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EFFECTS OF CREEPING EXERCISE ON UPPER LIMB STRENGTH

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ABSTRACT

This study determined the influence of creeping exercise on the strength and endurance of the upper body. A total of 32 young football players were divided into an experimental (EXP) and a control group (CON). The EXP group included 17 boys (11.6±0.6years), while the CON group included 15 boys (10.5±1.1years). Upper body strength and endurance were measured by five motor performance tests: push-ups, pull-ups, pulling and pushing on a bench and a complex creeping exercise ("driving a wheelbarrow"). Strength training consisted of a creeping exercise (6 weeks, 2-3 sets, 2-3 times a week, 10-15 minutes). The EXP group improved their performance in push-ups and pull-ups by ~90% (p<0.05) and ~26% (p<0.05), respectively. No significant differences were observed when pulling or pushing on the bench, while the EXP group improved performance scores in "driving a wheelbarrow" by ~13% (p<0.01). For the CON group, motor tests either remained unchanged or decreased. A significantly lower number of repetitions (~20%; p<0.05) was achieved only for pull-ups. Creeping exercises improved the results in the selected upper body strength and motor performance tests. This improvement could be attributed to changes in the neural mechanisms of muscular force generation in the shoulder girdle and trunk.

Keywords Arm strength; Children; Creeping exercise; 'Driving a wheelbarrow'.

INTRODUCTION

Muscle strength is the maximal force-generating capacity of a muscle or group of muscles (Hunsicker & Donnelly, 1955; Nuzzo *et al.,* 2018) and is an important predictor of functionality, mobility, independence and daily physical activity (Van Harlinger *et al.,* 2015). Motor performance tasks like creeping, throwing and jumping are often used as specific aspects of muscular strength (Malina *et al.,* 2004; Holm *et al.,* 2008). Upper limb muscle strength is an essential component of upper body motor performance in children and adolescents (Malina *et al.,* 2004). In addition, various upper body motor tasks (push-ups and pull-ups) are often used as indicators of upper limb strength/endurance (Malina *et al.,* 2004; Lin *et al.,* 2006).

Strength training has been the subject of much controversy among children and adolescents, but the safety and effectiveness of strength training is well documented (Gallagher & DeLorme, 1949; Ramsay *et al*., 1990; Falk & Tenenbaum, 1996; Payne *et al.,* 1997; Athanasiou *et al.,* 2006; Behringer *et al.,* 2011). Strength training in children and adolescents has been shown to be associated with several health-related benefits, including increased bone density, body composition, well-being, improved mental health (Blimkie *et al.,* 1989; Fontoura *et al.,* 2004; Faigenbaum, 2007; Ruiz *et al.,* 2009; Behringer *et al.,* 2011) and improved competitive performance (Bernhardt *et al.,* 2001). It is important to promote youth strength training and reduce sedentary lifestyles in children and adolescents, as youth sedentariness is an important predictor of adult physical activity levels (Raitakan *et al.,* 1994; Faigenbaum, 2000; Malina *et al.,* 2004). Furthermore, participation in regular physical activity contributes to the prevention of chronic diseases in later life (Malina *et al.,* 2004; Faigenbaum, 2007).

Various studies (Vrijens, 1978; Docherty, 1987; Faigenbaum *et al.,* 2001; Mountjoy *et al.,* 2008; Ratel, 2011) have already shown that upper body strength in children and adolescents can be improved by various training methods, which usually include: (1) progressive exercises with body mass (push-ups, pull-ups); (2) free weights or weight machines; (3) various devices that increase accommodation resistance.

Creeping exercises are also recommended as a means of strengthening the upper body in physical education (PE) and in extracurricular programmes (competitive sports and development of extracurricular activities) (Pistotnik, 2003; Virgilio, 2006; Payne & Isaacs, 2017; Haywood & Getchell, 2019). Creeping/crawling exercises are described as movements "on all fours" in which the trunk is lifted off the ground and the entire body weight is carried by the arms and legs (Pistotnik, 2003). Various types of creeping exercises are recommended for PE programmes, such as creeping on hands and knees or hands and feet (Malina *et al.,* 2004; Clements & Schneider, 2017). Additionally, creeping in all directions can be performed with arms and legs straight or bent. Creeping exercises include various types of "wheelbarrows", in which one person performs the movement with hands on the ground and legs raised, while the other person ("driver") holds the legs (Heath *et al.,* 1971; Sobo, 2015). Two or three persons can perform wheelbarrows. They are particularly useful when working with larger groups of children in PE classes and/or during sports training. Wheelbarrows are usually used as part of a dynamic warm-up or as activities to develop strength.

