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Research article

Effects of Different Contextual Interference Training Programs on Straight Sprinting and Agility Performance of Primary School Students

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Abstract
The aim of this study was to evaluate the effect of a different degree of contextual interference (CI) training program on the change of direction ability (CODA) itself and on the straight sprinting (SSP) performance (5 m and 15 m) in students in the first year of primary school. It also evaluated which CI training program was more effective. Eighty eight students (6.42 ± 0.38 yr) volunteered as participants for the present study. Participants were randomized into 5 different CI training programs (LCI: low contextual interference, MCI: moderate contextual interference, HCI: high contextual interference, VCI: variable contextual interference, and CG: control group) during a 3 week period. Significant CODA improvements ($p < 0.05$) in pre-post-test were found in MCI (4.39%, ES 0.41) and VCI (9.37%, ES 1.12) groups. Furthermore, LCI, MCI and HCI groups ameliorated their SSP performance, both in 5 m (5.92%, ES 0.81; 6.67%, ES 0.90; 8.05%, ES 1.33 respectively) and 15 m SSP (5.86%, ES 0.76; 6.47%, ES 0.80; 2.47% ES 0.41 respectively). These results suggest that training through games of tag (VCI) was the most effective in improving the CODA and training with moderate contextual interference (MCI) was the only type which induced improvements in both capacities (SSP and CODA).

Key words: Agility training, MAT, physical education, CODA, motor skills.

Introduction

Physical fitness is considered a key health marker in children and adolescents (Ortega et al., 2008; Ruiz et al., 2009). Furthermore, adequate physical activity levels have been reported to be necessary and decisive for the development and functioning of many physical, physiological, psychomotor and psychosocial processes in young people (Gallotta et al., 2009; Gutin et al., 2005; Ruiz et al., 2006; Strong et al., 2005; Zivcic et al. 2008). Physical activity levels have severely changed over the last few decades (Stalsber and Pedersen, 2010) and their consequences for children's overall development and health have attracted much attention from the media, scientific researchers, and policy makers (Fjortoft et al., 2011). In this sense, several practical guidelines for appropriate physical activity habits during childhood have been published (Gallotta et al., 2009; Twisk, 2001).

Physical education is an indispensable instrument to encourage young people to establish a long-lasting healthy lifestyle (Faircloughet al., 2002; Kirk, 2005). Specifically, straight sprinting (SSP) performance and change of direction ability (CODA) are considered primordial qualities in many activities (Sporis et al., 2010b; Young et al., 2001) and important physical components related to youth health status (Vicente-Rodriguez et al., 2011). CODA is defined as the ability to change the direction of the body in an efficient and effective manner (Young and Willey, 2010), whilst SSP is a relatively closed skill involving predictable and planned movements (Young et al., 2001). A proper attainment of these two fundamental and independent motor skills (Jovanovic et al., 2011; Salaj and Markovic, 2011) is considered important for an appropriate development of health processes in young people (Ortega et al., 2008; Vicente-Rodriguez et al., 2011).

Appropriate progressive practice (Brughelli et al., 2008; Holmberg, 2009) and specifically, contextual interference (CI) programs have been proposed as valid interventions to develop CODA and SSP (Holmberg, 2009; Magill and Hall, 1990; Shea and Morgan, 1979; Wrisberg and Liu, 1991). CI refers to the relative amount of interference created when integrating two or more tasks into a particular aspect of a training session (Little and Williams, 2005). Tasks can vary from involving one skill at a time up to the combination of different skills during a single drill (Holmberg, 2009). Previous research has tended to examine the influence of CI programs on the evolution of other fundamental motor skills, such as cardio-respiratory function (Ortega et al., 2008; Vicente-Rodriguez et al., 2011); however the influence of CI programs on CODA and SSP has not been ascertained.

Given the importance of fundamental motor skills in young people (Gallotta et al., 2009; Gutin et al., 2005; Ruiz et al., 2006; Strong et al., 2005; Zivcic et al. 2008) and the lack of studies on the influence of CI programs in this population, the aims of this study were to assess the CODA and SSP performance of students in the first year of primary school and to determine the influence of 5 different training programs on these two motor skills.

Methods

The sample consisted of 88 students (43 boys and 45 girls) in the first year of primary school (Table 1). Participants were randomized into 5 different CI groups: i) low contextual interference (LCI) group, ii) moderate contextual interference (MCI) group, iii) high contextual interference (HCI) group, iv) variable contextual interference (VCI) group and v) control group (CG). A description of the CI programs is presented in Table 2.

