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The effect of small-ball-based physical activity on multicomponent agility in 11-12-year-old students

El efecto de la actividad física con pelota pequeña sobre la agilidad multicomponente en estudiantes de 11 a 12 años

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Abstract

Developing multicomponent agility through school-based activities that integrate multidirectional movement and object manipulation remains an important but insufficiently investigated area in physical education. This study aimed to examine the effect of small-ball-based physical activity on multicomponent agility in students aged 11-12 years and to determine whether the effects differed by initial agility level. This study employed a matched pretest-posttest control-group design with a 2×2 treatment-by-level arrangement. A total of 80 students aged 11-12 years participated. The intervention group participated in a small-ball game program for 6 weeks, with 3 sessions per week (18 sessions in total). The program incorporated running, changes of direction, acceleration, deceleration, coordination, accuracy, and rapid responses, while maintaining a controlled intensity of approximately 65%-75% and RPE 12-14. The control group participated in matched free-play physical education activities. Multicomponent agility was assessed using the N-Challenge Test. The results a significant main effect of group was observed ($p < 0.001$, $\eta^2 = 0.842$), as well as a significant main effect of initial agility level ($p = 0.042$, $\eta^2 = 0.053$). However, the interaction between group and initial agility level was not significant ($p = 0.167$, $\eta^2 = 0.025$). Small-ball-based physical activity was effective in improving multicomponent agility among students aged 11-12 years. Within this six-week intervention, improvements were greater in the intervention than in the matched control condition, while no evidence indicated that the intervention effect differed according to initial agility classification. Future studies should therefore consider involving larger and more diverse samples and implementing longer intervention periods.

Keywords: activity multicomponent agility; schoolchildren; physical education; small-ball-based physical.

Resumen

El desarrollo de la agilidad multicomponente mediante actividades escolares que integran el movimiento multidireccional y la manipulación de objetos sigue siendo un área importante, aunque insuficientemente investigada, en la educación física. Este estudio tuvo como objetivo examinar el efecto de la actividad física basada en juegos con pelotas pequeñas sobre la agilidad multicomponente en estudiantes de 11 a 12 años y determinar si dichos efectos variaban según el nivel inicial de agilidad. Se empleó un diseño de grupo de control con pretest y postest y emparejamiento de sujetos, utilizando una estructura de tratamiento por nivel de 2×2 . Participaron un total de 80 estudiantes de entre 11 y 12 años. El grupo de intervención participó en un programa de juegos con pelotas pequeñas durante 6 semanas, con 3 sesiones semanales (18 sesiones en total). El programa incorporó carrera, cambios de dirección, aceleración, desaceleración, coordinación, precisión y respuestas rápidas, manteniendo una intensidad controlada de aproximadamente el 65 %-75 % y una escala de esfuerzo percibido (RPE) de 12-14. El grupo de control participó en actividades de educación física de juego libre equiparables. La agilidad multicomponente se evaluó mediante la prueba N-Challenge Test. Los resultados mostraron un efecto principal significativo del grupo ($p < 0,001$; $\eta^2 = 0,842$), así como un efecto principal significativo del nivel inicial de agilidad ($p = 0,042$; $\eta^2 = 0,053$). Sin embargo, la interacción entre el grupo y el nivel inicial de agilidad no resultó significativa ($p = 0,167$; η^2



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= 0,025). La actividad física basada en juegos con pelotas pequeñas resultó eficaz para mejorar la agilidad multicomponente en estudiantes de 11 a 12 años. En el marco de esta intervención de seis semanas, las mejoras fueron mayores en el grupo de intervención que en la condición de control equiparable, sin que se hallaran indicios de que el efecto de la intervención variara según la clasificación inicial de agilidad. Por consiguiente, futuros estudios deberían considerar la inclusión de muestras más amplias y diversas, así como la implementación de periodos de intervención más prolongados.

Palabras clave: pequeña agilidad multicomponente; escolares; educación física; actividad física con pelota.



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Introduction

Physical activity during the school-age years plays a critical role in supporting motor development, physical fitness, and active participation in physical education. Within the school setting, the development of movement abilities should not be limited to increasing overall physical activity levels. But should also focus on enhancing movement competence as a foundation for children's active participation in games, sports, and daily activities (Moon et al., 2024). A growing body of evidence indicates that school-based physical activity interventions can improve motor competence among elementary school children, with effects ranging from moderate to large (Bryce, 2021; Barnett et al., 2024). Similarly, structured and consistently implemented school-based interventions have been shown to effectively enhance children's motor skills (Bolger et al., 2021). Therefore, physical education programs require activities that are not only active and enjoyable but also specifically designed to target particular movement competencies.

