Original Article

Effectiveness of different options when teaching children basic movements due to certain handedness

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Abstract:

During the school year, we used three basic movement teaching methods, including manual dexterity (rolling, catching, throwing), walking, running, jumping, balance, climbing and crawling, that the children did not study previously. Each training method was used with girls and boys who had ambidexterity, left and right handedness who were from 3 years old to 3 years, 5 months and 29 days. We determined the effectiveness of training for achieving a high level of mastery (capitalization of freedom of degrees or CDF) only for those students with manual dexterity. Our data showed that the results were independent of sex or handedness. Two of the training methods included movement repetition by each hand (foot, left, right), but a different sequence was more effective than repetition of movement only by the leading hand (foot direction). More movements of the CDF level were achieved by first performing non-conductive hand (foot, non-conductive direction) movements to achieve an exploration level of freedom degrees (EDF), which then lead to CDF formation but with alternate implementation of the arm and conductive hand. After the most effective method of teaching was used, girls with ambidexterity, right and left handedness achieved CDF levels of 3, 2 and 5 movements, respectively, and boys achieved 4, 3 and 4 movements, respectively. Girls made the same two movements (to throw the ball to the instructor with both hands from chest and throw objects at a distance using both hands alternately), and the boys made three (throwing objects towards horizontal and vertical targets and at a distance with both hands alternately). Using the most effective methods of learning basic movements with four-year-old children, one can achieve the best results for the CDF formation for movements of manual dexterity, and in the longer term, the development of motor function at a higher level.

Key words: children, handedness, learning of basic movements.

Introduction

Triathlon The child's brain during the preschool period is already marked by functional asymmetry. It is genetically conditioned (DeVries, Wimmers, Ververs, 2001; Crow, Close, Dagnall, & Priddle, 2009), and some expressions of functional asymmetry include features of functional distribution in the cerebral hemispheres, the specifics of processing information in them, the violation and specific behavioural responses in the event of changes in the functional state of the cerebral hemispheres, and a dependence on emotions, memory, and adaptation type (Cherbuin & Brinkman, 2006).

From the point of functional asymmetry, motor asymmetry is considered to be one of its manifestations, and specifically, this involves handedness (Galamandjuk, 2015). The main feature of handedness is the dominance of one hand over the other in the case of a child selecting the one which will perform certain motor tasks with the highest quality. This leads to left-handedness, right-handedness, or the equivalence of both hands during a choice, which is also called ambidexterity (Gut, Urbanik, Forsberg, Binder, & Grabowska, 2007). Children with different handedness exhibit different degrees of cerebral hemisphere autonomy or cooperation of its cortical structures (Caliskan, & Dane, 2009; Gainotti, 2015). The children differ in their creativity and choice of strategy (Porac, 2016), their development of optical and visual-spatial functions (Rodrigues, Vasconcelos, Barreiros, Barbosa, & Trifilio, 2009; Corballis, 2010), and their ability to focus attention on a specific object,

their speed of distribution and switching attention, and their amount of short-term, long-term, spontaneous and imaginative memory (Kuhl, & Kazen, 2005). The development of emotional and volitional qualities occurs more quickly in children with left-handedness than in children with right-handedness (Shabbott, & Sainburg, 2008), but the latter have a better developed psychomotor quality and spatial perception (Ramaley, 2012; Schaefer, Haaland, Sainburg, 2009). Data from Iedynak, Galamandjuk (2011), Galamandjuk (2014) shows that during the fourth year of age, boys with left-handedness reach significantly higher levels than boys with right-handedness regarding speed strength, coordination of cyclic locomotion, ballistic movements for maximum range and accuracy of throwing using the left hand. For boys with right-handedness, this level marked the development of coordination of ballistic movements for maximum range and accuracy of throwing via the right hand. Boys with ambidexterity reach higher levels than boys with right-handedness or left-handedness regarding coordination of ballistic movements at a maximum range by throwing using left and right hands. However, in the development of other physical qualities, ambidextrous boys have fewer differences with boys who are either right-handed or left-handed. (Galamandjuk, Balatska, Iedynak, 2014).