All parents or guardians of students gave their

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Table 1. Descriptive statistics of the characteristics of the participants. Data are means (±standard deviation).

	LCI group (n=15; 7♀ 8♂)	MCI group (n=18, 8♀ 10♂)	HCI group (n=16, 8♀ 8♂)	VCI group (n=20, 11♀ 9♂)	CG group (n=19, 9♀ 10♂)	Sample (n=88)
Age (yr)	6.4 (.41)	6.4 (.4)	6.3 (.4)	6.5 (.4)	6.5 (.3)	6.4 (.4)
Height (m)	1.23 (.05)	1.24 (.05)	1.22 (.04)	1.24 (.04)	1.23 (.04)	1.23 (.04)
Body mass (kg)	24.9 (3.3)	25.6 (4.1)	25.1 (3.6)	25.4 (3.3)	24.9 (3.5)	25.2 (3.6)
BMI (kg·m^{-2})	16.5 (1.3)	16.8 (2.0)	17.0 (1.9)	16.6 (2.5)	16.5 (1.9)	16.7 (1.5)

LCI: low contextual interference; MCI: moderate contextual interference; HCI: high contextual interference, VCI: variable contextual interference; CG: control group; BMI: Body Mass Index.

written informed consent before inclusion in the study. Informed consent was also obtained from the school council and the school's management team. Tests were conducted in accordance with the ethical principles set forth in the Declaration of Helsinki. The research was approved by the local institutional board. All of the participants were free of injuries at the time of the study and refrained from intense physical activities 48 hours before testing.

Procedures

Each participant performed a pre-test and a post-test session separated by a 3 week period, where the participants were randomly assigned to five different CI training programs (Table 2). At both test sessions the participants performed a SSP test and CODA test. Prior to the pre-test, the researchers gave all participants graphic and direct instructions about how to successfully perform the test. Two test sessions were performed to practice the tests and to ensure that the participants performed both tests correctly.

Before the tests, the participants completed a 10 min warm-up, including jogging, bilateral movements, dynamic stretching, skipping and jumping. Photocell gates (Microgate, Polifemo Radio Light, Italy) 0.4 m above the grounds were used to register the time during both tests. Participants were given verbal encouragement to run as fast as possible during the tests. All tests were performed indoors on a synthetic pitch. During the testing and training sessions, the air temperature ranged from 22 to 26ºC and all test sessions were conducted in the morning (10-13 h) during school hours. The training sessions were conducted during the physical education class times.

The SSP test consisted of 3 maximum acceleration drills of 15 m with a 180 s rest between them. Running time was recorded using photocell gates (Microgate, Polifemo Radio Light, Italy) placed 0.4 m above the ground, with an accuracy of 0.001 ms. The timer was automatically activated as participants crossed the first gate at the starting line. Split times were recorded at 5 m and 15 m. Similar distances have been used previously in other studies in both adults (Gorostiaga et al., 2009; Sporis et al., 2010a) and children (Condello et al., 2013; Oxyzoglou et al., 2009; Yanci et al., 2012).

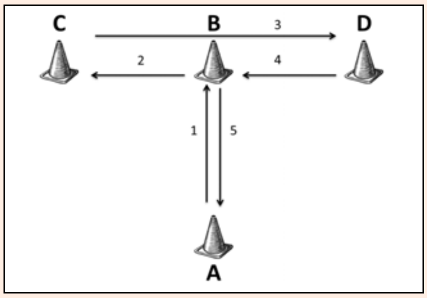

Figure 1. Design of the Modified Agility Test (MAT). A-B distance = 5 m; B-C and B-D distances = 2.5 m.

The CODA test was performed 48 hours after the SSP test. Based on a previous protocol for the T-design test (Sporis et al., 2010b), the Modified Agility Test (MAT) proposed by Sassi et al. (2009) and Pauole et al. (2000) was chosen for CODA assessment. This is considered a short duration test where linear movement in the antero-posterior and medio-lateral directions are required (Sassi et al., 2009). Previous studies (Yanci et al., 2012) conducted with primary school students showed excellent MAT test reproducibility values (ICC = 0.91, CV = 2.30%). The participants' movements during the MAT were as follows (Figure 1): i) A-B movements (5 m): Participants sprinted forward to cone B and touched the top of it with the right hand; ii) B-C movements (2.5 m): Moving laterally without crossing the feet, participants ran to cone C and touched its top with the left hand; iii) C-D movements (5 m): Participants ran laterally to cone D and touched its top with the right hand; iv) D-B

Table 2. Characteristics of the contextual interference (CI) programs.