The dependent variable examined in this study was multicomponent agility, which refers to the ability to move quickly and efficiently through a sequence of movement demands performed within a single task (Morral-Yepes et al., 2023); (Carvajal-Espinoza et al., 2025). This concept extends beyond simple change-of-direction ability by emphasizing the integration of acceleration, movement transitions, body control, and accurate task execution. The relevance of this construct is further supported by the development of the N-Challenge Test, which was specifically designed to assess multicomponent agility in elementary school children (Morita et al., 2022). The study demonstrated that the N-Challenge Test possesses excellent content validity and strong reliability, making it a suitable instrument for evaluating multicomponent agility in school-aged populations.

Children aged 11-12 years represent a particularly relevant population for examining the development of multicomponent agility. At this developmental stage, children are transitioning from late childhood to early adolescence, a period during which coordination, body control, and readiness to perform more complex movement tasks become increasingly refined (Santoso et al., 2024; Safitri et al., 2025). Empirical evidence suggests that age-related development during this period is associated with improved motor performance, including



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balance and fundamental movement skills (Karadeniz et al., 2023; Putro et al., 2025), while children who engage in higher levels of physical activity tend to demonstrate superior movement skill proficiency (Chaput et al., 2024). Furthermore, school-based physical activity interventions implemented among older school-age children have been reported to produce greater improvements in selected fitness components (Aly et al., 2025), including speed, agility, and coordination. Consequently, children aged 11-12 years represent an appropriate population for interventions targeting multicomponent agility.

Small-ball-based physical activity may be particularly effective for improving multicomponent agility because it incorporates dynamic, varied, and adaptive movement demands. Activities involving small balls typically require eye-hand or eye-object coordination, precise movement timing, body repositioning, acceleration, sudden stopping, and rapid responses to changing situations (Akin, 2019; Webster et al., 2023). From a motor learning perspective, these characteristics closely resemble those of open-skill exercise, which occurs in relatively unpredictable environments and requires continuous adaptation of movement (Feng et al., 2023). Rather than requiring isolated physical actions, small-ball activities combine locomotor movements with object manipulation and goal-directed responses. Such task characteristics may strengthen the functional integration between perceptual information and motor action, while simultaneously stimulating coordination and rapid movement transitions relevant to multicomponent agility. A recent meta-analysis reported that open-skill exercise positively influences children's executive functioning and may be more effective than closed-skill exercise in this regard (Hu et al., 2024). In addition, ball-sport-based training has been shown to improve coordination, stability, and movement responsiveness among school-aged children (Racil et al., 2024). Thus, the theoretical rationale for small-ball-based physical activity lies not merely in increasing physical activity volume, but in repeatedly exposing children to integrated perceptual, manipulative, and locomotor demands that resemble the multidimensional requirements of multicomponent agility.

Previous research generally supports the use of games and sports activities as effective means of promoting children's movement competence. A recent meta-analysis found that sports game interventions significantly improved children's fundamental motor skills, with the



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greatest benefits observed in programs lasting approximately 12 weeks, consisting of 35-minute sessions conducted three to four times per week (Sun & Chen, 2024). Within physical education settings, modified invasion games have been shown to effectively improve both actual and perceived object-control skills among fifth-grade students (Neira-Navarrete et al., 2024). Similarly, feasibility studies of school-based motor competence interventions have reported favorable changes in children's motor abilities following program implementation (Fairclough et al., 2024). Furthermore, multinational school-based physical activity interventions involving children aged 8-14 years have demonstrated improvements in several fitness components, particularly speed, coordination, and movement-performance-related physical capacities (Aly et al., 2025). Collectively, these findings support the assumption that dynamic, game-based, and task-oriented activities can serve as effective strategies for enhancing children's movement abilities. However, these studies predominantly address general motor competence, fundamental movement skills, or individual fitness components and therefore provide limited evidence regarding how integrated game-based tasks affect multicomponent agility as a distinct movement outcome.

Despite this growing body of evidence, a clear research gap remains. Most contemporary studies have focused on fundamental motor skills, object control, general motor competence, or overall fitness components (Sun & Chen, 2024), rather than specifically examining multicomponent agility. Moreover, intervention studies involving sports games have generally evaluated outcomes using measures of fundamental skills or general fitness indicators (Neira-Navarrete et al., 2024; Aly et al., 2025), whereas the N-Challenge Test has primarily been used in instrument-development research (Morita et al., 2022), rather than in experimental studies conducted within school-based physical education contexts. In addition, there remains a limited body of research specifically investigating the effects of small-ball-based physical activity on multicomponent agility among children aged 11-12 years. More importantly, the theoretical contribution of examining small-ball activities lies in testing whether repeated exposure to tasks that concurrently require object manipulation, rapid locomotion, directional transitions, spatial adjustment, and response selection can translate into improvement in a multidimensional agility outcome. This provides a more integrative perspective than examining



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isolated speed, change-of-direction, or object-control abilities independently. Accordingly, the present study addresses both an empirical gap and a theoretical question concerning whether game-based activities combining perceptual and motor demands can facilitate the development of multicomponent agility in school-aged children.

