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Could a Multitask Balance Training Program Complement the Balance Training in Healthy Preschool Children: A Quasi-Experimental Study

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Abstract: This prospective quasi-experimental study investigated the efficacy of a multitask balance training program to improve the balancing ability of healthy preschool children. A total of 85 (51.8% boys) healthy preschool children aged 4–6 years were randomly divided into an intervention group and a control group. The intervention group received a multitask balance training program, while the control group received a placebo training program. Outcomes were collected at baseline and immediately following the intervention. Independent members of the research team recorded balance skill measurements in the cohort at pre- and post-training using the Pediatric Balance Scale (PBS). Balance-related outcomes were recorded using the Battelle Development Inventory in Spanish using the second edition (BDI-II). A significant effect of time interaction (F = 7.27, $p = 0.015$; F = 6.16, $p = 0.02$ and F = 7.41, $p = 0.014$) existed for the PBS and BDI-II over balance immediately after the intervention ($p < 0.001$ for each). A significant group-by-time interaction was detected for the PBS and BDI-II ($p < 0.001$ and $p = 0.006$, respectively). This study supports the efficacy of multitask-based balance training programs to improve balance in children aged 4–6 years.

Keywords: balance; training; children

1. Introduction

Balance is an intrinsic part of any movement and is the cornerstone of postural control [1]. Several studies have shown that balance training (BT) interventions lead to improved postural control in children and adolescents older than 12 years [2–5]. However, the evidence that BT can improve postural control in younger children is much weaker.

It is well established that 4–6 years is a critical age in the process of acquiring balance. This is mainly because of the changing predominance between the main sensory information used for balance [6,7]. Babies can only rely on their visual system for postural control. Adult balance system relies mainly on proprioceptive information. However, the visual system in children aged 4–6 years takes back its predominant role, due to changes in somatosensory information. Children experience a peak of growth at this age and their somatosensory database is no longer reliable [8]. Some authors found that the influence of peripheral vision in balance increased at 3–6 years of age, reaching a peak when the child was 6 years old [9]. This makes this age especially interesting for balance intervention programs.

The criteria for drawing up a BT program depend on the concept of the program on the regulatory mechanisms of balance. It will either focus on the exclusive training of motor components or use a perspective interaction among different systems, including motor components, sensory components (visual, proprioceptive, and tactile), and cognitive components, such as attention [10]. Several studies have performed training programs in adolescents [11], young adults [12,13], and older adults [14,15] with favorable results being observed in these study populations; however, interventions in early stages, such as the age of children used in this study sample, have been largely unexplored despite the importance of the processes taking place at this time. Therefore, the development of BT programs is part of the daily practice of numerous healthcare professionals, including education providers, physical therapists, and physical activity. It is important to deepen our understanding of the factors that compete for balance resources during children's performance, so that teachers can design age-appropriate environments to improve balance, instead of general physical education programs that address all motor components without a specific rationale of intervention. At this age, 4–6 years, when the balance system is changing from proprioceptive to visual main control, the importance of specific training needs to be addressed.

The aim of this study was to investigate whether a BT program with multitask BT was effective in improving balance and postural control in healthy preschool children. The design of the BT program was under the perspective of the multisystem models of balance control, which have shown strong evidence about their efficacy in other populations [11–15].

2. Materials and Methods

2.1. Participants

A total of 88 consecutive children from the Monte Tabor School (Madrid, Spain) were screened from March 2016 to June 2016. A total of 44 boys and 44 girls aged 4–6 years were originally screened; however, three children failed to meet the inclusion criteria (or met the exclusion criteria) and were subsequently removed from the study. This left a total of 85 subjects who were enrolled by the principal investigator. The study was approved by the Rey Juan Carlos University Ethics committee (060520165416) and written informed assent was obtained from the participants' legal guardians.

The inclusion criteria were children aged 4–6 years whose parents agreed to sign the informed consent document. The exclusion criteria were any previous diagnosis of balance or motor impairment, an inability to walk alone, blindness or severely impaired sight, neuropsychologic disorders, and serious cognitive impairment.

2.2. Outcome Measures

2.2.1. Pediatric Balance Scale (PBS)

The aim of this scale was to measure balance [16]. Recorded events included standing with both eyes closed, standing with both feet together, standing with one foot in front of the other, and standing on one leg whilst reaching forward with one arm. The excluded items were moving from sitting to standing, moving from standing to sitting, transfers, standing without support, sitting without support, turning 360°, turning to look backwards, taking an object from the floor, and alternately putting one foot on a bench.

