometric characteristics (Table 1).

The absolute and predicted values of FVC and  $\text{FEV}_1$  were, on average, significantly lower in the SG (Table 2).

The ISWD values were significantly lower in the SG compared to the CG, both in the first and in the second test. Patients with scoliosis walked greater distance in the second test ( $p = 0.041$ ). Data regarding the ISWT and physiological responses are described in Table 3.

Among the submaximal relations, only  $\Delta\text{VT}/\Delta\ln\text{VE}$  and OUES presented statistical difference between groups, showing lower values

**Table 1.** Demographic, anthropometric and Cobb angles values.

Variables	SG	CG	P
N (%)	22 (51%)	21 (49%)	
Age, yr	15 ± 2	15 ± 3	0,768
Weight, kg	49 [45-55]	52 [45-60]	0,337
Height, m	1,62 ± 0,08	1,61 ± 0,08	0,726
BMI, kg/m <sup>2</sup>	19 [16-20]	20 [18-22]	0,264
CobbPT	9 [5-17]		
CobbMT	14 ± 6		
CobbL	12 ± 8		

SG – Scoliosis group; CG – control group; CobbPT: proximal thoracic Cobb angle; CobbMT: main thoracic Cobb angle; CobbL: lumbar Cobb angle.

**Table 2.** Respiratory pressures and pulmonary function in AIS patients at the late postoperative period and healthy adolescents.

Variables	SG	CG	p
<b>Respiratory pressures</b>			
MIP, cmH <sub>2</sub> O	66 ± 19	75 ± 21	0,179
MEP, cmH <sub>2</sub> O	62 ± 22	71 ± 20	0,206
<b>Spirometry</b>			
FVC, L	2,70 ± 0,47	3,33 ± 0,52	<0,001
FVC, % of predicted	86 ± 13	105 ± 15	<0,001
FEV <sub>1</sub> , L	2,41 ± 0,46	2,84 ± 0,52	0,007
FEV <sub>1</sub> , % of predicted	83 ± 14	99 ± 16	0,002
FEV <sub>1</sub> /FVC, %	89 ± 10	85 ± 8	0,150

SG – Scoliosis group; CG – control group; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; FVC: forced vital capacity; FEV<sub>1</sub>: forced expiratory in first second.

**Table 3.** Values of means and standard deviations or medians and interquartile ranges of the metabolic, ventilatory responses, cardiovascular and submaximal relations during ISWT.

Variables	SG	CG	p
<b>ISWT</b>			
1 <sup>st</sup> ISWD (m)	419 ± 92	444 ± 81	<0,001
2 <sup>nd</sup> ISWD (m)	567 ± 94	604 ± 86	<0,001
<b>Metabolic responses</b>			
VO <sub>2</sub> , ml/min	1108 ± 243	1474 ± 315	<0,001
VO <sub>2</sub> , ml/kg/min	22 ± 5	27 ± 4	0,001
VCO <sub>2</sub> , ml/min	1095 ± 318	1610 ± 326	<0,001
R, ml/min	1,05 [0,95-1,12]	1,19 [1,08-1,35]	0,002
<b>Ventilatory responses</b>			
RR (ipm)	42 [35-58]	47 [40-56]	0,136
VT (L)	0,91 [0,71-1,21]	1,34 [1,09-1,58]	0,001
VE (L/min)	37 ± 11	54 ± 11	<0,001
VE/VO <sub>2</sub>	34 [33-40]	41 [35-51]	0,075
VE/VCO <sub>2</sub>	39 [38-46]	40 [37-43]	0,940
VR (%)	75 ± 5	67 ± 10	0,008
<b>Cardiovascular responses</b>			
HR (bpm)	149 ± 29	185 ± 12	<0,001
PuO <sub>2</sub> (ml/min/bpm)	7,95 [6,62-12,52]	8,20 [7,20-9,20]	0,869
<b>Submaximal relations</b>			
ΔHR/ΔVO <sub>2</sub> (bpm/L/min)	63 ± 20	69 ± 30	0,498
ΔVE/ΔVCO <sub>2</sub> (L/min)	29 ± 4	29 ± 5	0,818
ΔVT/ΔlnVE	0,33 ± 0,11	0,43 ± 0,14	0,029
OUES (ml/min)/(L/min)	1491 ± 220	1778 ± 452	0,022
<b>Borg scale</b>			
Dyspnea	4 [2-5]	5 [3-8]	0,144
Lower limbs fatigue	4 [3-7]	5 [3-8]	0,399

