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RESEARCH ARTICLE

Effects of Open (Racket) and Closed (Running) Skill Sports Practice on Children's Attentional Performance

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Abstract:

Aims:

The first aim of the study was to examine the attentional performance of children (8–13 years of age) who practiced two different sport disciplines: Open skill sport – racket and closed skill sport – running and also to investigate the acute effects of these two specific training sessions on children's immediate and delayed attentional performance.

The second aim of the present study was to verify gender differences in attentional performance. Eighteen children+ (8 girls and 10 boys; age = 10.6 ± 1.5 yrs; height = 144.3 ± 12.2 cm; weight = 44.2 ± 12.5 kg; BMI = 20.8 ± 2.7 kg/m^2) engaged in a racket sports and eighteen children (9 girls and 9 boys; age = 9.9 ± 1.2 yrs; height = 142.4 ± 9.5 cm; weight = 40.0 ± 8.6 kg; BMI = 19.6 ± 2.4 kg/m^2) engaged in running were enrolled.

Methods:

Children's training and experience with these activities averaged 2.3 (± 1.0) years. Children's attentional capacity was measured before, immediately after and 50 minutes after each specific training session by the d2 test of attention.

This paper -and -pencil letter cancellation test evaluated concentration and sustained attention under stress induced by a fixed executing time. A 2 (Sport: open *vs* closed skill) x 2 (Gender: boys *vs* girls) x 3 (Time: pre *vs* 0' post *vs* 50' post) repeated measures ANOVA for time was used to compare the effect of an open skill session and a closed skill session on the individual attentional variables.

Results:

Children of open skill sport showed higher attentional scores (higher processing speed - TN, higher concentration performance - CP and lower percentage of errors - E%; p < 0.01), improved CP from pre to 0' post intervention ($p = 0.01$) and maintained this improved performance at 50' post intervention (50' post *vs* pre; $p < 0.01$), and decreased E% from pre to 0' post intervention ($p = 0.01$) and maintained this improvement at 50' post intervention (50' post *vs* pre; $p < 0.001$). Children of closed skill sport significantly decreased their CP from pre to 50' post intervention (50' post *vs* pre; $p = 0.001$ and 50' post *vs* 0' post; $p < 0.0001$) and worsened their E% across the time (50' post *vs* pre; $p = 0.001$ and 50' post *vs* 0' post; $p < 0.0001$). Boys showed significantly higher TN values than girls only in closed skill sport ($p = 0.023$). Finally, all girls of both open and closed skill sports significantly improved their CP from pre to 0' post intervention ($p = 0.04$).

Conclusion:

Results of the study showed that open skill sport practice and training session positively affects children's attentional performance.

Keywords: Acute exercise, Attentional response, Open skill sport, Closed skill sport, Gender, Post intervention.

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1. INTRODUCTION

Sport performance requires a multitude of contextual, movement-related cognitive demands for athletes [1], making cognitive processes essential to optimal sports performance [2]. At the same time, cognitive abilities developed by the sports practice may transfer to performance on everyday multitasking abilities [3 - 5]. This seems to be particularly relevant, especially during childhood, since children may benefit from higher cognitive abilities because of sport transfer skills to tasks of everyday living such as paying attention in class. Attention and concentration are two relevant aspects of the

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cognitive abilities during child development because they play a key role in the learning process [6], and in sports performances [2].

Regular participation in physical activity and sport leads to neurobiological adaptations that facilitate selected cognitive functions [7, 8]. Physical exercise arouses two types of neurophysiological changes: (a) a transient modulation of neural network involved in the cognitive task that underlies transitory behavioral and psychological changes; and (b) durable neurophysiological changes in brain structure that underlies stable behavioral and psychological changes [9, 10].

Acute exercise-induced modifications on cognitive performances are determined by the interactive effects between acute and chronic exercise [7]. Previous researchers reported that acute exercise produced beneficial effects on children's and adolescents' accuracy and speed of response [11], memory [12], attention and concentration capacity [13, 14], mental functioning [15], and executive functioning [16].