Against this background, the present study becomes particularly relevant because it was designed not only to compare intervention and control groups but also to consider students' initial agility levels. Therefore, the purpose of this study was to examine the effects of small-ball-based physical activity on multicomponent agility among students aged 11-12 years. The study also sought to determine whether outcomes differed according to initial agility level and whether an interaction existed between treatment type and initial agility level in influencing multicomponent agility performance. The novelty of the study extends beyond the use of a specific intervention or assessment instrument. Conceptually, it examines whether a structured school-based program integrating locomotor, manipulative, perceptual, and rapid movement-transition demands can enhance multicomponent agility, while simultaneously examining whether the magnitude of adaptation varies according to students' initial agility level.

Based on this rationale, three hypotheses were proposed:

- (1) students receiving small-ball-based physical activity would demonstrate greater improvements in multicomponent agility than students in the control condition;
- (2) improvements in multicomponent agility would differ according to initial agility level;
- (3) an interaction would occur between treatment condition and initial agility level, indicating that the effect of the intervention would vary according to students' initial agility classification.

Method

Research Design

This study employed a matched pretest-posttest control-group design with a 2×2 treatment-by-level factorial arrangement. The first factor was treatment type, consisting of



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small-ball-based physical activity in the intervention group and matched free-play physical education activities in the control group. The second factor was the participants' initial level of multicomponent agility, categorised as high or low based on pretest results. Initially, all participants completed the N-Challenge Test to obtain multicomponent agility data. Pretest scores were then ranked by completion time, with lower scores indicating better agility performance. Based on these rankings, participants were divided into two strata: high-agility and low-agility groups. Within each stratum, participants were allocated to either the intervention or control group using an ordinal pairing procedure following an A-B-B-A pattern to maintain balanced initial ability across groups. To preserve the principle of randomization, the assignment of code A to the intervention or control group and code B to the initial agility category was determined randomly at the beginning of the grouping process. This matching procedure was used to obtain groups with relatively comparable initial agility levels, rather than to randomly determine the participants' initial agility categories. The allocation procedure was carried out by the first researcher, and participants were assigned to four groups. Consequently, four research groups were established: intervention-high agility (A1B1), intervention-low agility (A1B2), control-high agility (A2B1), and control-low agility (A2B2).

Following group allocation, the intervention group participated in the small-ball-based physical activity program, whereas the control group participated in matched free-play physical education activities. At the end of the intervention period, all participants completed a posttest using the same procedures employed during the pretest. This design enabled the examination of the main effects of treatment and initial agility level, as well as the interaction between these two factors on multicomponent agility. This study received ethical approval from the relevant research ethics committee (B/1468/UN34.16/PT.01.02/2025). In addition, informed consent was obtained from the parents or legal guardians of all participating students before their involvement in the study.

Population and Sample

The target population consisted of fifth- and sixth-grade elementary school students aged 11-12 years from four elementary schools in Yogyakarta City, Indonesia: SD N Ngupasan,



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SD N Pingit, SD N Klegung 1, and SD N Klegung 2. These schools were selected as the accessible population because they included students whose characteristics aligned with the study's objectives: upper-elementary-aged children actively participating in physical education classes.

The sample comprised 80 students, including 40 boys and 40 girls, who voluntarily participated in all phases of the study. Twenty students were recruited from each school to ensure balanced representation across schools. The characteristics of the male participants were as follows: age, 11.5 ± 0.3 years; height, 148.9 ± 3.0 cm; and body mass, 44.6 ± 2.5 kg. The female participants had a mean age of 11.4 ± 0.2 years, height of 145.7 ± 1.3 cm, and body mass of 40.0 ± 1.1 kg.

Following the initial assessment of multicomponent agility, the 80 participants were divided into four groups of 20 students each: (1) intervention group with high initial agility, (2) intervention group with low initial agility, (3) control group with high initial agility, and (4) control group with low initial agility. This grouping procedure was consistent with the 2×2 treatment-by-level pretest-posttest design and enabled analysis of treatment effects, initial ability effects, and interaction effects on improvements in multicomponent agility.

Intervention Design for Small-Ball-Based Physical Activity

The intervention consisted of a small-ball-based physical activity program conducted over six weeks, three sessions per week, for a total of 18 training sessions. Each session was held from 08:30 to 10:00 a.m. and was designed as a game-based activity emphasizing running, changes of direction, acceleration, deceleration, movement coordination, accuracy, and rapid responses to game situations. The intervention was intentionally designed without progressive increases in movement speed, repetitions, or exercise volume across the 18 sessions. Instead, the training load was maintained within a predetermined moderate-intensity range of approximately 65%-75%, with perceived exertion monitored within an RPE range of 12-14 (Safitri et al., 2025). This fixed-intensity approach was selected to minimize excessive fatigue and injury risk while allowing students to remain attentive, engaged, and comfortable during the game-based activities.



