Article published online: 2023-09-26

Effect of Spinal Correction Surgery on Lower Limb Strength in Idiopathic Adolescent Scoliosis

Efeito da cirurgia de correção da coluna vertebral na força dos membros inferiores na escoliose idiopática do adolescente

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Rev Bras Ortop 2023;58(6):e912–e916.

Abstract

Objectives To analyze the lower limb strength in both untreated and surgically treated adolescent idiopathic scoliosis (AIS) patients and examine its correlation with the distance covered in a six-minute walking test (6MWT).

Methods A total of 88 participants ($n = 30$ pre-surgery AIS patients, $n = 30$ post-surgical AIS patients, and $n = 28$ control) underwent a 6MWT and a muscle strength assessment. The lower limb strength was measured at the knee joint using the knee extension (KE) and knee flexion (KF) peak torque (PT) measurements.

Results The control group covered a greater distance in the TC6 compared to both the pre-surgical (534 ± 67 m) and post-surgical (541 ± 69 m) groups, with a distance of 612 ± 70 m ($p < 0.001$). No differences were observed in KE PT (pre: 2.1 ± 0.63, post: 2.1 ± 0.7, control: 2.2 ± 0.7 Nm.kg^{-1}, $p = 0.67$) or KF PT (pre: 1.0 ± 0.3, post: 1.1 ± 0.3, control: 1.1 ± 0.5 Nm.kg^{-1}, $p = 0.46$). A moderate positive correlation was observed

Keywords
- adolescent
- scoliosis
- muscle strength
- exercise test

Study developed at the Instituto Nacional de Traumatologia e Ortopedia, Rio de Janeiro, RJ, Brazil.

received February 23, 2023
accepted March 27, 2023
article published online September 26, 2023

DOI https://doi.org/10.1055/s-0043-1770980.
ISSN 0102-3616.

Thieme Revinter Publicações Ltda., Rua do Matoso 170, Rio de Janeiro, RJ, CEP 20270-135, Brazil

between KE PT and 6MWT distance ($r = 0.53$, $p < 0.001$), as well as a low positive correlation for KF PT ($r = 0.37$, $p = 0.003$) with 6MWT distance.

Conclusion This study highlights the importance of lower limb maximal strength in the functionality of AIS patients. Our findings suggest that exercise programs aimed at enhancing lower limb strength, especially the KE, could improve the walking capacity of AIS patients. These results provide useful information for designing purposeful exercise programs for AIS patients with walking deficits.

Resumo

Objetivos Analisar a força dos membros inferiores em pacientes com escoliose idiopática do adolescente (EIA) submetidos ou não ao tratamento cirúrgico e examinar sua correlação com a distância percorrida em um teste de caminhada de seis minutos (6MWT).

Métodos Um total de 88 participantes (n = 30 pacientes com EIA antes da cirurgia, n = 30 pacientes com EIA após a cirurgia e n = 28 controles) foram submetidos ao 6MWT e à avaliação da força muscular. A força dos membros inferiores foi medida na articulação do joelho usando os valores de pico de torque (PT) de extensão do joelho (EJ) e flexão do joelho (FJ).

Resultados O grupo controle percorreu uma distância maior no 6MWT em comparação aos grupos pré-operatório (534 ± 67 m) e pós-operatório (541 ± 69 m), com distância de 612 ± 70 m ($p < 0{,}001$). Não foram observadas diferenças em PT EJ (pré: 2,1± 0,63, pós: 2,1± 0,7, controle: 2,2 ± 0,7 $Nm.kg^{-1}$, $p = 0{,}67$) ou PT FJ (pré: 1,0 ± 0,3, pós: 1,1± 0,3, controle: 1,1 ± 0,5 $Nm.kg^{-1}$, $p = 0{,}46$). Houve uma correlação positiva moderada entre PT EJ e a distância do 6MWT ($r=0{,}53$, $p<0{,}001$), assim como uma correlação positiva baixa entre PT FJ ($r=0{,}37$, $p=0{,}003$) e a distância do 6MWT.

Conclusão Este estudo destaca a importância da força máxima dos membros inferiores na funcionalidade de pacientes com EIA. Nossos achados sugerem que programas de exercícios destinados a aumentar a força dos membros inferiores, especialmente de EJ, podem melhorar a capacidade de caminhada de pacientes com EIA. Esses resultados fornecem informações úteis para o projeto de programas de exercícios intencionais para pacientes com EIA e déficits de marcha.