SG – Scoliosis group; CG – control group; ISWD: Incremental Shuttle Walking Test distance; VO<sub>2</sub>: oxygen uptake, VCO<sub>2</sub>: carbon dioxide production, R: rate of gas Exchange, RR: respiratory rate, VT: tidal volume, VE: minute ventilation, VE/VO<sub>2</sub>: respiratory equivalent of oxygen, VE/VCO<sub>2</sub>: respiratory equivalent carbon dioxide, OUES (ΔVO<sub>2</sub>/ΔlogVE): oxygen uptake efficiency slope, VR: ventilatory reserve, HR: heart rate, PuO<sub>2</sub>: oxygen pulse, ΔHR/ΔVO<sub>2</sub>: cardiovascular efficiency; ΔVE/ΔVCO<sub>2</sub>: ventilatory efficiency, ΔVC/ΔlnVE: ventilatory pattern.

in the SG. Figure 3 presents a typical example of a worse respiratory pattern and OUES in the SG.

Strong correlations were observed between ISWD with VO<sub>2</sub> and VO<sub>2</sub>/kg (Figure 1). Moderate correlation was observed between ISWD and CobbMT ( $r = -.47$ ;  $p = .116$ ) and HR ( $r = .44$ ;  $p = .076$ ). Moderate correlations were observed between VO<sub>2</sub> and OUES ( $r = .67$ ;  $p = .001$ ), FEV<sub>1</sub> ( $r = 0.48$ ;  $p = .035$ ) and the number of fixed vertebrae ( $r = .43$ ;  $p = .16$ ). In addition, VO<sub>2</sub> and OUES showed moderate correlations with ΔVC/ΔlnVE (Figure 2). Moderate correlations were observed between VO<sub>2</sub> and VR ( $r = -.46$ ;  $p = .046$ ).

Regarding the postoperative residual scoliotic curve and the physiological variables studied, moderate correlations were observed between CobbMT and VO<sub>2</sub>/kg ( $r = -.61$ ;  $p = .035$ ) and HR ( $r = -.40$ ;  $p = .222$ ).

## DISCUSSION

Data presented in this study indicate reduced exercise capacity in AIS patients in the late postoperative period compared to healthy participants. Moreover, we observed significant associations of exercise capacity with lung function, Cobb angle and ventilatory pattern during exercise.

All scoliosis patients in this study had a mild postoperative spinal curvature with angles lower than 20°. We observed correlation between VO<sub>2</sub> and CobbMT and the number of fixed vertebrae in the surgical procedure. These data suggest that the surgical technique may influence the exercise capacity in AIS patients at LPO.

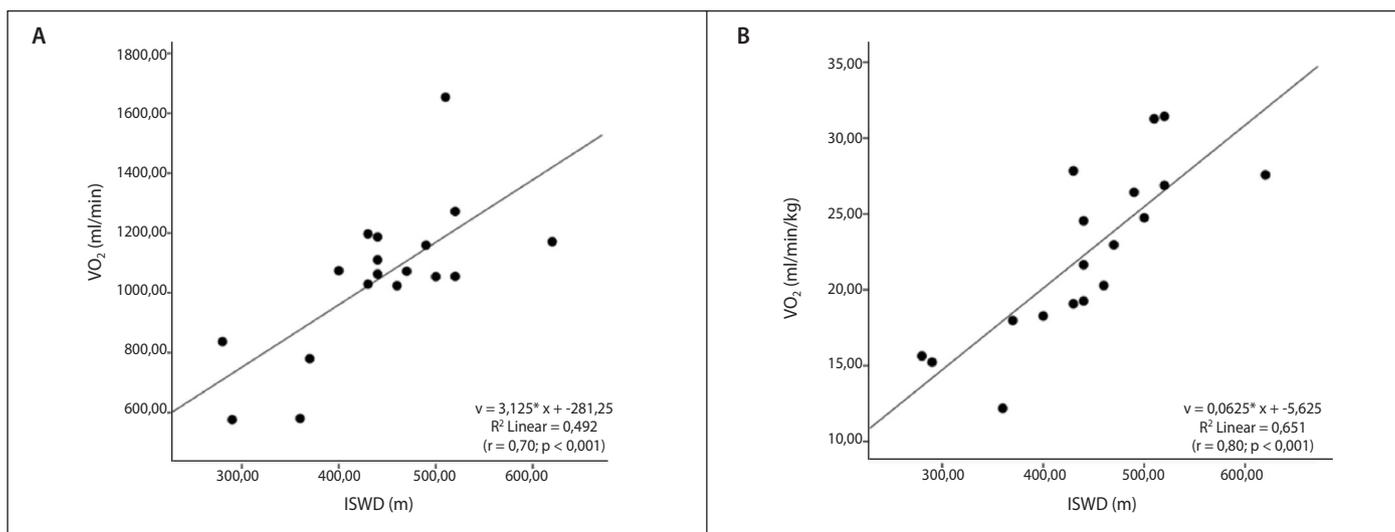
It is known that the walked distance in the six-minute walk test<sup>18</sup> and the ISWD<sup>3,7</sup> are reduced in the AIS patients in the preoperative period, but data on LPO period were not found in the literature. In the present study, we observed significantly lower walked distances in the SG, with a difference compared to CG of 25 m in the first test and 37 m in the second. These differences were lower than the minimum clinically important difference (MCID), known as 47.5 m for the ISWT in adults with chronic obstructive pulmonary disease,<sup>19</sup> but sufficient to observe a lower VO<sub>2</sub> at SG, both in the first and second test. Considering that the R values obtained in our study (> 0.95) indicate high-intensity exercise performance<sup>20</sup> and that the ISWD and VO<sub>2</sub> values were lower in the SG, we can highlight the presence of lower exercise capacity in this study group.