The differences in these and other functional performances is grounds for taking them into account during the planning of physical activity for children (Malina, Bouchard, Bar-Or, 2004; Gnitecka, Nowak, Romanowska-Tolloczko, 2015; Mysev, Iedynak, 2016). During the preschool period, children are taught to perform various movements in a way that is technically correct for that activity (Raiola, 2011; Schmidt & Lee, 2013; Buns, 2015). It is therefore advisable to take into account the child's handedness when studying the child's various movements (DeVries, Wimmers, Ververs, 2001). Moreover, despite the teaching methods, the child chooses convenient (wired) directions (right, left) of the arm (or leg) for performance during study (Pill, 2011; Di Tore, Schiavo, D'isanto, 2016). Wang and Sainburg (2007) recommend the performance of movements not only by leading the hand but also by non-conductive movements. This leads to activation of both hemispheres of the brain (Porac, 2016). One result of this activation is the development of different functions of each hemisphere (Volkmann, Schnitzler, Witte, & Freund, 1998). Physical activity promotes many different functions, skills, and systems, which are especially important during preschool. (Timmons, Naylor, & Pfeiffer, 2007; Altavilla, Di Tore, 2016). The implementation of this activity during different movements, not only by leading but also using non-conductive hand effects, positively affects the motor function of the child. However, data contradicts the conventional ideas that motor lateralization reflects a global advantage of one «dominant» hemisphere or limb system. Instead, each hemisphere or limb system appears to be specialized for stabilizing different aspects of task performance (Wang & Sainburg, 2007). Marinsek (2016) discovered that in preschool children, the unilateral practice of dribbling is more beneficial for reducing lateral asymmetry of performance compared with bilateral practice. Moreover, participants who practiced with their dominant limb exhibited the largest decrease in lateral asymmetry of performance and made the largest overall improvement. We did not find important differences between acquisitions of dribbling between the upper and lower extremities. Thus, the results support the idea that lateral asymmetry of performance is task specific. Other data on the characteristics of motor function in preschool children with different handedness are absent, and hand movements as control mechanisms are different (Kuhl, & Kazen, 2005; Porac, 2016). In particular, there is no information on the effectiveness of different training options for preschool children with different handedness regarding the achievement of basic movements at the highest level of mastery. Thus, it is important to conduct proper research on this subject.

Material & methods

Participants

In this study, 183 girls (n=53 with ambidexterity (A), n=68 with right (R) handedness, n=62 with left (L) handedness) and 178 boys (A-handedness – n=50, R-handedness – n=67, L-handedness – n=62). There were no distinctions registered by age ($p > 0.05$), and all early studies were for the age range of 3 years to 3 years, 5 months and 29 days. The research was conducted in compliance with the WMA Declaration of Helsinki, – Ethical Principles for Medical Research Involving Human Subjects, 2013. The study protocol was approved by the Ethical Committee of Ivan Ogienko National University in Kamianets-Podilsky.

Design

We randomly formed group of nine girls (six – intervention groups, three – control groups) and nine groups of boys. Within one year, intervention group-1 (IG-1) of girls (g) and intervention group-1 (IG-1) of boys (b) with different handedness learning every new movement meant that they performed first using the non-conductive arm and then using the leading arm. In these groups, there were 14 girls with A-handedness, 21 with R-handedness, and 19 with L-handedness, and for the boys, there were 12, 21, and 18 of each of these, respectively. The IG-2g and IG-2b study involved the reverse sequence with performance of each new movement first by the leading hand and then using the non-conductive hand. There were 14 girls with A-handedness, 21 with R-handedness, and 18 with L-handedness, for the boy there were 13, 21, and 18 of each of these, respectively. In each control group (CG) was 25 people, and each new movement they studied was repeated many times but only using the lead hand. There were six CGs: three with girls with A-, R-, and L-

handedness, and three with boys with the same handedness. The organization of the classes and studying methods for all IGs and CGs were the same.