Although many physical activity programmes recommend wheelbarrows as a strength development exercise, there is still a lack of literature on the actual load achieved with this type of exercise and its effectiveness in developing upper body strength in children. Even with the basic type of creeping exercises, the intensity of 40% repetition maximum (RM) could be achieved, whereas with more complex creeping exercises the load increases to 90% RM (Pistotnik *et al.,* 2002). The mentioned study suggests that wheelbarrows if used regularly, can improve the motor skills and strength of the upper body in physical education (PE) and in extracurricular programmes (youth performance sports).

PURPOSE OF RESEARCH

To our knowledge, no attention has been paid to the influence of creeping exercise on upper body dynamic strength in children. Therefore, the purposes of the present study were: (1) to determine the initial upper body strength of young football players; (2) to examine the effects of the creeping exercise of ‘driving the wheelbarrow’ on selected upper body strength tests in young football players; (3) to discuss the training of upper body muscular strength in young football players.

METHODOLOGY

This work was organised as a six-week intervention study. A total of 32 male boys from two football clubs from the same region in Slovenia participated in this study.

Ethical considerations

Student Affairs Commission at Faculty of Sport, University of Ljubljana approved the study (no. 3376, 1145/10) to ensure that all ethical standards were met and the study was conducted according to the declaration of Helsinki (World Medical Association, 2013). Each participant was informed about the purpose of the study, and written informed consent was obtained from all the pre-adolescents' legal guardians.

Participants

The participants were 32 boys from the football clubs Tolmin (control group: CON) and Kobarid (experimental group: EXP). None of the participants had any experience of strength training. The participants were divided into two groups based on their club membership (CON and EXP). The first group was the control group (CON) [n=15; age=10.5±1.1 years; height=151±7 cm, weight+43±5 kg]. The second group was the experimental group EXP [n=17; age=11.6±0.6 years; height=142±8 cm; weight=32±4 kg]. The physical fitness of all intervention group of children (n=32) was compared with the physical fitness of school children aged 11 years (n=176) (Strel *et al.,* 2011) from both included cities in order to identify possible biases. The t-test of independent samples showed that there were no statistical differences (p<0.05) between the 11-year-olds neither in physical fitness (long jump standing, sit-ups) nor in somatic characteristics (height, weight) compared to all boys from the previously mentioned cities.

Procedure and testing

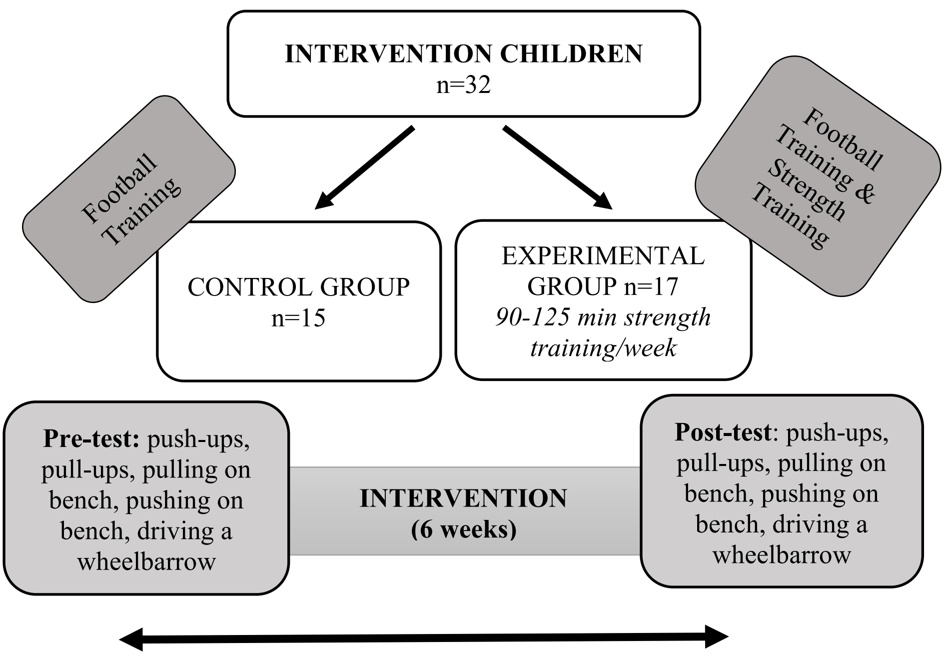
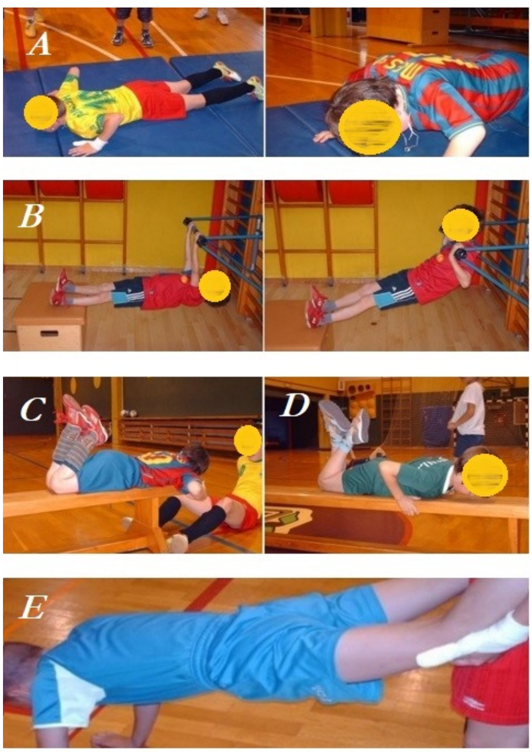