It might be noted that the difference in ISWD between the first and the second test in scoliosis patients was 148 meters and the control group was 160 meters. These differences reinforce the need for a second test in this population, due to the important learning effect observed.

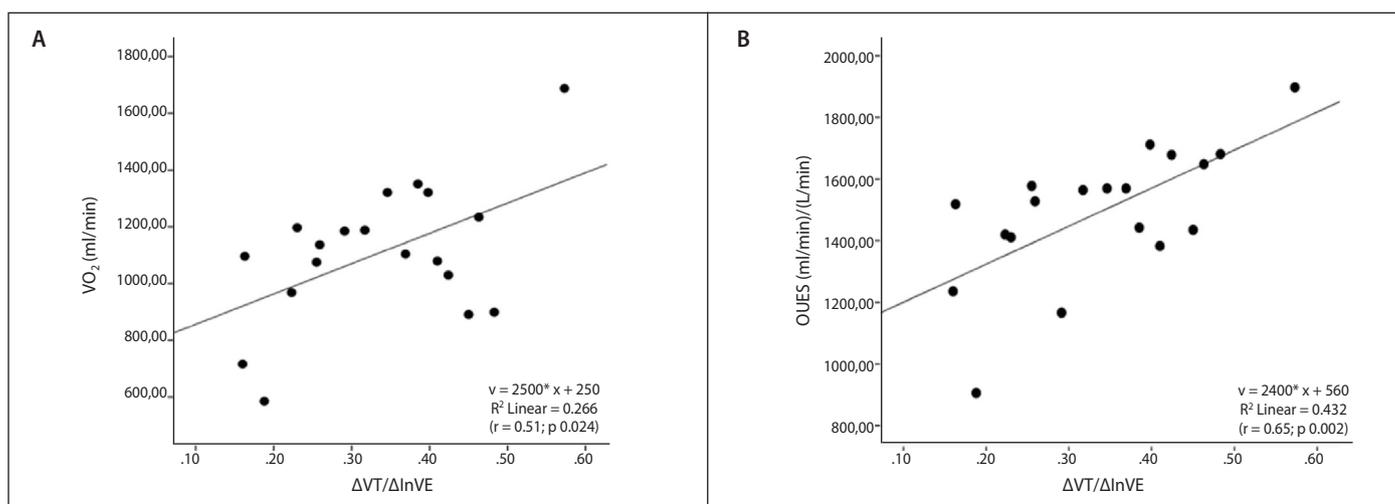
In a previous study was observed in AIS patients at the preoperative period ISWD of 69 meters less than that observed in our study.<sup>7</sup> The authors also observed higher VO<sub>2</sub> (1247 ± 450 ml/min) and lower ISWD (498 ± 144 m) when compared to our study. The patients in the LPO period in the present study presented lower VO<sub>2</sub> obtained in a higher ISWD. Although they are not the same individuals, these data suggest a better exercise capacity in AIS patients in LPO compared to patients in the preoperative period.