Programs	Weeks	Total sessions	Session time (min)	Description
LCI	3	6	25	Only one previously known skill. One orientation internal paced skill exercises with prearranged distance.
MCI	3	6	25	Two previously known skills. Two orientations internal paced skill exercises with prearranged distance.
HCI	3	6	25	Immediate answer after stimulus with two or more possible skills. External paced skills according to perceived signals. Auditory stimulus and discrimination on the numbers and colours.
VCI	3	6	25	Traditional games of tag in small field (15 m width × 25 m length)
CG	3	6	25	Body language games without movement contents

LCI: low contextual interference; MCI: moderate contextual interference; HCI: high contextual interference, VCI: variable contextual interference; CG: control group.

Table 3. Repeated measures ANOVA for the modified agility test and the straight sprinting running test. Data are means (±standard deviation).

Test	Group	Pre-test	Post-test	*F*	df	p	Dif. pre-post. (%)	ES
MAT (s)	LCI	9.82 (1.16)	9.37 (.85)	3.80	(14)	.071	4.58	.44
	MCI	10.03 (1.17)	9.59 (.73)	4.48	(14)	.050*	4.39	.51
	HCI	9.87 (1.07)	9.66 (.89)	1.89	(15)	.189	2.12	.25
	VCI	10.56 (1.26)	9.57 (.78)	21.38	(19)	.001**	9.37	.99
	CG	10.46 (.99)	10.20 (1.50)	1.59	(18)	.222	2.48	.22
SSPT at 5 m (s)	LCI	1.52 (.11)	1.43 (.09)	19.89	(14)	.001**	5.92	.98
	MCI	1.50 (.11)	1.40 (.09)	25.28	(14)	.001**	6.67	.99
	HCI	1.49 (.09)	1.37 (.08)	41.16	(15)	.001**	8.05	.00
	VCI	1.51 (.12)	1.55 (.08)	1.77	(19)	.198	-2.64	.24
	CG	1.46 (.09)	1.50 (.07)	4.38	(18)	.051	-2.74	.51
SSPT at 15 m (s)	LCI	3.75 (.29)	3.53 (.24)	31.27	(14)	.001**	5.86	.99
	MCI	3.71 (.30)	3.47 (.26)	35.22	(14)	.001**	6.47	1.00
	HCI	3.63 (.22)	3.54 (.21)	5.96	(15)	.028*	2,47	.63
	VCI	3.78 (.26)	3.77 (.25)	0.05	(19)	.836	.26	.05
	CG	3.59 (.21)	3.80 (.27)	34.78	(18)	.001**	-5.85	1.00

MAT: modified agility test; SSPT: straight sprinting running test; ES: effect size; LCI: low contextual interference; MCI: moderate contextual interference; HCI: high contextual interference, VCI: variable contextual interference; CG: control group; * p < 0.05, ** p < 0.01.

movements (2.5 m): Participants moved back to cone B and touched its top with the left hand; v) B-A movements (5 m): Participants ran backwards to line A. Trials where participants crossed their feet during B-C, C-D and D-B movements, failed to touch the top of the cone, and/or failed to face forward throughout the tasks, were repeated.

Data analysis

Descriptive statistics were calculated for all experimental groups, and the results are presented as means ± standard deviations. The best performance of each test was used for the calculation. The normal distribution of results for the variables applied was tested using the Kolmogorov-Smirnov test, and statistical parametric techniques were conducted. The $p < 0.05$ level of statistical significance was selected. One way ANOVA and Tukey's ad hoc analysis were conducted to find initial and final differences between groups, and Bonferroni correction has been applied for *p* values. A repeated measure ANOVA was conducted to analyze the differences among pre- and post-test results, and a related measures Student's t-test was carried out to analyze each group independently. Practical significance for pretest and post-test was assessed by calculating Cohen's d effect size (Cohen, 1988). Effect sizes (ES) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2 and lower than 0.2 were considered as large, moderate, small, and trivial respectively. Differences between means were expressed as pre-to-post percentage. Data analysis was performed using the Statistical Package for Social Sciences (version 19.0 for Windows, SPSS Inc, Chicago, IL, USA).