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During each session, participants engaged in several small-ball games lasting approximately 10-15 minutes per activity, interspersed with 10-15 minutes of recovery between games. Thus, the principal training stimulus was derived from repeated exposure to the specific movement demands of the five structured small-ball games rather than from progressive increases in external training load. Each game was supervised by four physical education students, consisting of two male and two female supervisors. Therefore, 20 physical education students were involved in supervising the five intervention activities. Their presence was intended to support safe implementation, maintain the predetermined activity intensity, and ensure that the games were conducted according to the established procedures.

The first activity, Ball Relay Attack, involved teams of 5-7 students, with two teams competing simultaneously. Each team lined up behind the starting line. The first player ran with a ball through a zigzag course of cones before returning to the start line and handing it to the next teammate. If the ball was dropped during the relay, the team was required to complete a light physical penalty, such as five jumping jacks, before continuing. Opposing teams were permitted to provide non-contact verbal distractions, such as applause or cheering, to increase concentration demands. This game stimulated multicomponent agility by combining sprinting, directional changes, ball control, concentration, and movement decision-making in a simple competitive environment. The structure, movement sequence, and general task demands of this activity were maintained consistently throughout the six-week intervention rather than progressively increased.

The second activity, Target Racket Relay, involved eight students, divided into two teams of four. Each team lined up behind a starting line, while several targets, represented by cones or bottles, were positioned approximately 5-7 m in front of the teams. The first player struck a lightweight ball with a racket toward the target and then ran to the back of the line, tagging the next teammate to continue the relay. Each knocked-over target counted as one point and was immediately reset by an assistant to maintain continuous play. The game consisted of two five-minute rounds. This activity required eye-hand coordination, rapid positional changes, striking accuracy, and quick movement transitions, making it relevant for developing multicomponent agility. No systematic increase in target distance, repetition number, movement



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speed, or exercise volume was introduced across the intervention period; the activity was maintained within the predetermined intensity range.

The third activity, Rounders Relay Ball, was played by 8-10 students divided into two teams on a square field measuring approximately 12 × 12 m. The attacking team threw the ball into the playing area and then ran sequentially around four bases before returning to home base. Simultaneously, the defending team retrieved the ball and passed it among teammates in relay fashion until it reached the home-base defender. The attacking team earned one point if the runner returned home before the ball arrived; otherwise, the runner was declared out. This activity provided stimuli for acceleration, directional changes, running speed, situational awareness, and team coordination, making it highly suitable for training agility through complex yet enjoyable movement tasks. The field dimensions, game rules, and overall movement demands were kept consistent across the 18 intervention sessions to maintain a stable and age-appropriate training stimulus.

The fourth activity, Mini Fortress Ball, involved 8-12 students divided into attacking and defending teams. The game was played on a rectangular field measuring approximately 15 × 10 m using a small plastic or rubber ball and cones or poles serving as fortresses. Attackers took turns throwing the ball into the playing area, then ran around the opposing team's fortress, attempting to return safely. Meanwhile, defenders attempted to catch the ball and throw it to their fortress before the attacker completed the circuit. Attackers earned one point for successfully returning, whereas they were declared out if the ball reached the fortress first. This game required sprinting speed, directional changes, spatial awareness, vigilance, and movement control, thereby supporting the development of multicomponent agility through competitive and contextually meaningful play. As with the other intervention activities, the task was not progressively intensified across weeks; instead, the same fundamental movement and game demands were retained to preserve consistency and enjoyment.

The fifth activity, Obstacle Relay, combined running, jumping, and target-throwing accuracy. Participants ran while carrying a ball, jumped over designated jumping zones prepared by the teacher, continued running while clearing safe hurdles, and then attempted to throw the ball into a basket. If the first attempt was unsuccessful, participants repeated the task



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until the ball entered the basket, then returned to the starting line and handed the turn to the next participant. The activity was conducted as an individual or team competition to maintain student engagement. From a training perspective, this game integrated acceleration, jumping, body control during movement transitions, dynamic balance, and accuracy, all of which are essential components of multicomponent agility. The obstacle configuration and general task structure were maintained across the intervention period, and no planned progression in repetition, volume, or movement speed was applied.

The control group participated in physical education classes involving free-play activities. However, program duration, frequency, intensity, and scheduling were matched to those of the intervention group to ensure that any differences in outcomes could be attributed primarily to the intervention's content rather than to disparities in training load. The control condition was conducted over the same six-week period, with three sessions per week, comparable activity duration, recovery intervals, and the same target intensity range of approximately 65%–75%. As in the intervention group, no progressive increases in speed, repetitions, or exercise volume were applied to the control condition. The principal distinction between conditions was therefore the content and organization of the activities: the intervention group received five structured small-ball-based games designed to repeatedly expose students to multidirectional, manipulative, and coordinative movement demands, whereas the control group participated in matched free-play physical education activities without the structured small-ball intervention protocol. This approach was adopted to strengthen internal validity and allow changes in multicomponent agility to be interpreted as resulting from differences in activity type, namely the structured small-ball game program versus free-play activities.

