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Effects of Balance Training Using Action Songs on Postural Control and Muscle Strength in Preschool Children

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Abstract

Postural control and muscle strength are important factors for the performance of everyday activities and reduce the possibility of fall-related injuries. The purpose of this study was to investigate the efficacy of a balance training program using action songs on balance and strength of preschool children. A total of 51 preschool children were randomly divided into an intervention group (25 children) and a control group (26 children). The intervention group received a balance training program with action songs (six weeks, two times a week, total 12 sessions), while the control group followed the normal curriculum. Prior to and after the intervention, both groups were assessed in dynamic balance (walking on balance beams), static balance (single-leg stance on forceplate and Flamingo test) and strength (long jump and handgrip). The results showed that the intervention group performed significantly better in the dynamic balance and Flamingo test. There were no significant differences in the centre of pressure (CoP) displacement in the Medio-Lateral direction (CoP/ML), the Anterio-Posterior (CoP/AP), and the strength variables. The reliability of the single-leg test on the forceplate was moderate. Moreover, there were no correlations between balance and muscle strength variables. It can be concluded that the balance training program with action songs constitutes an effective activity for developing preschool children's balance, but not strength. Perhaps balance and muscle strength are independent of each other and may have to be trained with complementary activities. Moreover, the results of the study and the behaviour of the children during the one-leg stance test on the forceplate gave rise to questions regarding the appropriateness of this test for preschool children.

Keywords:

Postural Control, Muscular Strength, Physical Education, Preschool Children, Action Songs

Introduction

Balance is fundamental in order to safely perform basic daily movements and sport activities. Moreover, the risk of falls-related injuries is particularly high in young children, because their postural control system is not fully developed (Altınkök, 2015). Recent studies show that balance control develops not only as children grow but also from interacting with their environment (Chatzopoulos, 2019). If a child does not receive the appropriate stimuli for balance improvement, this may result in limited efficiency in performing fundamental movement skills (Lykesas et al., 2020) and daily activities (Murphy et al., 2003).

Balance control is important for sport performance and past studies investigated the effectiveness of balance training programmes on postural control in healthy trained children, adolescents and adults (Gebel et al., 2018; Wälchli et al., 2018). The common feature of these programs is the inclusion of many repetitions of the same task (e.g. stand still for 20s, 3 times), many sets (3-5), rest periods (e.g. 30-120 s) between repetitions or sets, and competitive games (Abuín-Porras et al., 2020; Gebel et al., 2020; Granacher et al., 2010; Wälchli et al., 2018). Due to their intense training orientation these programs may be effective for athletes or older adults, but they are not attractive to young children. For instance, Granacher et al. (2011) reported that their balance programme was not efficient in improving the balance of elementary school children, and attributed the inefficiency of their programme to the lack of children's interest in participating in highly structured exercises. Their training programme included a 10 min warm-up, 45 min balance activities (4 sets of 20 sec of each exercise with 2 min rest between the exercises) and 5 min cooldown (total duration 60 min). Apparently, it is difficult for children to remain concentrated for so long (one hour) in a training program that involves many repetitions, sets and rests. Highly structured programs may be suitable for adults and athletes; however, they do not meet the needs of young children.

The average concentration span of pre-schoolers is less than 15 min and depends on their interest in the task and the challenges (Mahone & Schneider, 2012). Balance exercises require high levels of concentration and preschool children are overloaded when the duration of assigned structured motor programs is over 30 min (Hastie et al., 2018). Moreover, Kannass et al. (2006), reported that the average duration of young children's participation in the same motor activity is approximately 3 min. Therefore, a balance programme where the duration of each station lasts more than 3 min is difficult to maintain the concentration of young children in high levels.

Action songs combine music and movement and encourage children to move by following the directions in a song or by making movements to dramatize the lyrics. Moreover, action songs offer children the opportunity for personal expression and increase their motivation for participation in physical activities (Chatzihidiroglou et al., 2018; Sumantri et al., 2021). In the pretend play environment of action songs children can make mistakes and try out new challenging activities without the anxiety for performance outcomes. Therefore, an appropriate selection of action songs with balance requirements could be an attractive approach for improving young children's postural control. The first aim of the present study was to investigate the effects of a balance programme using action songs on children's postural control.

