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THE IMPACT OF PLYOMETRIC TRAINING ON PERFORMANCE SUCCESS IN SPEED CLIMBING

Original research

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ABSTRACT
The aim of this study was to examine the effects of a 10-week plyometric training program on performance in speed climbing among children. The sample consisted of 32 participants (20 girls and 12 boys, aged 7–12 years), divided into an experimental group (n = 15), which performed additional plyometric training, and a control group (n = 17), which continued regular climbing training without plyometric exercises. Speed climbing performance was assessed using dual stopwatch timing and the Speed Climbing Stopwatch mobile application, while jumping ability and reaction time were measured using the Microgate Optogait system. The experimental group completed two weekly climbing sessions and two additional plyometric sessions focusing on lower-limb explosive strength and reactive ability. Data were analyzed using paired and independent t-tests, with effect sizes expressed as Cohen's d.
The results demonstrated statistically significant improvements ($p < .05$) in the experimental group across multiple performance indicators. Speed climbing time decreased by 14.7%, accompanied by significant increases in countermovement jump height and reactive strength index, and a reduction in reaction time to auditory stimuli. The control group showed no significant changes. The calculated effect sizes indicated moderate to large practical effects for climbing time and jumping ability, confirming the efficacy of plyometric training in enhancing explosive performance.
These findings suggest that structured plyometric training effectively improves speed, power, and reaction in young climbers, making it a valuable supplement to standard climbing practice. The study highlights the importance of integrating plyometric exercises into youth climbing programs to optimize neuromuscular development and competitive performance.

Keywords: sport climbing, speed climbing, plyometrics, children

INTRODUCTION

Sport climbing can be defined as a competitive discipline in which a climber relies solely on their own body to ascend a rock surface, without the use of technical aids, while the equipment serves only for safety purposes. In sport climbing, the use of equipment to facilitate upward progress or for resting is not permitted (Hrestak & Janković, 2008). As a sport, climbing includes three competitive disciplines: Bouldering, Lead, and Speed (Sas-Nowosielski et al., 2021).
Although previous research has examined the effects of plyometric on speed performance in children and adolescents. Most existing studies have focused on the influence of plyometric training on improving general physical fitness or specific motor abilities in other sports, such as gymnastics (Granacher et al., 2011; Negra et al., 2017). Furthermore, the majority of past research has concentrated on adolescent and adult athletes (Lloyd & Oliver, 2012; Ramirez-Campillo et al., 2018), while little is known about the effects of plyometric training on very young athletes (Granacher et al., 2011). The aim of this study is to provide valuable insights into the effects of plyometric training on improving performance in speed climbing

among younger children, thereby contributing to the advancement of future training methodologies.

METHODS

Purpose of the study

The primary aim of this research was to determine the impact of plyometric training on performance success in speed climbing among children. The secondary aim was to examine the differences in performance outcomes between the group that performed plyometric training and the group that did not, as well as to assess the effect size.
Based on the purpose of the study, the following hypotheses were formulated:
H0: There is no statistically significant difference in performance success in speed climbing between the experimental and control groups after the intervention.
H1: There is a statistically significant difference in performance success in speed climbing between the experimental and control groups after the intervention, in favor of the experimental group.

Participants and procedure

Before the start of the study, written consent was obtained from each parent for their child's participation. The inclusion criteria were regular attendance at training sessions and the absence of any locomotor injuries during the previous two months. The research was conducted in several stages, including initial and final testing to assess motor abilities related to lower limb explosive strength and reaction time, as well as performance in speed climbing. The children first completed the speed climbing time assessment, followed by tests evaluating motor abilities. After the training intervention, the same procedure was repeated during the final testing. The study was approved by the Ethics Committee of the Faculty of Kinesiology in Osijek.
Measurements were conducted in the Gradski vrt sports hall, within the premises of SPK Bastion, on a climbing wall 8 meters and 50 centimeters high. After the initial testing, the speed climbing route was removed from the wall, and the children did not practice speed climbing during the training period to prevent any influence of climbing technique on the test results.

Measurement instruments

Initial and final assessments of speed climbing performance (VB, s) were conducted using two synchronized stopwatches and a mobile device equipped with the Speed Climbing Stopwatch application. The mobile phone was connected to an external speaker that emitted a standardized start signal. Each participant performed one familiarization climb prior to testing, followed by two timed climbs, and the arithmetic mean of the two valid attempts (in seconds) was recorded as the final VB score.
Motor ability assessments included tests of explosive strength (CMJ, cm), reactive strength (RJ, ratio of flight to contact time, dimensionless), and acoustic reaction (AR, s), all performed with the Microgate Optogait system, which enables high-precision measurement of flight and contact times. The Reactive Strength Index (RJ) test consisted of ten consecutive vertical jumps, from which the arithmetic mean of the five best flight-to-contact time ratios (no units) was calculated. The Countermovement Jump (CMJ) test included three individual jumps with brief rest intervals between attempts, and the best result was recorded for analysis in centimeters (cm). All jumps were executed with hands placed on the hips to minimize the influence of arm swing on jump height. The Acoustic Reaction (AR) test was performed three times consecutively to assess reaction speed to an auditory stimulus. Participants were instructed to respond to the sound signal by jumping as quickly as possible, and the arithmetic mean of the three trials was recorded as the reaction time in seconds (s).