Measurement Instrument

Multicomponent agility, the dependent variable in this study, was assessed using an adapted version of the N-Challenge Test developed by Morita et al., (2022). The test was specifically designed to measure multicomponent agility in children and consists of six sections: reaction, 6-m sprint, right turn, hurdle, left turn, and slalom, with total running time serving as the primary outcome measure. In its original validation study, the N-Challenge Test



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demonstrated excellent content validity ($I-CVI = 1.00$) and very high test-retest reliability ($ICC = 0.97$; 95% CI 0.96-0.98; $SEM = 0.18$ s, 1.9%), supporting its suitability for assessing agility performance in school-aged children.

In the present study, adaptation was limited to the field-based characteristics of the test, including the distance between movement sections, the equipment used, and the arrangement of the agility course. The fundamental movement components and sequence of the N-Challenge Test were retained so that the adapted protocol continued to represent the multicomponent nature of the original assessment.

The adapted N-Challenge Test was implemented using equipment that was readily available and appropriate for the school setting, including cones, low hurdles, poles, and markers used to define the running pathway and changes of direction. The course layout and distances between components were adjusted to the available testing area while preserving the sequence of reaction, straight-line sprinting, right and left directional changes, hurdle negotiation, and slalom movement. Importantly, the technological timing system used in the original N-Challenge Test, including photoelectric timing gates and computer-based recording, was not adopted in this study. Instead, completion time was recorded using stopwatch. This modification was made to enable the test to be administered feasibly within a school-based physical education environment while maintaining the principal movement demands of the original N-Challenge Test. Before testing, participants completed a standardized warm-up lasting approximately 15 minutes, followed by a demonstration of the course and one submaximal familiarization trial. Participants then performed two maximal trials separated by a minimum recovery period of five minutes. Trials were repeated if a false start or other technical error occurred.

The primary outcome variable was total running time measured in seconds, with lower scores indicating superior multicomponent agility performance. Pretest scores were used to classify participants into high- and low-agility groups, whereas posttest scores were used to evaluate performance changes following the intervention. To maintain internal validity, both pretest and posttest assessments were conducted using identical procedures, instructions, and testing conditions. The same adapted course dimensions, equipment configuration, timing



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procedure, testing personnel, and scoring criteria were maintained at both measurement occasions to minimize procedural variation between pretest and posttest assessments.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27. Descriptive statistics were reported as minimum values, maximum values, means, and standard deviations for each group. Before the primary analysis, assumptions were examined using the Shapiro-Wilk test for normality and Levene's test for homogeneity of variance. The primary analysis employed a two-way ANOVA with agility gain scores as the dependent variable. The fixed factors were treatment group (intervention vs. control) and initial agility level (high vs. low). This analysis was conducted to examine the main effects of treatment and initial agility level, and their interaction, on improvements in multicomponent agility. In addition, paired-samples t-tests were performed within each of the four groups to compare pretest and posttest scores as a supplementary analysis. Statistical significance was established at $p < 0.05$.

Results

Following the completion of pretest and posttest data collection, the data were analyzed according to the procedures described in the Statistical Analysis section. Descriptive statistics for each group are presented in Table 1.

TABLE 1. Pretest and Posttest Scores of Multicomponent Agility Across Groups

		Minimum	Maximum	Mean	Std. Deviation
Intervention Group - High Agility	Pretest	10.95	12.64	11.68	0.62819
	Posttest	7.44	11.45	9.01	1.16062
Intervention Group - Low Agility	Pretest	10.92	12.73	11.73	0.65255
	Posttest	7.44	12.01	9.71	1.26763
Control Group - High Agility	Pretest	10.94	12.62	11.70	0.61308
	Posttest	10.58	12.85	11.56	0.69061
Control Group - Low Agility	Pretest	10.95	12.64	11.72	0.64818
	Posttest	10.76	12.68	11.63	0.70229



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Table 1 shows that initial mean pretest scores were relatively similar across all groups, indicating comparable initial levels of multicomponent agility among participants. Following the intervention, the intervention-high agility group reduced mean running time from 11.68 s to 9.01 s, whereas the intervention-low agility group improved from 11.73 s to 9.71 s. Because lower scores indicate better performance, these findings suggest substantial improvements in multicomponent agility in both intervention groups. In contrast, the control-high-agility group showed only a slight reduction in mean running time, from 11.70 s to 11.56 s. In comparison, the control-low-agility group improved marginally, from 11.72 s to 11.63 s. Descriptively, the greatest improvement was observed in the intervention-high-agility group, followed by the intervention-low-agility group, whereas both control groups showed only minimal changes.