Figure 1. **INTERVENTION PROTOCOL**

The groups EXP and CON participated in regular football training sessions three times a week (same modes, duration and load), while only EXP carried out additional strength training programmes for six weeks (two to three times a week). The strength training programmes consisted of a creeping exercise, "driving a wheelbarrow". All children were evaluated at baseline (week 0) and after six weeks of strength training (week 7). Before the start of training, the children were taught all the protocols. All participants performed a standardised warm-up phase before the baseline and final test (20 minutes of low aerobic exercises followed by 10 minutes of dynamic stretching exercises). All measurements (baseline and post-testing, EXP and CON) were conducted by the same research staff and with identical equipment placement. The intervention protocol of the study is shown in Figure 1.

Upper body strength/endurance test

Upper limb strength/endurance was evaluated using five upper body performance tests: (i) push-ups [30 s]; (ii) pull-ups [30s]; (iii) pulling and pushing on a bench [3 connected benches=12 m]; (iv) driving a wheelbarrow [15 m] (Figure 2).



(**A**=Push-ups, **B**=Pull-ups, **C**=Pushing on a bench, **D**=Pulling on a bench, **E**=Driving a wheelbarrow)

Figure 2. **UPPER-BODY PERFORMANCE TESTS**

The participants were tested twice in a random order, taking the best attempt into account. The strength training consisted of only one additional strength/endurance test - "driving a wheelbarrow" (15 m) where the participants started the test with legs and trunk raised from the floor, arms fully extended, placed at a shoulder width distance, palms of hands facing forward and legs raised (~40 cm), supported by the partner (driver) through the knees. From this position they started to walk 15 m with their hands as fast as possible. Each participant had to complete the required distance. The time was measured to the nearest 0.1 seconds.

Training programmes

The six-week exercise programme consisted of 2 or 3 training sessions per week. The intervention lasted for six weeks, with each session lasting 60 minutes, including 10 minutes of aerobic warm-up, 10 minutes of dynamic stretching exercises and 15 minutes of strength training (Table 1). The strength training programmes consisted of only one creeping exercise: a "driving a wheelbarrow" at different distances (10-15 m as described). The exercise sets, distances and exercise days increased over the weeks (Table 1). The protocol of the strength training was designed according to the principles of the method Body Building I (Schmidtbleicher, 1984; Bompa & Buzzichelli, 2015). Each training session ended with football training and cool-down activities (±25-30 minutes).

Table 1. **STRENGTH TRAINING PROTOCOL**

Week	Sessions per week	Sets per training session	Rest period (min)	Distance per set (m)	Distance per week (m)
1	2	3	2	10	60
2	2	3	2	10	60
3	3	2	2	15	90
4	2	3	2	15	90
5	3	3	2	15	135
6	3	2	2	15	90

Statistical analysis

In order to qualify for inclusion in the study, participants had to attend at least 86% (13 out of 15) training sessions and both pre- and post-testing. For the present study, the statistics package IBM SPSS 22.0 and Microsoft Excel was used. All descriptive statistics are presented as mean value ± standard deviation. The data were checked for normality using a Kolmogorov-Smirnov test. The data measured before and after the training were statistically analysed using one within-subjects factor (time) and one between-subjects factor (group) ANOVA with repeated measurements (RM ANOVA). When significant main effects were found (time × group), Tuckey post hoc tests were used to localise the differences. The significance level for all comparisons was set at $p<0.05$.