Procedures

Accordingly to experimental factor our study of the non-conductive arm movements of "rolling, catching, throwing" and of the non-conductive foot (non-conductive direction) movements of other facilities ("walking", "running", "jumping", "balance", "climbing and crawling") does not imply mastery of movement at the highest level (capitalization of degrees of freedom, CDF) but at the previous level, which is the exploration of degrees of freedom (EDF) (Bernstein, 1967). Thus, attention was focused on the technique based on movement, and details were improved during multiple repeating of the movements. The main focus here was the ability to reproduce movement with maximum compliance with the foundation technique (exemplary performance). Then the movement was studied when using the leading hand (foot direction), and the goal was to reach the highest level. Simultaneously, the children continued to perform motion well using the non-conductive hand. However, for the non-conductive arms we planned multiple practical implementations of movements, and not reaching the level of CDF. This was the main task during mastering movement of the leading hand (foot) or in the leading direction. At the end of the school year, for all of the IG and CG the state of mastering movements was evaluated as complex rolling, catching, and throwing movements.

Measures

Handedness was determined according to the baseline of research using the Short Form of Edinburgh Handedness Scale (Veale, 2014). The levels of movement mastery were determined by taking into account the recommendations of the evaluation of motor development and function in the preschool children (Tieman, Palisano, & Sutlive, 2005; Timmons, Naylor, & Pfeiffer, 2007). We estimated the child traffic with scores from 0 to 3 (respectively, the lowest and highest points). At the beginning of the school year, we gave the lowest performance score to children who never before studied the movements that they were offered during the school year.

Statistical analysis

All statistical analyses were performed using SPSS Version 21. The descriptive statistics results in this study are presented as means, standard deviations, and percentages. Data were normally distributed. Independent samples of the test were used to compare the achievements of the IG-1, IG-2 and CG girls of a certain handedness and similar samples of boys. The 0.05, 0.01 and 0.001 levels of probability were used to indicate statistical significance (Vincent, 2005).

Results

At the end of the school year, for the IG-1 girls with R-handedness, the average performance scores for each patient motion was within 1.7 to 2.8, for IG-2, it was 1.6 to 2.7, and for the CG, it was only 0.9 to 2.1. The estimates showed different levels of movements that the girls reached after using different methods of studying the movements. For the performance of all of the movements studied, the CG did not meet the highest level (CDF) but instead was at the EDF or at the lowest level, called the reduction of degrees of freedom (RDF). Estimates indicate that most girls performed five movements at RDF (estimate in the range of 1.5 to 2.4 points), and the other three performed at EDF (range of 0 to 1.4 points). To the latter group, belonged the movement "roll the ball between objects in a goal," "after throwing the ball to the floor to try to catch it", and "throwing objects into the vertical target with both hands alternately." In the IG-1 and IG-2 groups, the results were much better than in the CG for execution of the movement in which "the instructor to throw the ball with both hands from the breast" and "throw objects at a distance using both hands alternately" was within 2.5 to 2.8 points (level CDF). For the remaining six motions, most girls in IG-1 and IG-2 performed at the EDF.

Upon comparing the students in the IG-1 and in the IG-2, the results, except for the movements "roll the ball between objects in the gate" and "throw the ball with both hands underneath a basket on the floor," were significantly (at the level of $p < 0.01$ to $p < 0.001$) higher than in the CG. Additionally, for all eight motions that were investigated, five girls in IG-1 performed at a higher level than girls in IG-2. For other movements, namely "roll the ball between objects in a goal," "throw the ball with both hands from chest to the instructor," and "throw objects at a distance with both hands alternately," the results for IG-1 and IG-2 were almost identical. The value "t" here were in the range of 0.54-0.94 ($p > 0.05$).

The data showed that learning the basic movements using the first non-conductive hand (foot, direction) and leading hand creates a higher level of mastery of these movements than with the use of the alternative reverse sequence. Even greater over these options is a motion still under study, which is using only the leading hand (foot towards the top).

A similar conclusion was made after analysing the data from the girls with L-handedness, although the evaluation groups were somewhat different. Thus, the average performance score for each patient movement in IG-1 was within 1.8-2.8 points, for the IG-2, it was 1.7-2.7 and for the CG, it was 0.8-2.3. These results indicated that most girls in the CG achieved CG movements only at the EDF or RDF levels and no movement was at the

highest CDF level. The IG-1 and IG-2 results were much better than in the CG. Our interpretation assessments confirmed that in the IG-1, most girls performed the following movements at CDF: "to catch the ball thrown by the teacher", "throw the ball with both hands underneath a basket on the floor," "throw the object in the horizontal target with both hands alternately" "throw the ball with both hands from chest to the instructor," and "throw objects at a distance alternately with both hands." In IG-2, most girls performed the last two movements at CDF. For the other movements studied, in the IG-1 and IG-2, most girls achieved them at the EDF level.