2.2.2. Battelle Developmental Inventory (BDI)

Global development was assessed in Spanish using the second edition of the BDI-II [17]. This assessment applied only to balance-related items including jumping on one foot, jumping on one foot for a distance of 3 m, tandem walking, standing on one foot with both eyes closed and jumping forward with the feet together.

All measurements were recorded at baseline and immediately after the intervention by the same examiner who was blinded to the group assignment and the aim of the study. The sequence of testing for the outcome measurements was randomized among the participants. The trial was designed according to the STROBE published guidelines [18].

2.3. Protocol

The participants were treated by physical therapists with more than 15 years of clinical experience in the management of pediatric patients. The physical therapist was blinded to all data that were collected for the study. The participants were consecutively assigned to one of two groups: the experimental group received a multitask BT program, whereas the control group received placebo training. Randomization was performed by means of a progressive list of numbers where each number was randomly assigned to a type of treatment (experimental or control) by a software procedure.

All participants received 40 treatment sessions scheduled over a period of 8 weeks, with sessions happening on 5 days per week. All outcomes were collected by an external assessor who was blinded to the training allocation of the participants. The variables were measured at baseline and after the intervention according to the sequence mentioned previously.

2.4. Experimental Group

Subjects in this group received a 30-min session of BT. This training was directed by two (or sometimes three) physiotherapists, with 15–22 children per therapist [12,13,19–22]. Training consisted of 30 min of activity preceded by a small warm-up period and a post-activity cool down, which was standardized for both groups and consisted in joint by joint soft circular movements. The children rotated through four different workstations. Depending on the progression of the training, the four stations consisted on flat floor, two different sets of unstable surfaces, and reduced base of support. They performed four sets of the exercise at each workstation, with exercises lasting for 20 s each with 40 s of rest between the sets and 3 min of rest between each workstation. The intensity of incremental training was achieved by reducing the support base (i.e., standing on one foot in the tandem position), reducing the sensory input (i.e., closing eyes) and including unstable surfaces. Multitask training was achieved by interfering with a motor task (i.e., making movements with the arms or taking a glass of water) or a cognitive task (i.e., counting backwards or attention tasks). This increased intensity was performed progressively and included new tasks with greater difficulty.

2.5. Control Group

The control group continued with a normal 30-min workout, which was based on the Doman Delacato methodology [23] and consisted of 'basic movement patterns'. The workout consisted of the teachers guiding children to perform the dynamic repetition of an activity to reproduce patterns of ontogenic development (i.e., rolling, creeping, and crawling). The teachers were specifically instructed not to carry out any activity that could be considered to improve balance.

2.6. Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM Corporation, Armonk, NY, USA). Descriptive statistics were used to summarize the data. Normal distribution of the sample was analyzed using the Kolmogorov–Smirnov test ($p < 0.05$). An Independent samples t-test and Chi-square comparisons were used to compare demographic and other covariates when appropriate. A mixed ANOVA was conducted, with time (pre- and post-treatment) as the within-subject factor, and group (experimental and control) as the between-subject factor. The effect size (ES) Cohen's d coefficient was also calculated to assess the magnitude of differences. The criterion for interpreting ES was: trivial (<0.2), small

(0.2–0.6), moderate (0.6–1.2), or large (>1.2). We also obtained the standardized effect sizes of the ANOVA tests; $p < 0.05$ was considered statistically significant in all analyses.

3. Results

A total of 88 healthy children were screened, and 85 (age (mean ± SD): 4.5 ± 0.5 years, 51.8% boys) satisfied all eligibility criteria and agreed to participate. A total of 43 children were assigned to the experimental group and 42 were assigned to the control group. The reasons for exclusion of the additional three children were attention deficit (n = 2) and the concurrent presence of a broken leg (n = 1) (Figure 1). There were no significant statistical differences between the control and intervention group with regards to these parameters (Table 1).