The impact of acute bouts of exercise on perceptual cognitive performance varies with the specific exercise and targeted perceptual cognitive process [17]. Mann *et al*. [18] asserted that the type of sport exercise or stimulus presentation affected the relationship between the athletes' perceptual cognitive processing and their level of expertise. Pesce *et al*. [19] demonstrated that a 40-minute intervention, including team games and a circuit training benefited memory recall, also suggesting that task conditions promote mental engagement. Moreover, Voss *et al*. [20] reported that different sports experiences could influence mechanisms of brain plasticity due to the different mental demands of different sport types, thus moderating the sport-cognition relationship.

In closed skill sports, the environment is stable, more predictable, and self-paced by athletes who can plan their responses (*e.g*., running, swimming) [21]. In open skill sports, athletes react within continuously changing conditions, unpredictable and externally-paced environments (*e.g*., basketball, tennis, fencing) [22].

Previous studies reported that coordinative and game-based activities that characterized open skill sports, such as racquet sports or team sports, are beneficial for executive functions since they require high effortful cognitive processing continually changing task demands and, therefore, due to the necessity do adapt movements to these demands. In contrast, repetitive activities (*e.g*., running, swimming) require less such cognitive activities [23 - 25].

Although, in a recent meta-analysis, de Greeff *et al*. [26] reported no significant effects of acute cognitively engaging physical activity on cognitive functions, little is known about whether children's mental functions can be modulated differentially through participation in different sport types (*e.g*., open skill and closed skill) [20] because of differences in required both cognitive and motor demands.

The last survey conducted by the National Institute of Statistics (Italy) revealed that the most popular sports among Italian youth were soccer, swimming, track and field (running, footing, and jogging) and racket sports [27]. However, football was almost exclusively practiced by boys, while swimming was mostly practiced by girls [27].

Therefore, the first aim of this study was to examine the attentional performance of children who practiced two different sport disciplines: open skill sport – racket and closed skill sport – running and to investigate the acute effects of these two specific training sessions on children's immediate and delayed attentional performance. The second aim of the present study was to verify gender differences in attentional performance.

2. MATERIALS AND METHODS

2.1. Participants

Thirty-six children were involved in this study. Eighteen children (8 girls and 10 boys; age = 10.6 ± 1.5 yrs; height = 144.3 ± 12.2 cm; weight = 44.2 ± 12.5 kg; BMI = 20.8 ± 2.7 kg/m^2) were already engaged in an open skill sport (racket sports as tennis and paddle) and eighteen children (9 girls and 9 boys; age = 9.9 ± 1.2 yrs; height = 142.4 ± 9.5 cm; weight = 40.0 ± 8.6 kg; BMI = 19.6 ± 2.4 kg/m^2) were engaged in a closed skill sport (running). Children's training and experience with these activities averaged 2.3 (± 1.0) years. All participants belonged to the junior team of the same sport club and were amateur athletes. They habitually trained 3 times per week (50-60 min/training session). The University Local Committee approved this investigation in accordance with the ethical standards provided by the Declaration of Helsinki of 1964 and its later versions. Written assent and informed consent were obtained from children and from their parents respectively, prior to study participation.

A priori power analysis [28] indicated that 14-18 participants per group were required to detect a medium effect size (f = 0.25 or 0.4) given a coefficient of correlation ρ = 0.80 with 80% power and α = 0.05, using within-between subjects mixed design.

This projection was consistent with previous attentional studies conducted by the research group that has shown moderate-large intervention effects [13, 14].

2.2. Attentional Measures

Attentional measures were conducted after children seated for 10-15 minutes in a quiet place.