Before conducting the primary analyses, assumptions of normality and homogeneity of variance were examined. The results of the Shapiro-Wilk normality test are presented in Table 2.

TABLE 2. Shapiro-Wilk Test Results

		Statistic	df	Sig.
Intervention Group - High Agility	Pretest	0.848	20	0.055
	Posttest	0.928	20	0.144
Intervention Group - Low Agility	Pretest	0.853	20	0.066
	Posttest	0.974	20	0.839
Control Group - High Agility	Pretest	0.870	20	0.062
	Posttest	0.928	20	0.144
Control Group - Low Agility	Pretest	0.843	20	0.064
	Posttest	0.842	20	0.104

As shown in Table 2, all significance values for both pretest and posttest scores across groups were greater than 0.05, indicating that the data were normally distributed. Homogeneity of variance was subsequently assessed using Levene's Test of Equality of Error Variances. The test yielded a p-value of 0.145 for the mean, indicating that the assumption of homogeneity of variance was satisfied. The results of the primary two-way ANOVA are presented in Table 3.



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TABLE 3. Two-Way ANOVA Results for Multicomponent Agility Gain Scores

	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	41.608	136.653	0.000	0.844
Intercept	151.443	497.379	0.000	0.867
Group	122.934	403.748	0.000	0.842
Initial_Agility_Level	1.298	4.263	0.042	0.093
Group * Initial_Agility_Level	0.593	1.949	0.167	0.025

The two-way ANOVA conducted on multicomponent agility gain scores revealed that the overall model was statistically significant, $F = 136.65$, $p < 0.001$, $\eta^2 = 0.844$. A significant main effect of group was observed, $F = 403.75$, $p < 0.001$, $\eta^2 = 0.842$, indicating that improvements in multicomponent agility differed significantly between the intervention and control groups. A significant main effect of initial agility level was also identified, $F = 4.26$, $p = 0.042$, $\eta^2 = 0.093$, suggesting that students with high and low initial agility achieved significantly different gain scores. However, the interaction between group and initial agility level was not statistically significant, $F = 1.95$, $p = 0.167$, $\eta^2 = 0.025$. This finding indicates that the intervention's effectiveness in improving multicomponent agility did not differ significantly by participants' initial agility level. Further analysis was conducted using estimated marginal means, as presented in Table 4.

TABLE 4. Estimated Marginal Means for Multicomponent Agility Gain Scores

		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Group	Intervention Group	2.616	0.087	2.442	2.789
	Control Group	0.136	0.087	-0.038	0.310
Initial_Agility_Level	High Agility	1.503	0.087	1.329	1.677
	Low Agility	1.249	0.087	1.075	1.422

As shown in Table 4, the intervention group demonstrated a substantially higher mean gain score ($M = 2.616$, $SE = 0.087$, 95% CI [2.442, 2.789]) than the control group ($M = 0.136$, $SE = 0.087$, 95% CI [-0.038, 0.310]). These results indicate that the improvement in



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multicomponent agility was considerably greater among participants who received the small-ball-based physical activity intervention. Regarding initial agility level, participants classified as having high initial agility demonstrated a slightly greater mean gain score ($M = 1.503$, $SE = 0.087$, 95% CI [1.329, 1.677]) than those with low initial agility ($M = 1.249$, $SE = 0.087$, 95% CI [1.075, 1.422]). Overall, these findings suggest that the small-ball-based physical activity program produced greater improvements in multicomponent agility. In contrast, participants with higher initial agility tended to achieve slightly larger gains than those with lower initial agility.

TABLE 5. Paired-Samples t-Test Results for Pretest and Posttest Multicomponent Agility Scores

	t	df	Sig. (2-tailed)
Intervention Group - High Agility	19.370	19	0.000
Intervention Group - Low Agility	13.175	19	0.000
Control Group - High Agility	2.747	19	0.013
Control Group - Low Agility	2.047	19	0.055

The paired-samples t-test results indicated that the intervention-high agility group showed a significant improvement in multicomponent agility, $t = 19.370$, $p < 0.000$. Similarly, the intervention-low agility group demonstrated a significant improvement, $t = 13.175$, $p < 0.000$. The control-high-agility group also showed a statistically significant, albeit smaller, improvement ($t = 2.747$, $p = 0.013$). In contrast, the control-low-agility group did not exhibit a significant difference between pretest and posttest scores ($t = 2.047$, $p = 0.055$).

Overall, the findings provided support for the first and second hypotheses but not for the third hypothesis. The significant main effect of group indicated that students who participated in the small-ball-based physical activity program achieved greater improvements in multicomponent agility than those in the control condition, thereby supporting H1. The significant main effect of initial agility level also indicated that the magnitude of improvement differed between students with high and low initial agility, supporting H2. However, the interaction between treatment condition and initial agility level was not statistically significant,



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indicating that the effect of the intervention did not vary significantly according to participants' initial agility classification. Therefore, H3 was not supported.