Plyometric training

After the initial measurement, the children were randomly assigned to two groups: experimental and control. Both groups participated in climbing training twice a week for ten weeks. The experimental group trained on Mondays and Wednesdays, while the control group trained on Tuesdays and Thursdays. In addition to the Monday climbing session, the experimental group performed a plyometric training session, which took place after the warm-up and before the climbing portion of the session. Furthermore, the experimental group had an additional session on Fridays dedicated solely to plyometric training (without climbing). Attendance at the plyometric training sessions was systematically recorded using an Excel spreadsheet. To be included in the final data analysis, participants were required to attend at least 70% of all supplementary plyometric training sessions.

Data analysis methods

The collected data were processed using the TIBCO Statistica software, version 12.5 (TIBCO Software Inc., Palo Alto, CA, USA). The normality of distribution was assessed using the Shapiro–Wilk test. After confirming normality for the initial and final speed climbing time data, a paired t-test was applied to determine the effect of plyometric training on performance success in speed climbing. To evaluate the effect size of the plyometric training on speed climbing, Cohen's d was calculated, with interpretation based on Cohen's (2013) criteria: small effect (>0.1), medium effect (>0.3), and large effect (>0.5). To determine differences between the experimental and control groups, initial and final climbing times were compared using an independent t-test. The predetermined level of statistical significance (p) for indicating significant differences was set at $p< .05$.

RESULTS

Table 1 presents the descriptive statistics and normality test results for the experimental and control groups at both measurement points. The groups demonstrated comparable baseline values, confirming the homogeneity of the sample. After the intervention, the experimental group showed noticeable improvements across all variables, including reduced speed climbing time (VB) and increased CMJ, RJ, and AR values, which indicate enhanced explosive strength and reaction ability. In contrast, the control group exhibited only slight and statistically insignificant changes. The results of the Shapiro–Wilk test confirmed the normal distribution of data ($p > .05$), supporting the use of parametric statistical analyses**.**

Table 1. Descriptive statistics and test of normality for the experimental and control groups at initial and final measurements

Variable	Group	M	SD	Min	Max	W	p
VB I	E	16.33	5.27	9.34	28.82	0.92	0.21
	C	19.18	5.54	11.12	30.37	0.94	0.3
VB F	E	13.93	3.62	9.14	20.46	0.91	0.14
	C	18.61	4.88	11.15	28.34	0.94	0.27
AR I	E	0.74	0.1	0.6	0.96	0.94	0.34
	C	0.72	0.07	0.58	0.83	0.96	0.56
AR F	E	0.65	0.09	0.55	0.82	0.9	0.09
	C	0.72	0.06	0.59	0.83	0.94	0.35
CMJ I	E	20.93	5.58	12.1	33.8	0.96	0.66
	C	21.03	4.44	14.4	32.4	0.94	0.34
CMJ F	E	22.93	5.48	14.9	35.7	0.96	0.62
	C	21.34	4.31	14.3	31.7	0.96	0.61
RJ I	E	0.72	0.16	0.43	0.97	0.95	0.54
	C	0.73	0.23	0.31	1.08	0.96	0.7
RJ F	E	0.78	0.18	0.46	1.1	0.95	0.51
	C	0.74	0.23	0.31	1.1	0.97	0.79

Note. E - experimental group; C - control group; I - initial measurement; F - final measurement; VB - speed climbing time; AR - acoustic reaction; CMJ - countermovement jump; RJ - reactive strength index.

Table 2 shows the results of the paired-samples t-test and Cohen's d. The experimental group achieved statistically significant improvements in all performance variables ($p < .001$), with small to moderate effect sizes ($d = 0.09–0.53$). In contrast, the control group showed a significant change only in CMJ ($p = .034$), while other variables remained unchanged. These results confirm the effectiveness of the plyometric training program in improving climbing-specific power and reactivity.

Table 2. Paired-samples t-test and Cohen's d for the experimental and control group

Variable	Group	M (I)	SD (I)	M (F)	SD (F)	df	p	Cohen's d
VB	E	16.33	5.27	13.93	3.62	14	0.003	0.53
	C	19.18	5.54	18.61	4.88	16	0.183	0.11
AR	E	0.74	0.10	0.65	0.09	14	< .001	0.09
	C	0.72	0.07	0.72	0.06	16	0.292	0.12
CMJ	E	20.93	5.58	22.93	5.48	14	< .001	0.36
	C	21.03	4.44	21.34	4.31	16	0.034	0.07

Note. VB – speed climbing time. AR – acoustic reaction. CMJ – countermovement jump. RJ – reactive strength index.

