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Effects of a Strength-Dominated Exercise Program on Physical Fitness and Cognitive Performance in Preschool Children

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Abstract

Wick, K, Kriemler, S, and Granacher, U. Effects of a strength-dominated exercise program on physical fitness and cognitive performance in preschool children. *J Strength Cond Res* 35(4): 983–990, 2021—Childhood is characterized by high neuroplasticity that affords qualitative rather than quantitative components of physical activity to maximize the potential to sufficiently develop motor skills and foster long-term engagement in regular physical activity. This study examined the effects of an integrative strength-dominated exercise program on measures of physical fitness and cognitive performance in preschool children. Children aged 4–6 years from 3 kindergartens were randomized into an intervention (INT) group ($n = 32$) or a control group ($n = 22$). The 10-week intervention period was conducted 3 times per week (each session lasted 30 minutes) and included exercises for the promotion of muscle strength and power, coordination, and balance. Pre and post training, tests were conducted for the assessment of muscle strength (i.e., handgrip strength), muscle power (i.e., standing long jump), balance (i.e., timed single-leg stand), coordination (hopping on right/left leg), and attentional span (i.e., "Konzentrations-Handlungsverfahren für Vorschulkinder" [concentration-action procedure for preschoolers]). Results from 2 × 2 repeated-measures analysis of covariance revealed a significant ($p \leq 0.05$) and near significant ($p = 0.051$) group × time interaction for the standing long jump test and the Konzentrations-Handlungsverfahren. Post hoc tests showed significant pre-post changes for the INT ($p < 0.001$; $d = 1.53$) but not the CON ($p = 0.72$; $d = 0.83$). Our results indicate that a 10-week strength-dominated exercise program increased jump performance with a concomitant trend toward improvements in attentional capacity of preschool children. Thus, we recommend implementing this type of exercise program for preschoolers.

Key Words: motor skills, cognitive skills, attention, kindergarten, structured physical activity program

Introduction

The Centers for Disease Control and Prevention and the World Health Organization (WHO) recommend that children aged 3–5 years should be physically active throughout the day for at least 60 and up to 180 minutes to promote growth and development (4,43). Early promotion of health-enhancing physical activity and fitness in kindergarten has thus been subject to many research studies over the past years (13,30). These studies confirm that many children do not follow these guidelines. Finger et al. (12) reported that less than half of the participating kindergarten children aged 3–6 years (42.5% girls; 48.9% boys) met the WHO physical activity recommendations of 60 minutes per day. As a consequence, low physical fitness levels and negative secular trends have been reported for various components of physical fitness (38) and for overweight and obesity (28). More specifically, a study including English children aged 10–10.9 years showed a significant decline for measures of muscle strength over a 10-year period ranging between −6.3% for handgrip strength and −27.0% for sit-up performance (5). In addition, Tomkinson and Olds (40) reported the global picture on secular trends in aerobic fitness. These authors showed a significant decline of −0.36% per year for aerobic fitness in youth.

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Journal of Strength and Conditioning Research 35(4)/983–990

Using an elegant description of the phenomenon, Myer et al. (25) recently introduced the term "exercise-deficit disorder" if children do not adhere to WHO physical activity guidelines (i.e., less than 60 minutes per day). The long-term negative consequences of the exercise-deficit disorder are deficits in motor skill competence, and movement confidence, sedentary behavior, and an increased risk of suffering from adverse health effects (25,34,37). Given that physical activity behavior is a rather robust phenomenon that tracks from later childhood to adulthood (16), it is important to implement intervention programs to promote physical activity and fitness at an early age when habits are still formed. Although WHO (43) and Centers for Disease Control and Prevention (4) guidelines provide quantitative recommendations on daily physical activity, these guidelines do not take motor skill learning into consideration. Childhood is characterized by high neuroplasticity that affords adequate exercise stimuli and professional instruction as well as feedback to promote and consolidate motor skill learning. Experts have postulated that integrative exercise programs are needed during childhood that include motor-skill enriched and intermittent activities such as core strength and stability, coordination and agility, balance, muscular fitness (i.e., muscle strength, muscle power, local muscular endurance), and fundamental movement skills (27). A broad foundation of physical fitness, especially muscular fitness, lays the fundamental development for complex and sport-specific skills and movement patterns (8). Thus, exercise programs should predominantly focus on the qualitative rather than the quantitative component of physical activity (27) to maximize a child's potential to sufficiently develop motor skills and foster the long-term engagement in regular physical activity (22,24).

