Reaction Times, Agility and Body Mass Index: Differences Between Boys and Girls in Multisport

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Abstract
Background: Children who practice multiple sports in an organized form demonstrate higher levels of motor coordination when compared to children who regularly practice only one sport. In sporting and non-sporting situations, the ability to react in the shortest time to external stimuli, agility in changes of direction and physical characteristics, are important qualitative aspects that affect performance and success in growing boys and girls. **Aim:** The purpose of this study is to compare whether the multi-sport activity carried out for several years, may have created significant differences between males and females aged 11-12 years on agility, simple reaction times to visual stimuli and body mass index (BMI). **Materials and methods:** In the present study 96 students participated, of which 49 girls (age: 11.52 ± .51 years) and 47 boys (age: 11.48 ± .51 years) practicing different sports disciplines (football, athletics, basketball, volleyball). Agility was assessed through the hexagon agility test (HAT). The measurement of simple reaction times to visual stimuli for the dominant upper and lower limb was carried out through the tests: Reaction Time simple upper limb dominant (RTs UL) and Reaction Time simple lower limb dominant (RTs LL) using mobile instrumentation with led light discs and tablets (FITLIGHT Trainer ™ Sports Corp, Canada). Height and weight were measured for the BMI calculation. The Student's t test for independent samples was used to determine if there is a statistically significant difference between the means of the two groups (male and female) independent of each other in each test administered. Statistical analyzes were performed using IBM SPSS vers. 25 for Windows. **Results:** In the comparison of the

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means of the results in all the tests administered and in the calculation of the BMI, no statistically significant difference was found for both sexes. **Conclusion and recommendations:** Boys and girls between the ages of 11 and 12 who regularly practice multi-sport have high levels of motor performance and a good state of physical fitness but it must be specified that the ability to react to visual stimuli in the shortest possible time and that of being more agile does not seem to depend on gender at this stage of growth. These indications are useful for implementing methodological interventions aimed at improving the ability to process information and more performing motor responses with similar interventions without distinction of gender.

Keywords: *agility, reaction time, BMI, gender, multisport.*

1. Introduction

Children who regularly practice sport or organized physical activity have better motor coordination, better levels of physical activity, greater motor competence especially when compared with children who do not play sports or who are sedentary (Fransen et al., 2012; Lai et al., 2014; Vandorpe et al., 2012). Physical activities based on the variability of the practice should be proposed to the very young as it is amply demonstrated that these have positive repercussions on long-term sports practice and also on future performance in elite athletes (Côté et al., 2003, 2007; Ford et al., 2009). Premature sports specialization is defined as mono-disciplinary sports practice carried out from childhood through many hours of deliberate practice with the aim of improving sports performance (CôTé et al., 2009), this anticipated start towards a single sporting discipline consequently involves an early involvement in high intensity sports training and a premature start to agonistic competition (Baker et al., 2009). In children, interventions focused on multi-sport lead to improved motor skills and perceptions of motor skills, which are essential for regular participation in health-related physical activity (Kirk, 2005). Recent systematic reviews and meta-analyzes have shown that regular physical and sporting activity has beneficial effects on the body max index (BMI), fitness and metabolic profile of children and adolescents (Bangsbo et al., 2016; Milanović et al., 2015, 2019), as well as their quality of life related to health, social and psychological well-being and academic performance (Jones et al., 2010). Children who practice multisport activities have higher levels of motor coordination than children who practice monodisciplinary activities (Sekulic et al., 2017). Among the many coordinating factors, the capacity to react in the shortest time, the speed of decision-making and agility in changing directions are important qualities for performance in many sports games and in multi-directional sports (Jakovljevic et al., 2012). Agility (or coordination) is a complex, specific and transversal quality that is closely connected with the speed, motor creativity and speed of information processing processes (Bernshteĭn & Feĭgenberg, 1991). In sport, agility has been defined as a rapid movement of the whole body with a change of speed or direction in response to a stimulus (Sheppard & Young, 2006) and it is therefore an important quality that contributes significantly to success in sports results (Sekulic et al., 2017; Young et al., 2015). Some authors have highlighted the lack of literature examining the development of agility during childhood and adolescence and have pointed out the current lack of understanding of the effects of maturation on its performance (Lloyd et al., 2013). It has been shown that physical activity and sport can be related to the improvement of motor reaction times (Jain et al., 2015; Okubo et al., 2017; van de Water et al., 2017; Walton et al., 2018; Yildirim et al., 2010) and agility (Sheppard & Young, 2006), although they are distinct physical qualities; however the reaction time (RT) is the first important step in performing agility tasks more effectively. There are many sports disciplines in which reacting as quickly as possible is essential in more diversified situations, because athletes must make quick decisions to be more likely to be successful in their actions (Mudric et al., 2015; Ruschel et al., 2011; van de Water et al., 2017). The simple reaction time (RTs) can be defined as the time that elapses from when a stimulus (signal) appears until a response is given and is considered a good measure for assessing the cognitive system's ability to process information (Jensen, 2006; Magill, 2007; Kuang, 2017). In sport, RT is often recognized by an identifiable total time as that necessary to perceive, identify, process an external stimulus and respond with movement, and has two partial components which are the reaction time and the movement time. In the present study, the RTs is considered as the time required from the presentation of the visual stimulus (LED light on) to its achievement (LED light off) through a rapid movement of the upper (hand) or lower (foot) limbs: RTs = Reaction time + Movement time.