Discussion

The main finding of this study was that small-ball-based physical activity effectively improved multicomponent agility among students aged 11-12 years. This was evidenced by the strong main effect of group, indicating that the improvement observed in the intervention group was substantially greater than that of the control group. The results also showed that initial agility level was associated with the magnitude of improvement, whereas the interaction between group and initial agility level was not significant. Taken together, the primary gain-score analysis indicates that the intervention produced a substantial treatment effect, whereas initial agility classification contributed a comparatively smaller effect and did not significantly modify the response to the intervention. These findings support the first and second hypotheses but do not support the third hypothesis concerning the interaction between treatment and initial agility level.

The effectiveness of the intervention may be explained by the characteristics of small-ball-based activities, which require a combination of acceleration, deceleration, changes of direction, coordination, body control, and movement adaptation in response to task demands. From a motor-learning perspective, repeated exposure to these tasks may facilitate the refinement of movement patterns through continuous practice, error correction, and adjustment of movement strategies (Sun & Chen, 2024; Santoso et al., 2024). From an ecological-dynamics perspective, the games also required students to continuously perceive relevant environmental information and coordinate their movements according to changing spatial, object-related, and task constraints. This repeated coupling between perception and action may have strengthened the ability to select and execute appropriate movements rapidly rather than merely reproducing predetermined movement patterns. From a theoretical perspective, such activities share many characteristics with open-skill exercises, which take place in dynamic environments and require the integration of perceptual, cognitive, and motor processes (Hu et al., 2024; Bidzan-Bluma et al., 2024). Accordingly, the improvement observed in the present study may reflect not only



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repeated physical exposure to directional changes but also enhanced sensorimotor integration and movement adaptability.

Previous studies have reported that open-skill exercise positively influences executive functions in children, particularly self-regulation, working memory, and movement quality (Sun & Chen, 2024; Santoso et al., 2024). Likewise, research related to the Movement-Oriented Games-Based Assessment has suggested that games involving diverse movement challenges can enhance complex movement skills among children aged 8-12 years (Morley et al., 2021). In the present study, small-ball activities may have supported multicomponent agility by combining coordination, movement decision-making, ball manipulation, rapid locomotion, and directional transitions. These task demands likely required students to integrate visual information with timely motor responses, while repeated exposure across 18 sessions may also have promoted neuromuscular adaptations related to braking, re-acceleration, postural control, and rapid force production (Santoso et al., 2024). However, these findings should be interpreted as evidence of broader perceptual-cognitive and motor demands rather than direct proof that changes in executive function caused the observed improvement in agility. Collectively, these mechanisms provide a plausible explanation for the effectiveness of the game-based intervention.

The findings are consistent with previous studies showing that structured game-based and physical education interventions can improve agility and other fitness components in children. A 10-week after-school game-based program improved T-test agility, sprint performance, balance, standing long jump, and handgrip strength in 12-year-old children (Kurnaz et al., 2024). Other studies have reported significant improvements in cardiorespiratory fitness, agility, lower-limb power, and speed following physical education interventions among school-aged children (Wang et al., 2022; Zhao et al., 2023; Reis et al., 2024). Similarly, the FIT FIRST FOR ALL project reported significant improvements in agility and physical fitness among students aged 7-16 years participating in school-based physical activity programs (Olsen et al., 2024). Furthermore, the meta-analysis conducted by Sun and Chen (2024) concluded that sports game interventions generally produce greater improvements in fundamental movement skills than control conditions. Nevertheless, the control-high-agility group in the present study



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also showed a significant pretest–posttest change, suggesting that some improvement may be related to regular physical education, matched free play, test familiarization, or natural performance variation. However, the intervention group demonstrated a substantially greater improvement, as reflected by the strong main effect of group.

The significant main effect of initial agility level indicates that participants' initial motor condition remained an important factor in determining the magnitude of their response to the intervention. This finding may be explained by the fact that children with better foundational coordination and movement control are generally more prepared to benefit from complex training stimuli. Previous research has identified evidence of a proficiency barrier between certain fundamental movement skills and sport-specific skills (Pacheco et al., 2022; Ribeiro et al, 2024), while also demonstrating that age influences performance across a range of motor tasks. Consistent with these findings, children with higher levels of fundamental movement skill (FMS) proficiency tend to perform better in complex motor tasks and are better able to adapt to technical, tactical, and physical demands (Zhang et al., 2024; Makaruk et al., 2025). This may help explain why students with high initial agility achieved slightly greater gain scores. However, this finding should be interpreted cautiously because the high- and low-agility categories were derived from the same pretest scores used to calculate gain scores. Therefore, baseline classification and regression to the mean may have influenced the observed difference between the two strata, and the result should not be interpreted as definitive evidence that students with higher baseline agility are inherently more responsive to the intervention.