In comparison, by mastering all movements, except for the movement "roll the ball between objects in a goal," the girls in IG-1 and IG-2 received significantly (at the level of $p < 0.05$ to $p < 0.001$) higher scores than girls in CG. Additionally, most girls in IG-1 performed the five movements (with exception of "roll the ball between objects in a goal," "throw the ball with both hands from the chest to the instructor," "throw objects at a distance with both hands alternately") at much higher levels than the girls in IG-2. This indicated in value of "t", which within 2.91 to 4.69 (from $p < 0.05$ to $p < 0.001$).

In IG-1, girls with A-handedness, the scores for the performance of each of the eight movements of the complex was investigated and found to be in the range of 2.1 to 2.6 points. In IG-2, they were within 1.6 to 2.5, and in CG, the scores were within 1.1 to 2.1 points. Therefore, most CG girls achieved the five motions at the lowest level (RDF) and the other three ("roll the ball between objects in a goal," "throw the ball with both hands from the chest to the instructor", "throw objects at a distance with both hands alternately") at a higher level (EDF). The girls in this group did not reached any higher level for any motion test. In IG-1, most girls performed three movements at the highest level of CDF, and the other five at EDF. In IG-2, they achieved level CDF for consistent performance motion "to throw objects at a distance with both hands alternately," and the other four achieved the level of EDF, whereas the other three ("throw objects into the vertical target with both hands alternately", "throwing things at the horizontal target with both hands alternately" "after throwing the ball to the floor to try to catch it") achieved the level of RDF. However, the IG-1 and IG-2 grade point averages for the execution of all movements except for "roll the ball between objects in the gate" were much higher than in CG. This indicated that for value "t", their boundaries were 3.12 to 5.14 (from $p < 0.01$ to $p < 0.001$).

In the groups of boys with different handedness at the end of the school year, the results were similar to those of the girls, with the exception of some estimates. In IG-1 and IG-2, all except the score for the execution of the movement "roll the ball between objects in a goal" were significantly (at the level of $p < 0.01$ to $p < 0.001$) higher than in the CG (see Table 1). In IG-1 and IG-2, the ratings for the three movements did not differ, and the achievement of the remaining five was higher than in the first group.

Table 1. Point evaluations for the execution of learned movements of "rolling, catching, and throwing" in boys' groups with R-handedness ($M \pm \sigma_M$)

Movement	IG-1 (n=21)	IG-2 (n=21)	CG (n=25)	t (IG-1 – CG)	t (IG-2 – CG)	t (IG-1 – IG-2)
movement-1	2.4±0.18	2.1±0.11	1.8±0.10	2.91*	2.02	1.42
movement-2	2.4±0.07	2.1±0.08	1.5±0.09	7.89***	4.98***	2.82*
movement-3	2.4±0.07	2.3±0.06	1.9±0.07	5.05***	4.34***	1.08
movement-4	2.3±0.05	2.0±0.05	1.7±0.09	5.83***	2.91*	4.24***
movement-5	2.1±0.04	1.8±0.10	0.9±0.10	11.1***	6.36***	2.79*
movement-6	2.6±0.05	2.3±0.04	1.9±0.11	5.79***	3.42**	4.69***
movement-7	2.5±0.06	2.2±0.05	1.7±0.08	8.0***	5.3***	3.84**
movement-8	2.7±0.06	2.7±0.05	2.1±0.06	7.07***	7.68***	0

Note: movement 1 – roll the ball between the target objects; 2 – to catch a ball thrown by the tutor; 3 – throw the ball with both hands from the chest to the instructor; 4 – throw the ball with both hands underneath the basket on the floor; 5 – after throwing the ball to the floor to try to catch it; 6 – throwing objects at a horizontal target with both hands alternately; 7 – throwing items in a vertical target with both hands alternately; 8 – throw objects at a distance alternately with both hands; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

A similar result was obtained in the groups of boys with L-handedness and in the groups of boys with A-handedness (see), excluding value assessments and movements, which achieved the highest level of CDF (see Tables 2 & 3).

