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Eye-hand relationship of proprioceptive motor control and coordination in children 10–11 years old

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Abstract
Background. Eye-hand coordination refers to the capacity to use the vision skill to guide hand movements and is vital not only in sports activities but also in everyday life and jobs.
Aims. Our investigation tried to identify statistically significant variations between 110 children, aged 10–11 years old, from five different schools in Targu Mures - Romania, who practice or not sports activities, comparing genders, and also correlating those who practice predominantly arm or leg sports.
Methods. As a research method, we used the hand-eye coordination test and also examined the obtained data with professional statistical programs.
Results. The results showed that between genders there is a statistically significant difference with better results in the eye-hand coordination test in the male gender. Also, a statistically significant difference was found between those who practiced sport and those who did not, and also between genders. No statistical difference was found between predominantly leg and arm sports.
Conclusions. The conclusions of our investigation highlighted a statistically significant difference between the numbers of executions in the female gender compared with males and also between the median number of executions in students who practice sports and those who do not, and between the average number of executions for the female and male gender for those who practice sports.
Key words: eye-hand coordination; balance; motor activities.

Introduction

Recent studies in visual attention prove that this cognitive process allows fundamental data, from dissipated and various visual scenes, and worthless data to be sifted through (McMains & Kastner, 2009).

The eye-hand coordination quality which is characterized by the usage of vision cognitive perception that implies leading hand movements such as apprehending and reaching is fundamental for upper limb dexterity (Crawford et al., 2004). This process demands the implication of many cognition elements such as the visual apparatus, the lower and upper extremities of the body to make controlled, fast reactions and accurate movements (Shandiz et al., 2018).

The eye-hand coordination process takes place in an organized manner that implies, first of all, the visual finding of the focused object or target, then the process of focusing attention on that target, followed by the perceptual recognition of its location, the cognitive process, and the scheme of reaching the target, and finally the excitation of the extremity muscular system for initiating the movement process (Gao et al., 2010).

In other words, eye movements are interconnected with lower extremity movements, as the eyes start and finish their process of recognition faster than the hands (Carey, 2000). The coordination malfunction is described as any difficulty or restriction at the level of motor coordination that results in a low level of anticipated performance, relying on the patient's chronological age (Coetzee & Pienaar, 2013).

As presented in some research investigations (Ellison, 2015), the prompt reaction time of the visual system regarding the eye-hand movement is issued by the

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fulfillment of assignments that requires numerous findings and resulting motor movements (Laby et al., 2018).

The capacity of motor coordination consists of binding the nervous and musculoskeletal systems that produce a fast, precise, and well-balanced motor reaction which can be evaluated by measuring and comparing the reaction time of the eye-hand or eye-foot coordination skill (Corbin et al., 2000; Lopes et al., 2012). Agility skill refers to the rapidly changing position and direction of the body through space, having high parameters of rapidity and also being very precise. This experience of physical activity during early childhood can create a predisposition for an active lifestyle later in youth and adulthood (Barnett et al., 2009).

Some studies on gymnasium students discovered a significant link among maximum cardiorespiratory fitness (VO_2max), the procedure of cognition, specific attention skill, and visual memory, which was affiliated with basal ganglia and activation of the prefrontal and parietal cortices (Chaddock et al., 2012). Other researchers found that the dorsal striatum is mainly responsible for cognitive control responses, which can positively affect aerobic fitness (Chaddock et al., 2010). Every motor activity or aerobic workout can contribute to the children's cognitive level of performance.

It was found that short periods of intense coordination exercise, up to 10 minutes, can develop the concentration and attention level of children from gymnasium school compared to a regular PE class with the same duration (Budde et al., 2008).

Scientific papers concentrate their attention on analyzing eye-hand coordination influence as phenomenological, using a drift-diffusion framework, which implies the first movement as a development to a fixed limit (Ratcliff & Van Dongen, 2011; Ratcliff et al., 2016), to recommend two opposite sets of rules and methods for highlighting the eye-hand coordination skill. For utilizing a double task paradigm with a reduced RT correlation (Dean et al., 2011), it was observed that taking individually the eye and hand movement development is more efficient.