DISSCUSSION

Based on the normality tests, it can be concluded that the data for all variables, both before and after the plyometric training, were normally distributed. This finding supports the reliability of the measurements and allows for further analysis of the training effects using parametric tests.

The experimental group showed a decrease in the mean value between VB I (16.33) and VB F (13.93), indicating improved performance following plyometric training. The standard deviation for VB F (3.62) was smaller than that for VB I (5.27), suggesting more consistent results. The difference was statistically significant ($p = .003$), indicating a significant improvement in speed climbing performance. In the control group, the mean value for VB I was 19.18 s, while VB2 was 18.61 s. The decrease was minimal, and the standard deviations (5.53 for VB1 and 4.88 for VB2) showed relatively stable variability. The difference was not statistically significant ($p = 0.183$), suggesting that, without plyometric training, no notable performance improvements occurred.

The improvements observed in the experimental group align with previous studies on the effects of plyometric training on sports performance. Plyometric training has been shown to enhance explosive strength and reactive ability in sports requiring rapid and powerful movements, such as athletics and basketball (Marković & Mikulić, 2010). Similarly, studies on adult climbers have shown that plyometric training can improve lower limb strength, which is crucial for performance in speed climbing (Padilla-Crespo et al., 2025).

In the experimental group, the average AR1 value was 0.74, decreasing to 0.65 for AR2. Despite the lower mean value, the standard deviation also decreased from 0.10 to 0.09, suggesting reduced variability after the training sessions. The mean difference was 0.09, with a p-value of 0.000016, indicating a significant improvement in reaction to sound following plyometric training. In the control group, the average AR1 and AR2 values were nearly identical (0.72 and 0.72), with minimal changes in standard deviation (0.07 for AR1 and 0.06 for AR2), indicating no significant change in this variable ($p = 0.3$).

The average CMJ1 value in the experimental group was 20.93, increasing to 22.93 for CMJ2. This rise indicates an improvement in performance, accompanied by a slight reduction in standard deviation (from 5.58 to 5.48), again suggesting more consistent results after training. The difference was statistically significant ($p = 0.000002$). The control group showed a smaller increase in the mean CMJ1 value (21.03) to CMJ2 (21.34), indicating minor progress without specific training ($p = 0.03$). The standard deviations were similar (4.44 for CMJ1 and 4.31 for CMJ2), indicating stable performance without significant changes ($p = 0.08$).

In the experimental group, Cohen's d for the VB variable was 0.53, indicating a moderate effect size. This suggests that plyometric training had a meaningful practical impact on improving climbing time. The CMJ and RJ variables also showed moderate effect sizes, with Cohen's d values of 0.36 and 0.37, respectively. These results indicate that although statistically significant differences were present, the practical impact was moderate. On the other hand, Cohen's d for AR was 0.09, indicating a small effect size. While the statistical test showed significant changes, the small Cohen's d suggests that the practical effect of plyometric training on AR was relatively minor.

In the control group, all variables showed small effect sizes according to Cohen's d, indicating that changes in these variables after training were not substantial.

Speed climbing is characterized by the need for an optimal combination of explosive strength, coordination, and reactive ability. The key motor abilities in speed climbing include reaction time, explosive lower limb strength, and the ability to perform repeated rapid movements with minimal energy loss (Laffaye & Wagner, 2013). Plyometric training specifically targets these abilities, as reflected in the improvements observed in the CMJ and RJ variables in the experimental group. The increase in jump height (CMJ) from 20.93 cm to 22.93 cm and the improvement in RJ (from 0.71 to 0.78) indicate a positive influence of the training on explosive strength and cyclic movement efficiency.

The relationship between plyometric training and performance improvement in other sports further supports these findings. For example, in sports such as soccer, basketball, and athletics, plyometric training has proven effective in improving sprint speed, explosive power, and jumping ability (Ramirez-Campillo et al., 2018). Given that speed climbing shares certain biomechanical demands with these sports, it is reasonable to expect that plyometric training would produce similar positive effects.

CONCLUSION

The purpose of this study was to determine the effect of plyometric training on improving speed climbing performance among children. The results showed that plyometric training had a significant positive impact on climbing time, reaction speed, vertical jump, and reactive jump in the experimental group. Conversely, the control group, which did not perform plyometric training, showed no significant improvements in these variables. These findings suggest that plyometric training can be an effective tool for enhancing performance in speed climbing among young climbers.

However, certain limitations of the study should be acknowledged, such as the small sample size, suboptimal climbing conditions, and the use of less precise timing instruments. Future research should include a larger number of participants, more standardized climbing conditions, and more accurate measurement tools.

Despite these limitations, the study provides valuable information for coaches working with young climbers. The results indicate that plyometric training should be incorporated into training programs for young climbers aiming to improve their performance in speed climbing.

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Conflict of Interest

The authors do not have any conflicts of interest to disclose. All co-authors have reviewed and concurred with the manuscript's content, and no financial interests need to be reported.