Results

There were no significant differences between groups for the pre-test scores in the MAT, and the SSP tests, and homogeneous groups were assumed prior to the intervention. After the CI training programs, significant differences were observed for the MAT ($F(1,80) = 25.64$; $p < 0.001$; $\eta p^2 = 0.243$), and at the SSP test both at 5 m ($F(1,80) = 26.64$; $p < 0.001$; $\eta p^2 = 0.250$), and at 15 m ($F(1,80) = 20.40$; $p < 0.001$; $\eta p^2 = 0.205$). Interaction effects were found with the group variable, specifically for MAT ($F(4,80) = 2.52$; $p < 0.05$; $\eta p^2 = 0.112$), and 5 m ($F(4,80) = 14.10$; $p < 0.001$; $\eta p^2 = 0.414$) and 15 m ($F(4,80) = 26.64$; $p < 0.001$; $\eta p^2 = 0.571$) SSP tests. No interaction effects were found with the gender variable.

Table 3 shows the results of the repeated measures ANOVA among pretest and post-test scores for each group (LCI, MCI, HCI, VCI and CG). For the MAT test, significant differences were only reported for the MCI and VCI groups, which improved their performance by 0.44 s and 0.99 s after the intervention respectively. There were no significant differences among groups after the program for the MAT test. No significant differences were obtained between groups after the training.

Regarding the 5 m SSP test, LCI, MCI and HCI groups improved their performance (0.09 s, 0.10 s and 0.12 s, respectively). Significant differences were found between groups in the post-test scores ($F(4,80) = 12.86$; $p < 0.001$; $\eta p^2 = 0.391$), specifically VCI with regard to LCI ($p < 0.01$), MCI ($p < 0.001$) and HCI ($p < 0.001$) groups. Thus, the VCI group reported higher acceleration scores than the other three groups (+0.12 s, +0.15 s, and +0.18 s, respectively). Furthermore, MCI and HCI groups showed a shorter SSP running time at 5 m (0.10 s for $p < 0.05$ and 0.13 s for $p < 0.001$, respectively) in comparison to the CG.

Similarly to the previous results, in the 15 m SSP test, LCI, MCI and HCI improved their performance (0.22 s for $p < 0.01$, 0.24 s for $p < 0.01$ and 0.12 s for $p <0 .28$). On the contrary, the CG showed a longer SSP running time at this distance (0.21 s for $p < 0.01$). Significant differences were found between groups in the post-test scores ($F(4,80) = 6.02$; $p < 0.001$; $\eta p^2 = 0.232$), once again VCI with regard to LCI ($p < 0.05$), MCI ($p < 0.05$) and HCI ($p < 0.05$) groups. This time, the VCI again reported higher SSP scores regarding the other three groups (+0.24 s, +0.3 s, and +0.23 s, respectively). There were also significant differences between the control group with regard to LCI ($p < 0.05$), MCI ($p < 0.01$) and HCI ($p < 0.05$) groups, with higher SSP scores of +0.27 s,

+0.33 s and +0.26 s, respectively.

Discussion

To our knowledge this is the first study to analyze the influence of 5 different CI training programs on CODA and SSP ability of students in the first year of primary school. The VCI training was the most effective in improving the CODA and MCI training and was the only one that induced improvements in both capacities (SSP and CODA).

The MCI and VCI groups showed significant CODA improvements after a 3 week training period (ES = 0.51, 4.39% and ES = 0.99, 9.37%, respectively). Considering the effectiveness of the specificity of the exercises to improve the conditional characteristics (Sporis et al., 2010a), the similarities between the training exercises in two directions performed by the MCI group and the MAT could explain, in part, the significant reduction of the MCI in the MAT (Young et al., 2001). The VCI group, which performed several games of tag, improved the MAT test times significantly. These results coincide with the previous results obtained by Oxyzoglou et al. (2009). They found significant differences in agility between children who performed specific handball training and children who only took part in the physical education classes. The children who attended the handball training program scored better agility results (Oxyzoglou et al., 2009). The different actions and CODAs during the handball training program might be an adequate stimulus ameliorating agility. Therefore, considering these results, traditional games of tag, might be a positive element to improve CODA. It is considered necessary to determine the reason for these differences to analyze the specific motor actions that occur during these tasks. The high number of CODA during motor actions, depending on the stimuli, might be adecuate to improve the performance of the CODA. Given that this is the first study carried out to evaluate the consequences of the games of tag more research is needed. It is very important that children be introduced to the principles of training and active recreation, in theory as well as in practice. Good habits and motivation must be developed early in life (Astrand et al., 1986). In this sense, the traditional games of tag can be a good catch element because of its high degree of motivation and benefits in acquiring motor skills.