Other scientists (Gopal & Murthy, 2015) utilized a quick and simultaneous reach task to highlight that a usual accumulator with a hand-specific peripheral delay had main attributes to generate a high level of coordinated eye-hand movements. The coordination condition can be explained as an issue or malfunction in motor coordination that is manifested in poor performance, also being associated with the patient's chronological age (Coetzee & Pienaar, 2013).

Skills such as visual attention, eye-hand coordination, and balance were considered in the specific modern literature in terms of general knowledge, mainly in investigation papers that monitored the effects of exercises on this feature (Udermann et al., 2004; Hardy et al., 2011; Mohammadi et al., 2012). Eye-hand coordination represents one of the system's capacities for re-evaluating information for controlling the upper limbs of the body, helping in tasks such as writing or successfully catching a ball (Natarajan & Malliga, 2011).

In other scientific papers (Williams et al., 1999) it was found that athletes use perceptual tools to improve the level or shorten the eye-hand visual reaction time, even planning and modeling the responses to specific visual information. Those panning models that focused on other experiences than sportive enabled athletes to select pre-programmed motor actions and allowed them to foretell and choose the appropriate model, so they were not merely reacting.

It was discovered that visual-motor coordination has a too high value in executing basic movements in motor activity and cardiorespiratory fitness in young athletes (Wilson et al., 2013). In the essential learning of motor skills, having high levels of performance in unusual motor actions implies more perceptual and cognitive strain in moving (Kerick et al., 2004).

The first phase of visual perception is the visual-motor integration of objects and events that are evaluated and is the basis of cognitive operations (Goodale, 1998). As part of the usual youth development, the system of visual perceptual function has a good development at the age of three and five years, stabilizes at the age of seven and nine years, and can develop up to the age of about ten years (Case-Smith, 2010).

Visual-motor coordination is essential in acquiring visual information from the environment, about objects coming during sports practice (e.g. a ball), requiring a high level of eye-hand coordination for players so they can rapidly react to the external stimuli with efficiency and also improve their adaptation movements needed for specific situations on the field (Przednowek et al., 2019).

Objectives

The study aimed to analyze the hand-eye coordination capacity of youth regarding gender, practicing sports activities, and practicing predominantly leg sports or predominantly arm sports.

The main objective of our research was to analyze the hand-eye coordination capacity of youth from five schools and to identify whether there are significant statistical differences between those who practice sports activities and those who do not, between boys and girls, and also between those who practice predominantly leg sports compared with those that practice predominantly arm sports.

Hypothesis

The research started from the assumption that children who practice sports activities have a superior level of hand-eye coordination compared to those who do not practice sports.

Material and methods

Research protocol

This investigation was performed under the Declaration of Helsinki (2013) and authorized through the Ethics Committee of the "Lucian Blaga" University in Sibiu before the commencement of the study. It also met the ethical standards for Sport and Exercise Science Research.

In the process of investigation during the research, the European Union regulations regarding the privacy of

personal information were respected and an agreement was signed with every legally responsible person of our subjects from the experiment sample, given that our subjects were under 18 years old and are considered minors in our country. All the participants in the investigation agreed to participate voluntarily and had the possibility to end their involvement at any time, without any consequence. The participants' documented informed consent was received through an instructed and independent person.

a) *Period and place of the research*

The investigation took place in five gymnasium schools from Târgu Mureş, Romania: "Romulus Guga" Gymnasium School, "Dr. Bernady Gyorgy" Gymnasium School, "Mihai Viteazu" Gymnasium School, "Dacia" Gymnasium School, "Rakoczi Ferenc II" Roman Catholic Theological High School, in partnership with the "George Emil Palade" University of Medicine, Pharmacy, Science, and Technology of Targu Mures, over a 3-month period starting on 1 February 2019, and ending on 31 May 2019.

b) *Subjects and groups*

The experiment sample consisted of 110 children aged 10–11 years, 60 girls and 50 boys, 50 of them practicing sports, and 60 playing no sports.