Palavras-chave
- adolescente
- escoliose
- força muscular
- teste de esforço

Introduction

Scoliosis is a pathological spinal deformity characterized by a marked coronal curvature and vertebrae rotation.[1] It can be caused by congenital factors, secondary to a neuromuscular disorder, or have no obvious cause.[2] Adolescent idiopathic scoliosis (AIS) is the most prevalent type of scoliosis,[2] affecting 0.6-2.0% and 2.2–4.6% of the boys and girls between 12–14 years old,[3,4] respectively. In Brazil, the estimated prevalence is 1.8–4.8% for the age range between 10 and 16 years old.[5,6] Given the high incidence of AIS, it is important to better understand the detrimental effects of this condition.

The AIS can have a significant impact on various aspects of a patient's life, including their pulmonary function and physical abilities. There have been numerous reports documenting a decrease in forced vital capacity and inspiratory pressure in patients with AIS.[7–10] Furthermore, their ability to walk, or deambulation capacity, is also impacted,[7,9] with patients typically exhibiting a reduced stride length[11] and diminished pelvic motion, along with increased muscle activation in the erector spine and gluteus medius.[12] In addition to these physical limitations, patients with AIS also tend to have a more sedentary lifestyle, engaging in regular physical activity for only half the time of their healthy counterparts.[7]

Human motion is dependent on muscle tissue and its capacity to produce muscle force. Despite the limitations in movement faced by individuals with AIS, little is known about their muscle strength. Research has shown that the paraspinal muscles in these patients are smaller[13] and have a higher content of fat and fibrous tissue,[14] which may contribute to the deficits in trunk rotational strength[15] and respiratory strength that have been observed.[8,10] The only study to analyze limb muscle strength found reductions in handgrip and knee extension compared to an age-matched control group.[16] Interestingly, both measures of strength were correlated with respiratory strength in the AIS patient group. Despite the potential value of limb strength in providing information about the patient's condition and insight into their motion problems, the topic has received limited attention in recent years.

To counteract the limiting effects of AIS on physical function, patients often undergo spinal correction surgery through vertebral arthrodesis.[17] This surgical intervention restricts spine mobility but has been shown to improve gait mechanics,[18,19] pulmonary function,[20] and other aspects of the patient's physical characteristics. Despite these improvements, the effects of the surgery on other elements of the patient's physical function, such as deambulation capacity and limb muscle strength, remain unclear. To shed light on this topic and better understand the relationship between these factors, we aimed to assess lower limb maximal strength in both pre- and post-surgery AIS patients and examine its correlation with the distance covered in a six-minute walking test (6MWT).

Methods

Participants

A total of 60 patients with AIS previously enrolled in our group's study[10] are participating in this study. These patients are either on the waiting list for surgery (n = 30) or have undergone posterior vertebral arthrodesis with a minimum one-year post-operative follow-up (n = 30). Demographic data of pre- and post-surgical patients can be found in a previous publication.[10] Briefly, pre-surgery patients (age: 18.5 ± 2.4 years, total mass: 54.1 ± 11.0 kg, height: 162.3 ± 7.6 cm) and post-surgery (age: 24.5 ± 4.5.4 years, total mass: 59.4 ± 14.8 kg, height: 165.0 ± 7.9 cm). A control group (n = 28, age: 22.4 ± 4.9 years, total mass: 61.9 ± 12.4 kg, height: 164.0 ± 8.3 cm), was conveniently selected from the hospital staff and their close relatives. Inclusion criteria for the control group were an age between 15 and 25 years, and a negative result on the Adam's test for spinal deformity. The study was approved by the Institutional Review Board (CAAE: 98957118.8.0000.5273).

Procedures

All procedures were conducted during a single session, lasting approximately 40 minutes. Participants were first subjected to the Six-minute walking test (6MWT) and then underwent a Muscle Strength Assessment of knee extensors and flexors.

Six-minute Walking Test (6MWT)

The participant was encouraged to walk as fast as possible for 6 minutes along a straight and level 30-meter corridor with a hard surface, marked at 3-meter intervals.[10]

Muscle Strength Assessment

The peak torque (PT) of knee extension (KE) and knee flexion (KF) was measured during an isokinetic test at 60°/s (HUMAC NORM II, CSMI, USA). Participants sat upright with their hips at an angle of 85° and their knee joint aligned with the dynamometer's axis. Inelastic straps were used to secure their chest. A familiarization and warm-up set of 5 progressive repetitions (ranging from 50% to maximum perceived effort) was performed, followed by a 30-second rest interval. Participants then performed 5 maximal repetitions. The PT was defined as the highest torque recorded during KE and KF, normalized by the participant's body weight. The limbs were assessed in a randomized order.