Discussion

In general, our results confirm the advantage over other methods of learning basic movements, such as repetition of movement, from the beginning using the non-conductive hand (foot) achieve the EDF level. Then, repetition and using the leading hand (foot) helped achieve the highest level of CDF. In the latter case, the non-conductive hand carried out the motion as well, each in turn.

Table 2. Point evaluation for the execution of learned movements of "rolling, catching, and throwing" in boys' groups with L-handedness ($M \pm \sigma_M$)

Movement	IG-1 (n=18)	IG-2 (n=18)	CG (n=25)	t (IG-1 – CG)	t (IG-2 – CG)	t (IG-1 – IG-2)
movement-1	2.4±0.10	2.2±0.09	1.6±0.18	3.89**	2.98**	1.49
movement-2	2.2±0.09	2.1±0.10	1.2±0.11	7.04***	6.05***	0.74
movement-3	2.6±0.07	2.6±0.08	2.0±0.11	4.6***	4.41***	0
movement-4	2.8±0.04	2.6±0.05	2.3±0.10	4.64***	2.68*	3.12**
movement-5	2.3±0.05	1.9±0.11	0.6±0.14	11.4***	7.3***	3.31**
movement-6	2.8±0.04	2.6±0.05	2.3±0.07	6.2***	3.49**	3.12**
movement-7	2.6±0.05	2.3±0.09	1.6±0.16	5.97***	3.81**	2.91*
movement-8	2.9±0.07	2.6±0.05	2.3±0.11	4.6***	2.48*	3.49**

Table 3. Evaluation for the execution of learned movements of "rolling, catching, and throwing" in boys' groups with A-handedness ($M \pm \sigma_M$)

Movement	IG-1 (n=18)	IG-2 (n=18)	CG (n=25)	t (IG-1 – CG)	t (IG-2 – CG)	t (IG-1 – IG-2)
movement-1	2.4±0.16	2.3±0.15	2.0±0.17	1.71	1.32	0.46
movement-2	2.3±0.06	2.1±0.1	1.7±0.16	3.51**	2.12*	1.71
movement-3	2.6 ±0.06	2.3±0.08	1.8±0.15	4.95***	2.94*	3.0**
movement-4	2.8±0.06	2.5±0.1	2.0±0.19	4.02***	2.33*	2.57*
movement-5	2.4±0.06	2.0±0.07	1.3±0.14	7.22***	4.47***	4.34***
movement-6	2.7±0.05	2.4±0.04	2.0±0.12	5.38***	3.16**	4.69***
movement-7	2.5±0.05	2.2±0.08	1.6±0.17	5.08***	3.19**	3.18**
movement-8	2.7±0.05	2.7±0.07	2.3±0.06	5.12***	4.34***	0

This effectiveness of these study methods was observed in both girls and boys with R-, L- and A-handedness. Thus, the effectiveness of training methods that included the repetition of movement by each hand (foot) and in both directions (left, right) was much higher (at the level of $p < 0.05$ to $p < 0.001$) than for the performance of only one leading hand (foot) and in the leading direction.

One of the reasons for this result is the relationship of handedness within the human motor cortex. As discussed by Volkmann, Schnitzler, Witte, Freund (1998), this connection is very strong ($r = -0.76$, $p < 0.01$). Thus, the expansion of the hand motor cortex in the dominant hemisphere may provide extra space for cortical encoding for a greater motor skill repertoire of the preferred hand. However, the reasons for different performances of arm movements that are conducive for this are not a negative factor for the development of motility. In particular, the results of the review strongly suggested that manual experience acquired during tool manipulation can influence the hemispheric representation of tools and other artefacts (Di Tore, Raiola, 2012; Gainotti, 2015). The data from our study confirm that movement performance that children learn during the school year, not only is not a negative factor in the development of motor function but rather contributes to its higher level of development than after performing these movements only by one, the leading hand. This is due to the adding of the non-conductive hand to perform certain movements. Additionally, Gut, Urbanik, Forsberg, Binder, & Grabowska (2007) found that in right-handers, there was a general predominance of left hemisphere activation relative to right hemisphere activation. In lefthanders, this pattern was reversed. The switched subjects showed no such volumetric asymmetry. Increasing levels of complexity of motor activity resulted in an increase in the volume of consistently activated areas and the involvement of ipsilateral and contralateral activations. In both right- and left-handers, movements of the preferred hand activated primarily the contralateral hemisphere, whereas movements of the non-preferred hand resulted in a more balanced pattern of activation in the two hemispheres, indicating greater involvement of the ipsilateral activations. Overall, this study shows that in both left- and right-handed subjects, the preferred hand is controlled mainly by the hemisphere contralateral to that hand, whereas the non-preferred hand is controlled by both hemispheres. The switched individuals share features of both lefthanders and right-handers regarding their motor control architectures.