It should also be emphasized that the relationship between agility and reaction times has not been extensively studied in the literature, especially in the gender differences in young athletes. Many authors have conducted studies on children, from infancy to adolescence, in which they show that due to the increase in the capacity and speed of information processing that the central nervous system is able to manage, the motor reaction times tend gradually to diminish (Nicolson, 1982; Sugden, 1980). Generally women have longer reaction times than male peers (Henry & Rogers, 1960). However, one study (Silverman, 2006) in which a 72-dimensional meta-analysis of the effect from 21 studies (n = 15,003) was published over a 73-year period, the author reported that male advantage in Visually stimulated RTs are decreasing (especially outside the United States), likely because more women are involved in driving and fast-acting sports. In this study we want to examine whether the multi-sport activity carried out for several years may have created significant differences between males and females aged 11-12 years in agility, simple reaction times to visual stimuli and body mass index (BMI). It has been hypothesized that giving children multidisciplinary sports opportunities would optimize the development of agility and motor reaction times without distinction of gender, also considering the possibility of variation in individual development typical of the age group considered.

2. Materials and methods

2.1. Participants

In the present study 96 children participated, of which 49 girls (age: 11.52 ±.51 years) and 47 boys (age: 11.48 ± .51 years) practicing different sports disciplines (football, athletics, basketball, volleyball) in different sports clubs in the city of Foggia (Italy).

2.2. Measures and Instruments

Anthropometry and Body Composition

The height (cm) of the subjects was measured to the nearest 0.1cm using a portable stadiometer Seca, Hamburg, Germany, the mass (kg) was measured to the nearest 0.1kg, using a Seca digital scale with shoes and bulky clothing removed. Two measurements were recorded for both height and weight for each participant, the results representing the average of the 2 measurements. The BMI for each subject was calculated using a spreadsheet set on Excel (office 2007) according to the summary report (Barlow & Committee, 2007).

Hexagon Agility Test (HAT)

L'Hexagon agility test (HAT) is described as "a measure of agility and speed of the feet involving balance and coordination capacity" (Baechle et al., 1994; Roetert et al., 1992). It has been shown that the HAT, as a field test, has excellent test-retest reliability when rigorous test procedures are followed (Beekhuizen et al., 2009; Pauole et al., 2000). In this study, a modified version of the original HAT was used (Beekhuizen et al., 2009) for example, including two sequences instead of three and using a light signal for starting. The test involves the subject facing forward, in the center of a hexagon drawn on the ground with adhesive tape. The length of each side is 24 inches (60.96 cm), each inner angle is 120 degrees. At the center of the hexagon is positioned solidly on the ground, a conductance platform connected to a chronometric detection system (Chronojump system, Barcellona, Spain). The platform is connected directly to a portable PC, all managed by a software (Chronojump software 2.2, Barcellona, Spain) which allows to detect the times in thousandths of a second. Starting from the center of the hexagon, the test involves 6 subsequent round-trip jumps, successively overcoming each side, the first jump is towards the front line, then the lateral one and so on. The test is performed both clockwise and counterclockwise. A 1 minute pause was performed between one round and the next. The average time is calculated as a score, given by the sum of the total times of the hourly and anticlockwise lap divided by 2. Two total trials were administered for each participant interspersed with 2 minutes rest. The best average time between the two tests was taken into consideration.