The exclusion criterion used in the investigation was the health confirmation document certifying the appropriate level of health for sports practice. Students that did not have the paper were excluded from the research. Also, another criterion was that the participants in the study had to fit in the age range of 10–11 years and be gymnasium students at the investigated schools.

The investigation procedure objective was to track the capability of children's vision process to organize the data obtained with their eyes with the main aim to manage, guide, and coordinate hands in catching a ball tossed to the wall.

c) *Tests applied*

The protocol of the experiment required the children to throw a tennis ball with their right hand against the wall and catch it with the left hand, and then switch, throw it with the left hand and catch it with the right hand for 30 seconds. The evaluator counted the maximum number of catches in 30 seconds (Mackenzie, 2009).

d) *Statistical processing*

Statistical analysis included descriptive statistics (frequency, percentage, 95% confidence interval, mean, median, standard deviation), and inferential statistics. The Shapiro-Wilk test was implemented to determine the normal distribution of the analyzed data series. For the comparison of means, the t-Student test was applied for unpaired data and the ANOVA test, the Mann-Whitney test and the Kruskal-Wallis test, non-parametric tests, for comparing the medians. The significance threshold chosen for the p-value was 0.05. Statistical evaluation was conducted using the GraphPad Prism, the trial variant.

Results

Regarding gender distribution, 54.55% were females, and 45.45% were males (Table I).

Table I
Gender frequency.

Gender distribution	Frequency	Percentage	95% confidence interval
Female gender	60	54.55%	44.77%-64.07%
Male gender	50	45.45%	35.93%-55.23%
Total	110	100.00%	-

Considering sports practice distribution, 50 of the study participants practiced sports, and 60 never played any sports (Table II).

Table II
Sports practice frequency.

Practice sport/do not practice sports	Frequency	Percentage	95% confidence interval
Practice sports	50	45.45%	35.93%-55.23%
Do not practice sports	60	54.55%	44.77%-64.07%
Total	110	100.00%	-

Taking into consideration the type of practiced sport, the majority of the study participants played basketball (30.00%), football and handball (22.00%) (Table III).

Table III
Practiced sport.

Practiced sport	Frequency	Percentage	95% confidence interval
Basketball	15	30.00%	17.86%-44.61%
Basketball, Handball, Swimming, Ballet	1	2.00%	0.05%-10.65%
Dance	4	8.00%	2.22%-19.23%
Football	11	22.00%	11.53%-35.96%
Gymnastics	1	2.00%	0.05%-10.65%
Handball	11	22.00%	11.53%-35.96%
Field Hockey	1	2.00%	0.05%-10.65%
Swimming	3	6.00%	1.25%-16.55%
Volleyball	3	6.00%	1.25%-16.55%
Total	50	100.00%	-

Regarding the schools, the majority of the study participants were selected from "Romulus Guga" Gymnasium School and "Dr. Bernady Gyorgy" Gymnasium School (Table IV).

Table IV
School attended.

Attended school	Frequency	Percentage	95% confidence interval
"Romulus Guga" Gymnasium School	25	22.73%	15.28%-31.70%
"Dr. Bernady Gyorgy" Gymnasium School	25	22.73%	15.28%-31.70%
"Mihai Viteazu" Gymnasium School	20	18.18%	11.47%-26.67%
"Dacia" Gymnasium School	20	18.18%	11.47%-26.67%
"Rakoczi Ferenc II" Roman Catholic Theological High School	20	18.18%	11.47%-26.67%
Total	110	100.00%	-

In the whole group, the average number of executions was 7.327±5.069 (Table V).

Table V
Number of exercises - descriptive statistics.