Another positive performance of both hand (feet, left and right) movements under study is the ability to effectively and fully use the potential of both hemispheres of the brain. This is dynamic dominance hypothesis of motor lateralization, i.e., that the dominant hemisphere has become specialized for controlling task dynamics as required for coordinating efficient trajectories. The non-dominant hemisphere has become specialized for controlling limb impedance, as required for achieving stable postures (Shabbott, Sainburg, 2008). In addition, the results of this experiment do not support the hypothesis that asymmetries in reaching behaviours result from

specialization of the dominant hemisphere for visual-based correction processes, as previously proposed. Thus, exercise can improve the effectiveness of non-conductive hands. This is especially true for those of preschool age up to four years of age (Schmidt, & Lee, 2013; Pasichnyk, Melnyk, Levkiv, Kovtsun, 2015).

As for the features, which were marked with different handedness in the girls and boys, this issue needs further examination. However, upon analysing the findings, one of the features is the attainment by all girls of CDF in learning the movements of "to throw the ball with both hands from his chest to the instructor" "throw objects at a distance with both hands." Girls with A-handedness achieved CDF by also mastering the movements of "roll the ball between objects in a goal," and girls with L-handedness achieved CDF by also mastering the movements of "catch the ball thrown by the educator", "throw the ball with both hands underneath a basket on the floor" and "throwing things at the horizontal target with both hands alternately". For the boys, the movements that they performed at CDF were somewhat different from the girls. Their CDF movements included "throwing objects into the horizontal target with both hands alternately", "throwing objects into the vertical target with both hands alternately", and "throwing objects at a distance alternately with both hands". In addition to these, boys with A- and L-handedness "throw the ball with both hands on the breast to the instructor" and "throw the ball in the bottom basket on the floor."

Another feature was associated with divergence points, which at the end of the school year rated the execution of movements in which the children reached the level of EDF. As shown in Table 1-3, the quality of performance of certain movements compared with boys with a different handedness. The quality of certain other movements was the best for boys with L-handedness compared with the rest of the investigated complex movements for the boys of R-handedness. Similarly, there were girls with different handedness.

One reason for the differences can be the great variety of degrees of freedom in the activity of cortical structures resulting from greater autonomous cerebral hemispheres and less rigid interactions in cortical structures in each hemisphere in children with L-handedness (Porac, 2016). This feature leads to another, i.e., the tendency of choosing a flexible, diverse, and programmed strategy for various activities (Jordy, 1995; Kuhl, & Kazen, 2008). In our case, for girls and boys with L-handedness, this feature led to their advantage over the other children for mastering certain movements at CDF. For some of the other complex movements investigated, they achieved the same level of EDF, but more efficiently. The data support the existence of features in the motor development of children with a particular handedness in preschool, which was assumed based on the results of other studies (Galamandjuk, 2014; Galamandjuk, 2015). The study of the conditions for the 5 to 6-year-old children who had A-, L and R-handedness to achieve the best results identifies new areas of scientific problems for future research.

Conclusions

The most effective method of learning basic movement is the one that involves the mastery of certain movement first by the non-conductive hand (foot, non-conductive direction) to achieve the EDF level and then by leading hand (foot, direction) to achieve the highest level of CDF with simultaneous repetition of movement by the non-conductive hand but without emphasis on achieving this level. This method of learning contributes to the achieving by four-year-old children with different handedness of CDF the largest number of movements based on manual skill. The less effective method of learning appeared to be the one, which is based on a reverse sequence of movements, and the worst performance was achieved via the traditional method, which includes multiple execution of only one movement with the leading hand (foot, conductive direction). Additionally, our hypothesis regarding the peculiarities of motor function development of preschool children in connection with a particular handedness was partially confirmed.

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