Pre, immediately (0') post and 50 min (50') post each experimental session, children completed the d2 test of attention [29] to evaluate the concentration and sustained attention under stress induced by a fixed executing time. The d2 test is a paper -and -pencil letter cancellation test made up of 14 different lines, each one composed of 47 mixed letters (p or d in random order), with distractors such as from one to four dashes either over and/or under each letter. Children had to mark only the letters "d" that have double dashes within 20 s for each line. The test lasted 4:40 min:s. Each child's score was determined by the total number of items processed (TN – processing speed), by the number of correct "d" letters marked minus errors of commission (CP – concentration performance), and by the percentage of errors (E% – performance quality) made throughout all the items processed. The validity coefficient of the test was 0.47 and the range of its reliability was 0.95 – 0.98 [29].

2.3. Experimental Sessions

Each group participated in one of the two training sessions corresponding to open or closed skill sport: racket sport and running, respectively. Children completed the same attentional test before, immediately after and 50 min after the training session. The two training sessions occurred in the afternoon, at the same time.

Both training sessions were designed and conducted by a specialized trainer of tennis (or paddle) or track and field. Both sessions had the same structure, duration, and intensity. Each session started with a warm-up (15 min of aerobic activities and dynamic stretches), continued with moderate-to-vigorous physical activities (MVPA) (30 min), and ended with a cool-down (5 min of static stretches). The exercise intensity of each training session was monitored using an OMNI scale [30] to respect exertion in the MVPA range of a 5 < RPE < 8 and to avoid possible differences between training sessions. OMNI RPE measures were collected during each MVPA session, for three times, every 10 minutes of exercise (at around the fifteenth, the thirtieth and the forty-fifth minute of exercise). Children were asked to verbally indicate the number after looking at the scale to have an indication of how hard the exertion felt during the training session.

Training sessions of open skill sport consisted of a specific situation of the game with two couples of players to organize and to combine different movements for strokes and footwork. Specifically, children were asked to throw the ball between players with a different pattern of games, as a function of spatial and temporal parameters, varying progressively components for executive time, in executive situations of increasingly complexity (*i.e*., bimanual movements or with two balls).

Training session of closed skill sport was focused on the improvement of cardiovascular endurance. Children were asked to perform different types of gaits (*e.g*., fast walking or running, skipping), running and jumping games, followed by a continuous aerobic circuit training without any specific coordinative request.

After completing the experimental session, participants spent 50 min sitting in a quiet place. The only activity allowed was watching club sports activities.

2.4. Statistical Analyses

All results were expressed as mean ± standard deviation (SD). Children's age and anthropometric data differences between Sport (open *vs* closed skill) were verified using an unpaired t-test. Moreover, differences between Gender (boys *vs* girls) and Sport (open *vs* closed skill) for baseline attentional performance scores were verified using independent t-test. A 2 (Sport: open *vs* closed skill) x 2 (Gender: boys *vs* girls) x 3 (Time: pre *vs* 0' post *vs* 50' post) repeated measures ANOVA for time was used to compare the effect of an open skill session and a closed skill session on the individual attentional variables (TN, CP, E%). Effect size was also calculated considering Cohen's definition (small, medium, and large effect size as partial η^2 = 0.01, 0.06, 0.14) [31]. When interactions were significant, a Bonferroni adjusted post-hoc analysis was performed. Significant differences between open and closed skill sports were verified by a paired t-test. Statistical significance was set as $p < 0.05$.

3. RESULTS

Attentional variable scores for girls and boys of open and closed skill sports are reported in (Table **1**). No significant differences in age and anthropometric data between children of open and closed skill sports were revealed ($p > 0.05$). For each training session, differences in the baseline attentional scores were verified, revealing better attentional performances (higher TN, higher CP and lower E%; $p < 0.01$) in open *vs* closed skill sport. Moreover, no significant differences in the baseline attentional variable scores between boys and girls were revealed ($p > 0.05$).