Statistical Analysis

All variables demonstrated a normal distribution, determined using the Shapiro-Wilk test. Group differences for the studied variables 6MWT and maximal strength were analyzed using one-way ANOVA. When necessary, Bonferroni post-hoc tests were conducted. Correlation was analyzed in the combined AIS patient groups (pre- and post-surgery) using the Pearson correlation coefficient between maximal strength with the 6MWT distance. A significance level of 0.05 was used for all tests. The analysis was performed using custom-made routines in Python 3.0.

Results

The control group covered a greater distance in the 6MWT compared to both the pre-surgical (534 ± 67 m) and post-surgical (541 ± 69 m) groups,[10] with a distance of 612 ± 70 m ($p < 0.001$).

However, no differences were observed in KE PT ($p = 0.67$), KF PT ($p = 0.46$) (►**Table 1**). We observed a moderate positive correlation between KE PT and 6MWT distance ($r = 0.53$, $p < 0.001$), as well as a low positive correlation for KF PT ($r = 0.37$, $p = 0.003$) with 6MWT distance (►**Table 1**).

Discussion

This study aimed to examine the effect of surgery treatment on lower limb maximal strength in AIS patients. Also, to investigate the correlation between lower limb maximal strength and deambulation capacity. The results showed that there was no significant difference in the KE and KF maximal strength between the treated and untreated AIS patients and the control group and a positive correlation between both KE and KF strength and the 6MWT distance in AIS patients.

Table 1 Knee extensors and flexors maximal strength

	Pre-surgery	Post-surgery	Control
KE PT ($Nm.kg^{-1}$)	2.09 ± 0.63	2.09 ± 0.68	2.23 ± 0.70
KF PT ($Nm.kg^{-1}$)	0.97 ± 0.34	1.10 ± 0.34	1.05 ± 0.45

Abbreviations: KE, knee extension; KF, knee flexion; PT, peak torque.
Note: No significant differences were observed.

To date, there have been limited studies that have compared the muscle strength of AIS patients to non-scoliotic individuals.[15,16] Those previous studies have reported deficits in trunk rotational,[15] handgrip and knee extension isometric strength.[16] While, our findings suggest that AIS does not lead to a reduction in both KE and KF maximal strength. Must be highlighted that Martinez-Llorens et al.[16] measure strength isometrically and reported it in absolute terms (kgf), which could lead to different conclusions to the present investigation. Although surgical spine correction has been shown to improve gait kinematics[18,19] and standing balance,[21] the present results suggest that surgery alone does not have a significant impact on lower limb maximal strength, as demonstrated by the lack of differences between the pre-surgical and control groups.

Interestingly, the results of this study suggest that both KE and KF maximal strength are positively associated with the ambulatory capacity of AIS patients. KE showed a stronger relationship with the distance covered in the 6MWT than KF, likely due to the importance of knee extension in overcoming gravity and push the body forwards during walking. This highlights the crucial role played by muscle strength in the functional abilities of these patients. These findings are especially relevant in light of previous research that has only found a relationship between respiratory strength and walking capacity in AIS patients.[7] With this information, targeted exercise programs can be designed to enhance both respiratory and lower limb strength, particularly KE, in AIS patients with walking deficits.

Despite the valuable insights gained from this study, it is important to acknowledge its limitations. One significant limitation is the difference in age between the pre- and post-surgical groups, which showed high variability. This difference is representative of a real-world population, where post-surgical patients often have to wait on a list and go through screenings before undergoing surgery, leading them to be older on average. Additionally, the study only evaluated the lower limb strength at the knee joint, and it is possible that other muscle groups, such as the ankle and hip, may have different behavior. Another limitation is the cross-sectional design of the study, which limits the ability to establish causality. Future studies with a longitudinal approach could help to confirm and improve upon the observations made in this study. These limitations should be considered when interpreting the results and future research should aim to address these limitations to gain a more comprehensive understanding of the relationship between lower limb strength and deambulation capacity in AIS patients.

Conclusion

The results showed that the control group covered a significantly greater distance in the 6MWT compared to both the pre-surgical and post-surgical groups. However, no differences were observed in KE PT and KF PT between the groups. Our findings revealed a moderate positive correlation between KE PT and 6MWT distance, as well as a low positive correlation between KF PT and 6MWT distance. These results highlight the importance of lower limb strength in the functionality of AIS patients and suggest that exercise programs aimed at enhancing lower limb strength could improve the walking capacity of AIS patients.

Financial Support
The present survey has not received any specific funding from public, commercial, or not-for-profit funding agencies.

Conflict of Interests
The authors have no conflict of interests to declare.

Acknowledgements
Our gratitude goes out to all the participants who generously gave their time and effort to participate in the study. Special thanks to interns Ana Paula Oliveira de Souza and Larissa Oliveira Soares for their assistance in data collection. We would also like to extend our appreciation to Juan Daniel Aquino for their support in scheduling the participants.

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