Test: Reaction Time simple upper (RTs UL) and lower (RTs LL) limb dominant

The measurement of the simple reaction times for the dominant upper and lower limbs respectively was carried out through the use of 2 tests: Reaction Time simple upper limb dominant (RTs UL) and Reaction Time simple lower limb dominant (RTs LL), (Wilke et al., 2020). Both tests use a mobile equipment (Fitlight Trainer ™ Sports Corp, Canada) consisting of a control tablet and moving discs, each disc (diameter: 10 cm) in relation to the program used, emits light signals through LED lights or sound and it is also equipped with proximity sensors. The system allows you to measure and record times in thousandths of a second at each contact. RTs UL (Wilke et al., 2020) is a test that evaluates the simple reaction times (ICC/Rho: 0.81* (95% CI: 0.48-0.94), $p < .001$), of the upper limbs. The subject standing, is positioned with the palm of the dominant hand (defined as the hand that he uses intuitively for sports activities, eg. throwing, pushing) resting on a table adjusted at the elbow. A sensor is positioned on the same table at a distance from the subject, equal to the length of the forearm. RTs LL (Wilke et al., 2020) evaluate the simple reaction times of the lower limbs (ICC/Rho: 0.89* (95% CI: 0.67-0.97), $p < .001$). The subject is standing, feet parallel (distance between the feet equal to the width of the shoulders), a sensor has been placed in front of the participant's feet. The sensor distance is normalized to the length of each participant's dominant foot, which is measured as the distance from the apex of the big toe to the heel. For both tests the task is to deactivate the sensor as soon as it lights up, as quickly as possible by swiping over it with the dominant hand (RTs UL) or with the dominant foot (RTs LL), contact with the sensor was not required. Each test for each test consists of a total of 20 led switching on with variable (random) intermediate time intervals. The response time in seconds, thousandths is measured on all repetitions. The result of the test is given by the average of the reaction times. Each participant for each test is given two tests with a 3 minute break in between, the shortest mean time in seconds of the two tests for each test was recorded and used in the analysis.

3. Procedures

The data was collected on the occasion of a summer sports meeting in Italy in which young athletes who had been participating for 2 years in a national project called "Educamp - Multidisciplinary Sports Centers" by Italian National Olympic Committee (CONI), a project that favors the practice of multisport.

During each sporting year, boys and girls from 7 to 14 years of age registered with the companies participating in the multisport project, practice recreational and sporting activities for 10 months, from September to June, introducing the most important elements of at least 3 sports team or individual, with frequency 3-4 times a week, under the guidance of qualified technicians from the Italian sports federations and doctors in physical and sports sciences.

On this occasion, the companies participating in the rally were contacted and permission was asked to let their athletes participate in this study.

Through the proposal of a cognitive questionnaire, the inclusion criteria were considered: (i) aged between 11 and 12, (ii) adherence to the "Multidisciplinary Sports Centers - CONI" project for 2 years, (iii) knowledge and practice of at least 3 sports disciplines, (iiii) regular participation in physical education classes at school (2 hours per week); and the exclusion criteria: (i) any recent injury requiring medical attention, (ii) neurological adverse events for example seizures, (iii) having had Covid 19 infection.

The objectives of the study and the effects of the results for the improvement of sports performance were communicated to the responsible technicians of the respective companies, to the participants and to their parents. Informed consent was requested for data collection.

All procedures conformed to the directives of the Declaration of Helsinki (2013).