Table **2** reports the ANOVA results on attentional variable scores: main effects of Time, Sport, Gender, and Time x Sport, Time x Gender, Time x Sport x Gender, Sport x Gender interactions. Children of open skill sport revealed better attentional performances than children of closed skill sport ($p < 0.001$). The ANOVA revealed differential effects of Sport on CP and E% change after experimental sessions. Specifically, the Bonferroni adjusted post-hoc analysis revealed that children of open skill sport significantly improved their CP from pre to 0' post intervention ($p = 0.01$) and maintained this improved performance at 50' post intervention (50' post *vs* pre; $p < 0.01$). Children of closed skill sport did not change their CP from pre to 0' post intervention and significantly decreased their performance at 50' post intervention (50' post *vs* pre; $p = 0.001$ and 50' post *vs* 0' post; $p < 0.0001$) Fig. (**1A**). Moreover, children of open skill sport significantly improved their E% from pre to 0' post intervention ($p = 0.01$) and maintained this improvement at 50' post intervention (50' post *vs* pre; $p < 0.001$). Children of closed skill sport did not change their E% from pre to 0' post intervention and significantly worsened their performance at 50' post intervention (50' post *vs* pre; $p = 0.001$ and 50' post *vs* 0' post; $p < 0.0001$) Fig. (**1B**).

Table 1. Pre-, 0' post-, and 50' post intervention attentional variable scores (mean values ± SD) for girls and boys of open and closed skill sports.

Open skill sport													Closed skill sport											
		Pre				0' post				50' post				Pre				0' post				50' post		
Girls	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TN	-	408.44	±	77.02	-	457.17	±	105.44	-	467.72	±	113.92	-	336.41	±	50.03	-	362.41	±	104.32	-	353.35	±	76.88
CP	-	136.94	±	29.85	-	170.50	±	40.81	-	182.778	±	46.35	-	93.88	±	22.06	-	97.05	±	23.60+	-	58.47	±	17.55

(Table 1) contd.....

		Open skill sport												Closed skill sport											
		Pre				0’ post				50’ post				Pre				0’ post				50’ post		
E%	-	8.26	±	3.70	-	4.47	±	2.75	-	3.78	±	1.44	-	13.86	±	4.9	-	13.93	±	7.05+	-	24.12	±	7.60
Boys	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TN	-	398.78	±	82.15	-	450.57	±	115.75	-	470.57	±	124.22	-	334.11	±	49.51	-	362.11	±	101.21	-	352.38	±	74.69
CP	-	133.21	±	38.23	-	160.12	±	49.43	-	173.06	±	54.94	-	95.82	±	22.12	-	96.58	±	22.64	-	60.88	±	17.37
E%	-	7.64	±	3.27	-	4.37	±	2.74	-	3.68	±	1.54	-	14.11	±	5.01	-	13.20	±	7.38	-	23.00	±	7.40

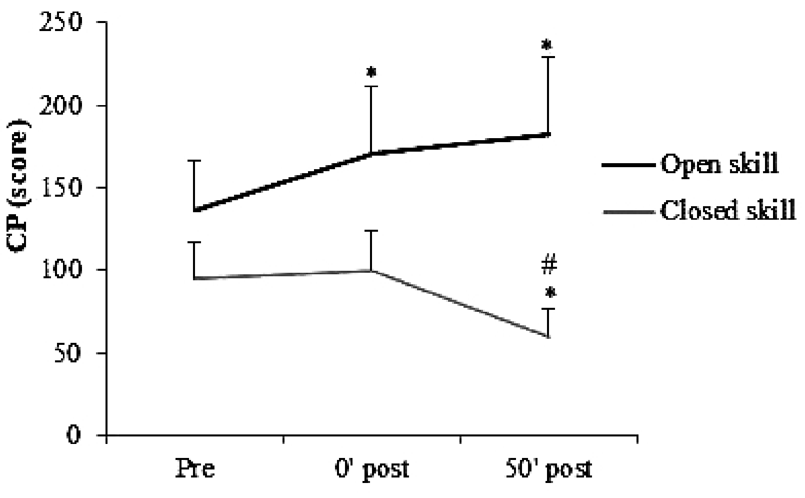
TN, total number of items processed; CP, number of letters correctly marked minus errors committed; E%, percentage of errors.