Nevertheless, no significant differences between the pre and post-tests (ES = 0.44, 4.58%) where obtained in the LCI group, where one previously known action and closed skill exercises in one direction over a prearranged distance were included (Holmberg, 2009). These results coincide with the results obtained by Young et al. (2001) who evaluated the specificity of the response to different training types both in a SSP or with CODA during a 6 weeks period in young sportmen (24.0 ± 5.7 years, 180.1 ± 4.4 cm, and 81.1 ± 8.4 kg) and concluded that SSP training had no relationship with the CODA. In this sense, several authors have defined CODA and the SSP ability as relatively independent qualities (Jovanovic et al., 2011, Sporis et al., 2010a; Sassi et al., 2009; Salaj and Markovic 2011). In our study, the group that performed SSP tasks, that is the LCI group, did not show significant differences on the CODA (MAT test). The tasks performed by the LCI group, in one direction and previously unknown, may not have been a sufficient stimulus to improve the CODA. According Vescovi et al. (2006) between 5-8 years of age versatility should predominate, whereby a variety of general movement patterns are utilized in an effort to develop a large foundation of motor skills. Implementing locomotor drills that incorporate spatial orientation can all be beneficial during this stage of development.

Even though the HCI group, during the 3 week period, attending a total of 6 physical education classes, practiced immediate motor responses after unknown stimuli it didn't show significant differences either (Holmberg, 2009) (ES = 0.25, 2.12%). Several studies have shown that HCI training programs tend to exhaust beginners in the earlier stages of skill acquisition, and performance may decrease as a result (Herbert et al., 1996; Holmberg, 2009; Landin and Herbert, 1997). Consistent with these studies, the participants included in the HCI group did not show significant improvement in CODA performance. The tasks set for the HCI group in our study required the subjects to respond to an unknown stimulus, which could cause a decrease in execution intensity. In line with these results, Serpell et al. (2011) did not observe significant improvements in a test without stimulus (COD) in young rugby players, after a 3 week program performing tasks with a video stimulus, where the CI is high. As several researchers claim (Drabik, 1996; Vescovi et al., 2006) complex tasks can be more effective in stages after 8-9 years. Considering the significant improvement in the VCI program observed in our study, it could also expect an improvement for the HCI program, because a motor response to a know stimulus is expected in both programs. Nevertheless, as Oliver and Meyers (2009) and Veale et al. (2010) pointed out, using a light as stimulus does not replicate a specific stimulus, because the possibility to anticipate the change of direction is eliminated (Sheppard et al., 2006). The "stimuli" types presented in the VCI and HCI program should not be considered homologous and the motor response could change depending on their characteristics.

On the other hand, the results of the SSP tests in 5 m and 15 m, suggest a significant improvement of the LCI, MCI and HCI between the pre and post-tests. Nevertheless, no significant differences were observed in the VCI and CG groups in 5 m (ES = 0.24, -2.64%, ES = 0.51, -2.74%). Furthermore, a significant loss of acceleration capacity was observed in 15 m in the GC after a 3 week period (ES = 1.00, -5.85%).

The LCI group improved the results obtained in 5 m (ES = 0.98, 5.92%) and in 15 m (ES = 0.99, 5.86%). Young et al. (2001) observed that agility training is barely related to aceleration perfomance and viceversa. The LCI group, which perfomed one way direction tasks, improved the SSP test significantly but not the COD test. This result coincides with the results obtained by Young et al. (2001) and is consistent with the concept of training specificity (Salaj and Markovic, 2011; Sassi et al., 2009; Sheppard and Young, 2006; Sporis et al., 2010a).

The group that performed an intervention program where a rapid response to a known stimulus with two actions was required (MCI) also improved significantly in 5 m (ES = 0.99, 6.67%) and in 15 m (ES = 1.00, 6.47%). The higher CODA and SSP capacity improvement observed in the MCI group, in comparison to other groups, suggests that the MCI training was the most efficient to ameliorate both abilities (CODA and SSP capacity) in first year students.