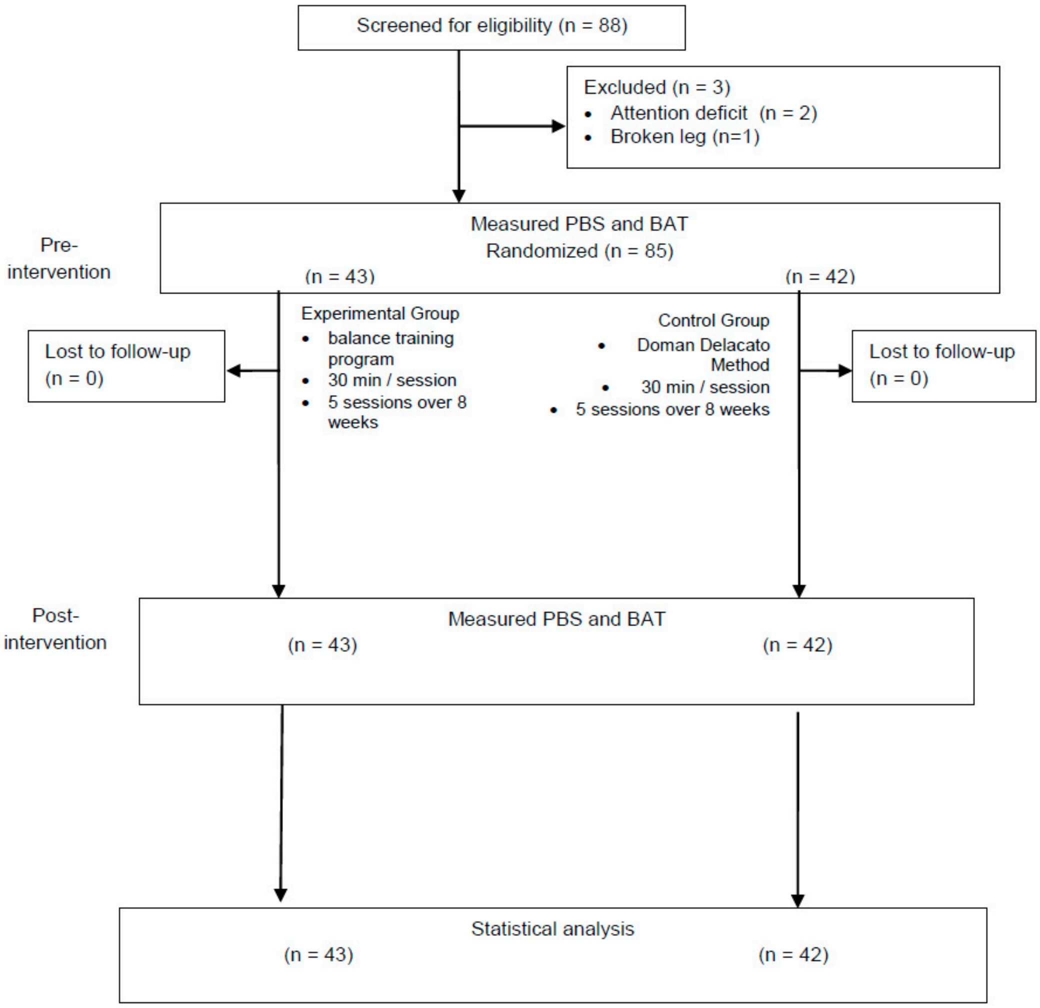

Figure 1. Flow chart of participants through the trial. (PBS: Pediatric balance scale, BAT: Battelle developmental inventory).

Table 1. Baseline demographics for both groups.

	Experimental (n = 43)	Control (n = 42)	*p*-Value
Age (years)	4.5 ± 0.5	4.6 ± 0.5	0.796
Male gender [n (%)]	21 (51.2%)	23 (54.8%)	0.685
PBS	12.4 ± 3.4	12.4 ± 3.3	0.978
BDI	5.8 ± 2.6	5.3 ± 2.9	0.786

Abbreviations: PBS: Pediatric balance scale, BDI: Battelle developmental inventory.

Balance

For the balance measurements using the PBS and BDI-II, there were significant effects of time (F = 9.179, ES = 0.19, $p < 0.001$ and F = 24.773, ES = 0.01, $p < 0.001$, respectively) and group-by-time interaction (F = 12.585, ES = 0.39, $p = 0.001$ and F = 5.716, ES = 0.22, $p = 0.02$, respectively). Post hoc analysis indicated that the children in the experimental group improved their balance immediately after the intervention when compared to those children receiving the control intervention (experimental group (95% CI) = 3.6 (2.7; 4.6), $p < 0.001$; control group = 1.2 (0.2, 2.2), $p = 0.02$), and there was also a significant effect for group-by-time ($p < 0.001$ and $p = 0.006$), (Table 2).

Table 2. Mean (SD) for Outcome at all study visits for each group, mean (SD) difference within groups, and mean (95% CI) difference between groups.

Outcome	Groups				Difference within Groups		Difference between Groups
	Pre		Post		Post minus Pre		Post
	Exp (n = 43)	Con (n = 42)	Exp (n = 43)	Con (n = 42)	Exp (n = 43)	Con (n = 42)	Exp minus Con (n = 85)
PBS	12.4 (3.4)	12.4 (3.3)	16.1 (2.9)	13.6 (3.0)	3.7 * (0.5)	1.2 * (0.01)	−2.5 # [−3.8 to −1.2]
BDI	5.8 (2.6)	5.3 (2.9)	7.4 (2.4)	5.8 (2.8)	1.6 * (0.3)	0.5 (0.6)	−1.6 # [−2.7 to −0.5]

Abbreviations: PBS: Pediatric balance scale, BDI: Battelle developmental inventory. # Significant difference between-group, $p < 0.05$ (95% confidence interval) * Significantly different within-group, $p < 0.05$ (95% confidence interval).

4. Discussion

The results regarding balance ability after the intervention showed that the group receiving the BT program had significantly better test scores. Other reports in the literature have used training protocols with similar methodologies in different age groups. For example, Granacher et al. [19] implemented a BT program in adolescents, Gruber et al. [12] and Heitkamp et al. [13] performed a similar program in young adults, and Granacher et al. [20,21] and Silsupadol et al. [22,24] used a BT program in the elderly.

The program used for this study was based on those found in the literature; however, it also introduced some modifications to suit the age group of the cohort. Work and rest times were taken from the literature, and the increase in the training intensity was achieved by reducing the support base, reducing the sensory input (i.e., closing the eyes and using unstable surfaces), and adding concurrent tasks, both motor (i.e., upper limb activities) and cognitive (i.e., counting backwards and including attention tasks). The modifications were mostly included to keep the children motivated during the training time, as will be discussed later.

Granacher et al. [21] attempted to increase balance and strength using a program with the same work and rest times. The authors found tendencies, but not statistically significant improvements, in balance, when it was measured using a force platform. These results disagree with those of the present study and this is likely due to the differences in the methodologies of the training programs. Another reason for the difference in the results could be the difference in sample size. Physiotherapists responsible for implementing the training program in this study carefully planned the training sessions, transforming them into activities with a large recreational component. These resources were used to maintain the involvement and motivation of children during all training sessions.

Wälchli et al. [25] found that postural control in transfer tasks and explosive strength could be improved in children and adolescents by applying child-oriented BT; however, it should be noted that age-specific training adaptations with the greatest gains were found in the youngest group [25].

The nature of motor development could be enough to explain the improved balance of the control group. As children age, their postural control increases until the appearance of adult balance responses. The motor abilities of rolling, creeping, and crawling may also have contributed to an indirect improvement of balance, which may have affected the study in terms of the group differences being higher in the post-intervention measures. Nevertheless, the differences between groups could potentially be a consequence of the multisystem intervention, providing training not only for the motor components of balance, but also enhancing the practice of the interaction between every other component (sensory and cognitive), as previous studies have shown in other populations [11–15].

Further studies using larger sample sizes should be performed to determine whether the inclusion of BT programs in early stages can significantly prevent falls and their psychological consequences in preschool children. Many children that are not diagnosed as balance-impaired do have troubles in this area, and are labeled as "clumsy" between teachers and, more importantly, between their peers. These children tend to participate less in motor games and sports, which generates a circle of less activity leading to poorer motor development. It is also important to highlight this kind of motor intervention in school environments, as the preschool years are crucial for developing the sensorimotor system. Educational systems tend to focus excessively upon pure cognitive learning and forget about the multisystemic nature of childhood development.

Limitations

Despite the positive results from this study, many aspects of multitask BT in preschool children remain to be quantified and studied further. For example, the dose and length of the training program have yet to be defined. Further randomized controlled studies implementing this training in larger cohorts of children and extension of the program duration are needed to confirm these results and the long-term benefits of the multitask BT.

5. Conclusions

The study supports the efficacy of multitask-based BT programs to improve balance in children aged 4–6 years.

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