Table 2. ANOVA results on attentional variable scores.

Variable	Factors	F	df	*p*	Partial η^2
TN	**Time**	**3.73**	**2**	**0.03**	**0.104**
-	**Sport**	**20.81**	**1**	**0.00**	**0.394**
-	Gender	0.00	1	0.99	0.000
-	Time x Sport	0.87	2	0.42	0.027
-	Time x Gender	1.21	2	0.31	0.036
-	Time x Sport x Gender	1.05	2	0.36	0.032
-	**Sport x Gender**	**4.85**	**1**	**0.04**	**0.132**
CP	**Time**	**4.80**	**2**	**0.01**	**0.130**
-	**Sport**	**115.98**	**1**	**0.00**	**0.784**
-	Gender	0.37	1	0.55	0.011
-	**Time x Sport**	**21.19**	**2**	**0.00**	**0.398**
-	**Time x Gender**	**3.18**	**2**	**0.05**	**0.090**
-	Time x Sport x Gender	0.09	2	0.92	0.003
-	Sport x Gender	2.81	1	0.10	0.081
E%	**Time**	**9.81**	**2**	**0.00**	**0.235**
-	**Sport**	**116.36**	**1**	**0.00**	**0.784**
-	Gender	2.17	1	0.15	0.064
-	**Time x Sport**	**23.45**	**2**	**0.00**	**0.423**
-	Time x Gender	1.82	2	0.17	0.054
-	Time x Sport x Gender	2.89	2	0.06	0.083
-	Sport x Gender	1.10	1	0.30	0.033

TN, total number of items processed; CP, number of letters correctly marked minus errors committed; E%, percentage of errors.

1A



(Fig1) contd....

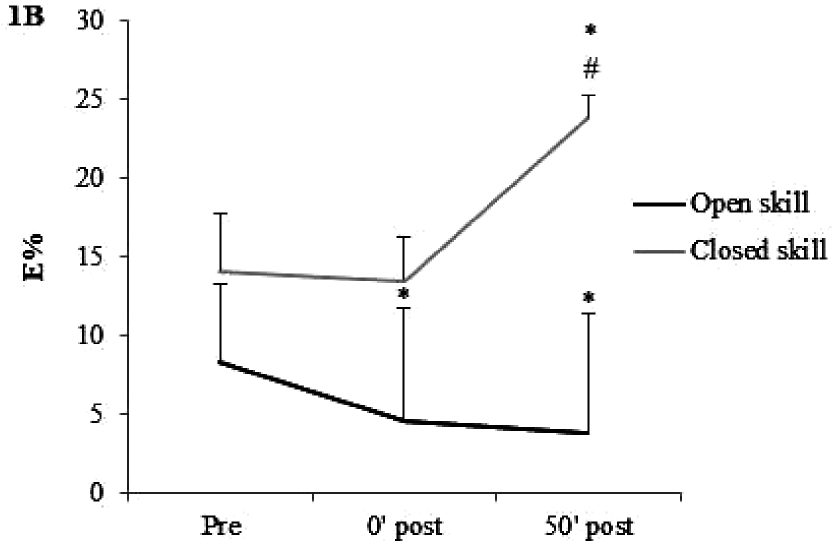


Fig (1). Pre intervention, 0' post intervention, and 50' post intervention CP (concentration performance) (**1A**) and E% (percentage of errors) (**1B**) scores for open and closed skill sports.

Boys showed significantly higher TN values than girls only in closed skill sport (p = 0.023) Fig. (**2**). Finally, all girls of both open and closed skill sports significantly improved their CP from pre to 0' post intervention (p = 0.04) Fig. (**3**).