We observed lower VO<sub>2</sub> and VO<sub>2</sub>/Kg values in SG compared to the CG with a strong correlation between VO<sub>2</sub> and ISWD. Considering that VO<sub>2</sub> is the best aerobic capacity index and the gold standard to determine physical fitness in CPET<sup>21</sup> and whereas evidence that the correlation between ISWD and VO<sub>2</sub> at the end of ISWT ( $r = 0.81$ ) is similar to that observed in CPET performed on a treadmill ( $r = 0.88$ )<sup>22</sup>, our data underline the presence of physical deconditioning in SG.

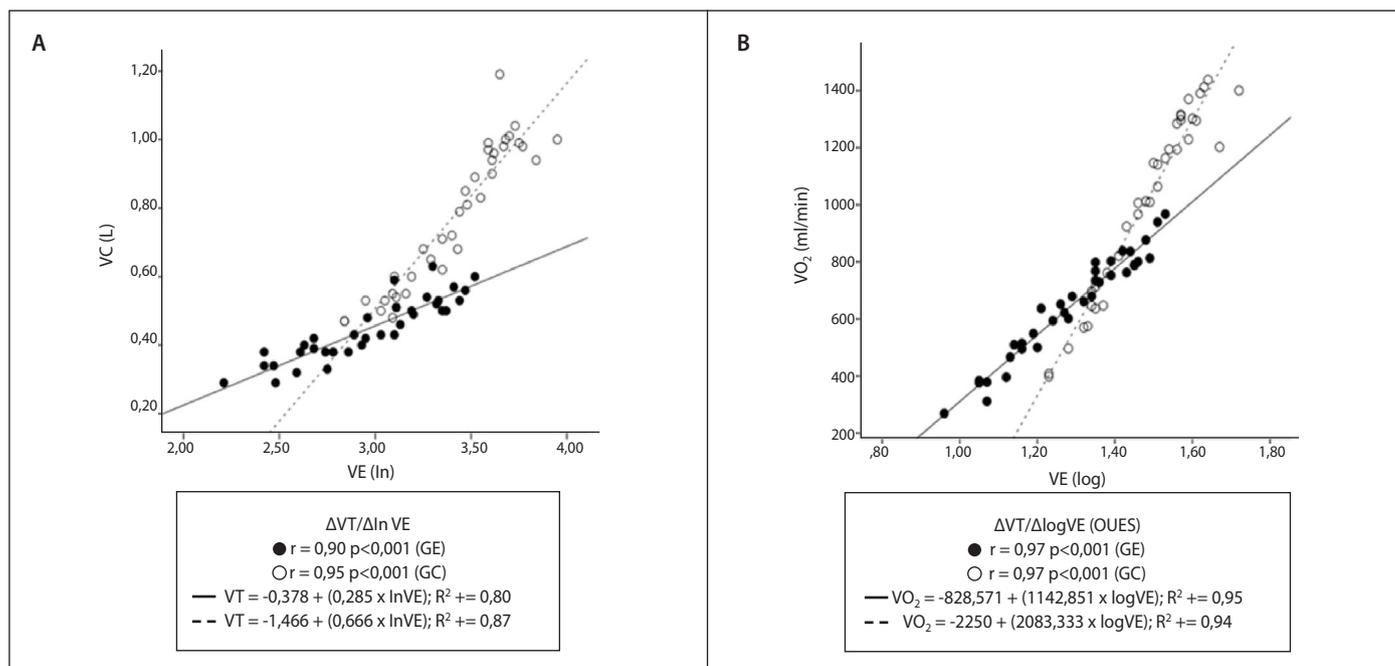
It is important to highlight the reduced OUES values in SG and its correlation with VO<sub>2</sub> in this study, indicating a reduction in O<sub>2</sub> uptake and utilization, and reduced exercise capacity. It is known that OUES is an



**Figure 1.** Significant correlations between oxygen consumption (A) and oxygen consumption corrected by the body (B) with the distance on the Incremental Shuttle Walk Test.



**Figure 2.** Significant correlations between oxygen consumption (A) and Oxygen Uptake Efficiency Slope (B) with the linearized ventilatory pattern ( $\Delta VT/\Delta \ln VE$ ).