Statistical interpretation	Number of exercises
Number of values	110
Minimum	0.0
25% Percentile	3.000
Median	6.000
75% Percentile	11.00
Maximum	22.00
Mean	7.327
Std. Deviation	5.069
Std. Error	0.4833
Lower 95% CI of mean	6.369
Upper 95% CI of mean	8.285

When comparing gender, we observed a lower mean of the number of executions in females (5.100±3.606) than in males (10.00±5.303) and a higher mean of the number of executions in those who practiced sports (11.38±4.337) than in those who never practiced any kind of sports (3.950±2.514) (Table VI).

For the Mann-Whitney test, $p < 0.05$, we found a statistically significant difference between the median number of executions in the female and male gender.

Also, for the Mann-Whitney test, $p < 0.05$, we observed a statistically significant difference between the median number of executions in those who practiced and did not practice sports.

Using the t-Student test, $p > 0.05$, we discovered no statistically significant difference between the mean number of executions in those practicing sports predominantly with their arms and those practicing sports predominantly with their legs. Predominantly arm sports: basketball, handball, and volleyball. Predominantly leg sports: football, grass hockey, dance, gymnastics, and swimming.

For the t-Student test, $p < 0.05$, we found a statistically significant difference between the mean number of executions for the female and male gender for those practicing sports.

Also, using the Mann-Whitney test, $p > 0.05$, we discovered no statistically significant difference between the median number of executions in females practicing sports predominantly with their arms contrasted with those practicing sports predominantly with their legs.

Using the t-Student test, $p > 0.05$, we observed no statistically significant difference between the mean number of executions in males practicing sports predominantly with their arms and those practicing sports predominantly with their legs.

Table VII
Comparison between schools regarding the number of executions of those not practicing sports.

School attended	Number of executions	Value of p
"Romulus Guga" Gymnasium School	7.960±4.218 (8.00)	<0.0001
"Dr. Bernady Gyorgy" Gymnasium School	12.04±5.564 (12.00)	
"Mihai Viteazu" Gymnasium School	4.850±3.602 (4.00)	
"Dacia" Gymnasium School	5.550±4.236 (4.00)	
"Rakoczi Ferenc II" Roman Catholic Theological High School	4.900±3.024 (4.00)	

Table VIII
Comparison between schools regarding the number of executions of those practicing sports.

Schools attended	Number of executions	Value of p
"Romulus Guga" Gymnasium School	11.15±2.734 (11.00)	<0.0001
"Dr. Bernady Gyorgy" Gymnasium School	16.00±3.783 (16.00)	
"Mihai Viteazu" Gymnasium School	9.000±2.309 (8.00)	
"Dacia" Gymnasium School	9.375±3.462 (10.00)	
"Rakoczi Ferenc II" Roman Catholic Theological High School	7.750±2.765 (8.50)	

Table VI
Number of exercises - descriptive statistics.

	Female gender	Male gender	Value of p
Number of executions	5.100±3.606 (4.00) Practice sports	10.00±5.303 (10.00) Do not practice sports	*<0.0001
Number of executions	11.38±4.337 (11.00) Predominantly arm sports	3.950±2.514 (3.00) Predominantly leg sports	*<0.0001
Number of executions	11.57±4.470 (11.00) Females practicing sports	11.10±4.229 (10.50) Males practicing sports	0.7134
Number of executions	8.696±2.867 (9.00) Females practicing arm sports	13.67±4.086 (13.00) Females practicing leg sports	<0.0001
Number of executions	8.941±2.947 (9.00) Males practicing arm sports	8.000±2.757 (8.00) Males practicing leg sports	*0.3770
Number of executions	15.00±3.764 (14.00)	12.43±4.108 (12.00)	0.1032

* Mann-Whitney test

Discussion

In a recent study, it was found that the influence of particular sets of exercises with specialized focus on cognitive performance can be very efficient (Chang et al., 2012). Taking into account the literature from a particular exercise that focused on visual attention development, it can be seen that visual attention can be developed through web-based training (Scanlon et al., 2007). By observing the investigation results, it can also be concluded that highly specialized exercises can improve the level of hand-eye coordination skills. Also, other conclusions of the related investigation proved that eye-hand coordination effects on balance skills in swimming training also have positive effects on hand-eye coordination (Hsu et al., 2010).