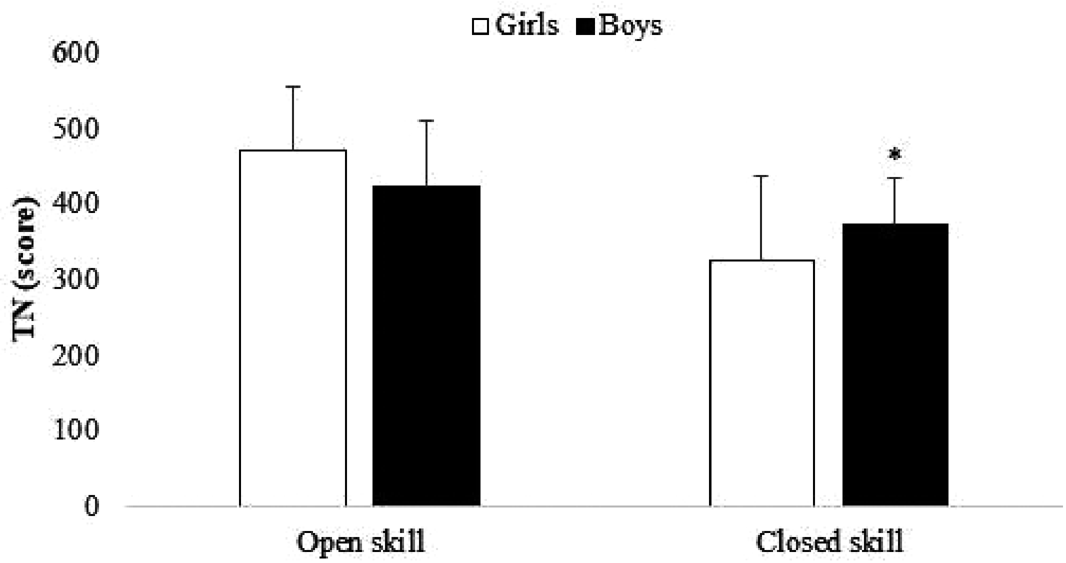


Fig. (2). TN (total number of items processed) score in girls and boys of open and closed skill sports.

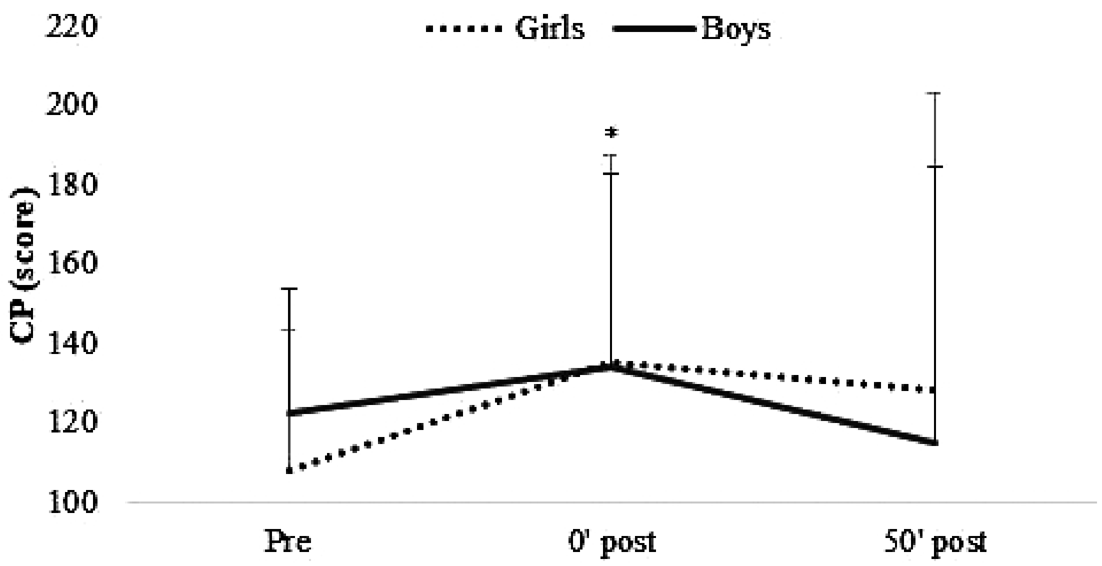


Fig. (3). Pre intervention, 0’ post intervention, and 50’ post intervention CP (concentration performance) score of girls and boys. * $p < 0.05$ *vs* pre (only for girls).