3.1. Statistical analysis

Data are reported as mean ± standard deviation (SD).

Before using the parametric tests, the hypothesis of normality was tested using the Shapiro-Wilk test.

The Student's t test for independent samples was used to determine if there is a statistically significant difference between the means of the two groups (boys and girls) independent of each other in each test administered.

Statistical analyzes were performed using IBM SPSS vers. 25 for Windows.

4. Result

No discomfort or adverse effects during test were noticed or reported.

4.1. Anthropometry and Body Composition

The distinction of the characteristics of age, height, mass, BMI between boys and girls are summarized in the tables (Table 1, Table 2).

Table 1. Characteristics of the groups: Boys (mean ±; N = 47) and Girls (mean ±; N = 49)

Parameter	Boys	*p* value	Girls	*p* value
Age (year)	11.48 ±.51	< .0001	11.52 ±.51	< .0001
Height (cm)	147.30 ±7.05	.0603	147.67 ±4.84	.4480
Body mass (kg)	39.99 ±4.92	.5538	42.33 ±3.32	.7310
BMI (kg)	18.38 ±1.30	.0465	19.40 ±1.02	.2726

Values are expressed in mean ± standard deviation; Body Max Index (BMI).

Table 2. Characteristics of groups by gender with reference to percentiles (Barlow & Committee, 2007)

	Boys	Girls	Totals
Number of children evaluated	47	49	96
Underweight (<5th% ile)	0%	0%	0%
Normal BMI (5th - 85th %ile)	96%	95%	95%
Overweight or obese (≥ 85th% ile) *	4%	5%	5%
Obese (≥ 95th% ile)	0%	0%	0%

Body Max Index (BMI)
* Terminology based on: Barlow SE and Committee of Experts. Recommendations of the Expert Committee on the Prevention, Assessment and Treatment of Overweight and Obesity in Children and Adolescents: Summary Report (Barlow & Committee, 2007).

The data in table 2 show that 96% of the boys and 95% of the girls examined have normal BMI values, therefore no particular gender differences are highlighted.

4.2. Hexagon Agility Test (HAT), Reaction Time simple upper (RTs UL) and lower (RTs LL) limb dominant test

The preliminary analyzes conducted through the construction of the boxplots (Figures 1) in which the averages of the results of each test (HAT, RTs UL dominant and RTs LL dominant) of the boys and girls were compared, did not show the presence of outliers between groups.

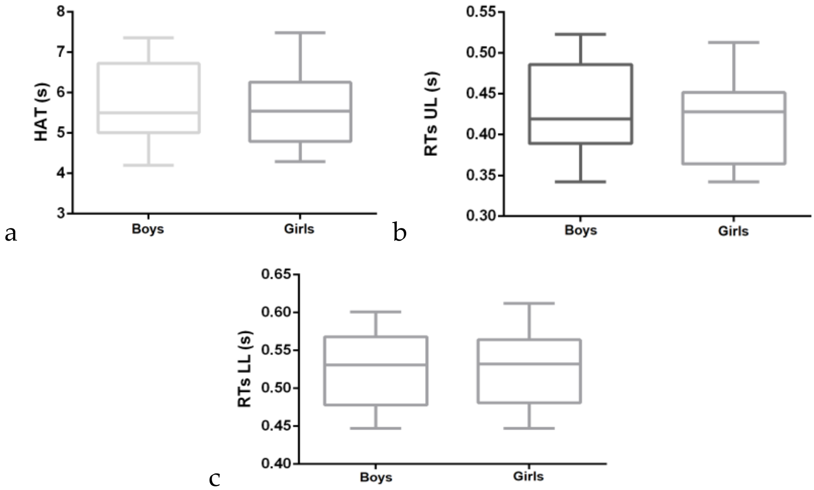

Figure 1. Comparison between boys and girls of the means time (s) in (a) Hexagon Agility Test (HAT), (b) Reaction Time Simple Upper Limb dominant (RTs UL) and (c) Reaction Time Simple Lower Limb dominant (RTs LL) test

Table 3. Hexagon Agility Test (HAT), Reaction Time Simple Upper Limb dominant (RTs UL), Reaction Time Simple Lower Limb dominant (RTs LL): means, standard deviations (SD) and p-value (Shapiro-Wilk Test; p> 0.05) between boys and girls.

