Abstract

Title: Climbing in children and youth: acute physiological responses to climbing and their implications for upper body strength.

Objectives: The aim of this thesis was to determine the physiological responses of children and youth to climbing and its implications for upper body strength.

Methods: One hundred and twelve children (aged 9,8 ± 1,4 years) participated across two studies. Study one (91 children) explored the effects of climbing on upper body strength, with the aid of a battery of climbing specific tests (bent arm hang on the trapeze, finger hang on the wooden bar and maximal hand grip with the manual dynamometer). These tests were designed for the measurement of the key muscle groups involved in climbing. Study two (21 children) assessed acute physiological response to climbing using the indirect calorimetry method. Energy expenditure was used as an indicator of the climbing skills and to express the total climbing work completed. Study two lasted for 16 weeks, during this time the children underwent three measurements. Instructors recorded the routes climbed and their difficulty during each session. The period of the study corresponded with the duration of the climbing course for children during the school year.

The results of the acute physiological response of children during climbing were evaluated using either a repeated analysis of variance (rANOVA) or for the evaluation of specific climbing tests a repeated covariance analysis (rANCOVA) with a covariance variable of the number of metres climbed.

Results: The results of the study indicated significant increases in the bent arm hang test ($p < 0,02$; $\eta_p^2 = 0,04$) and finger hang test ($p < 0,04$; $\eta_p^2 = 0,04$) but no changes in the hand grip test after sixteen weeks. The covariate variable, climbing meters, had a significant effect ($p = 0,02$; $\eta_p^2 = 0,04$) only on bent arm hang test scores.

No significant effect was found for climbing energy expenditure on the vertical or slightly overhanging routes over the sixteen weeks. Energy expenditure was around 25 $kJ \cdot min^{-1}$ for both routes (peak values of oxygen consumption were ~ 1,20 $l \cdot min^{-1}$ for the vertical route and ~ 1,30 $l \cdot min^{-1}$ for slightly overhanging route). The children were able to climb approximately three routes 10 metre high routes during one climbing course. The pure climbing time during sixty minutes climbing course was 10,8 ± 0,2 minutes. Over each 60 minute

climbing course, climbing energy expenditure was 260 ± 0,9 kJ, at around ~ 65 kcal for each climbing route.

Energy expenditure, as an indicator of adaptation to load, showed a decreasing trend - the consequence of improved adaptation to climbing. Over the 16 weeks there was a significant decrease in energy cost for both of the climbing routes, in vertical route about 0,6 $l \cdot min^{-1}$ ($p < 0,01$) and 0,9 $l \cdot min^{-1}$ ($p < 0,05$) for the overhanging route, thus there was a significant improvement in the physical adaptation to the climbing load. The children climbed vertical route faster (~ 30 s; $p = 0,03$) and improved their climbing time on the slightly overhanging route by ~ 1 min ($p = 0,01$) after 16 weeks.

Conclusion: Children's oxygen consumption while climbing (~ 37-40 $ml \cdot kg\text{-}1 \cdot min^{-1}$) meets the requirements for effective development of aerobic fitness in children. There were no significant changes in energy expenditure over the sixteen weeks, however there was a tendency to the decrease. This is likely to have resulted because of an improvement in climbing skill achieved through repeatedly climbing the same route, which was also confirmed by significant reductions in climbing time.

There was also a downward trend in energy expenditure and an improvement in climbing ability. There were significant decreases in the energy cost, demonstrating good adaptation of climbing movement and the improvement of mechanical efficiency of the muscle over 16 weeks.

There were significant changes in both bent-arm hang $p < 0,05$ and finger hang $p < 0,05$ performance over 16 weeks. These tests were found to be suitable for the measurement of upper body strength in children. The bent-arm hang test was positively related to the number of meters climbed. The test of grip strength was not suitable for the assessment of maximal hand grip in children.

Regular climbing (ones per week) improves upper body strength, despite the number of meters climbed being small (approximately 30 m per week). At the same time, the climbing course must be completed regularly for sufficient amount of time (one week, approximately eleven minutes of climbing). Furthermore, roped climbing on an artificial wall once a week leads to significant improvements in upper body strength assessed by tests bent arm hang and finger

hang even though the number of meters climbed is small (about 30 m per week or about 11 minutes of pure climbing time spent on the wall).

Keywords: children and youth, climbing, oxygen consumption, energy expenditure, energy cost