Original Article

Effect of the TGMD-2-based physical activity on the motor skills of healthy children and children with autism spectrum disorder at an earlier school age

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Abstract

In the study, we focused on the motor skills of children at an earlier school age. The aim of the study was to carry out a parallel experiment with two groups of children to determine how physical activity can affect the motor performance of healthy children and children with autism spectrum disorder before and after a 2-month implementation of the test of gross motor development –2 (TGMD-2). The group consisted of 18 boys. Eight of them were healthy boys, who on average were 7.25 ± 1.16 years old. The second group consisted of ten verbal boys with autism, who on average were 7.60 ± 1.57 years old. TGMD-2 was used to determine the motor performance level in these children. This test consisted of two subtests. The overall effect of the test ($p = 0.005$; $r = 0.889$) established a 1% statistical significance level in children with autism spectrum disorders and a 5% statistical significance level in healthy children ($p = 0.012$; $r = 0.892$). Among healthy children, the locomotion subtest established a 5% statistical significance level ($p = 0.012$; $r = 0.893$). The same applies for the object control subtest ($p = 0.012$; $r = 0.891$). In the group of children with autism spectrum disorders, the subtest established a 1% statistical significance level ($p = 0.005$; $r = 0.886$) and the same figure for the object control subtest ($p = 0.005$; $r = 0.892$). The results clearly indicate the effectiveness of physical activity using TGMD-2 in children at an earlier school age.

Key words: sport; exercises; motor abnormalities; children.

Introduction

Inheritance is essential in motor development. The set of hereditary traits an individual receives from his/her ancestors, known as genotype, is a determining factor (Kasa 2006). Motor learning is the system of hierarchically arranged biochemical processes that occur in anatomical structures and that are organized by higher synaptic changes resulting from neuronal system reactions (Brodal 2008).

At a younger school age, children are very dynamic and enjoy moving. Their physical activity is demonstrated by numerous movement games and sport activities. Movement speed, accuracy, and endurance continuously increase. Movement control and coordination continue to improve (Končeková 2007).

Learning new skills enhances the natural experience children have with motor skills. Initially, this is achieved in a playful way by learning to imitate, i.e., mimic learning. Adults are a natural authority for children. Therefore, a physical education teacher or trainer should become a perfect example (Peričet al. 2012).

In children with autism spectrum disorder (ASD), this is more complicated because autism is a pervasive developmental disorder and mostly affects individuals with several other problems (Vermeulen 2006). Its incidence is constantly increasing. Children with ASD have socio-emotional problems and performance problems (Greco & De Ronzi 2020). Autism can be accompanied by various motor disorders. Therefore, a more thorough and systematic investigation of motor abnormalities in autism is a promising path (Gottesman & Gould 2003). Although motor abnormalities are not listed among the major diagnostic domains, they form part of the entire autistic spectrum, and individuals with ASD struggle with them throughout their lives.

Compared to healthy children, children with ASD achieve below-average performance in the field of motor fitness (Lourenco et al. 2020). Motor difficulties affect not only the skills necessary to lead an independent life but also their quality of life (Ardalan et al. 2019). Improved health and positive socialization can be achieved by including fine and gross motor skills in therapeutic interventions in children with ASD (Liu et al. 2019). Currently, several research areas show a growing interest in the concept of quality of life (Koňošová 2015).

Individuals with ASD often have some non-specific features that are not part of the diagnostic criteria such as an uneven cognitive ability profile, decreased ability to mimic movement, inclined gait or toe walking, clapping, and finger cracking (Čadilová et al. 2012). Movement disorders frequently occur in individuals with ASD. These disorders include disabilities in the field of locomotion, gross motor skills, fine motor skills, eye

movement, and the ability to develop more complex movement stereotypes. These individuals move differently. Atypical movements are not limited to one functional area (e.g., handwriting) but can affect many aspects of daily life. Children with motor disorders show several traits such as awkwardness in various games, restlessness, problems with self-care, and difficulty mimicking movements. There are many techniques for training and improving motor skills in autistic children (Yirmiya&Charman 2010; Kilner 2011; Ostatníková et al. 2015; Cook 2016).

Currently, there are studies that confirm the positive effect of physical activity on improving motor skills in children with ASD. A 12-week karate training, which occurred twice a week for 45 per session, positively affected ($p < 0.01$) the social-emotional competence (communication, cooperation, engagement) of 8-11-year-old children; specifically, these children had better performance functional abilities compared to the control group (Greco & De Ronzi 2020). Further, a 32-week trampoline exercise program significantly improved the lower limb strength ($p < 0.05$) and improved motor fitness ($p = 0.00$) in children with ASD (Lourenco et al. 2015). In addition, a 12-week mini-basketball training improves physical fitness and social communication in children with ASD (Cai et al. 2020). Therefore, the use of any exercise intervention is recommended as a therapeutic tool for children with ASD.

Based on this information, physical education teachers or trainers have at their disposal some techniques and tests to constantly monitor the motor performance levels not only in healthy children but especially in children with ASD.

Materials and Methods

The aim of this study is to determine the effectiveness of physical activity in increasing the motor performance of healthy children and children with autism spectrum disorder before and after a 2-month implementation of TGMD-2.

Research hypothesis:

1. We expect the implementation of a 2-month exercise load in the TGMD-2 test to result in a significant improvement of the locomotion and gross motor skills of healthy children at an early school age.
2. We expect the implementation of a 2-month exercise load in the TGMD-2 test to result in a significant improvement of the locomotion and gross motor skills of children with autism spectrum disorder at an earlier school age.
3. We expect the implementation of a 2-month exercise load in the TGMD-2 test to result insignificantly larger differences in the motor skills of healthy children compared to children with autism spectrum disorder at an earlier school age.

This study was approved by the Ethics Committee of the Faculty of Physical Education and Sports at Comenius University in Bratislava, Slovakia, and it was performed according to the Declaration of Helsinki. This research is conducted in the frame of the VEGA 1/0608/20 grant task and the Youth Grant UK/260/2020.

Participants

The group consisted of 18 boys. Eight of them were healthy boys (on average, 7.25 ± 1.16 years old) from the "Hrajna tie nohy" sports club in Bratislava. In addition to our experiments, the boys participated in athletic training twice a week for 60 min per session. The second group consisted of ten verbal boys with autism, who on average were 7.60 ± 1.57 years old. Apart from our experiment, they had no regular physical activity. The boys with ASD were diagnosed with autism at the Academic Centre for Autism Research in Bratislava and were diagnosed with two globally acknowledged ADOS-2 and ADI-R levels. The data were collected from October 1, 2019 to November 22, 2019.

Procedure

The training load consisted of an 8-week training plan that included a TGMD-2 test, which focused on increasing motor performance levels in children. The training sessions occurred twice a week for 30 min. During the first month, all 12 exercises were performed in 3 series with 30-second breaks between different exercises. During the second month, intensity was increased to doing 5 series of all 12 exercises with 20-second breaks.

TGMD-2 includes 12 motor exercises that are focused on improving motor performance levels. The first part of the locomotor subtest exercises includes a run, gallop, hop, leap, horizontal jump, and slide. The second part of the object control subtest exercises includes striking a stationary ball, stationary dribble, catch, kick, overhand throw, and underhand roll. During the test, each child had to perform each exercise twice. A total of 3-5 performance criteria were used for the evaluation. If the given criterion was not performed correctly, it was marked 0. Conversely, if the given criterion was performed correctly, it was marked 1 (Ulrich 2000). In TGMD-2, the maximum score a child can reach is 96. The maximum score per child in the subtests is shown in Table 1.

Table 1 Maximum score per 1 child in TGMD-2

Locomotor Subtest	Score	Object Control Subtest	Score
Run	8	Striking a Stationary Ball	10
Gallop	8	Stationary Dribble	8
Hop	10	Catch	6
Leap	8	Kick	8
Horizontal Jump	6	Overhand Throw	8
Slide	8	Underhand Roll	8
Overall score	48	Overall score	48

The testing methodology used to obtain empirical data included the use of evaluation sheets, which were provided in the TGMD-2 examiner's manual by Dr. Ulrich (2000).

Statistical analysis

The obtained data were processed using the IBM SPSS 23 program as follows. Data normality was tested by the Shapiro–Wilk test, which did not confirm any data distribution normality. The differences between input and output measurements in both groups were evaluated using the Wilcoxon T test. The nonparametric Mann–Whitney U test was used to identify significant differences between groups. Significance was determined at 1% and 5% significance levels. Effect size was expressed using Cohen's R.

Results

The highest score that the group of eight healthy children (7.25 ± 1.16 years old) could have achieved was 384 in the locomotion subtest and 384 in the object control subtest, with the maximum total score of 768. Their score in the initial locomotion subtest was 204, and 203 in the object control subtest; the total score was 407. In the final locomotion subtest, they scored 343; while in the object control subtest, they scored 334; the total score was 677.

The results (Table 2) show that after the implementation of the 2-month exercise load through TGMD-2, the overall motor skills in healthy children improved at 5% statistical significance level because they scored 270 points higher, which was 35.15% higher than at the beginning of the experiment ($Z = -2.524$; $p = 0.012$; $r = 0.892$). In the locomotion subtest, their score improved by 139 points, which was 36.19% higher than at the beginning of the experiment ($Z = -2.527$; $p = 0.012$; $r = 0.893$). The object control subtest showed an increase of 131 points, which was 34.12% higher than at the beginning of the experiment ($Z = -2.521$; $p = 0.012$; $r = 0.891$).

The group of ten children with ASD (7.60 ± 1.57 years old) could achieve the maximum score of 480 in the locomotion subtest, and 480 in the object control subtest, with the total score of 960. During the initial locomotion subtest, they scored 219, and 232 in the object control subtest; the total score was 451. In the final locomotion subtest, they scored 402, and 381 in the object control subtest; the total score was 783.

After the 2-month implementation of exercise load through TGMD-2, children with ASD showed an overall improvement in motor skills at 1% statistical significance level because they scored 332 points higher, which corresponded to a 34.58% increase ($Z = -2.812$; $p = 0.005$; $r = 0.889$). During the locomotion subtest, they improved by 183 points, which was 38.12% higher than at the beginning of the experiment ($Z = -2.803$; $p = 0.005$; $r = 0.886$). During the object control subtest, they improved by 149 points, which was 31.05% higher than at the beginning of the experiment ($Z = -2.821$; $p = 0.005$; $r = 0.892$).

Table 2 Results of input and output measurements by group

Probands	Input			Output		
Healthy children (%)	Locomotor subtest	Control object subtest	Overall	Locomotor subtest	Control object subtest	Overall
	53.13	52.86	53.00	89.32*	86.98*	88.15*
Children with ASD (%)	45.63	48.33	46.98	83.75**	79.38**	81.56**

Note. ASD- autism spectrum disorder; * $p < 0.05$; ** $p < 0.01$

No differences in motor skills (Fig. 1) were statistically confirmed in healthy children and in children with ASD at an earlier school age. Likewise, the locomotion subtest (Fig. 2) did not reveal any statistically significant differences between both groups. The control object subtest (Fig. 3) did not show any statistically significant differences between the groups.