RESULTS

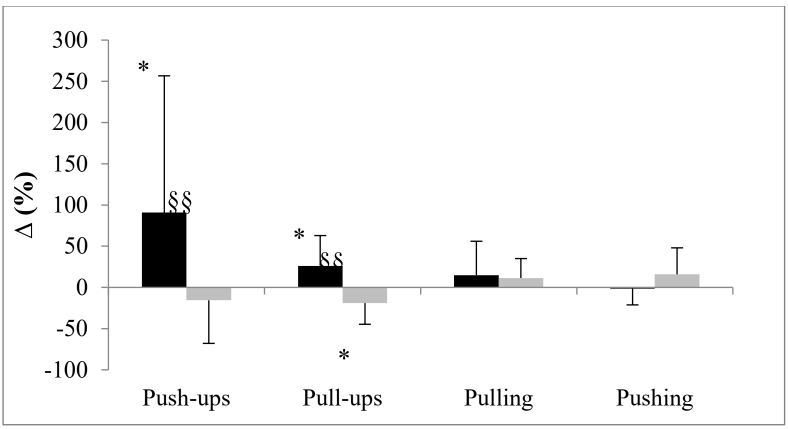
The 32 young male football players in both groups were generally well matched at baseline testing (pre-test), with mean age 10.5±1.1 years and 11.6±0.6 years in control and experimental groups respectively. There were no significant differences in all five strength/endurance test between CON and EXP in the pre-test ($p<0.05$), nevertheless, the EXP group performed better in the baseline testing for all tests (Table 2).

Table 2. **DESCRIPTIVE STATISTICS OF STRENGTH/ENDURANCE TESTS IN PRE-TEST AND POST-TEST**

Tests	PRE-TEST **Exp** (n=17)	PRE-TEST **Con** (n=15)	POST-TEST **Exp** (n=17)	POST-TEST **Con** (n=15)
Push-ups (number)	17.6±8.2	12.7±7.3	23.5±6.5	10.2±6.8
Pull-ups (number)	12.1±5.1	10.2±4.8	14.6±5.7	8.2±3.8
Pulling on a bench (s)	13.2±2.8	16.1±5.8	15.3±7.8	17.0±4.5
Pushing on a bench (s)	27.4±8.6	27.9±9.0	25.9±5.1	31.1±8.7
Wheelbarrow (s)	9.1±2.2	10.4±2.5	7.9±2.2	11.0±2.6

EXP=Experimental group CON=Control group Wheelbarrow=Driving a wheelbarrow test.
Comment: Lowest score presents the better results for 'pulling on a bench', 'pushing on a bench' and 'driving a wheelbarrow

As indicated by the significant training × group interaction ($F_{(1, 30)}=14.4$; $p<0.01$), the EXP and CON differed in the number of push-ups after the "wheelbarrow" training (Figure 3).



§§ = p<0.01 Between Groups
* =p<0.05 Between Baseline and Post-Training

§§ =p<0.01 Between Groups
* = p<0.05 Between Baseline and Post-Training

Figure 3. **RELATIVE CHANGES (% from baseline) IN UPPER BODY STRENGTH AND MOTOR PERFORMANCE TESTS**

EXP improved their performance in the number of push-ups, while CON decreased their performance (~90%; p<0.05 and ~15%; p>0.05, respectively, Figure 3). Furthermore, EXP improved their performance in pull-ups (~26%; p<0.05), while the pull-ups of the CON decreased significantly (~19%, Figure 3). In pulling on the bench, the EXP gave a slightly poorer performance (15.0±41.1%), however, the difference was not significant (p>0.05). The time of pulling on the bench of the CON also did not differ significantly, even though their time was longer at an average of 11.4±23.7%. The between group differences were not significantly different ($F_{(1,30)}$=0.3; p>0.05). Results of pushing on the bench had the same times before and after the exercise in EXP, while the time for 'wheelbarrow' training (15.9±32.1%) of the CON declined slightly afterwards, however, the difference was not statistically significant (p>0.05). Statistical significance of the differences was not achieved for between group comparisons either ($F_{(1,30)}$=2.8; p>0.05).