**Figure 3.** Typical examples of curves observed in patients with AIS. Graph comparing data from one patient with AIS (SG) in the late postoperative period (14 years) and one healthy individual from the control group (CG) (15 years). A: breathing pattern during the Incremental Shuttle Walk Test, measured by linear regressions between tidal volume (VT) and minute volume (VE) linearized by natural logarithm. B: Oxygen Uptake Efficiency Slope (OUES) evaluated by linear regressions, from the logarithmic relation between oxygen consumption ( $VO_2$ ) and VE. Graphical representations show a flatter slope in SG compared to the CG. The magnitude of the slope appears in bold in the equation.

independent and submaximal cardiorespiratory reserve variable, without the need for maximum effort, reliable in children, adolescents and adults.<sup>23</sup> The evaluation of OUES in submaximal tests such as ISWT becomes an important tool to identify the limitation of exercise capacity. This fact can be confirmed in our study, because, even with reduced ISWD, we observed a significant reduction of OUES in the SG and correlation with the ventilatory pattern. In addition, we observed a significant slope flattening of the curve in the OUES graph in our results. Although there is evidence in our study of physical deconditioning in SG, we believe that pulmonary function and respiratory mechanics can play an important role in the reduced exercise capacity found. The lower values of VT, VE and  $\Delta VT/\Delta InVE$  found in our study suggest a restrictive ventilatory pattern during exercise in AIS patients. Even though the RR was not different between the groups, the RR reached at the end of ISWT in SG occurred with lower VT values when compared to CG. Therefore, we believe that the restrictive respiratory pattern during walking and physical deconditioning in SG were crucial for the reduced ISWD and exercise capacity.

The increase in respiratory work seems to be present in the scoliosis patients at the late postoperative period, since the patients presented worse respiratory pattern, represented by the worse relation  $\Delta VT/\Delta InVE$ , showing an important flattening of the curve in our results. In addition, we observed a moderate correlation between the ventilatory pattern and the OUES, indicating that oxygen uptake during exercise is lower when there is a worse respiratory pattern. We suggest that the worse respiratory pattern contributes to the physical deconditioning, independent of the surgical correction. The correlations with OUES reinforce the influence of the respiratory pattern on exercise capacity. Beyond the worse ventilatory pattern in the SG, we found significantly higher ventilatory reserve (VR) values, reinforcing the presence of physical deconditioning.<sup>20</sup> The negative correlation between  $VO_2$  and ISWD with VR, found in our study, shows that a better performance is observed when VR is lower. As the scoliosis patients at the LPO presented higher VR values, we suggested that ventilatory limitation may be the cause or contribute to exercise intolerance.<sup>24</sup>

Although restrictive ventilatory disorders are described as frequent in AIS patients,<sup>25</sup> especially in curvatures greater than 45°, we observed that even with slight residual curvatures after the surgical procedure, patients presented significantly lower FVC and FEV<sub>1</sub> values when compared to the CG. Studies have found increased pulmonary function

(FVC and FEV<sub>1</sub>) two years after the surgical procedure in AIS patients.<sup>26</sup> However, its effects are still controversial, it is not clear if lung function improves or worsens after the surgical procedure.<sup>27</sup>

For reasons that are still unknown, patients with scoliosis may be less physically active than those of the same sex and age. The exercise capacity seems to be reduced in the preoperative phase<sup>3,7</sup> and we observed in our study that this reduction is also observed two years after the surgical procedure. Considering that exercise capacity may be reduced even in patients with mild and moderate scoliosis, other factors may influence this variable may be due to the low adherence of individuals to the practice of physical activity.<sup>28</sup>

The reduced participation of AIS individual in physical activities may be related to some constraint on their appearance, reducing the willingness to participate in aerobic activities.<sup>29</sup> However, our data demonstrate that correcting deformity does not seem to be synonymous with better exercise capacity and that a sedentary lifestyle is likely to be maintained.

Among the limitations of the study, we can mention the non-performance of CPET and the absence of objective assessment of daily physical activity level. However, it is worth mentioning that the ISWT was able to identify a reduction of exercise capacity in this sample and the data suggest the presence of physical deconditioning. In addition, this is the first study known by the authors using ISWT in AIS patients at the late postoperative period and reinforces the need to include these patients in physical activity programs.

Further studies that correlate the daily physical activity level and aerobic training with exercise capacity in individuals with AIS are necessary since the cause of exercise limitation in this population has not yet been elucidated and may be a consequence of physical deconditioning

## CONCLUSIONS

Patients with AIS after two years of surgery present a significant exercise capacity reduction associated to a reduced pulmonary function and residual spinal curvature. The ISWT was capable to assess the exercise capacity in this population and showed that AIS patients present a compromised ventilatory pattern during walking.

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All authors declare no potential conflict of interest related to this article

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