The execution of balance activities requires muscle strength, and recent studies reported that balance training (BT) has the potential to improve strength parameters in adults (participants age up to 40 years) (Gruber et al. 2007; Zech et al. 2010) and older adults (60 years and older) (Shim et al. 2018). Regarding youth athletes (10–18-year-old soccer players), Hammami et al. (2016) reported medium correlation between balance (Stork test) and strength (standing long jump) in 16–18-year-old athletes and low correlation in 10-11-year-old athletes. Moreover, Gebel et al. (2020), reported that the correlation between balance and muscle strength in youth athletes is low and it increases with maturity. However, these studies provide only a correlational link between balance level and strength rather than a causal effect that balance training improves strength. For example, the correlation between balance and strength in athletes could be attributed to their training content.

Regarding young elementary non-athlete children (first grades of elementary school), the findings of a few studies investigating the impact of BT on the muscle strength are controversial. Wälchli et al. (2018) and Schedler et al. (2020) reported strength improvements, whereas, Granacher et al. (2011) reported no effects of BT on strength. To our knowledge, no study has investigated the effects of BT on strength performance in preschool children. It is well established that intersegmental coordination is not fully developed in preschool children (4-5 years old) and that they activate more muscle groups for postural adjustments compared to elementary school children (Assaiante et al., 2005). Specifically, preschool children increase the head-trunk stiffness in order to maintain balance control, which suggests an "en bloc" operation of the head-trunk unit. Moreover, preschool children show higher activation levels of hip and knee muscles for balance control compared to elementary school children (Assaiante et al., 2000). Therefore, the hypothesis of the present study was that balance training programmes may be effective in improving muscle strength in preschool children because the level of their muscle activation is higher compared to that of elementary school children and adolescents (Assaiante et al., 2005).

Previous research examining the effects of balance programs on children has used expensive equipment (e.g. air cushions, Bosu) and can hardly be implemented in physical education preschool settings (Wälchli et al., 2018). Moreover, typical balance training programs for older children and adults include many repetitions of the same exercises and are not appealing to preschool children. On the other hand, preschool children are involved in action songs with great enthusiasm. If a child is having fun and enjoying participation in an activity (e.g. action songs), it is more likely to repeat the balance activities and thereby increase balance control. Therefore, the aim of the present study was to investigate the effects of a BT program using action songs on postural control and muscle strength in preschool children.

Methods

Participants

According to G*Power the minimum required sample size is 34 participants (effect size f = .25, alpha = .05, and power = .80) (Faul et al., 2007). The sample of the current study comprised 51 preschool healthy children (24 boys, 27 girls). The children were recruited from 2 volunteering preschool centre and were randomly assigned to the intervention (25 children, 12 boys and 13 girls), and the control group (26 children, 12 boys and 14 girls). The eligibility criteria were a) the children had no physical condition affecting their participation in Physical Education and b) they had no diagnosed disorder of cognition (assessed by teacher questionnaire). The characteristics of the children are presented in Table 1. Informed consent was obtained from the guardians of the children, and they could withdraw from the study at any time. The study was conducted in accordance with the ethical guidelines of the local University and all procedures followed the latest version of the declaration of Helsinki.

Procedures

The intervention group followed a 6-week balance training program using action songs (two times a week, total 12 sessions, 30 min/session). Each activity in the action songs (i.e. movement steps and poses of the choreography) had three progression levels (Table 2).

The intensity of the exercises was progressively increased (a) by reducing the base of support, (b) by using dynamic arm/leg movements to perturb the centre of mass, and (c) by using different surfaces (hard surface, soft mat). Progression within the program was done with safety in mind and great attention was given to develop children's understanding of safe practices. In order to increase the motivation of the children they could perform the activities in their own way and instructions were given with analogies (Chatzopoulos et al., 2020).

The tempo of the action songs was 120-130 beats/min, which is close to the preferred tempo of preschool children and the meter simple duple time of 4/4

Table 1.
Characteristics of the children

	Intervention	Control
Age (years)	4.82±.59	4.90±.49
Weight (Kg)	20.03±3.48	20.21±3.04
Height (cm)	109.32±4.29	110.11±4.96

Table 2.
Progressive balance program

Balance exercise	Level 1 Reducing the base of support	Level 2 Displacement of the centre of mass	Level 3 Surface
Two leg Standing balance activities	Double-leg balance, upright stance (variations including wide stance, narrow stance, semitandem, and tandem).	Dynamic arm movements (e.g. rise right hand, rise left hand, rise both hands and down). Forward and backward arms sway, lateral sway (side to side). Body sways (forward/backward, sideways).	Hard surface Soft mat Half foam roll
Single-leg balance activities	On toes, heels.	Dynamic leg movements. Combinations of arm/leg movements.	

(Chatzihidiroglou et al., 2018; Chatzopoulos et al., 2018). The movement patterns included: Step touch, Step knee, Leg curl, Step kick (front, side), Plieu touch, Turn, Toe tap, Heel touch, Lunges (forward, sideways) and heel-toe walk. For example the song "Hokey Pokey": "You put the right foot in (Toe tap front), you put your right foot out (Toe tap back) and shake it all about (one leg standing and shake the other)....". The combinations of the movement patterns were structured in 32 count blocks. The program included the following action songs:

- A Puppet said to Me...
- I'm a Stork.
- Hokey Pokey.
- Do the bear walk (https://www.youtube.com/watch?v=KG3AO6lJ4BQ).
- Balance On One Foot (https://www.youtube.com/watch?v=aQ2Vco_giiE).
- Balancing Song for kids (https://www.youtube.com/watch?v=Vclldqzt_-w&list=RDVclldqzt_-w&start_radio=1).
- Hop a little jump (https://www.youtube.com/watch?v=TmXS7Rxx-Xo).

The intervention group was taught by a physical education (PE) teacher with a preschool teacher certification. During the 6-week intervention period, the control group was taught by their teacher and attended the regular PE lessons with fundamental movement skills (locomotor movements and object control with no specific balance exercises) (Kapodistria et al., 2021). All study procedures took place between 10:00–12:00 hr.

Measures

The tests were administered prior to and after the intervention in a quiet room at the preschool center. Every child was tested individually, under the same conditions. The Physical Education post graduate students responsible for administering the tests were blinded to group allocation.

Single leg stance on forceplate

The children performed one practice trial and two 10 sec trials of the one-leg stance on a force platform (KINVENT, www.k-invent.com, sampling rate 75 Hz), with a rest of 30 sec in between. The dependent variables were peak-to-peak amplitude of Center of Pressure (CoP) in the Anterior-Posterior (CoP/AP) and Medial-Lateral (CoP/ML) direction. The mean of the two trials was used for analysis. During the measurement some children could not perceive the point of the task and after a few seconds, they lost their concentration and started to move/laugh or look at the examiner. For this reason, we decided to use a second test for static balance the Flamingo test. The reliability of the test is presented in the results section and is further discussed in

Flamingo test

The children stand on a beam (5 cm high, 3 cm wide), on their preferred leg for 60 sec. Each contact of the free leg with the ground is recorded as a penalty point. The measurement is stopped at 30 points. For data analysis was used the sum of the points. The lower the number of penalty points the better the performance of the child. The reliability of the test is r≥.70 (Bös et al., 2004)

Dynamic Balance

Dynamic balance was assessed using the test "walking on balance beams" (6, 4.5, and 3 cm wide, 3 m long) (Krombholz, 2018). After a practice trial, the children started the test with the 6 cm beam. The number of steps on each beam without losing balance (feet touches the floor) was recorded. The maximum number of steps on each beam is 8, and the maximum score 24 (8 steps x 3 beams). In a pilot study with 18 preschool children the test-retest reliability was very high (*r* = .75).

Standing long jump

The muscle strength of the lower limbs was assessed using the standing long jump test. The children were instructed from a standing position to jump as far as possible. The best performance of two trials was used for statistical analysis. The test is reliable in 4-6 year old children (test-retest reliability *r* = .68), (Wick et al., 2021).

Handgrip strength

The handgrip strength test was used for upper-limb muscular strength (acquisition frequency 75 Hz, KINVENT, www.k-invent.com). The children squeezed the dynamometer at maximum effort for 3 sec. The best performance of two trials was used for analysis. The test is reliable in 4-6 year old children (ICC=.91) (Wick et al., 2021).

Statistical analyses

The data was analysed using a mixed ANOVA with the between-subject factor "group" (intervention vs. control), and the within-subject factor "time" (pre vs. post-testing). Homogeneity of variances (Levene) tests were conducted for all dependent variables. In case the assumption of sphericity was violated, the Greenhouse-Geisser correction was used. In the case of significant interaction, follow up t-tests were conducted to identify significant differences. The correlation between the variables and intra-session reliability was assessed using Pearson's r correlation coefficient. Moreover, effect sizes of ANOVA are presented as partial eta square and for t tests as Cohen's d values. All statistical analyses were conducted using SPSS version 22 (IBM Corporation). Statistical significance was set at $p \leq .05$.

Results

Mean and standard deviation of the variables are presented in Table 3.

Abbreviations: *Significant difference between the two groups ($p < .05$), Dynamic Balance (DB), Centre of Pressure (CoP) displacement in Mediolateral (CoP/ML) and Anterioposterior direction (CoP/AP).

Dynamic Balance

Mixed ANOVA demonstrated a significant interaction effect between group (intervention vs. control) and time of measurement (pre vs. post-testing) ($F_{1,49} = 4.59$, $p = .03$, $\eta p^2 = .08$). At post-testing, follow up t-tests showed that the intervention group improved significantly compared to control ($t = 2.10$, $p = .04$, $d = .59$).

One leg stance on forceplate

Center of Pressure (CoP) in the Medio/Lateral (CoP/ML)

No significant interaction effect was observed between time of measurement and group ($F_{1,49} = 3.79$, $p = .06$, $\eta_p^2 = .07$). Moreover, there were no statistically significant differences between the groups neither at pretesting ($t = 1.32$, $p = .19$, $d = .37$) nor at postintervention measurement ($t = .41$, $p = .68$, $d = .11$). The intra-session reliability was moderate ($r = .53$, $p < .001$).

Center of Pressure (CoP) in the Anterior/Posterior direction (CoP/AP).

There was no statistically significant interaction ($F_{1,49} = 3.26$, $p = .08$, $\eta_p^2 = .06$). Follow up t-tests showed no significant differences between the two groups neither at preintervention ($t = .84$, $p = .40$, $d = .23$) nor at postintervention testing ($t = .77$, $p = .44$, $d = .21$). The intra-session reliability was moderate ($r = .598$, $< .001$).

Flamingo test

Mixed ANOVA showed a significant interaction effect between group and time of measurement ($F_{1,49} = 15.96$, $p = .001$, $\eta_p^2 = .24$). At pretesting, there were no differences between the groups ($t = 1.27$, $p = .20$, $d = .35$). At the post-testing, the intervention group performed significantly better in comparison to control ($t = 2.09$, $p = .04$, $d = .60$). The intra-session reliability was high (Pearson's $r = .702$, $p < .001$).

Standing long jump distance

There was no significant interaction effect ($F_{1,49} = .69$, $p = .69$, $\eta_p^2 = .41$), and follow up t-tests showed no significant group differences neither at pretesting ($t = .94$, $p = .34$, $d = .26$) nor at postintervention testing ($t = .68$, $p = .09$, $d = .47$). The intra-session reliability was high ($r = .917$, $p < .001$).

Hand-grip strength

According to repeated measures ANOVA there was no significant interaction ($F_{1,49} = .02$, $p = .87$, $\eta_p^2 = .001$). Moreover, no significant group differences were observed neither at the beginning ($t = 1.57$, $p = .12$, $d = .44$) nor at postintervention measurement ($t = 1.60$, $p = .11$, $d = .44$). The intra-session reliability was strong ($r = .92$, $p < .001$).

Correlations

Table 4 summarizes the correlations between the variables (Pearson's r). There was no correlation between balance (dynamic or static) and strength (jump or handgrip). Jump and Handgrip showed a moderate correlation ($r = .517$).

Table 3.
Mean and SD of the variables in pre- and post-tests

	Intervention group		Control group	
	Pre	Post	Pre	Post
DB (steps)	11.56 ±8.06	17.56 ±9.52*	10.19 ±6.29	12.26 ±8.36
CoP/ML (mm)	30.16 ±7.47	26.86 ±5.26	27.61 ±6.27	27.47 ±5.21
CoP/AP (mm)	43.89 ±16.06	40.45 ±12.99	41.09 ±13.63	44.62 ±18.31
Flamingo (contacts)	20.36 ±6.64	13.82 ±6.76*	18.30 ±4.67	17.28 ±4.96
Jump (cm)	70.22 ±20.49	73.76 ±18.31	65.38 ±15.82	66.09 ±13.92
Handgrip (Kg)	5.55 ±1.44	5.73 ±1.38	4.95 ±1.25	5.17 ±1.12

Table 4.

Correlation matrix between Dynamic Balance (DB), Flamingo test, Centre of Pressure (CoP) Displacement in the Mediolateral (CoP/ML) and Anterioposterior direction (CoP/AP), jump and grip

	Flamingo	CoP/ML	CoP/AP	Jump	Grip
DB	-.545**	-.377**	-.276*	-.074	.171
Flamingo		.351*	.230	.098	.138
CoP/ML			.798**	.178	.188
CoP/AP				.117	.183
Jump					.517**

Abbreviations: Pearson's correlation *p < .05, **p < .01.

Discussion

The purpose of the present study was to investigate the effects of BT using action songs on the balance and strength of preschool children. Six weeks of BT resulted in improvements in static and dynamic balance in 4- to 6-year-old children but not in strength. Moreover, no correlations were observed between postural control and muscle strength.

Given that no study has been done to examine the impact of BT using action songs on balance and muscle strength in preschool children in a school setting, the findings of the present study have to be compared with those few studies with conventional balance training programs, i.e. with specific balance equipment and competitive activities (Wälchli et al., 2018). Shim et al. (2021), reported that 15-20 minutes of continuous movement of pedal-less bicycle riding (4 weeks duration, 3 times a week), resulted in postural control improvements in preschool children (aged 3-5-years old). The advantage of the present study compared to Shim et al. (2021) is that no particular equipment is required for the balance training program. Moreover, specific balance equipment like bicycles or other unstable training devices (e.g. air cushions, ankle disks) not only are expensive, but also for safety reasons require a ratio of one teacher to one preschool child during the training, which is impossible within a regular preschool physical education setting.

Although past literature seems to agree that BT is effective in promoting postural control in adolescents and adults, there are conflicting results regarding the effects of BT on pre-adolescent children (Granacher et al., 2011; Wälchli et al., 2018). Granacher et al. (2011), reported that 4 weeks (3 times a week) of BT using unstable support surfaces with a predefined number of sets and durations (i.e. typical BT) did not improve balance parameters of elementary school children. The authors attributed the insignificant improvements to the maturational deficits in the postural control system of prepubertal children, and speculated that prepubertal children lacked important neurophysiologic prerequisites for adaptive processes after BT. On the contrary, Wälchli et al. (2018) reported balance improvements in elementary school children after a BT with unstable devices (e.g. Pedalo) and competitive balance games. Similar balance improvements in 10-year-old children were reported by Donath et al. (2013) after slackline training and Muehlbauer et al. (2013) after inline skating (11 years old). It seems that apart from children's maturation stage, the content of the BT may greatly influence the outcome in postural control. Highly structured balance training regimens with many repetitions and rest times are not appealing to young children. Especially preschool children lose their interest in highly structured activities quickly, due to their limited attention span (Oliveira et al., 2019). Therefore, for future studies with preschool children great caution should be given to the attractiveness of the intervention content. Moreover, for future research the investigation of children's interest for balance activities would be particularly enlightening.

In the present study, balance training using action songs had no effect on children's strength. Since this study is the first that examined the effects of balance training on preschool children's muscle strength, the findings are discussed in relation to studies with cohorts of older children. A few recent studies on older children (8-12 years) showed that balance training with specific devices generated significant increases in strength (Wälchli et al., 2018). Kocjan et al. (2020) reported that unicycling riding proved to be an effective tool to develop strength in 12-year-old children (six weeks, 12 sessions, 2 training sessions per week, 45 min per-session). In addition, Muehlbauer et al. (2013) demonstrated significant strength improvements (jump height) after a 4-week inline skating program (2 times/week, 90 min. each). The divergent findings of these studies compared to our study could be attributed to the different training content of the studies. Learning to ride a unicycle (or inline skating) and jumping with it around the marks requires much more strength resources than standing on one leg and moving arms/legs as in the present study. Apparently, different balance exercises have different effects on strength. Another reason for the insignificant strength results in the present study could be the maturation stage of the cohort in combination with the duration of the intervention. It is well established that inter- and intramuscular coordination (i.e. neural parameters, that are decisive for strength improvements), is not fully developed in preschool children (Assaiante et al. 2005). Moreover, Wick et al. (2021) demonstrated muscle strength improvement (in standing long jump performance) in preschool children after 30 sessions of a strength-dominated exercise program involving countermovement jumps, lunges, single leg jumps, plank and table position. Similar improvements in muscle strength in preschool children were reported by Andrieieva et al. (2021) after a fitness program in a sport club that lasted 9 months. Perhaps due to the low maturation stage of preschool children, a longer intervention duration than the 12 sessions applied in the present study, is needed for strength improvements. Further research is necessary to elucidate the strength issue after balance training in terms of exercise content and intervention duration.

According to the results of the present study there were no correlations between strength and balance variables. To the authors' knowledge there are no other studies available that investigated the relation between balance and muscle strength variables in preschool children. Thus, the findings are discussed in relation to studies with older age groups. In contrast to our results Gafner et al. (2018) reported associations between muscle strength (hip muscle and hand-grip strength) and postural control in older participants (>65 years old). Moreover, Jeon et al. (2022) demonstrated that the muscle strength of knee extensors was positively related to the star excursion balance test (SEBT) in young adults. The controversy results between the aforementioned studies and the present study could be attributed to the different measurements applied in the studies. In the study of Jeon et al. (2022) was applied the SEBT, whereas in the present study the one-legged stance test. In the SEBT the participant is required to maintain standing with one leg while maximally reaching in several directions with the other leg. The more one participant has strong lower limb muscles and can flex the hip and knee of the standing leg the longer he/she can reach with the opposite leg. Therefore, the muscle strength of the stance-leg is important for maximum reaching distance in the SEBT and it is plausible to find correlations between muscle strength and SEBT (Filipa et al., 2010).

The lack of correlation between muscle strength and balance variables of the present study are consistent with the results of Granacher et al. (2011), who reported no association between one-legged stance and countermovement jump in adolescents participants. Moreover, McCurdy et al. (2006) demonstrated no relationship between one-legged stork stand and squat strength in young adult participants (mean age 22 ± 2 years). Our data agree with those of Granacher et al. (2011) and McCurdy et al. (2006) and extend their findings by adding an additional age group (preschool children) to the existing knowledge on adolescents and adults. Based on these results it can be argued that muscle strength and postural control are independent factors that may have to be trained with specific activities. This speculation could be reinforced by the results of Andrieieva et al (2021), who reported balance and muscle strength improvements in preschool children after a fitness program of nine months.

The single-leg stance test on the forceplate is one of the most frequently used tests in the literature for postural control evaluation (Zumbrunn et al., 2011). However, we observed that this task was not appealing to young children. They could not comprehend the point of the task, and after a few seconds they lost their concentration and started to play (e.g. hopping, looking at the evaluator, laughing). The medium reliability of CoP/ML and CoP/AM (r = .530 and r = .598 respectively) could be attributed to the children's lack of interest in performing the task. On the other hand, the reliability coefficient in the flamingo test was very high (r = .702). Based on our experience, our impression is that the flamingo test was much more interesting than the single-leg stance test. Therefore, for future studies with young children, we suggest the implementation of attractive tests where children can evaluate their own performance.

Limitation

A limitation of the present study relates to the concentration of young children during the measurements. Although the tests were conducted in a quiet room and were presented like games, we cannot be sure about the level of children's concentration and that they really gave their best.

Conclusion

The results of the present study demonstrated that a short-term balance training program (12 lessons) using action songs produces significant balance improvements in preschool children. However, it seems that this short period is not sufficient to induce significant muscle strength improvements. Moreover, there were no correlations between balance and muscle strength variables in preschool children. This finding could be an indication that these variables are independent of each other and maybe they should be trained with complementary activities in preschool children. Based on the findings, the implementation of action songs with balance requirements in the regular preschool curriculum is a safe and feasible training modality for the improvement of postural control of young children.

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