In contrast, significant training × group interaction ($F_{(1,30)}$=13.8; p<0.001) was also calculated in the test 'driving a wheelbarrow'. The EXP improved their performance by an average of 12.9±16.9% (p<0.01), while the time of the CON remained unchanged

DISCUSSION

To our knowledge, this was the first study to investigate the effects of a six-week training protocol with the creeping exercise "driving a wheelbarrow" on upper body strength and selected motor performance tests in young football players. Significant time × group interactions were found for push-ups, pull-ups and the "driving a wheelbarrow" test. It was observed that the young football players of the group EXP were able to perform more push-ups and pull-ups in 30 seconds after training (increase of ~90% and ~26% from baseline, for both tests (p<0.05) than the football players of the group CON.

The results of this study clearly show that "driving a wheelbarrow" could be used as an efficient means to improve upper body strength in young football players, even though the EXP group produced better results at the baseline testing. Better results of the EXP group could probably be due to lower body mass at the beginning of the study protocol rather than differences in training status between groups. At this point it should be noted that Gillen *et al.* (2017) have shown that the push-up test can be a reliable (ICC≥0.80) and a sensitive (CV≤19%) measure of upper body strength in 10-15 year old boys. In addition, the young football players of the EXP group were able to perform the "wheelbarrow driving" test for a distance of 15 m faster than the football players of the CON group (increase of ~13% from the baseline, both p<0.05).

In contrast, "driving a wheelbarrows", in which one person performs the movement with his hands on the ground and his legs raised, while the other person ("driver") holds the legs (Heath *et al.,* 1971; Sobo, 2015), did not lead to an increase in pushing and pulling on a bench among the young football players in the EXP group (Table 2; Figure 3). This is due to the fact that the result of pulling on a bench depends mainly on the concentric contraction of the elbow flexors, whereas the result of pushing on a bench depends on the concentric contraction of the elbow extensors. On the other hand, "driving a wheelbarrow" requires multi-limbed upper body coordination, which can be achieved by complex upper body muscle activation. To date, there is no precise data on the activation of the upper body muscles in "driving a wheelbarrow".

Due to the similarity with other forms of traveling trunk stabilisation exercises, it can be assumed that "driving a wheelbarrow" requires significant activation of the front, lateral and rear trunk muscles. The study of Pyka *et al.* (2017) showed a considerable activation of m. external oblique (~140% of the maximum voluntary contraction - MVC), m. rectus abdominis (~25% of MVC) and m. erector spinae (~13% of MVC) during quadruped traveling (Pyka *et al.,* 2017). Accordingly, Pyka *et al.* (2017) suggested that traveling forms of trunk stabilisation exercises are a viable strategy to increase trunk muscle strength. In the present study, however, the initial and final status of trunk muscle strength were not measured, so one could only speculate that they play an important role in improving the results of push-ups, pull-ups and "driving a wheelbarrow".

Ebben *et al.* (2011) quantify the training load by evaluating the peaks of the vertical ground reaction forces (GRF) in push-ups. They found that GRF corresponds to 60% of body weight in push-ups with the feet on the floor. In addition, "driving a wheelbarrow" can be done with relatively straight elbows, which places greater strain on the shoulder girdle and trunk muscles. In contrast, when pushing and pulling, the entire body weight must be pulled or pushed on the bench and this may only be done with elbow flexors and elbow extensors. Thus, it appears that “driving a wheelbarrow" is more of an exercise to develop the strength of the trunk stabilisers than an exercise to develop the strength of the elbow flexors and elbow extensors (Pyka *et al.,* 2017).

Determining the intensity of a resistance training stimulus enables the progression of the training intensity and the calculation of the training volume. However, quantifying wheelbarrow intensity is much more difficult than in strength training with dumbbells and weight plates with clearly defined mass. Ebben *et al.* found in 2011 that push-ups with raised feet produce a higher GRF than all other push-up variations, which corresponds on average to 74% of body mass. Based on this data, one could speculate that GRF is similar to push-ups with raised feet from the ground when driving a wheelbarrow. Therefore, driving a wheelbarrow could be an interesting way to strengthen the upper body of young football players. Furthermore, wheelbarrows, like push-ups, are part of a limited number of closed kinetic chain (with a fixed external load) of upper body exercises (Blackard *et al.,* 1999).

