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3-D SCAPULAR KINEMATICS DURING ELEVATION AND LOWERING OF THE ARM IN TYPICAL CHILDREN AND HEALTHY ADULTS

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SUMMARY
The literature shows an increase in the incidence of shoulder injuries, such as rotators cuff tears and also some associated shoulder pathologies, in the pediatric population due to the early practice of sports, specially throwing. However, little is known about scapular kinematics in children. This study aimed to compare the 3-D scapular kinematics during the elevation and lowering of the arm in the scapular plane in typical children and healthy adults. Twenty-six healthy adults (35.3 ± 11.6 years, 1.7 ± 0.1 m, 70 ± 12.3 kg) and 33 typical children (9.1 ± 1.5 years, 1.4 ± 0.1 m, 35.4 ± 10.4 kg) participated in this study. Three-dimensional kinematics were obtained using an electromagnetic tracking device. The subjects were asked to elevate and lower their arm in the scapular plane. The results showed that children had less internal rotation (p<0.05) compared to adults at 120° during arm elevation and more anterior tilt (p<0.05) than adults at 60°, 90° and 120°. More anterior tilt was also seen during lowering of the arm as compared to elevation (p<0.05). For scapular upward rotation, no difference (p>0.05) was found during elevation and lowering of the arm. The study showed small but significant differences in scapular kinematics between children and adults. These results can help clinicians to improve diagnosis and treatment protocols directed to children with dysfunction and achieve more successful results.

INTRODUCTION
The literature shows an increase in the incidence of shoulder injuries, such as rotators cuff tears and also some associated shoulder pathologies, in the pediatric population due to the early practice of sports, specially throwing [1,2,3]. However, little is known about scapular kinematics in children.

It was only found one study that compared 3-D scapular kinematics between children and adults during elevation of the arm [4]. Investigations are warranted to better understand scapular kinematics in children and help clinicians to decide on more adequate exercise approaches for rehabilitation in children with upper extremity injuries such as rotator cuff tears, associated pathologies in shoulder and also in the rehabilitation of the upper extremity in children with neurological disorders such as cerebral palsy, brachial plexus injury and spinal cord injury.

The hypothesis of this study was that adults and children would have different patterns of scapular kinematics in both elevation and lowering of the arm. Thereby, the aim was to compare the 3-D scapular kinematics during elevation and lowering of the arm in the scapular plane in typical children and healthy adults.

METHODS
Twenty-six adults (35.34 ± 11.65 years) and 33 typical children (9.12 ± 1.51 years) participated in this investigation. The study included individuals who had no history of shoulder/cervical dysfunction and with range of motion of shoulder elevation next to 150°. It was approved by the research ethical committee of the University.

The capture and analysis were performed using the electromagnetic tracking device Flock of Birds® (miniBird®) integrated with MotionMonitor™. Surface electromagnetic sensors were attached to the sternum, the acromion of the scapula and a thermoplastic cuff attached to the distal humerus.

Local coordinate systems were established using the digitized landmarks following the International Society of Biomechanics recommended protocol [5]. The z-axis pointed laterally, the x-axis anteriorly and the y-axis superiorly.

Subjects had to maintain light fingertip contact with a flat planar surface to keep positioning of the arm in the scapular plane. Three repetitions were performed of elevation and lowering of the arm.

Scapular kinematics was analyzed at 30°, 60°, 90° and 120° of elevation and lowering of the arm. The YXZ sequence was used to describe scapular motions relative to the trunk. The scapular rotations were described in the order of internal/external rotation, upward/downward rotation and anterior/posterior tilt. The humeral position with reference to the trunk was determined using the Y'XY" sequence.

The data were averaged over the three repetitions. Shapiro-Wilk test was used to check the normality. A 3-way mixed model analysis of variance (ANOVA) was used. In the presence of interaction of group x phase x humeral angle, a 2-way mixed ANOVA was conducted for each phase (elevation and lowering), in separate. The Bonferroni test for post hoc analysis was used when necessary. A $p < 0.05$ was considered significant.

RESULTS AND DISCUSSION

In general, the scapula internally and upwardly rotated, and progressed from anterior to posterior tilt during elevation of the arm in both groups, and returned to the initial position during lowering of the arm. However, some differences were identified between children and adults.

Children showed less internal rotation at 120° humeral angle during elevation of the arm when compared to adults ($p<0.05$). Children actually presented more external rotation at 120° of arm elevation. No difference ($p>0.05$) was found during lowering of the arm. It was already demonstrated that more internal rotation can occur with aging [6]. However, the children evaluated by Dayanidhi et al. [4] showed an external rotation pattern earlier in the range of motion (beyond 60° of arm elevation).

For scapular upward rotation, no difference ($p>0.05$) was found during elevation and lowering of the arm. This was the most consistent motion of the scapula during elevation and lowering of the arm in both groups. These findings are contrary to what was previously demonstrated by Dayanidhi et al. [4], who identified children to have more upward rotation from 25° to 125° of humeral elevation in the scapular plane.

Children showed more anterior tilt at 60°, 90° and 120° humeral angles ($p<0.05$) than adults. The scapula of the children remained mostly in anterior tilt, except at 120° humeral angle where it was slightly posteriorly tilted. Considering that scapulothoracic musculature in children is still in development and that the serratus anterior contributes substantively to scapular posterior tilt, this fact might have contributed to differences found in the tilt.

The serratus anterior is the only scapulothoracic muscle with the capability to both upwardly rotate and posteriorly tilt the scapula on the thorax making its contribution to normal scapular kinematics very significant. Its line of action will directly approximate the scapula to the thorax, which can serve as a stable base [7]. In children, who still under development process, this line of action might be differently from the adults, occurring a change in the scapular kinematics.

Scapula also presented more anteriorly tilted at 30° and 60° humeral angles during lowering of the arm when compared to elevation of the arm ($p<0.05$). This is of interesting because in a clinical screening, the inferior angle and/or medial border of the scapula usually become more prominent during mid range of lowering of the arm when eccentric controlled motion of the scapula is necessary. It was already demonstrated that the scapulothoracic muscles present lower activity during lowering of the arm when compared to the elevation [8]. This suggested decreased activity of the scapulothoracic muscles may have contributed for the difference found on scapular tilt during elevation and lowering of the arm in the present research.

CONCLUSIONS

The findings of this study indicate that there is similarity in scapular kinematics pattern between children and adults during elevation and lowering of the arm, except for internal rotation at 120° of humeral elevation where children present less internal rotation. Children also present more anterior tilt than adults, and more anterior tilt is seen during lowering of the arm as compared to elevation.

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