	N	Mean (s)	SD	p-value
HAT boys	47	5.824	.962	p>.05
HAT girls	49	5.599	.921	p>.05
RTsUL boys	47	.429	.053	p>.05
RTs UL girls	49	.416	.050	p>.05
RTsLL boys	47	.525	.050	p>.05
RTs LL girls	49	.524	.046	p>.05

Student's t test for independent samples was used to determine if there is a statistically significant difference between the means of two independent groups (boys and girls) in each test administered. In the HAT, RTs UL and

RTs LL tests, the Levene test for assumed equal variances was significant for all tests, therefore the null hypothesis, ie that there is equality of variances, is discarded. Therefore, having accepted the hypothesis of non-equality of the variables, the results in table 4 show that for the tests HAT (p = .431), RTs UL (p = .431) and RTs LL (p = .921) there are no differences significant among the averages of boys and girls.

Table 4. T-test for the equality of means between boys (N = 47) and girls (N = 49) in the Hexagon Agility Test (HAT), Reaction Time Simple Upper Limb dominant (RTs UL), Reaction Time Simple Lower Limb dominant (RTs LL).

		t	gl	Sign. (two-tailed)	Difference of the mean	Standard error difference	Confidence Interval of 95% difference Inferior	Superior
HAT (s)	Equal variances not assumed	-.795	41.897	**.431**	-.225	.284	-.799230	.347416
RTs UL (s)	Equal variances not assumed	-.827	41.911	**.413**	-.013	.016	-.044407	.018585
RTs LL (s)	Equal variances not assumed	-.100	41.998	**.921**	-.001	.014	-.030816	.027913

In the HAT test, the average time in the boys group (5.824 ±.962 s) is higher than in the girls group (5.599 ±.921 s), with a difference equal to -.225 s, therefore there is no statistically significant difference between the two groups (p =.431). In the RTs UL test the average time in the boys group (.429 ±.053 s) is slightly higher than the girls group (.416 ±.050 s), in fact the difference is equal to -.013 s, there is no statistically significant difference between the two groups (p = .413). In the RTs LL test, the difference in the mean times in the group of boys (.525 ±.050 s) and girls (.524 ±.046 s) is minimal (diff. = -.001 s), so much so that it is considered negligible, also in this case we did not have a statistically significant difference between the two groups (p = .921).

5. Discussion

The ability to quickly and accurately execute movements in response to external stimuli is a key factor in athletic performance (Galpin et al., 2008). Variability in task and context is deemed crucial in basic research on learning and brain plasticity (Green & Bavelier, 2008). There are many studies that have shown the existence of significant relationships between agility and reaction tests to visual stimuli both for the use of the upper and lower limbs (Fiorilli et al., 2017; Homoud, 2015; Horicka et al., 2018; Moradi & Esmaeilzadeh, 2015), but few that show gender differences in pre-pubertal age. Physical exercise and motor and sports practice have positive effects on the reaction times of the upper and lower limbs (Akarsu et al., 2009). The objective of the present study is to verify whether there are differences in performance on simple motor reaction times to visual stimuli, agility and BMI, between boys (N = 47) and girls (N = 49) aged 11-12. years, practicing multi-sport activities. Adult men generally have shorter and less variable motor reaction times than women. One hypothesis could be that gender differences in the variability of motor reaction times may originate from the effects of sex hormones on the central nervous system and therefore can consequently be predicted in adults but not in pre-adolescents (Der & Deary, 2006).

There are few studies that deal with the development of responsiveness in the pre-pubertal period, while there are similar studies in boys and girls up to ten years of age (Feč, 2010) or adults (Der & Deary, 2006; Luchies et al., 2002).

A study conducted on boys and girls between the ages of nine and twelve demonstrated a significant relationship between agility and motor reaction times (Moradi & Esmaeilzadeh, 2015).