Other research investigations on hand-eye coordination in table tennis players concluded that improving this skill can raise the level of performance of those athletes compared with others that do not train this skill (Paul et al., 2011).

Substantial gains through brain training exercises are the possibility of moving the legs and arms through a variety of combinations, catching and tossing objects, and at the same time, developing visual perception and hand-eye coordination (Demirakca et al., 2016).

In recent studies (Ellison et al., 2014), researchers use the Sports Vision Trainer program for analyzing and assessing the eye-hand and visual-motor reaction time ability. The results of the investigation highlighted the high-retest validity values (with a value of r = 0.82 to 0.89), showing that the testing system is a valid method to assess the eye-hand visual-motor reaction time.

Other researchers (Wells et al., 2014) reported their experimentation of eye-hand visual-motor assessment with the program Dynavison D2 for measuring the reaction time of athletes. The conclusions of their investigation highlighted the increased viability of this device, after using three attempts for an acquaintance before the final assessment.

Taking a look at other inquiries having visual attention development and brain exercise as a primary purpose, it was found that in this domain of visual training, significant progress has been made in the direction of hand-eye coordination in youth university students (Du Toit et al., 2011).

Recent research has discovered a new set of visual training skills termed “eyerobic”, which consists of exercises for female football players allowing an excellent development of balance and hand-eye coordination in the experiment group compared with the control group (McLeod, 1991).

Conclusions of other investigations highlighted the idea that using brain exercises can positively affect visual attention in high-level athletes (Vural, 2016).

In an article (Ciuffreda, 2011) contributing to the ideas of Ando et al., it was discovered that the hand-eye capacity and the visual-motor reaction time can be developed through training for short periods; this process of training affects the central and peripheral visual skill and has durability at least for a short period.

The problem of brain workout exercises and their contribution to hand-eye coordination are analyzed by many modern scientific studies showing that those activities are focused on simultaneous moves that provide substantial variation of movement, improving hand-eye coordination for short to medium periods of training time, comparing the results with those of the control group. However, in some investigations, the parameter of dynamic balance and visual attention did not develop significantly over short periods of training time (Cetin et al., 2018).

Some specialists also tried to stimulate the noise effector-specific system (Gopal & Murthy, 2015) and the distinct interacting accumulators model (Dean et al., 2011) in developing the temporal part of the hand-eye coordination skill, in the pursuit of finding significant differences comparing the computational structure that eye-hand coordination in the dual and search task may affect the purpose of the central executive system (Seeley et al., 2007; Sridharan et al., 2008), which enables the athlete to pass from an ordinary to a separate accumulators model and in the opposite direction.

Other findings linked hand-eye coordination and visual-motor skill regarding their response time systems to being trainable and developed. Using the particular designed Sports Vision Trainer, researchers found out that this device has a 25% rate of progress and that the potential of development of hand-eye coordination on the visual-motor reaction time can also bring a high level of performance in different sports such as baseball or others that involve working with the hands and the visual system (Zupan et al., 2006).

Conclusions

1. The conclusions of our investigation highlighted a statistically significant difference between the median number of executions in females compared with the male gender in the eye-hand coordination test.

2. Also, we observed a statistically significant variation between the median number of executions in those practicing and those not practicing sports and between the mean number of executions for the female and male gender for those practicing sports.

3. No statistical difference was found by comparing the mean number of executions of those practicing sports predominantly with their arms and those practicing sports predominantly with their legs, the executions of females and males practicing sports predominantly with their arms compared to those practicing sports predominantly with their legs.

4. The conclusions of the investigation showed that males have better hand-eye coordination than females and also, those practicing sports registered more correct executions compared with those not practicing sports, proving that sports activities can improve skills such as balance and eye-hand coordination.

Conflicts of interest
Nothing to declare.

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