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Effects of Integrative Neuromuscular Training on Fitness Performance in Children

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The aim of this study was to evaluate the effects of integrative neuromuscular training (INT) during physical education (PE) class on selected measures of health- and skill-related fitness in children. Forty children from two 2nd grade PE classes were cluster randomized into either an INT group ($n = 21$) or a control (CON) group ($n = 19$). INT was performed 2×/wk during the first ~15 min of each PE class and consisted of body weight exercises. INT and CON participants were assessed for health- and skill-related fitness before and after 8 wks of PE with or without INT, respectively. A significant interaction of group by time was observed in INT participants with improvements noted in push-ups, curl-ups, long jump, single leg hop, and 0.5 mile (0.8 km) run performance ($p < .05$). These data indicate that INT is an effective and time-efficient addition to PE as evidenced by improvements in health- and skill-related fitness measures in children.

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Physical activity is associated with numerous physiological and psychosocial benefits and has the potential to improve the quality of life for children and adolescents (23,31). Yet despite these potential health benefits, recent studies have shown a decline in regular physical activity that appears to begin during early childhood (4,30). Clearly, efforts are needed to provide children of all abilities and socioeconomic strata with an opportunity to participate in meaningful physical activity interventions. School-based physical education (PE) programs are recognized as an ideal setting to develop fundamental movement skills (FMS; e.g., locomotor, object control and stability skills), enhance physical fitness and promote lifetime physical activity (12,21). FMS proficiency developed during childhood appears to predict subsequent time spent in both moderate-to-vigorous physical activity and organized activity during adolescence (3). Thus, a specific mix of activities may be needed for children to become motorically competent and physically skillful.

While the need to promote physical activity in school-age youth is apparent, a recent systematic review examining FMS in youth concluded that school- and community-based interventions are needed to develop FMS, and that such skills should be taught during preschool and primary school when children are at an optimal age to learn locomotor, object control and stability skills (15). By modifying existing PE lessons, significant improvements in FMS mastery can be achieved (32). We reported that plyometrics and resistance training with medicine balls can be effective methods of conditioning for school age youth during PE (6,7). However, we have observed some instances when a child cannot catch a ball proficiently or has difficulty decelerating or changing direction during FMS activities (6). The lack of success can result in frustration or embarrassment, and the child may withdraw from the activity or participate with less interest and vigor than their more advanced peers (28). These examples highlight the importance of addressing individual needs and providing children with developmentally appropriate and meaningful tasks during PE (11).

Over the past decade, resistance training has proven to be safe, effective and beneficial for children provided that education and instruction by qualified professionals are available (8). More recently, integrative neuromuscular training (INT) which includes general and specific physical activities that are intentionally designed to enhance both health- (e.g., muscular strength and cardiorespiratory endurance) and skill-related (e.g., agility and balance) components of physical fitness has been recognized as an innovative approach for school-age youth (19). We are not aware of any published studies that have tested empirically an INT intervention that addressed common barriers to implementing school-based programs (e.g., lack of resources and insufficient time) and was generalizable to primary school PE curricula. The objective of the current study was therefore to determine the effects of INT implemented during PE in a public primary school on health- and skill-related fitness measures in children.

Materials and Methods

Subjects

Forty children from two different 2nd grade PE classes in a public school participated in this study (Table 1). Classes were cluster randomized into either an INT group or a control (CON) group. One female in the CON group who was absent

Table 1 Anthropometric and Demographic Characteristics of the Study Participants

Characteristic	INT (*n* = 21)	CON (*n* = 19)
Age (y)	7.5 ± 0.3	7.6 ± 0.3
Height (cm)	122.1 ± 6.7	127.2 ± 5.0 *
Body mass (kg)	30.8 ± 8.6	28.3 ± 6.6
Body mass index (kg/m^2)	18.8 ± 3.1	18.8 ± 3.3
Gender	*n* = 10 male, *n* = 11 female	*n* = 6 male, *n* = 13 female

Values are mean ± *SD*; INT = Integrated neuromuscular training group; CON = Control group;

* CON > INT, p £ .05.

for pretesting was excluded from this study. This investigation was approved by the College's Institutional Review Board and written parental permission was obtained from all parents before the start of the study.