Studies have shown that exercises with a closed kinetic chain have advantages for strength development over exercises with an open kinetic chain, because exercises with a closed kinetic chain are more similar to functional, multiplantar movements than exercises with an open kinetic chain (exercises with a moving external load, such as dumbbells and weight plates) (Blackard *et al.,* 1999). Secondly, exercises with a closed kinetic chain are generally safer for children than exercises with an open kinetic chain (Panariello, 1991). For exercises with an open kinetic chain, children usually use weights and dumbbells. It has been reported that in children aged 8-11 years, more than 65% of injuries during strength training are due to poor handling and manipulation of the weights and not to the stress caused by the strength training itself (Myer *et al.,* 2011).

Although not measured in the current study, the main mechanism that could be attributed to an increase in post-training push-ups and pull-ups could be related, at least in part, to a more efficient recruitment pattern of the motor units of the trunk and shoulder girdle muscle when young football players are "driving a wheelbarrows". Indeed, Ramsay *et al.* (1990) found that pre-pubertal strength gains in boys are independent of changes in muscle cross-sectional areas, but are due to neurophysiological adaptations. This concept was also strongly supported by other authors (Fukunaga & Funato, 1992; Ozmun *et al.,* 1994; Malina *et al.,* 2004). In addition, the "wheelbarrow" strength training only lasted six weeks, so changes in the contractile properties of the muscles involved were not expected, since it is well established in the literature that a period of six weeks is too short to show pronounced metabolic adaptations in skeletal muscles (Ross & Leveritt, 2001).

Stabilisation of the trunk and shoulder girdle is an important factor for the overall function of the upper body muscles (Kobesova *et al.,* 2015). In particular, the pectoralis major and the latissimus dorsi transfer arm forces directly to the thorax and the serratus anterior and the rhomboids press the shoulder blade onto the thorax and provide a stable basis for humeral movements (Veeger & Van der Helm, 2007). Since push-ups are performed with activation of the trunk muscles (pectoralis major, serratus anterior, rectus abdominis, external and internal oblique) and the shoulder girdle muscles (Youdas *et al.,* 2010; Freeman *et al.,* 2006), it was concluded that "driving a wheelbarrow" increases the force output of the most important muscles that stabilise the trunk and shoulder girdle.

LIMITATIONS AND STRENGTHS

Some limitations of the present study must be acknowledged. It was based on five motor tests of higher complexity, which are dependent on a myriad of factors. For a more detailed analysis, it would be necessary to use a larger number of tests together with laboratory tests for measuring the strength of the individual muscle or muscle groups, making it easier to track progress in the development of the strength of individual muscles. Furthermore, the motor test used did not allow the direct examination of training effect, therefore, additional measurements of the level of activation and contractile characteristics of muscles would allow insight into the mechanisms that enable this improvement. The execution of pushing and pulling on the bench has also been affected by the equipment of children, so it would be necessary to consider this factor in the following studies. Nevertheless, the results of our study clearly showed that a creeping exercise like “driving a wheelbarrow” could be used as a core and shoulder girdle stabilisation exercise in pre-pubertal boys (10-11 years of age).

RECOMMENDATIONS FOR FUTURE RESEARCH

The findings of this study offer indicated that non-specific strength training (creeping exercise) improves performance in upper body strength and motor performance tests. Therefore, this exercise can be a suitable instrument for strength development in pre-pubertal boys. These results justify a debate on the organisation of school work. Therefore, the following recommendations are proposed to schools and policy makers at the level of educational policy: (1) consistent and high quality implementation of regular physical education for all pupils; (2) presentation of different exercise programmes for pre-pubertal children (transfer from goal-oriented activities to body-oriented activities designed in the form of problem-oriented authentic tasks); (3) enrichment of current activities and appropriate organisational allocation for extracurricular sports activities in the last triennium of compulsory education; (4) inclusion of strength training in extracurricular activities; and (5) inclusion of strength training in physical education.

A further study should evaluate the duration of strength training with creeping exercise over a longer period (>6 weeks). Finally, further studies should also investigate the influence of other types of creeping exercises on upper body strength and other types of creeping exercises on different motor skills, in pre-pubertal children.

CONCLUSION

This study represents a significant contribution to the understanding of strength training in young football players (~11 years old) and has confirmed that non-specific methods of strength training using creeping exercises over six weeks, influence the dynamic upper body strength in young football players. Young football players in the EXP group were able to perform more push-ups and pull-ups in 30 seconds and to perform the test, "driving a wheelbarrow" for a distance of 15 m, faster than the CON group. The differences are probably due to changes in the neural mechanisms of muscle force generation in the shoulder girdle and trunk. A better intramuscular and intermuscular coordination could be the reason for a higher motor efficiency in the EXP group.

Disclosure statement

No potential conflict of interest was reported by the authors.

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