The HCI tasks were not effective to improve the CODA. Nevertheless, these tasks improved the SSP performance in 5 m (ES = 1.00, 8.05%) and in 15 m (ES = 0.63, 2,47%). These results contrast with those presented by Young et al. (2001), who hypothesized the specificity of agility and straight acceleration training). Therefore, the CODA and SSP training is not well understood in children. In our study, in the HCI group, no CODA changes were observed. On the contrary, the HCI group significantly improved its SSP capacity. This finding confirms the results of an earlier study by Sporis et al. (2010a), who observed significant improvements in acceleration capacity (5 m, 10 m and 20 m) in physical education students (19±0.9 yr) performing specific agility training. More studies are needed to analyze the influence of high CI interference agility training programs on the SSP performance.

The VCI group, which performed variable CI tasks, showed significant improvements (ES = 0.99, 9,37%) in the CODA after a 3 week training program. Nevertheless, no differences were obtained either in 5 m (ES = 0.24, -2.64%) or in 15 m (ES = 0.05, 0.26%). Therefore, considering these results, traditional games of tag may be appropriate to improve CODA, but not SSP capacity. As was previously described by Davies et al. (2013), narrowing the field space and having a higher density of players causes more frequent CODs and a reduction in fast running and sprinting actions. In this line, the games played on a larger field resulted in a greater total distance covered, and more distances covered in moderate, high, and very high velocity movement intensities (Gabbett et al., 2012). In the motor games observed in our study, the smaller field (10 x 25 m and 20 players), may have produced a higher frequency of CODA than during fast running and sprinting actions, which could explain the lower SSP capacity.

The control group (CG), which did not perform any task involving specific movements in the physical education classes, did not obtained improvements either in the CODA (ES = 0.22, 2.48%) or in 5 m (ES = 0.51, -2.74%) and a significant decrement of performance was observed in 15 m (ES = 1.00, -5.85%). These results suggest that due to the lack of stimuli, the first year students of primary school, do not improve performance in these two skills, and that the differences observed in the other groups are not due to maturational processes.

Agility is a capacity which is highly dependent on motor coordination and control. Furthermore, there are several factors that influence agility such as joint mobility, dynamic balance, power, flexibility, energy resources, force, velocity and the optimal biomechanical movement structure (Sporis et al., 2010a). Some authors defined agility as the ability of an athlete to change direction and perform rapid, efficient and repetitive movements (Miller et al., 2006). Agility is a very complex concept that results from physiological and biomechanical interactions (Sassi et al., 2009). In this line, the complexity of the motor control and the coordination of several muscle groups could contribute considerably to the variability of acceleration and COD capacity (Young et al., 1996). Agility training is thought to be a reinforcement of motor programming through neuromuscular conditioning and neural adaptation of muscle spindles, Golgi tendon organs, and joint proprioceptors (Barnes and Attaway, 1996; Craig, 2004; Potteiger et al., 1999). By enhancing balance and control of body positions during movement, agility theoretically should improve.

There are limitations to the current study. First, considering that the students' motivation could have been is a confounding factor influencing the results of the SSP and CODA, it would have been interesting to determine the motivation of the students prior to their participation in the study. Second, even though the results of the present study support the idea of a significant influence of different contextual interference programs after a 3 week training period on SSP and CODA, no information was given about the evolution of these two independent motor skills during a longer period of time. In addition, because this is the first study that evaluates the influence of games of tag on the SSP performance, more studies are needed to evaluate the CODA and SSP performance in primary school childrens in order to draw conclusions.

Conclusion

Significant differences were found in agility improvements in MCI and VCI groups after a 3 week agility training period with primary school children. By contrast, no significant difference was found in the LCI and HCI and CG groups. The most important improvement was found in the VCI group.

Significant differences were found in 5 m and 15 m performance in LCI, MCI and HCI groups after a 3 weeks agility training period. No significant difference was found in the VCI group.

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Key points

- We investigated the CODA and SSP performance of students in the first year of primary school and the influence of 5 different training programs on their CODA and SSP ability.
- Training through games of tag (VCI) was the most effective in improving the CODA
- Training with moderate contextual interference (MCI) was the only one which induced improvements in both capacities (SSP and CODA).

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