Testing Procedures

Following an orientation session which included a review and practice of skill-based fitness tests, all participants were assessed individually by PE professors, research assistants and a PE teacher. The same professionals administered each test at both pre- and posttesting. Height and body mass were measured using standard techniques with a standiometer and standard physician scale and body mass index (BMI, kg/m^2) was calculated. Standardized protocols for fitness testing were followed according to methods previously described (18,26,29).

Briefly, the curl-up and push-up tests were used to assess abdominal and upper body strength/endurance, respectively. The cadence of the curl-up test was set with a metronome (1 curl-up/3 s) and the push-up test required participants to lower their chest to a rubber square until their elbows were at 90° and then return to the starting position with back flat, legs extended and feet positioned wider than shoulders. Lower body power was evaluated by the standing long jump and single leg hop tests. Participants were required to hold the landing of each jump and maintain body control until the distance was measured. Test-retest reliability for the single leg hop test in children from our laboratory is $R = .82$. Each jump test was performed three times and the best score was recorded to the nearest whole cm. Lower back and hamstring flexibility were evaluated by the sit and reach test. Balance was assessed with the stork stand which required participants to maintain a stable body position while standing (without sneakers) on one plantar-flexed foot with hands on hips and eyes open. Participants were required to hold this position for as long as possible, and the best time of three trials was recorded to the nearest 0.1 s

Speed and agility were evaluated with the shuttle run (4 × 10 yd [9.1m]) whereby two small blocks were placed behind a line marked 10 yd (9.1 m) from the start line. Participants ran to the blocks, picked up one block, returned to the start line and placed the first block behind the line, ran back and picked up the second block and then ran across the start line. The best time of two trials was recorded to the nearest 0.1 s. Cardiorespiratory endurance was assessed with the 0.5 mile run (0.8 km). Following instructions about pacing, participants were encouraged to cover the entire distance as fast as possible, although walking interspersed with running was permitted (29). Test-retest reliability of standard PE fitness tests have been previously reported (13,26).

Training Procedures

The INT program used in this study was specifically designed for primary school children and was based on earlier reports on resistance training and neuromuscular conditioning for school-age youth (5,17,20). The intervention was performed twice per week (Monday and Wednesday) during the first ~15 min of each regularly scheduled 43 min PE class and was purposely designed to be time-efficient, inexpensive, and developmentally appropriate for children. The regular PE teacher and a Certified Strength and Conditioning Specialist who had experience training youth provided instruction every class and developed a supportive and challenging learning environment. The principal investigator supervised all classes and documented exercise adherence and compliance with the INT program.

The INT program consisted of a two min dynamic warm-up (e.g., marching in place and multidirectional chops) followed by five primary exercises that focused on enhancing muscular power, lower body strength, and core strength (e.g., abdominals, trunk and hip), and secondary exercises that aimed at improving FMS (e.g., primarily object control and stability skills). The secondary exercises progressed from simple to complex over the 8 week training period. Table 2 outlines the structure and content of the INT program. Participants were active throughout the entire INT program and alternated between one set on a higher intensity primary exercise and one set on a lower intensity secondary exercise which is characteristic of how children move and play (1). Participants performed two sets on all primary exercises and during the 8 week training period they progressed from 7 to 10 repetitions on the dynamic exercises and from 10 to 30 s on the plank exercise. Secondary exercises were performed for ~15–30 s and the exercises progressed every two to three weeks. Subjects performed all exercises with a durable punch balloon (minus the rubber band) that was blown up to the size of a basketball. Since young children are still learning how to manipulate both their bodies and objects through space, fitness training with balloons can provide an opportunity for children to gain confidence in their abilities to perform skills that require balance, coordination and a sense of rhythm (9). Further descriptions of exercises used in the INT program have been previously published (9,17).