Another important finding was the absence of a significant interaction between group and initial agility level. This indicates that the intervention's effectiveness did not differ significantly between students with high and low initial agility. More precisely, the analysis provided no statistical evidence that the effect of treatment depended on initial agility classification. From a practical perspective, this finding suggests that the program was relatively inclusive, as its benefits were evident across different levels of initial ability. This result differs from findings reported among young futsal players, where a significant interaction was observed between training type and dynamic balance level (Ilham et al., 2025), indicating that agility adaptations depended on the athletes' initial neuromuscular profiles. Such



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differences may be attributed to variations in participant characteristics and the moderator variables examined (Safitri et al., 2025). Accordingly, the absence of an interaction in the present study may reflect the broader and less specialized movement profile of school-aged participants, for whom repeated exposure to varied small-ball tasks may provide sufficiently general motor stimulation across different initial ability levels.

On the other hand, research involving young soccer players reported that reaction training produced the greatest improvements in agility (Klatt et al., 2025), while a meta-analysis involving basketball players found that reaction-based training also enhanced agility, although training models such as speed and strength training tended to produce only minimal effects (M. Zhang et al., 2025). These findings suggest that agility adaptations may depend on the specificity of the training stimulus and participants' characteristics. However, the literature is not entirely consistent. School-based physical activity interventions have shown no significant improvements in FMS competency or physical activity among children with intellectual disabilities (Noetel et al., 2025). Similarly, a study examining a 12-week soccer instruction program in early childhood reported no significant interaction effects for agility, despite observing benefits in inhibitory control (Aoyama, 2024). Furthermore, a comparative meta-analysis by Kunz et al. (2019) showed that small-sided games and high-intensity interval training (HIIT) produced similar benefits across several performance parameters in young soccer players (Kunz et al., 2019). These contrasting findings indicate that game-based activity does not automatically improve agility; its effectiveness likely depends on task specificity, implementation quality, participant characteristics, program duration, and the suitability of the assessment tools. Therefore, the positive findings of the present study should be interpreted within the specific context of the intervention and population examined.

The findings have practical implications for physical education teachers and school extracurricular coordinators. Small-ball-based physical activity may provide an effective, enjoyable, low-cost, and easily implemented approach within regular lessons and extracurricular programs. Rather than relying solely on mechanistic agility drills, teachers can use games involving ball manipulation, directional changes, rapid responses, and movement control to create more contextualized agility training. The present intervention also suggests



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that meaningful agility-related stimulation can be achieved without progressive increases in repetitions, movement speed, or exercise volume, provided that multidirectional and coordinative demands are maintained within a controlled intensity range. This may help preserve safety, concentration, and enjoyment while supporting perceptual-motor learning. These implications are supported by evidence that school-based interventions can improve FMS (Yin et al., 2025), and that game-based after-school programs can enhance physical fitness in children (Onarici Gungor et al., 2025). Thus, small-ball-based activities may offer schools a practical way to promote multicomponent agility through structured and engaging physical education.

This study has several limitations. First, the sample was limited to students aged 11-12 years from a specific school context, which restricts generalizability to other populations and settings. Second, the agility assessment primarily involved pre-planned movement patterns and may not fully represent reactive agility, which requires more complex perception-action coupling. The adapted N-Challenge Test also did not use the technological timing system of the original protocol, and evidence regarding its validity and reliability in girls remains limited. Third, assessor blinding was not implemented, which may have introduced measurement or expectancy bias. Fourth, although all activities were supervised, no formal quantitative measure of intervention fidelity was used. Fifth, initial agility categories were derived from the same baseline scores used to calculate gain scores, which may have introduced regression-to-the-mean effects and reduced information through dichotomization. Finally, the six-week intervention limits conclusions regarding the persistence of the observed improvements. Future studies should involve larger and more diverse samples, longer intervention periods, baseline-adjusted analyses using continuous measures of initial ability, reactive agility assessments, formal intervention-fidelity monitoring, and blinded assessors where feasible.

Conclusion

This study demonstrated that small-ball-based physical activity is effective in improving multicomponent agility among students aged 11-12 years. The findings showed that the intervention group achieved greater improvements than the control group, suggesting that



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small-ball-based physical activity may represent a more effective strategy than conventional physical education activities for enhancing multicomponent agility. In addition, initial agility level influenced the magnitude of improvement, indicating that initial motor competence contributes to participants' responsiveness to the training program. However, the absence of a significant interaction between group and initial agility level suggests that the intervention's effectiveness was relatively consistent among students with both high and low initial agility. From a practical perspective, these findings support the use of small-ball-based physical activity in physical education classes and school extracurricular programs because it is active, engaging, and relevant for developing students' movement capabilities. Overall, this study provides evidence that a simple yet structured game-based program can be an effective approach to improving multicomponent agility in school-aged children.

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