4. DISCUSSION

Open skill sports practice may advantage athletes with a greater improvement in the development of executive processes respect to closed skill sports practice [32]. In open skill sports, accurate timing, temporal estimations, temporal production, and spatial adjustments were required to provide improved cognitive performances [33]. In our study, children engaging in racket sport showed higher attentional performances in all attentional variables than their peers engaging in running. Voss *et al*. [20] argued that sports training leads to more efficient brain networks and brain plasticity, enhancing cognitive processing. Davis *et al*. [34] hypothesized that exercise-related cognitive benefits might be due to neural stimulation by the coordinative and cognitive complexity of the open-skill intervention, which enhances the efficiency of the brain. They also proposed the existence of a link between exercise and cognitive performance as a direct result of neural stimulation by movement [34]. The biological mechanisms due to exercise induce brain activity changes facilitating children’s cognitive functions. Racket sports, categorized as open skill sports, providing more competition, reaction to multiple different stimuli, varied scenarios/conditions and social interaction than running, positively affected children’s attentional performance. Our results agree with previous researches revealing that athletes from open skill sports performed better in cognitive tasks than those practicing closed skill sports [18, 20] and the practice of open skill sports was associated with the improvement of the executive functions [32]. The sensorimotor learning in sports plays a key role in linking training experiences with an enhancement of attentional performance [35]. The more cognitively demanding is the sports training, the greater are the cognitive effects that occur [35]. Therefore, training background in sports that require complex bodily movements and skill learning (*e.g*. tennis) could lead to better attentional performance than simpler and repetitive exercises (*e.g*. running).

The second aim of the present study was to investigate the acute effects of an open or a closed skill sport training session on children’s immediate and delayed attentional performance. Our study highlighted differences across sport types. Children of open skill sport significantly improved their attentional performance after the experimental session. Specifically, they improved their CP with a lower E% immediately after the experimental session and retained these effects until 50’ post. Conversely, children of closed skill sport did not change their concentration performance and accuracy (CP and E%) immediately after the experimental session but decreased their concentration performance and accuracy at 50’ post. In our study, children of racket sport completed a complex number of movements in relation to spatio-temporal dimensions (succession reversibility, simultaneity) with another player. The movements (integrating different stimuli, timing strategy, temporal accuracy, reaction time and coordination) resulted to be effective to induce an improvement of attentional performances.

Our results are in line with the previous findings by Budde *et al*. [36] who observed that 10 min of acute exercise with high coordinative and attentional requests produced higher benefits on 13–16-year-old adolescents’ attentional performance and concentration than aerobic exercise. These authors hypothesized the existence of a possible relation between concentration performance and coordinative exercise. Acute bouts of exercise of high complexity induced beneficial effects on attentional performance and concentration due to the activation of specific brain regions. Specifically, the activation of the prefrontal cortex during movement of high complexity seemed to be the possible mechanism responsible for this relationship between acute exercise and attention. The complex coordination exercises in racket sport required frontal-dependent cognitive processes enhancing prefrontal neural functioning. The mental switching process from internal to external, from narrow to broad during performance, could induce an improvement of attentional functions, such as visual perceptual speed and concentration performance. Previous research reported that children who are involved in the play and structured games that involved learning and group cooperation might adapt differently than children who are involved in individual physical activities [37]. Moreover, repetitive exercise did not rely on frontal circuitry to induce an improvement of attentional variables, explaining our results of the running group. The greater is the cognitive engagement of exercise, the stronger is the effect on attentional performance [38]. Our results are inconsistent with those of our two previous studies [13, 14], showing that coordinative exertion type led to a lower improvement of concentration performance over time than cognitive exertion and physical exertion types. The different context where the experimental sessions were conducted (sport club *vs* school setting) and participants' age (8–11-year-old primary school students *vs* 8–13-year-old athletes) may be the reason for the disparate findings.