Integrative strength-dominated exercise programs have proven to be effective in increasing muscle strength (9,10) and cognitive skills in primary school-aged children (24,26,27). To the authors' knowledge, such a study does not exist with preschoolers. However, there is evidence that programs promoting physical fitness and motor skills are successful even in kindergarten children (29,35,43). In addition, there is debate on the appropriate timing of initiating strength training with children (21,22). It is unresolved whether a strength-dominated exercise program in the long term is even more effective if it is started already at preschool age. Lloyd and Oliver (21) emphasized the importance of promoting motor skills and physical fitness (e.g., speed, muscle strength) at all developmental stages starting during early childhood.

We therefore performed a strength-dominated kindergarten-based exercise program aiming to increase physical fitness and cognitive performance in healthy children aged 4–6 years. With references to studies conducted in school-aged children (10,27), we hypothesized that the applied intervention program is more effective to enhance primary (e.g., muscle strength of upper body, muscle power of lower body) and secondary (e.g., static balance, coordination, attention) outcomes compared with a regular physical activity promoting kindergarten curriculum. Our study hypothesis is based on the assumption that a strength-dominated exercise program is particularly effective if started during the early developmental stages (i.e., kindergarten) (8) to lay a foundation for motor skill learning. This may again positively affect physical activity behavior during the later stages of life (22,35).

Methods

Experimental Approach to the Problem

This study was conducted between August and November 2018 using a quasi-experimental design (a 2-group repeated-measures design) to evaluate the effects of a 10-week strength-dominated kindergarten-based exercise program on measures of physical fitness and cognitive performance in preschool children. A convenience sample was selected that includes 3 kindergartens located in east Germany (i.e., Federal State of Brandenburg). Selection criteria were similarity in size, available resources (i.e., staff, play equipment), and funding body (i.e., run by public institutions). The participating kindergartens were cluster randomized into either an intervention (INT) or a control (CON) group. Before the start of the study, all 3 kindergartens offered similar physical activity or sport programs during daily care. Pre- and posttests were carried out at the same time of the day by trained assessors (sport scientists, bachelor and master students). The participating children were familiarized with all test procedures before testing. After completion of the intervention period, children from the CON received the same supervised intervention program.

Subjects

An a priori power analysis with reference to the study of Faigenbaum et al. (10) was computed using G x Power (Version 3.1.9.2; University of Kiel, Kiel, Germany) and the F test family (11) with a desired Bonferroni adjusted significance level of 0.025 (type I error) for 2 primary outcomes, and a statistical power of 0.80 (type II error rate) for the effects of a strength-dominated exercise program on components of physical fitness. The analysis revealed that 41 subjects would be needed to find medium-sized group × time interaction for physical fitness components. We expected a 15% dropout rate over the course of the study because of a loss of motivation, illnesses, or injuries.

Fifty-four children aged 4–6 years with a mean age of 4.5 ± 0.7 years (i.e., 48–74 months, mean 59.5 ± 7.0 months; mean ± *SD*) were enrolled in the present study. Exclusion criteria were trisomy and chronic diseases, such as respiratory tract diseases or diabetes. In addition, subjects were excluded if orthopedic disorders (e.g., acute, overuse injuries) were diagnosed 6 months before the start of the study. Kindergartens were cluster randomized into either an intervention (INT, $n = 32$) or a control (CON, $n = 22$) group. Baseline anthropometric data are provided in Table 1. Before the start of the study and any form of data collection, parents or legal representatives received written information on the aims, the procedures, and the risks and benefits of the study and data collection. Written informed consent was obtained from all parents or legal representatives as all participating children were aged <18 years and also from all the subjects. This study was approved by the Ethics Research Committee of the University of Potsdam, Germany (submission No. 34/2018). The study was conducted in accordance with the latest version of the Declaration of Helsinki.

Procedures

Experimental Groups. The strength-dominated kindergarten-based exercise program was developed by a trained exercise scientist in close collaboration with experienced kindergarten teachers. The intervention program was performed in the kindergartens and was carried out by the own kindergarten staff. Before the start of the intervention, 2 workshops were provided for the participating kindergarten teachers. Each workshop lasted 90 minutes and contained information about the overall aim of the program, the contents of the 30 sessions including detailed descriptions of all exercises. Furthermore, questions with regards to movement competency, training-load (volume and intensity), and equipment were answered. Over the 10-week training period, 3 exercise sessions were conducted per week (Monday, Wednesday, Friday). Because of a limited attentional span of preschoolers, each session lasted 30 minutes (33) and was offered in the mornings. Each week, the intervention program focused on the promotion of different aspects of physical fitness mainly to improve not only muscle strength and muscle power but also balance, coordination, and motor skills. Balance exercises included walking on tiptoes, standing on one leg (eyes opened/closed), balancing on ropes or benches. In addition, coordination exercises, such as handling (i.e., throwing, catching, kicking,

Table 1
Baseline anthropometric characteristics.*

Variables	INT ($n = 32$) Mean ± *SD*	CON ($n = 22$) Mean ± *SD*	*p* (Cohen's *d*) Between-group differences
Gender (m/f)	16/16	12/10	
Age (y)	4.6 ± 0.8	4.5 ± 0.5	0.455 (0.15)
Age (mo)	60.1 ± 8.1	58.6 ± 5.2	0.446 (0.22)
Body height (cm)	112.4 ± 5.4	110.0 ± 5.6	0.116 (0.44)
Body mass (kg)	20.2 ± 2.7	18.5 ± 2.1	0.015 (0.70)
BMI ($kg \cdot m-^2$)	16.0 ± 1.4	15.2 ± 1.0	0.043 (0.66)

*INT = intervention group; CON = control group; BMI = body mass index.

dribbling) objects (i.e., balloon, ball, stick, sheet, hoop), moving like animals, moving to the music, were offered using different forms of small games. Nevertheless, strength exercises constituted the main part. Furthermore, basic elements from gymnastics were selected to complete the strength-dominated program. A description of the strength and gymnastic exercises are provided in Table 2. To ensure an adequate level of intensity during each session, numbers of repetitions or time under tension were provided for each exercise. The degree of difficulty and intensity was progressively increased according to the individual progress of the children. The structure of each session was basically the same. It started with an 8-minute warm-up (i.e., small games), a 12- to 15-minute main session (e.g., muscle strengthening exercises), and a 5- to 10-minute cooldown (i.e., relaxation and social games). All children of the INT conducted the same intervention contents of the program. The waiting CON continued their usual kindergarten curriculum, which included 1 exercise session per week (30–45 minutes) and at least 1 hour of free play per day. Members of the kindergarten staff were asked not to increase physical activity levels of the waiting CON over the course of the study. After the intervention period, the CON received the same intervention program as the intervention children.

Testing Procedures. Measurements were performed at baseline and after the 10-week intervention period. All tests were conducted at the kindergartens between 8.30 AM and noon by the same trained assessors who were blinded to group allocation. Test time and sequence were similar between pre- and posttests. Physical fitness of the participating children was tested in specific exercise rooms located within the kindergartens. Anthropometric and cognitive testing was realized in quiet rooms in the respective kindergartens. Every child was tested individually. The entire test program lasted between 20 and 30 minutes per child. All primary and secondary outcomes were tested within a 2-week period. All participating children received standardized verbal instructions and a visual demonstration regarding test procedures. Thereafter, each child performed 1 familiarization trial before the test trial.

Anthropometrics. Body height was determined to the nearest 0.5 cm, and body mass was measured without shoes and in light indoor clothing using an electronic scale to the nearest 0.1 kg (Tanita BC-730). Body mass index (BMI) was calculated using the standardized equation (mass/height [in kilograms per square meter]).

Primary Outcomes. In accordance with our strength-dominated kindergarten-based exercise program, we defined muscle strength of the upper body and muscle power of the lower body operationalized through the handgrip strength test and the standing long jump test as primary outcomes. Thereby, muscle strength of the upper body was evaluated applying the handgrip strength test using a hand dynamometer (Jamar plus digital with LCD display). Before the performance of the handgrip strength test, the diagonal length (span length) of the hand was assessed in centimeters (from the tip of the little finger/pinky to the tip of the thumb) of the participating children. Of note, the Jamar handheld dynamometer has 5 notches (levels). According to the span length of a child's hand, we used level 1 (girls $<$14 cm; boys $<$10.8 cm) or level 2 (girls 14–19.1 cm; boys 10.8–20.1 cm) to enable an individualized biomechanical position for the handgrip strength test. Thereafter, subjects were placed on a chair with shoulders relaxed and elbows flexed at 90° and were required to press the dynamometer continuously at maximum effort for at least 3–4 seconds (22). The test was performed twice with the dominant hand, the best trial was used for further analysis. The dominant hand was determined by reports of the kindergarten teachers (36) as the preferred hand when performing fine and gross motor tasks. Muscle strength of the upper body was measured to the nearest 0.1 kg. The handgrip strength test proved to be reliable (intraclass correlation coefficient [ICC] of 0.91 long-term 29 days) in children aged 4–6 years (22). Additionally, the National Institutes of Health has tested feasibility, reliability, and validity of fitness tests in children aged 3 years and older and recommended to conduct a handgrip strength test using a hand dynamometer to assess muscle strength of the upper body (32). The standing long jump test was used to assess muscle power and coordination of the lower limbs. For this purpose, children started from a parallel standing position with arms hanging loose to the side and were instructed to jump with both feet as far as possible in a horizontal direction with the aim of landing on both feet (31). The test was performed twice, and the

Table 2

Strength exercises included in the strength-dominated kindergarten program.*

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
Strength exercises										
Countermovement jumps	1 × 5	n/a	1 × 10	2 × 10	n/a	2 × 15	2 × 15 BW	2 × 20	n/a	2 × 25
Countermovement jumps with rotation	n/c	n/a	1 × 10	2 × 10	n/a	2 × 15	n/a	n/a	n/a	n/a
Lunges	1 × 8/leg	n/a	n/a	n/a	n/a	n/a	n/a	2 × 8/leg	n/a	n/a
Ankle hops	n/a	n/a	n/a	1 × 10	n/a	n/a	2 × 10	2 × 15	n/a	n/a
Lateral jumps	n/a	n/a	n/a	1 × 10	n/a	n/a	2 × 10	n/a	n/a	n/a
Single leg jumps	n/a	n/a	n/a	2 × 5/leg	n/a	n/a	n/a	n/a	n/a	2 × 10/leg
Squats with partner	n/a	n/a	n/a	2 × 5	n/a	n/a	n/a	2 × 10	n/a	n/a
Quadruped walk	1 × 15 s	n/a	n/a	n/a	2 × 15 s	n/a	n/a	n/a	2 × 20 s	n/a
Front plank	n/a	2 × 8 s	n/a	n/a	2 × 15 s	n/a	n/a	2 × 20 s	2 × 30 s	2 × 30 s legs open/close
Bridging	n/a	2 × 8 s	n/a	n/a	n/a	n/a	n/a	2 × 10 s	3 × 10 s	n/a
Stretch seat†	3 × 3 s	3 × 5 s	3 × 10 s	n/a	3 × 12 s	3 × 15 s	4 × 15 s	n/a	n/a	n/a
Straddle seat†	3 × 3 s	3 × 5 s	3 × 10 s	n/a	3 × 12 s	3 × 15 s	4 × 15 s	n/a	5 × 15 s	5 × 15 s
PP lifting arms and legs†	n/a	2 × 5 s	2 × 10 s	n/a	2 × 12 s	2 × 15 s	3 × 15 s	n/a	4 × 15 s	5 × 15 s
SP lifting arms and legs†	n/a	2 × 5 s	2 × 10 s	n/a	2 × 12 s	2 × 15 s	3 × 15 s	n/a	4 × 15 s	5 × 15 s
Table position†	n/a	n/a	n/a	n/a	n/a	2 × 10 s	n/a	n/a	3 × 10 s	4 × 10 s

*BW = backward; n/a = not applicable—no exercises were offered during that week; PP = prone position; SP = supine position.
†Basic elements from gymnastics.

best value of the 2 trials was used for further analysis. The jumping distance was documented using a measuring tape to the nearest 1.0 cm. If children lost balance during landing and fell backward, the trial was considered invalid and children had to try again. The standing long jump test has proven to be reliable (test-retest reliability $r = 0.68$ long term 8 months) in 4 year olds (17).

Secondary Outcomes. Static balance was assessed barefoot and with eyes opened using the single-leg stance test (31). Before testing, the dominant leg was determined using the ball kick test. The kicking leg was defined as the dominant leg (1). Thereafter, children had to stand in straight position holding the non-dominant leg in front with hip and knee joints both flexed at 90°. The stopwatch was started as soon as one leg was lifted and stopped when the child touched the floor with the nondominant leg or started jumping to achieve stability. If children were not able to pass 2 seconds in the first trial, they had to try again (14). After 2 unsuccessful trials up to 2 seconds, the test was considered as not possible because the child was not capable of performing the single-leg stand. For test results >2 seconds, time was measured by stopwatch to the nearest one-tenth of a second up to a maximum of 30 seconds. The single-leg stance test is a reliable test-retest reliability $k_w = 0.45$ (14) and valid (31) test to analyze static balance in early childhood. Moreover, the National Institutes of Health has recommended the single-leg stance test for the assessment of static balance in children aged 3 years and older (32). Secondary outcomes also included coordination operationalized through the hopping on right/left leg test (17). Children were instructed to hop on one leg as often as possible to a maximum of 20 hops. The test was performed alternately once with each leg. A hop is considered valid when takeoff and landing was achieved on the same foot and at least one time. The one-leg hopping test proved to be reliable (right $r = 0.84$ left $r = 0.82$) in 4- to 6-year-old children (17). Attention as one domain of cognition was applied with the Konzentrations-Handlungsverfahren für Vorschulkinder (concentration-action procedure for preschoolers) (KHV-VK) (7). Thereby, children had to sort 40 cards with familiar images into 4 different boxes within 10 minutes according to no, single, or double key images. Sorting time and error quote analyzed quantitative and qualitative dimensions of the KHV-VK on attention. The test has been validated in children aged 4–6 years and proved to be sufficiently valid as a developmental diagnostic procedure. Test-retest reliability was $r = 0.88$ for sorting time and $r = 0.67$ for number of correct cards (7).

Statistical Analyses

All analyses were performed using SPSS version 25.0 (IBM SPSS Statistics, Armonk, NY). Normal distribution of data was tested and confirmed using the Shapiro-Wilk test. Accordingly, data are presented as group mean values and *SD*s. Subsequently, a *t*-test for independent samples was calculated to determine significant baseline between-group differences. If baseline between-group differences were detected, the respective baseline values were included as covariates in the statistical model to adjust for baseline differences. The effects of a strength-dominated exercise program on variables of physical fitness and cognitive performance were analyzed using a separate 2 ("group": INT vs. CON) × 2 ("time": pre vs. post test) repeated-measures analysis of covariance (ANCOVA). In case of statistically significant group × time interactions, group-specific post hoc tests were calculated to identify the comparisons that were statistically significant. Furthermore, to estimate effect sizes, partial eta-squared were taken from ANCOVA output and converted to Cohen's *d*. Effect sizes were used to ascertain if an effect was practically meaningful. According to Cohen (6), effect size of ≤ 0.19 indicates trivial, $0.20 \leq d \leq 0.49$ small, $0.50 \leq d \leq 0.79$ medium, or $d \geq 0.80$ large effects. The significance level was set at $p < 0.025$ for the primary outcomes. Moreover, test-retest reliability was assessed for primary and secondary outcome measures using ICCs. For this purpose, data from pre-post testing of the CON was used (39).

Results

All children of the INT received the intervention contents as allocated and completed the study according to the methodology described above. None of the participating children reported any test- or training-related injuries over the study period. The attendance rate of INT was 83 ± 13%. At baseline, significant between-group differences were found for body mass ($p < 0.05$; $d = 0.70$) and BMI ($p < 0.05$; $d = 0.66$). Children from INT compared with CON were slightly heavier (8.4%) and had a higher BMI (5.0%). Differences were also found for the single-leg stance test ($p < 0.05$; $d = -0.73$) and the standing long jump test ($p < 0.005$; $d = -0.89$) in favor of the CON. No significant between-group baseline differences were found for age or sex. Inferential statistics for primary and secondary outcomes are reported in Table 3. Table 4 illustrates ICCs for all primary and secondary outcome measures.

Primary Outcomes

Our analyses showed a significant group × time interaction ($p < 0.001$; $d = 1.09$) for the standing long jump test. Post hoc analysis revealed significant pre-post changes for the INT ($p < 0.001$; $d = 1.53$) but not the CON ($p = 0.72$; $d = 0.83$) as shown in Figure 1. No statistically significant interaction effect was found for handgrip strength.

Secondary Outcomes

No statistically significant interaction effects were observed for the single-leg stance and the hopping on right/left leg test. A near significant group × time interaction ($p = 0.051$; $d = 0.58$) was found for attentional span (sorting time, quantitative dimension KHV-VK), with the post hoc analysis revealing an improvement in the INT with 22.2% ($p < 0.001$; $d = 1.69$) compared with no significant change in the CON ($p = 0.27$; $d = 0.52$) as presented in Figure 2. No significant interaction was observed for the qualitative dimension (number of correct cards) of the KHV-VK.

Discussion

This is the first study that examined the effects of a strength-dominated kindergarten-based exercise program on different components of physical fitness and cognitive performance in healthy children aged 4–6 years. The main findings showed that a 10-week strength-dominated exercise program resulted in larger gains in jump performance and concomitant trends toward improved attentional span in preschool children compared with active control children who followed the regular kindergarten curriculum.

In accordance with the study hypothesis, our findings indicate that the strength-dominated exercise program induced a significant large effect ($d = 1.09$) for the primary outcome muscle power of the lower body and a near to significant medium effect ($d = 0.58$) for the secondary outcome attention (quantitative dimension of the KHV-

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Table 3

Main and interaction effects of the strength-dominated exercise program for primary and secondary outcome measures.*

	INT			CON			p (Cohen's d)		
Variables	Pre Mean ± SD (95% CI)	Post Mean ± SD (95% CI)	Delta (%)	Pre Mean ± SD (95% CI)	Post Mean ± SD (95% CI)	Delta (%)	Main effect: time	Main effect: group	Interaction: group × time
Primary outcomes									
Standing long jump (cm)†	73.8 ± 15.6 (68.1–79.5)	85.9 ± 16.1 (80.0–91.7)	19.3	93.0 ± 17.2 (86.0–99.7)	87.8 ± 16.3 (80.8–94.9)	−5.6	0.077 (0.51)	0.014 (0.72)	0.001 (1.18)‡
Handgrip strength (kg)†	7.3 ± 1.6 (6.8–7.9)	8.0 ± 1.7 (7.4–8.6)	9.6	7.5 ± 1.6 (6.8–8.2)	8.5 ± 1.7 (7.8–9.2)	13.3	0.001 (1.04)	0.403 (0.24)	0.458 (0.21)
Secondary outcomes									
Fitness									
Single-leg stand (max. 30 s)†	10.1 ± 8.1 (7.2–13.0)	13.7 ± 9.1 (10.5–17.0)	35.6	17.2 ± 8.2 (13.7–20.7)	19.1 ± 9.2 (15.1–23.0)	11.0	0.031 (0.62)	0.005 (0.83)	0.481 (0.20)
Hopping on right leg (max. 20)†	11.6 ± 7.0 (9.0–14.2)	12.4 ± 6.9 (9.9–14.9)	6.9	16.7 ± 7.1 (13.7–19.8)	18.1 ± 7.0 (15.1–21.1)	8.4	0.143 (0.42)	0.006 (0.82)	0.699 (0.11)
Hopping on left leg (max. 20)†	12.3 ± 7.6 (9.5–15.2)	13.8 ± 7.1 (11.2–16.5)	12.2	14.3 ± 7.7 (11.0–17.6)	17.4 ± 7.2 (14.3–20.5)	21.7	0.004 (0.87)	0.175 (0.40)	0.337 (0.28)
Cognition									
Sorting time KHV-VK (in min)	7.2 ± 2.0 (6.5–7.9)	5.6 ± 1.4 (5.0–6.1)	22.2	6.4 ± 1.7 (5.5–7.2)	5.9 ± 1.6 (5.2–6.5)	7.8	0.001 (1.09)	0.484 (0.20)	0.051 (0.58)‡
Correct cards KHV-VK (number)	31.9 ± 5.3 (29.4–34.3)	33.0 ± 5.7 (30.8–35.1)	3.4	31.5 ± 8.3 (28.4–34.5)	32.9 ± 6.0 (30.3–35.5)	4.4	0.187 (0.39)	0.871 (0.06)	0.840 (0.06)

*CI = confidence interval; INT = intervention group; CON = control group; KHV-VK = Konzentrations-Handlungsverfahren für Vorschulkinder.

†Adjusted pre- and posttest values of physical fitness outcomes, adjusted for body mass.

‡Post hoc tests were calculated.

Table 4

Intraclass correlation coefficients for all included measures.*

Measures	ICC
Primary outcomes	
Handgrip strength test	0.829
Standing long jump test	0.888
Secondary outcomes	
Single-leg balance test	0.755
HRL	0.597
HLL	0.876
Sorting time KHV-VK	0.428
Correct cards KHV-VK	0.727

*ICC = intraclass correlation coefficient; HRL = hopping on right leg test; HLL = hopping on left leg test; KHV-VK = Konzentrations-Handlungsverfahren für Vorschulkinder.

VK). It can be assumed that a strength-dominated exercise program 3 times per week over a 10-week period seems to be successful to develop jump performance and tend to improve attentional capacity in healthy preschool children.

Our findings with regards to the standing long jump are in accordance with the literature. Behringer et al. (2) reported similar results in their meta-analysis, demonstrating significant improvements in jump performance after structured strength training programs for school-aged children. In contrast, studies from Faigenbaum et al. (9,10) found no treatment effects for the standing long jump in primary school children as response to an 8-week training period. The authors assumed that the content of the strength program focusing on truncal muscular power (i.e., abdominal, hip, and lower back) and the effective traditional physical education lessons of the CON may have been the reason for a lack of treatment effects (10). For the primary outcome handgrip strength, we could not find a significant intervention effect, although integrative exercise programs have been shown to improve muscle strength of the upper body measured with the push-up test in primary school children (10). It can be anticipated that on the one hand, the contents and the design of the present intervention program did not affect muscle strength of the upper body, and on the other hand, the assessment method using a hand dynamometer did not display possible interaction effects.

Our findings for the single-leg stance test (main time effect $p < 0.05$; $d = 1.09$; no significant interaction effect $p = 0.481$; $d = 0.20$) are in contrast to a study conducted by Kordi et al. (15) who found significant interaction effects for static balance after a 12-week strength training program in primary school children with developmental coordination disorders. For the hopping on right/left leg test, we cannot compare our results to other studies because there is no study available that applied the hopping on right/left leg test. Of note, Krombholz (18) obtained a general motor skill score including hopping on the right/left leg in his intervention study. He reported that children of the INT following a physical activity enhancing program over 20 months significantly improved their motor performance (general motor skill score) compared with the CON (18). Our null results for the single-leg stance and hopping on one leg test could be further explained by the small sample size and the large variance in children's performance. Additionally, the content and design of our intervention program, targeting muscle strength (of upper and lower body), core strength, and overall coordination may not have affected static balance skills and jumping coordination abilities such as hopping on one leg in kindergarten children. For the secondary outcome cognitive performance, children of the INT tended to improve their attentional span by becoming faster in sorting 40 cards measured by the KHV-VK compared with the CON. Our findings are in line with preliminary evidence published

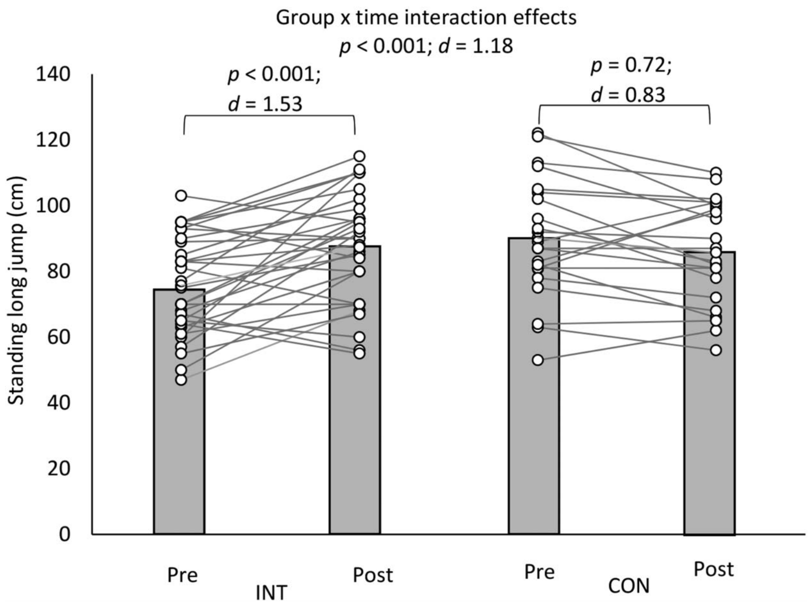

Figure 1. Effects of a strength-dominated exercise program on standing long jump performance in children aged 4–6 years. Data are presented in group means (grey bar) and individual scores. CON, control group; INT, intervention group.

in studies and reviews for school-aged children (26,27) showing that higher levels of physical activity and physical fitness foster attention and concentration. Moreover, our data imply that already kindergarten children appear to respond to the structured weekly strength-dominated activity bouts by improving their attentional capacity compared with an active CON that performed regular physical activity during kindergarten.

However, following the 10-week study period, observable overall time effects for the handgrip strength test, the single-leg stance test, and the hopping on left leg test can be reported (Table 4), indicating that the unspecific physical activity sessions 30–45 minutes once a week of the CON and also biological maturation appear to have occurred in concert. Besides, biological maturation, growth, and genetic factors (24) also play a major role especially in childhood when biological changes occur consistently and fast. Nevertheless, the kindergarten age seems to be an important time to target muscle strength in an age-appropriate way. Accordingly, children should perform muscle strengthening exercises in kindergarten because sufficient strength levels are needed for motor skill learning (8). This fact is underlined by a work of Lloyd and Oliver (21) showing that the long-term development of motor skills, physical fitness components (i.e., muscle strength), and especially their trainability is

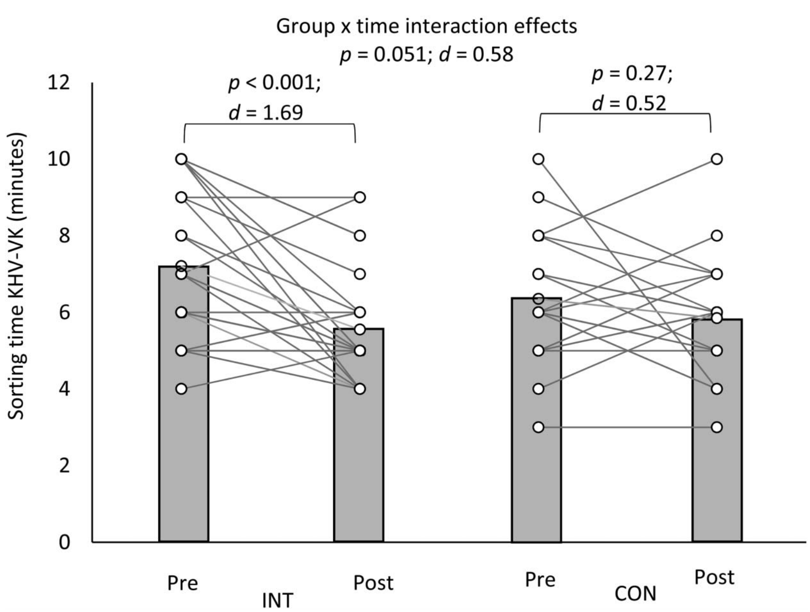

Figure 2. Effects of a strength-dominated exercise program on attentional span (sorting time of the KHV-VK) in children aged 4–6 years. Data are presented as group means (grey bar) and individual values. CON, control group; KHV-VK, Konzentrations-Handlungsverfahren für Vorschulkinder, INT, intervention group.

possible at all age stages starting with early childhood. The main reasons for these arguments are that motor and cognitive capabilities are highly "plastic" and responsive to adequate exercise stimuli (27) and professional instruction (41) during that age period. Moreover, a broad foundation of physical fitness components, such as muscle strength, lays the fundamental development for complex and sport-specific skills and movement patterns (8).

This study has some limitations that warrant discussion. First, our study involved a relatively small (N = 54), and none-representative sample as the participating children were selected from 3 kindergartens located in east Germany (i.e., Federal State of Brandenburg). Second, we observed baseline differences between the intervention and control group for body mass, BMI, the standing long jump test, and the single-leg stance test. To adjust for these baseline between-group differences, we computed an ANCOVA and not an analysis of variance. Third, selection bias may have occurred in terms of the participating kindergartens which already had programs for the promotion for physical activity and fitness. Finally, we cannot rule out that the children's parents may have increased the physical activity behavior of their children over the course of the study. We expect though that this potential effect was the same in INT and CON, which is why it should not have caused bias.

Practical Applications

Findings from this study indicate that a strength-dominated kindergarten-based exercise program resulted in significant and near to significant improvements in jump performance and attentional capacity in preschool children. With reference of the findings of this study, kindergarten teachers are advised to implement muscle strengthening exercises in the regular kindergarten physical activity curriculum, to build a solid foundation of muscular fitness (i.e., muscle strength, muscle power, local muscular endurance), which is a prerequisite for motor skill development.

Moreover, the program was instructed by qualified kindergarten teachers who were trained before the intervention period to provide appropriate delivery of intervention contents with professional instruction, feedback, and interaction. It is important to involve members of the kindergarten staff in the preparation and implementation of physical activity programs because this may lead to intrinsic motivation, sustainable long-term effects, and sharpen the awareness of the topic (42).

The kindergarten is a well-suited setting to promote physical activity and fitness because children can be reached irrespective of their family's socioeconomic background (44). The participating children had the opportunity to engage in 3 weekly physical activity sessions, learn new movement skills, and improve their physical fitness in a joyful and age-appropriate environment (42). As an additional finding that was not measured objectively, the participating kindergarten staff reported that the intervention also resulted in improved psychosocial behavior, particularly in younger (4 years) children.

The applied intervention program proved to be age appropriate, safe, joyful, and feasible with no injuries occurring during the intervention period. Nevertheless, more research is needed to examine the effects of resistance training in kindergarten children on measures of physical fitness and cognitive performance using larger samples.

Acknowledgments

The authors thank the children for participating in this study and the kindergarten directors and teachers for supporting this study. The authors declare no conflicts of interest and do not have any financial disclosures.

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