Participants in the INT group received skill-specific feedback on the quality of each movement and were taught the value of initiating exercises from an athletic stance (e.g., eyes level, chest over knees, back slightly arched, knees slightly bent and feet wider than shoulders). The phrase "look like an athlete" was used throughout the program to reinforce proper body mechanics and correct errors in movement skill technique. Subtle perturbations were periodically added to certain exercises to enhance the challenge of the movement (e.g., feet flutter during the plank exercise). Following INT, children participated in a variety of traditional PE activities (e.g., stick handling, ball dribbling, and group games) as directed by the PE teacher for the remainder of each class. Participants in CON did not perform specific INT but attended their regular PE class twice per week during the study period and participated in the same traditional PE activities under the guidance of

Table 2 Structure of INT Program With 5 Primary Exercises and Progressive Secondary Exercises

Primary	Secondary		
Weeks 1–8	Weeks 1–2	Weeks 3–5	Weeks 6–8
1. Front squat	SL balance	SL balance & OH press	SL balance & CP
2. Squat jump	OH press & catch	SL OH press & catch	Get up and catch*
3. 90° jump	Knee tap & catch	ALT knee tap & catch	Knee tap, turn & catch
4. Plank	Hip twister	OH chop	Diagonal chop
5. Balloon drop & catch¥			

INT = Integrative neuromuscular training, SL = single leg, OH = overhead, CP= chest press; ALT = alternate right and left knee *From a sitting position on the floor with a balloon in front of the chest, children tossed the balloon into the air and stood up as quickly as possible to catch the balloon in an athletic stance. ¥Exercise was performed with eyes open weeks 1–4 and eyes closed weeks 5–8

a PE teacher. The principal investigator and Certified Strength and Conditioning Specialist were not present during control group PE activities.

Statistical Analyses

Descriptive data were calculated for all variables. A mixed-design repeated measure ANOVA (2 × 2) was used to test for interactions and main effects for time (pre- vs. posttest) and group (INT vs. CON) on the dependent health- and skill-related fitness variables. Statistical analyses were conducted in SPSS (SPSS, Version 18.0, Chicago; IL). Statistical significance was established a priori at $p < .05$ to test the directional (one-sided) hypothesis that INT would be more effective than CON in improving physical fitness measures in children.

Results

All participants completed the study according to aforementioned procedures and no injuries were reported. The INT and CON groups had a participation rate of 100% during the study period. A significant interaction of group and time was observed following the study with selected health- and skill-related fitness measures which indicate that training responses were different between INT and CON.

The INT program increased the maximum number of curl-ups from a mean (95% confidence interval [CI]) pretest score of 9.3 (6.2–12.4 repetitions) at pretest to 28.4 (22.0–34.9 repetitions; $p < .05$) following the intervention (Figure 1). The push-up test showed similar results as INT increased the maximum number of push-ups from a mean pretest score of 1.9 repetitions (0.7–3.1 repetitions) to a mean posttest score of 2.5 repetitions (1.4–3.6 repetitions; $p < .05$). No significant change was evident in CON push-up between a pretest score of 2.1 repetitions (0.83–3.3 repetitions) to a posttest score of 2.1 repetitions (0.97–3.2 repetitions; $p > .05$). Performance on the 0.5 mile (0.8 km) run also revealed a significant time by group

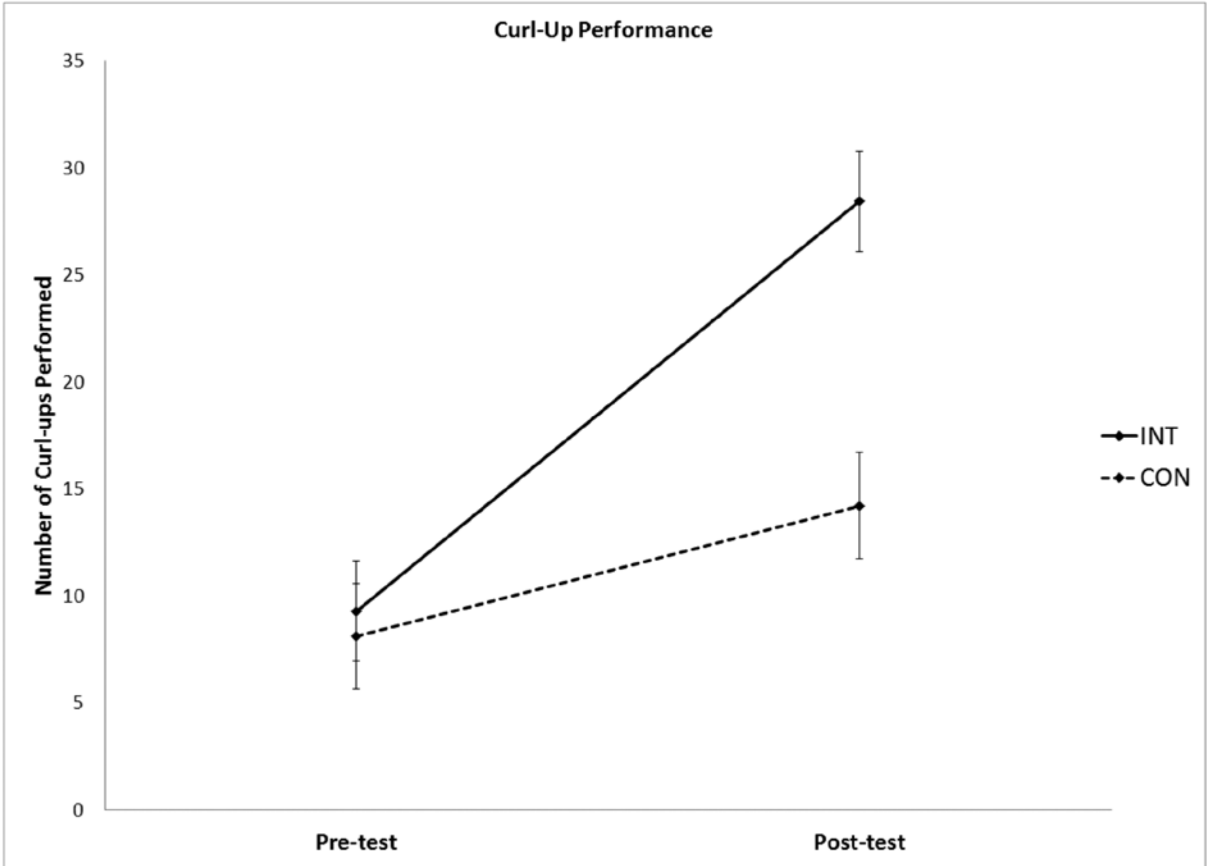

Figure 1 — Pre- and posttest scores for the abdominal curl-up in the intervention group (INT, solid line) and control group (CON, dashed line) following the 8 week training period. Values mean ± *SE*.

interaction in the INT group. The endurance run showed the greatest improvement following INT group with a reduced time from pretest 322.2 s (300.1–344.3 s) to 298.2 s (278.4–318.0 s; $p < .05$) at posttest. Analysis of sit and reach flexibility performance did not reveal a significant interaction of group by time effect following INT. Accordingly, main effect values were assessed. Improvements in mean sit and reach flexibility scores were observed in both the INT and CON groups from pretest, 40.5 cm (36.7–44.2 cm) and 37.2 cm (33.2–41.1 cm), respectively, to posttest, 41.3 cm (37.6–44.8 cm) and 39.1 cm (35.3–42.9 cm), respectively, ($p < .05$).

A significant interaction of group and time was also found following the INT program on selected skill-related fitness measures. Relative to CON, the INT program showed greater improvement in the standing long jump from a mean (95% CI) pretest score of 111.9 cm (104.2–119.6 cm) to 116.4 cm (108.7–124.0 cm; $p < .05$). Likewise, compared with CON, the single leg hop test revealed a significantly greater improvement in performance following INT as indicated with a group by time interaction. The single leg hop test increased from 72.5 cm (65.5–79.4 cm) at pretest to 80.1 cm (73.8–86.5 cm; $p < .05$) following the intervention. Relative improvements in fitness performance highlighting significant group interactions are presented in Figure 2. There was no significant interaction of group by time indicated for either the shuttle run or balance measures. While there was a main effect of time for shuttle run performance ($p < .05$) in both INT and CON, there was no change in balance performance for either the INT or CON groups ($p > .05$). Mean shuttle run times in the INT and CON groups at pretest were 13.3 s (12.7–13.9 s) and 13.7 s (13.1–14.3 s), respectively, and at posttest the times were 13.7 s (13.1–14,3 s) and 14.4 s (13.8–14.9 s), respectively, ($p < .05$). Mean balance times in the INT and CON groups at pretest were 2.1 s (1.8–2.4 s) and 1.6 s (1.2–1.9 s), respectively, and at posttest the times were 2.1 s (1.8–2.4 s) and 1.7 s (1.4–2.0 s), respectively.

Discussion

The primary finding from this study was that participation in an INT program was found to be a safe, effective and worthwhile method of conditioning for children. Specifically, children who performed INT with balloons during PE made significantly greater gains in muscle strength/endurance, lower body power and cardiorespiratory fitness as compared with age-matched controls who participated in PE without INT. The improvements in both health- and skill-related fitness measures are evidence of this treatment's efficacy. No injuries occurred throughout the training period and our observations suggest that INT was well-received by the participants. These data demonstrate the potential value of incorporating a time-efficient, inexpensive, and developmentally appropriate INT program into primary school PE.

A novel finding from the present investigation was that ~15 min of INT performed twice per week resulted in significantly greater gains in health and skill-related fitness measures than normally achieved with standard PE in children. Since both groups participated in the same traditional PE lessons during the study period, such differences in fitness performance are likely due to the specific training adaptations that resulted from INT. Although the mechanisms responsible for these gains were not examined in this study, it is likely that changes were neuromuscular in nature and related to motor unit activation, coordination, recruitment and firing (24).

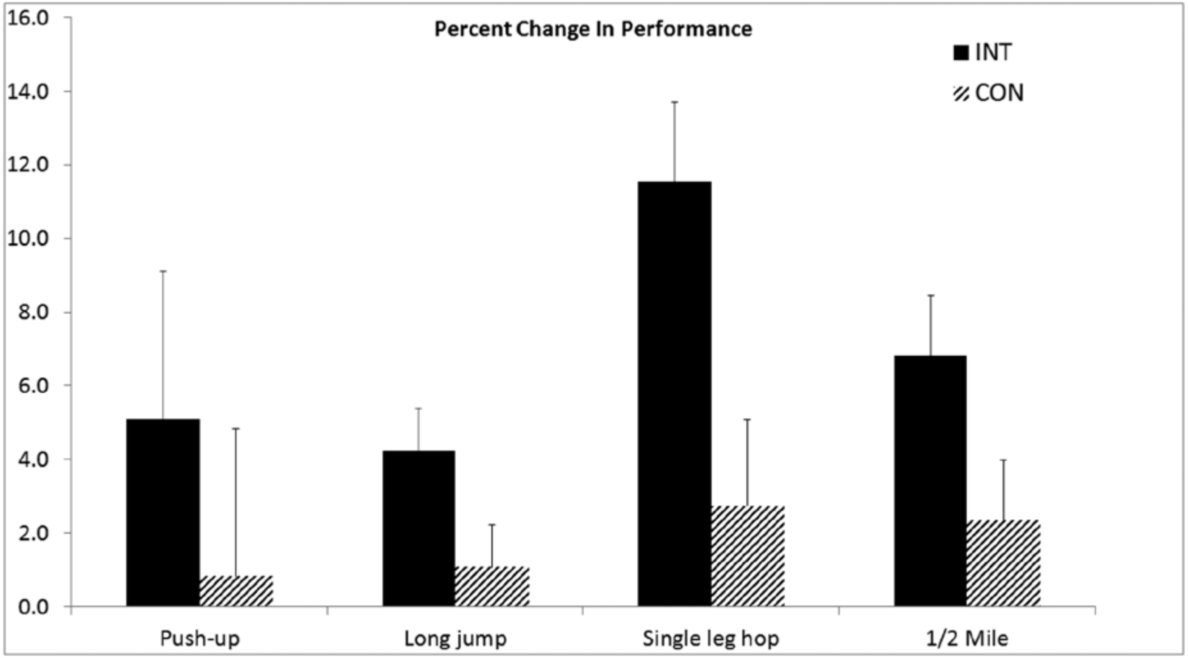

Figure 2 — Performance changes for health- and skill-related fitness tests following the 8 week training period in the intervention group (INT, black bar) and control group (CON, white bar). Values mean ± *SE*.

Participants in the INT group made significantly greater gains in selected health-related fitness measures following the training period than CON. These findings suggest that primary school students respond to INT by increasing their muscular strength/endurance and ability to perform endurance exercise. While others have reported gains in muscle strength and local muscular endurance following progressive resistance training with external loads (14,24), our findings suggest that these health-related fitness variables can be enhanced when INT is incorporated into traditional PE. Performance gains in the abdominal curl-up test following INT were particularly notable since the training intervention included only one exercise specifically designed to enhance core strength. It is possible that the performance of other movements with proper exercise technique and body control contributed to these findings. Since a strong and stable core will allow for optimal force production and postural control (22), the observed gains in abdominal strength/ endurance may have influenced the positive adaptations in other health- and skill-related fitness measures observed in this investigation.

Improvements in the 0.5 mile (0.8 km) run suggest that children respond to INT by improving their ability to perform endurance events. While training adaptations in adults tend to be specific to the metabolic demands of the exercise, these findings support the concept that children demonstrate a propensity to be "metabolic nonspecialists" (2). That is, regular participation in a pediatric program designed to enhance strength and power can also improve the ability of children to perform cardiorespiratory exercise. Even though continuous endurance activity is more established as a training mode to improve aerobic capacity, our findings indicate that INT can enhance cardiorespiratory fitness as measured by an endurance run in children. Other studies confirm that intermittent activities (e.g., short sprints or plyometrics) can improve aerobic performance in youth (6,25). For example, a sample of primary school children who participated in an 8 week plyometric program during PE made significant improvements in endurance performance following this intervention (6).

Participation in the INT program also resulted in significantly greater gains in the standing long jump and single leg hop performance than CON. Improvements in these skill-related components of fitness were expected as the INT program included jumps and hops. Others reported significant gains in various motor performance measures in children following structured resistance training (14) or an after-school physical activity intervention (16). While reported improvements in fitness and skill level ranged from 30% to 270% in one of the aforementioned reports (16), their after-school intervention included a daily (Monday to Friday) 90 min activity session of structured and nonstructured physical activity. These observations suggest that the intensity as well as the design of the intervention may be a critical factor for success. In the present investigation, children in the INT group participated in only 240 min of training (15 min/class × 2 classes/week × 8 weeks) over the study period, yet the relative gains in performance were comparable with those previously reported (16). The advantage of a short, concentrated lesson in primary school PE is that children remain engaged and eagerly complete all activities before they lose interest.

Subjects in the INT and CON groups made significant improvements in flexibility and shuttle run performance following training, although no between group differences were evident in the current study. While these findings highlight the value of traditional PE, they also demonstrate the necessity of supplemental exercises in INT interventions if additional improvements in these performance measures are desired. Because others noted improvements in flexibility and agility following fitness training in children (7,16,27), more comprehensive INT lessons may be needed in future interventions. However, the time available for additional training is an important consideration when INT is incorporated into PE classes.

Neither traditional PE nor the addition of INT to PE influenced balance performance in the present investigation for either study group. Although these findings are consistent with others who reported no significant improvements in postural sway following 4 weeks of balance training in prepubertal children (10), the smaller than hypothesized impact on balance in our investigation may be because the 15 min INT program was not of the magnitude required to enhance balance in 7 year old children. Additional dynamic stabilization exercises or more frequent training sessions may be needed to elicit further INT-induced treatment effects in primary school children.

INT provided a unique training stimulus in an instructive class environment with a PE teacher and a Certified Strength and Conditioning Specialist. It is possible that the quality of instruction along with the intensity, volume and design of the INT program may explain improvements in selected health- and skill-related fitness measures. Since the performance of FMS requires the manipulation of one's body against gravity, the importance of developing muscle strength should be recognized as a fundamental component of INT. Children with inadequate levels of muscle strength will not be able to perform FMS correctly, and therefore will be less likely to master movement skills and engage in various physical activities (15,19).

Our findings suggest that INT programs that emphasize the development of basic conditioning movements and FMS in a socially supportive environment can be an effective approach for improving the physical fitness of school-age youth. Most children in primary school enjoy physical activity and, unlike adolescents, they are not as self-conscious about making a mistake in front of their peers. Because primary school children, particularly students in kindergarten to 2nd grade, are still learning how to manipulate their bodies through space, INT with balloons seem to increase the likelihood that participants master FMS. Moreover, it is important to emphasize that children are at an optimal age in terms of motor skill learning when they are in primary school (15). Indeed, recent investigations have found that FMS proficiency developed in primary school has a strong influence on subsequent fitness during adolescence (3).

A limitation of this study is that it addressed only the initial phase of INT with balloons in children. Thus, the results from this investigation may not be applicable to older populations nor do the results provide insight into long-term training adaptations. In addition, we did not assess performance on object control skills which may have improved in both groups due to the activities taught during PE (e.g., stick handling and ball dribbling). Further, it was not possible to include a no-PE control group due to ethical concerns associated with such a group in this school district.

Nevertheless, the practical importance of incorporating INT into primary school PE or possibly after-school recreation programs should not be overlooked. Children in this study had an opportunity to learn proper movement mechanics on a variety of exercises and develop the skills and confidence that may lead to a greater willingness to participate in sport-related activities later in life (3,33). In particular, our findings suggest that INT that develops muscle strength and motor proficiency may be an important "first step" for enhancing basic FMS and promoting physical fitness in children. Following the training period, without encouragement from the PE teacher, participants in the INT group demonstrated perceived competence and confidence by creating new games with balloons that required higher levels of FMS.

In conclusion, findings from the present investigation indicate that INT instructed by qualified professionals can result in significant improvements in selected health- and skill-related fitness components in children, and is a cost-effective and time efficient method for promoting physical activity in pediatric fitness programs. The salient findings from the present investigation indicate that ~15 min of INT performed twice weekly results in significantly greater gains in health and skill-related fitness measures than gains normally achieved with traditional PE. Multifaceted interventions such as INT may be an important component of pediatric fitness programs because children are at an optimal age in terms of motor skill learning and need to be provided with developmentally appropriate and meaningful tasks during physical activity programs (11). Future interventions should focus on potential gender differences as well as the long-term effects of INT during childhood on physical activity habits and health-related conditions in later life.

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