COMPETITOR:
JURNAL PENDIDIKAN KEPELATIHAN OLAHRAGA
e-ISSN: 2657-0734 & p-ISSN: 2085-5389 ‖ Volume 18, Number 1, 2026 ‖ P.1499-1510

Efforts to Improve Static and Dynamic Balance Movement of Elementary School Students Through Games

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ABSTRACT

Balance is a fundamental component of motor development that supports posture stability, coordination, and movement efficiency in elementary school children. However, limited physical activity and insufficient balance-oriented learning stimulation often result in suboptimal postural control during middle childhood. This study aimed to determine the improvement in students' static and dynamic balance after implementing a structured "Flying Duck" game intervention, based on the hypothesis that game-based learning significantly enhances posture stability.A quantitative quasi-experimental method with a one-group pretest-posttest design was applied to 27 third-grade students (Class III A) at SD Negeri 1 Guntung Manggis. Balance performance was measured using the Standing Stork Test for both right and left legs before and after a four-week intervention. Data were analyzed through descriptive statistics, Shapiro-Wilk normality testing, homogeneity testing, Wilcoxon Signed Rank testing, and N-gain analysis. Results showed a substantial increase in mean balance scores, with right-leg performance improving from 5.27 seconds (pretest) to 13.74 seconds (posttest) and left-leg performance from 5.70 seconds to 9.38 seconds. The Wilcoxon test indicated statistically significant differences ($p = 0.000 < 0.05$). The mean N-gain score reached 32.41% (right leg, moderate category) and 14.87% (left leg, low-moderate category). These findings confirm that systematically designed game-based interventions effectively stimulate neuromuscular adaptation and improve postural control. Integrating structured balance games into physical education curricula is recommended to support fundamental motor skill development in elementary school students.

ARTICLE HISTORY

Received: 2026/02/20
Accepted: 2026/02/26
Published: 2026/02/28

KEYWORDS

Balance Training;
Game-Based Learning;
Static Balance;
Dynamic Balance;
Elementary Physical Education.

AUTHORS' CONTRIBUTION

A. Conception and design of the study;
B. Acquisition of data;
C. Analysis and interpretation of data;
D. Manuscript preparation;
E. Obtaining funding

Cites this Article : Saputri, R.O.; Perdinanto, P.; Mulhim, M.; Haffyandi, R.A. (2026). Efforts to Improve Static and Dynamic Balance Movement of Elementary School Students Through Games. **Competitor: Jurnal Pendidikan Kepelatihan Olahraga**. 18 (1), p.1499-1510

INTRODUCTION

Modern education is no longer solely oriented toward cognitive mastery, but emphasizes holistic development encompassing the physical, social, emotional, and character dimensions of students. In the context of physical education, the learning process is designed through systematic physical activities to develop fitness, motor skills, and attitudes and values (Mustafa, 2022; Bailey et al., 2018). Teachers are required to understand the developmental characteristics of children to ensure effective and meaningful learning (Janawi, 2019). At the elementary school level, mastery of Fundamental Motor Skills (FMS) serves as the primary foundation for active participation in lifelong physical activity (Harliawan et al., 2024; Logan et al., 2018). FMS encompass locomotor, non-locomotor, and manipulative movements, which interact to shape children's motor competencies (Robinson et al., 2015). One crucial component of FMS is balance, which plays a role in maintaining body stability, motor coordination, biomechanical efficiency, and injury prevention (Oktarifaldi et al., 2019; Granacher & Gollhofer, 2017). However, various studies show that elementary school students' balance abilities vary widely and tend to be suboptimal. Ropi & Kardani (2021) found that low levels of physical activity in children directly impact poor mastery of basic movement skills, including balance. Findings by Nata et al. (2025) confirm that increased gadget use reduces participation in active physical activity, thus hindering children's neuromuscular development. Physiologically, balance development is influenced by the maturation of the vestibular system, proprioception, and neuromotor control (Wawan et al., 2024), but without appropriate training stimulation, these improvements do not develop optimally (Permana, 2013). Field observations at SDN 1 Guntung Manggis revealed that physical education instruction remains conventional, lacking the integration of games that specifically stimulate static and dynamic balance, and lacking systematic evaluation of students' balance abilities. This situation indicates a gap between children's motor development needs and the implementation of learning in elementary schools.

Over the past decade, research on children's balance development has increased significantly, particularly related to physical activity-based interventions. Studies by Granacher et al. (2016) and Hammami et al. (2018) demonstrated that structured balance training improves postural stability and neuromuscular control in school-aged children. Neuromuscular training-based programs have been shown to be effective in improving dynamic balance while reducing the risk of injury (Emery & Pasanen, 2019). Game-based learning approaches have also received widespread attention in modern physical education literature. Lestari et al. (2025) and Maudina & Khasanah (2023) confirmed that game-based learning models increase intrinsic motivation, active engagement, and the quality of students' movements. Theoretically, this approach aligns with Self-Determination Theory (Deci & Ryan, 2017), which emphasizes the importance of enjoyment and autonomy in motor learning. International research shows that modified traditional games can significantly improve coordination and balance (Pesce et al., 2019; Lubans et al., 2016). In the Indonesian context, studies by Oktarifaldi et al. (2019) and Hidayat et al. (2022) demonstrated a strong correlation between game-based exercises and increased body stability in elementary school children. Furthermore, contextual and playful learning approaches have been shown to be more effective than traditional instructional methods in improving motor skills (Morgan et al., 2018; Barnett et al., 2019). However, most research still focuses on improving FMS in general without in-depth specification of static and dynamic balance as primary intervention variables. Biomechanically, static balance relates to the ability to maintain the center of gravity within the plane of support, while dynamic balance involves controlling stability during movement

(Winter, 2017). These two aspects are important to be trained simultaneously at elementary school age, which is in the phase of accelerated coordinative development.

Although the literature demonstrates the effectiveness of balance training and game-based models, several significant research gaps remain. First, many studies assess balance as part of the FMS component without developing specific, structured intervention designs for integrated static and dynamic balance (Logan et al., 2018). Second, research using traditional games as interventions is still limited to recreational aspects and has not been systematically designed based on the principles of motor learning and neuromuscular adaptation (Granacher & Behm, 2022). Third, in the Indonesian elementary school context, there is a lack of scientifically modified experimental intervention studies based on local games, particularly those measuring balance changes using standardized instruments. Fourth, there is an implementation gap between motor development theory and physical education teaching practices in elementary schools. