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Original Article

The effect of a trampoline-based training program on the muscle strength of the inferior limbs and motor proficiency in children with autism spectrum disorders

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Abstract:
Motor proficiency is positively correlated with physical exercise, which is sometimes reduced in children with autism spectrum disorders (ASD). The main goal of this study was to evaluate the effects of a trampoline-based training program, over a period of 32 weeks, on both the muscular strength of inferior limbs and the motor proficiency in children with ASD. Sixteen children diagnosed with ASD (3 girls and 13 boys, 4–10 years-old) were included in this study. The children were randomly assigned to two groups: experimental group (EG, n=8) and control group (CG, n=8). Over the course of the program, children kept their regular school activities. The groups were evaluated before the onset of the program, at week 16 after the beginning of the program and at week 32. Motor proficiency was evaluated using the Bruininks–Oseretsky test for motor proficiency (2ªed.), (BOT2). The strength of inferior limbs was measured using the standing long jump without run-up. The statistical analysis included the multivariate analysis (ANOVA). The trampoline-based program contributed in a significant way to the improvement of both the strength of the inferior limbs ($p>0.05$) and motor proficiency ($p=0.00$) in children with ASD.
Keywords: Physical activity; autism spectrum disorders; trampolines; motor proficiency; inferior limbs' strength.

Introduction

Autism is a neurodevelopmental condition clinically defined by impairments in communication and social interaction, which is characterized by repetitive and stereotyped restricted patterns of behavior, interests and activities (American Psychiatric Association, 2000 in Bradley, Caldwell and Underwood (2014). In many children who have autism spectrum disorders (ASD), motor and sensory difficulties are observed (Baranek, 2002). Several studies have also reported changes in the motor development profile of these children, which contribute to a lower physical fitness (Loh et al., 2007; Ozonoff et al., 2008; Pan, 2009; Fournier, Hass, Naik, Loadha, and Cauraugh, 2010).

The strategies for the treatment of ASD focus primarily on cognitive stimulation, social and language development and also on the elimination of stereotyped movements (Koring et al., 2010; Sowa and Meulenbroek, 2012). Physical activity plays an important role in the quality of life of these individuals and has been widely regarded as an important strategy in the promotion of physical fitness (Yilmaz, Yanardag, Birkan, and Bumin, 2004; Lochbaum and Crews, 2003; Pan, 2011) and the reduction of the maladaptive and stereotyped behavioral patterns (Lancioni and O'Reilly 1998; Elliott, Dobbin, Rose, and Soper (1994) and Yilmaz et al (2004), as well as aggressive and antisocial behaviors (Allison, Basile, and Bruce MacDonald (1991);. Pan, 2010). The practice of physical activity is also regarded as having an enormous significance in improving the nutritional status (Pitetti, Rendoff, Grover, & Beets, 2007), sensory skills (Bass, Duchowny, & Llabre, 2009), attention, perception and communication (Hameury, et al (2010.), and academic performance (Nicholson, Kehle, Bray, and Heest 2011; Rosenthal-Malek, and Mitchell, 1997).

Physical activity programs employing trampolines have been used in several areas, as they seem to promote the improvement of balance, walk, muscle tone and joint flexibility in cases of traumatic spinal cord injury (Citero, Mederdrut, and Power, 2012) and multiple sclerosis (Garcia, Mederdrut, Veloso & Fontes, 2008), as well as in balance recovery capacity in the elderly (Aragon, Karamanidis, Vaz, & Arampatzis, 2011) and the postural control in stroke patients (Miklitsch, Krewer, Freivogel, & Steube, 2013). In addition, the perception of the temporal and rhythmic space, overcoming fear (Botelho, 1992), the flexibility and resistance of the abdominal lower limb muscles and the heart rate (Leite et al. 2009) can be improved with this type of training. Notably,

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Ferrarezi and Guedes (2000) reported the existence of progress in the balance and flexibility of adolescents with cerebral palsy.

There is no study addressing the effects of trampoline-based programs on the physical fitness of children with ASD. Therefore, in order to fill this gap in the literature, this study seeks to assess the effect of a trampoline-based training program in the motor proficiency and muscle strength of the lower limbs of children with ASD.

Methods

Participants

We sampled 16 children (13 boys and 3 girls) diagnosed with ASD. These children were attending pre-school and schools of the 1st cycle of basic education in the district of Viseu. The sample was then divided into two groups of eight children each: experimental (EG) and the control (CG) groups. Participants were between 4 and 8 years of age (EG: 5:43 ± 1:53 years; CG: 7.60 ± 1.60 years). The EG underwent a 32-week program of trampoline training in a gym fully equipped with various types of trampolines (1 session per week lasting 45 minutes); during the same period, the GC did not participate in any organized or systematic sport activity.

Instruments

Motor proficiency was assessed using a Bruininks–Oseretsky battery of tests (2nd ed., 2005) in its reduced form (bot2), as previously used children with ASD (Dewey, Cantell, & Crawford, 2007; Gabriels et al 2012 ; Mattard-Labrecque Ben Love, & Couture, 2013). This battery consists of the following 12 trials: fine motor precision (two tests: completion of a star and line drawing through a path); fine motor integration (two tests, drawing two overlapping circles and drawing a diamond as similar as possible to the images presented); manual dexterity (threading blocks); bilateral coordination (two tests: touching one's nose with the tip of the index finger, pivoting index and thumb while keeping the eyes closed); balance (move forward on a line heel-to-toe); speed and flexibility (one leg walk from one side of a line to the other); coordination of upper limbs (two tests: catching and throwing a ball with one hand and dribbling the ball alternating hands), and strength (performing kneeling push-ups). These tests were applied individually to each child, according to the published protocol (Bruinninks, & Bruininks, 2005), and lasted from 15 to 20 minutes. The strength of the lower limbs was estimated by a long jump with both feet together (without run up). Each participant had three trials, in which the goal was to jump as far as possible. For the analysis, the best jump was selected.
Both tests took place in schools attended by students and were made in three stages: before the intervention program, at week 16 and at the end of the 32 weeks. All participants concluded the trampoline-training program.

Trampoline program

The training program took place in a gym/hall equipped with several trampolines, namely: elastic bed trampoline, double-mini-trampoline, mini-trampoline, round elastic bed trampoline and trampolines 80 cm in diameter. All weekly training sessions, which were planned in accordance with the objectives of the investigation and taking into account the particular limitations of the participant population, lasted 45 minutes. Each training session was divided into three parts: initial (5 minutes), main (35 minutes) and final (5 minutes) parts. In the first part, through different running exercises, joint mobilization and different games, the participants warmed-up for the exercises. In the second and main part, and to improve all the evaluated components, specific exercises were carried out through the use of trampolines, mats, balls, bows, chairs, tables, Swedish gymnastic bench, Swedish ladders and ropes. In the last part of the training session, in order to stimulate social development, children collaborated with the teacher, participating in the arrangement of the material used in the session. All training sessions were implemented and developed by a physical education teacher. Parents/guardians attended the training and collaborated if needed.

Statistical Analysis

Descriptive statistics were employed (mean and standard deviation) to characterize the different distributions of values. All variables followed the normal distribution according to the Kolmogorov–Smirnov test. Differences in mean basal values of variables from the different groups were assessed using the t-test for independent measurements. To evaluate the effectiveness of the trampoline program, analysis of variance (ANOVA) of the repeated measures was used. The level of significance was set at 0.05. Statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

Results

Table 1 presents the results of ANOVA for repeated measures models for the different tests. It can be observed that before the implementation of the trampoline program the CG showed mean values of leg strength higher than the EG. Over the course of the training program there was a statistically significant improvement in leg strength in the EG, contrary to the CG, which did not show significant changes ($p > 0.05$).

Table 1. Mean values (standard deviation) of the different variables in the EG and CG at three time points.

Variables	**Baseline (A=0)**	**Intermediate (A=16)**		**Final (A=32)**		**ANOVA results**			
	EG	**CG**	**EG**	**CG**	**EG**	**CG**	**G**	**T**	**G*T**
Lower limbs strength	26.425 (30.364)	78.900 (26.953)	53.413 (36.393)	75.588 (20.272)	74.013 (35.201)	80.950 (23.103)	0.071	≤0.001	≤0.001
Fine Motor Precision 1	1.25 (0.886)	2.38 (0.518)	1.50 (0.756)	2.38 (0.518)	1.63 (0.518)	2.13 (0.641)	0.009	0.712	0.132
Fine Motor Precision 2	1.38 (1.506)	4.13 (1.553)	2.63 (2.504)	4.75 (1.753)	2.38 (1.408)	4.00 (1.927)	0.019	0.031	0.259
Fine motor integration 1	3.38 (2.875)	4.88 (0.641)	3.88 (2.949)	5.13 (0.835)	4.13 (2.167)	5.25 (0.707)	0.181	0.203	0.830
Fine motor integration 2	0.88 (1.642)	3.63 (1.188)	1.13 (1.642)	2.88 (1.642)	3.38 (1.598)	3.75 (0.886)	0.016	≤0.001	0.011
Manual dexterity	1.38 (0.744)	2.88 (1.246)	2.13 (1.126)	3.25 (1.669)	3.13 (1.126)	3.88 (1.356)	0.042	0.001	0.501
Bilateral Coordination 1	0.63 (0.916)	1.88 (1.553)	1.50 (1.690)	1.38 (1.408)	2.88 (1.458)	1.50 (0.535)	0.880	0.020	0.002
Bilateral Coordination 2	0.13 (0.354)	1.38 (1.188)	0.25 (0.463)	0.75 (1.035)	1.13 (1.356)	1.50 (0.926)	0.097	0.005	0.143
Balance	0.75 (1.035)	1.88 (1.126)	2.38 (1.408)	2.38 (1.188)	3.88 (0.354)	2.38 (1.408)	0.761	0.000	0.003
Flexibility and Speed	0.38 (0.518)	1.38 (0.744)	0.75 (0.707)	1.63 (1.061)	1.88 (1.808)	1.75 (1.282)	0.231	0.004	0.075
Upper limb coordination 1	0.38 (0.744)	0.25 (0.463)	0.75 (1.165)	0.38 (0.744)	0.75 (1.035)	0.88 (1.727)	0.792	0.093	0.532
Upper limb coordination 2	0.25 (0.707)	0.88 (1.246)	0.50 (0.756)	1.00 (0.926)	1.13 (1.727)	1.50 (1.414)	0.370	0.004	0.845
Strength	0.00 (0.000)	0.38 (1.061)	0.50 (1.069)	0.25 (0.707)	0.50 (0.926)	0.63 (0.916)	0.823	0.184	0.297
BOT-2 Result	10.75 (8.362)	25.88 (8.774)	17.88 (12.495)	26.13 (8.254)	26.50 (12.189)	29.00 (7.635)	0.092	≤0.001	≤0.001

EG= Experimental Group; CG= Control Group; G=group; I=intervention.

Concerning motor proficiency, there were obvious changes over the course of the intervention program. At baseline there is a considerable difference between the experimental and control groups; the former has an average much lower in all variables, except for the coordination of upper limbs 1. Although both groups showed improvements in the course of 32 weeks, the change in the experimental group is more significant and there is a significant interaction between the groups and the training program ($P = 0.000$). After the training program there was a significant progress in fine motor integration 2, bilateral coordination 1 and balance ($p<0.05$). The speed and agility improved significantly with the training program, with notable changes occurring from the second to the third evaluation. For the other variables there were clear improvements, but which were not statistically significant changes.

Discussion

Green et al. (2008) reported that the existence of motor limitations is very common in individuals with autism spectrum disorders. In this regard, and considering the benefits of performing the trampoline exercises mentioned before, this study aimed mainly to evaluate the effects of a trampoline training program on the muscle strength of the lower limbs and motor proficiency of children with ASD. The results obtained shed light on the impact a 32-week trampoline program has on these variables.

The training program significantly improved the leg strength, contrary to what was found for the strength of the upper limbs, which showed less obvious improvements. This result can be explained by the design of the training program that was implemented. In fact, in all training sessions, the exercises and proposed content comprised various types of jumps and consequently greater demands on the lower limbs. However, it should be noted that the arms were also used to keep balance, maintain a correct body posture and perform some tasks during the jumps (clapping, raising and lowering the arms, launching and receiving a ball). This positive effect of a trampoline program on physical fitness components has been observed in different studies (Lieberman et al, 2013;. Citero et al, 2012;. Aragon, et al, 2011; Leite et al, 2009). Although these studies were not performed on children with ASD, improvements in leg strength, cardiovascular endurance, balance and trunk stability were found. Moreover, Yilmaz et al (2004) concluded that after 10 weeks of swimming training, there were improvements in balance and Cheldavi, Shakerian, Shetab Boshehri and Zarghami (2014), after an intervention program for balance training, found improvements in postural control. In the latter cases presented, the studied participants had ASD. Although no significant improvements were obtained, there were improvements in speed and flexibility in the experimental group when compared with the control group. Contrary to our findings, in a study of adolescents Todd and Reid (2006) found that the training significantly increased the distance walked or ran by children aged between 6 years and 7 months and 11 years and one month, and in the participants in the study of Fragala - Pinkham , Haley , and O'Neil (2008) it reduced the time needed to finish the path. Two facts may help explain these differences: compared to our study, in these two reports the children were older and the training was more frequent (two weekly workouts). In our study, the variables that make up the fine motor skills and manual dexterity have not changed significantly, except for the Fine Motor Integration 2 (drawing a diamond as close as possible to the displayed image), which was expected, since these dimensions were not considered in the training. With regard to the variable that recorded significant differences, we associate it with the work that was carried out with balls (catching the ball with one hand and then jump, jumping and throwing the ball to a target).

The two variables of bilateral coordination showed different values. Bilateral coordination 1, corresponding to the touch display on the nose with the eyes closed, change significantly after the intervention. In contrast, bilateral coordination 2, the pivoting of the thumb and index finger, showed no significant improvements. We believe that the exercises described above have positively influenced the bilateral coordination 1, as well as the more specific exercises of coordination that have been conducted over the trampolines (spreading and joining legs, performing scissors, raising arms while jumping, clapping while jumping). However, as the coordination of the upper limbs was not so stimulated, our intervention program did not lead to significant improvements in the coordination of the upper limbs. Contrary to our study, through an intervention program conducted with trampoline Mitsiou, Sidiropoulou, Giagkazoglou, and Tsimaras (2011) improved the neuromuscular coordination of 6–11-year-old children with Developmental Coordination Disorder. It is important to stress that our experimental group had a mean age of 5.43 years, that is, younger children than those studied by Mitsiou et al. (2011). To evaluate the coordination of the upper limbs, tasks with a ball are performed, as already described in the methodology. Papadopoulos et al. (2012) found that the high-functioning autism group showed more difficulty at the motor level, such as in ball skills and balance exercises, than children with Asperger syndrome, which may explain the fact that we could not achieve statistically significant results.

As for the total score of the Bruininks–Oseretsky (2nd ed. 2005) battery of tests applied, the reduced form that evaluates the driving proficiency showed significant improvement ($p = 0.000$) in contrast to the study of Wuang, Wang, Huang e Su (2010), in which only autistic children who joined the horseback riding program and attended the occupational therapy sessions had significant improvements. According to Wrotniak, Epstein, Dorn, Jones and Kondilis (2006), motor proficiency is positively associated with physical activity and inversely associated with sedentary activity in children.

Although no specific studies were found in the literature on the effect of trampoline training programs in children with ASD, some research has been done in particular populations (Apoloni , Lima, and Vieira, 2013; Ferrarezi and Guedes 2000). The study by Apoloni et al. (2013) consisted of implementing a 12-week program of trampolines (jumping, playing and running in the trampoline elastic bed) in children with Down syndrome, and the results have shown a significant improvement in the postural control in these children. After 16 weeks of intervention, the use of the trampoline has also brought progress in the balance and flexibility of adolescents with cerebral palsy Ferrarezi et al. (2000). Furthermore, Miklitsch, Krewer, Freivogel and Steube (2013) found improvements after an intervention using a trampoline-based program in the neuromuscular coordination of patients who suffered a stroke.

The data of this study should be interpreted and analyzed taking into account some limitations. First, since the selected sample is very small, it is impossible to generalize the results to the ASD population. Second, although both groups were similar from the point of view of biological and morphological variables, their formation in this study was not based on randomization and thus we cannot exclude the presence of some confounding factors in the results.

Conclusion

Considering the results described in this study, it can be concluded that the trampoline-based training significantly contributed to the improvement of both the motor proficiency and strength of the inferior limbs. Taking into account that children with ASD have balance problems, it is urgent and necessary to develop and implement new strategies and intervention programs designed according to principles of exercise and motor learning for children with ASD (Bhat, Landa, & Galloway, 2011). Thus, we recommend the trampoline training, which is an excellent strategy to address these problems, in addition to having a valuable playful component.

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