Fig. 1 Mean improvement in differences between groups in the overall score

Note. ASD – autism spectrum disorder; n.s. – not significant

Fig. 2 Mean improvement in differences between groups in the locomotor subtest

Note. ASD – autism spectrum disorder; n.s. – not significant

Fig. 3 Mean improvement in differences between groups in the object control subtest

Note. ASD – autism spectrum disorder; n.s. – not significant

Discussion

This study showed that an 8-week exercise load for 30 min twice a week using TGMD-2 was effective and sufficient to improve the motor skills in children with ASD. In these children, motor abnormalities are considered to be one of the hallmarks of autism (Freitag et al. 2007). A recent study has reported that a 30-min motor training 3 times per week significantly affected the gross motor skills and social communication in children with ASD (n = 60). The children were between the ages of 6 and 12 and went through 30 scheduled

workouts, i.e., 14 workouts less than in this study. In addition, their motor skills were measured using TGMD-2 (Arabi et al. 2019). Furthermore, TGMD-2 has been confirmed to be a suitable tool for the assessment of motor skills in visually impaired children at a younger school, as determined by Houwen et al. (2010). The obtained results revealed a medium to high correlation ($r = 0.40$; $r = 0.80$) of this test. Imitation skills and motor function in children with ASD ($n = 20$) are mutually related to each other and also to early social communication skills at pre-school age (Dadgar et al. 2017). By comparing those results with ours, it was appropriate to start at pre-school age.

Kaur & Bhat (2019) have evaluated the effect of 8 weeks of creative yoga on improving motor skills in children with ASD ($n = 24$). Similar to our research, they determined that for children with ASD, this time period was sufficient to improve their gross motor skills. At the same time, they also observed an improvement in mimicking training-specific yoga exercises, where children with ASD made fewer mistakes.

In addition, this research revealed that this type of exercise load improved motor skills in healthy children. Other authors have confirmed that TGMD-2 is a suitable tool for assessing motor development in healthy children (Kim et al., 2014; Melo et al., 2018). Nur et al. (2020) have shown that activities implemented during the learning process can improve the gross motor skills of healthy children. In addition, Aye et al. (2017) have established that TGMD-2 greatly affected healthy children; their results showed that TGMD-2 was a highly reliable and suitable tool for identifying and evaluating the motor skills of children both at an earlier school age and at the preschool age.

Because the research did not show statistically significant differences in the motor performance between healthy children and verbal children with ASD, it was possible to conclude that in terms of locomotion and gross motor skills, they were almost the same. This was confirmed by the score percentage achieved by both groups during the TGMD-2 test. While healthy children reached 53% of the total of 100% in TGMD-2 at the beginning, children with ASD achieved 46.98%. The output measurement revealed no major differences either. Healthy children reached 88.15% of the total of 100% in TGMD-2 and 81.56% in children with ASD. Melo et al. (2018) have examined the effect of physical activity on the physical performance of healthy 6–10-year-old children and determined that healthy children had poor motor skills performance.

TGMD-2 offers excellent psychometric qualities for the assessment of motor skills in children with normal development. The reliability and validity of this test was also confirmed by Ulrich (2013) in children with mild mental and learning disabilities.

Conclusion

It is important to indicate that the differences between children with ASD and healthy children at an earlier school age were not statistically significant even though the group of healthy children had regular physical activity for 60 min twice a week at their sports club in addition to our experimental stimulus. Unlike healthy children, children with ASD did not have any regular physical activity besides our experimental stimulus. The obtained results indicate the importance of monitoring and testing motor skills in both groups of children at an earlier school age.

This study showed that the selected 8-week exercise intervention was sufficient to produce a significant improvement in healthy children and in children with ASD. It was determined that the selected training load frequency (i.e., 30 min twice per week) using the TGMD-2 test was sufficient, as the test showed a statistically significant improvement.

Finally, we would like to advise trainers, physical education educators, and physiotherapists to regularly use this TGMD-2-type physical activity to improve the motor performance in healthy children and especially in children with autism spectrum disorders at an earlier school age to help them improve their quality of life.

Conflicts of interest – The authors declare that there is no conflict of interest.

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