Finally, our results revealed gender differences in attentional performance. Previous studies showed higher performances in mathematical and spatial abilities and working memory in males respect to females who outperform males in fine motor skills, verbal fluency, perceptual speed, and accuracy [39, 40]. Even our study showed differences between girls and boys for processing speed (TN) only in closed skill sport. Specifically, boys showed higher values than girls. We hypothesized that running exercises proposed during the closed skill experimental session were more effective in boys to induce a quantitative improvement of the amount of work completed but not inaccuracy or concentration performance of the attentional test. Moreover, our study showed differences between girls' and boys' acute exercise response. Specifically, all girls of both open and closed skill sports benefitted from intervention improving their CP after experimental sessions. These results confirmed general findings supporting the idea that girls are more able in focusing their attention on a target, ignoring distractors, and executing a quick response [39]. Maturity could also play an important role in the gender differences in attentional performances. In particular, gender differences in cognitive abilities are more pronounced at puberty. During puberty, behavioral, hormonal, and neuroanatomical changes occur. Moreover, in this period there is the reorganization of the prefrontal cortex. It seems that pubertal onset is a critical transition for neural development and consequently for the cognitive functions [41, 42]. Boys mature later than girls [43], thus this delayed degree of development could differently affect cognitive performance and attentional responses to physical exercise. Therefore, in our study, it is not possible to exclude a potential influence of pubertal stage on boys' and girls' attentional response.

Finally, although most of the methods used to determine exercise intensity are based on heart rate (HR), in our study the exercise intensity of each training session was controlled using the OMNI scale [30]. A study reported significant relationship between heart rate and RPE using the OMNI (r = .69–.93) scale with children age 9 to 13 years involved in running activities [44]. However, this HR method was not a good indicator of the intensity of open skill sports characterized by certain circumstances such as motivational status, intermittent nature of training and cognitive demands [45]. A previous study showed that the RPE method was the better indicator of both physical and psychological stress of open skill sports, which also included technical and tactical objectives [45]. Moreover, the construct validity for the OMNI scale to control open skill exercise demands was previously demonstrated [45].

There are some limitations to the present study. First, it is difficult to generalize the change of attentional performances without the assessment of other neuropsychological functions beyond the performance on the d2 test of attention. The lack of a study of the relationship between sports experience and attentional capacity while controlling for physical fitness reduces the amount of causal evidence since fitness level may moderate the sport–cognition relationship. The association of attention data with racket sports and running could limit the generalizability of the study for all open and closed skill sports.

Further research is needed to investigate the effects of different open and closed skill sports on the function of attention maintenance in children with different levels of fitness.

CONCLUSION

In conclusion, our findings suggest the beneficial effect of racket (open) sport on children's function of immediate and delayed attention when compared to running (closed). Therefore, we suggest including multilateral activities and varying type of exercises in closed skill sports training program, to favour not only physical and technical acquisition but also to improve cognitive functioning in these sports. Moreover, a multi-sport approach to children sports training, balancing open and closed skill activities, could be beneficial for the long-term athlete's physical and cognitive development. Further investigations are needed to verify if children's attentional improvements due to sports practice may be transferred to performance on everyday abilities, including school learning.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

All research procedures in this study were performed in accordance with the ethical standards of the responsible committee on human experimentation of University of Rome, Italy.

HUMAN AND ANIMAL RIGHTS

No animals were used in this research. All human research procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1975, as revised in 2013.

CONSENT FOR PUBLICATION

Written informed consent obtained from all participants.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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