In the present study in the analyzed sample (boys; N = 47 and girls; N = 49) the t-test for the equality of means (Table 4) shows that there are no significant differences between gender and in UL dominant RTs (mean difference of times = -.013 s; p = .413) that RTs LL dominant (mean difference of times = -.001 s; p = .921), this is equivalent to saying that the reaction times for this age group 11-12 years do not depend on the gender; a probable explanation could be that the rates of reaction times are determined by predominantly cognitive processes in which there are no sex differences. The results obtained are however consistent with the hypothesis that the sex differences in the variability of the UL RTs and the dominant LL RTs, may be attributable to the effects on the central nervous system (CNS) of sex hormones, in particular of estrogens, whose receptors are present in different regions of the brain involved in information processing and attention, systems that are involved in regulating variability in information processing. Therefore, according to this hypothesis, gender differences in reaction times should be present after puberty, but not in pre-pubertal children (Ghisletta et al., 2018) such as those present in this study.

A hypothesis to consider is that from an anatomical-physiological point of view in pre-adolescent age girls are naturally disadvantaged compared to boys in simple reaction times, as the neural impulses involved in the production of a motor response must travel a longer path. long from the brain to the muscles recruited, this is because from about 2 to 14 years old girls are on average taller than boys (Tanner & Tanner, 1990). In the analyzed sample, the measured values of average height in boys (147.30 ±7.05 cm) and in girls (147.67 ±4.84 cm) are almost the same (Table 1), therefore this hypothesis in this case is null.

Conditions similar to the results of the tests described above were also found in HAT, i.e. that statistically there are no significant differences between boys and girls (mean difference of times =-.225 s; p =.431), therefore similarly to what was stated for the tests of motor reaction, agility performances for this 11-12 year age group do not depend on gender. However, it should be noted, as can be seen in the data in table 3, that in the agility test the average time recorded in girls (5.599 ± .921 s; p>.05; N = 49) is in any case lower than that of boys (5.824 ± .962 s; p>.05: N = 47) despite statistical insignificance; this aspect could have a matrix of mere randomness also linked to the small number of subjects examined. In fact, it is known that up to the age of twelve, girls and boys do not have great differences from a coordinative and conditional point of view, in particular related to muscle strength.

The values of the anthropometric factors (weight, height) in this study were used to determine the BMI of boys and girls, assuming that theoretically, factors such as body fat and lengths of body segments can particularly affect performance of agility. The data show that 96% of the boys (N = 47) and 95% of the girls (N = 49) examined fall within normal BMI values (Table 2) therefore, given the low number of the sample analyzed (N = 96), there are no particular differences between the two groups. The estimated BMI was however taken into consideration to verify the homogeneity of the reference sample in each group.

6. Conclusions and recommendations

Boys and girls between the ages of 11 and 12 who regularly practice multisport have high levels of motor performance and good physical fitness. Studies have already shown for some time that groups of young people who practice multidisciplinary and multilateral sports activities have statistically significant improvements compared to groups who practice only one sport and sedentary (Massacesi et al., 1996). A hypothesis to be confirmed for coaches or teachers is whether specific motor exercises or tasks on the development of agility and motor reaction times in pre-pubertal children should be differentiated by gender. The present study, within its limits, confirms how in children who practice multisport, reacting to visual stimuli in the shortest possible time and being more agile, does not seem to depend on gender. The development of the ability to react improves with increasing age, it is therefore known that the phase ranging from seven years up to the pre-pubertal and pubertal (11-12 and 13-14 years) is considered a sensitive period for development of these skills (Horníková et al., 2019). These indications are useful for implementing methodological interventions aimed at improving the ability to process information and more performing motor responses with interventions without gender distinction in pre-pubertal age. Physical exercise and sports practice have positive effects on the reaction times of the upper and lower limbs (Akarsu et al., 2009) and therefore on the closely related agility, it is still necessary to reflect and develop subsequent research programs aimed at analyzing which types of activities have the greatest influence on children.

Disclosure statement

The authors report no conflicts of interest.

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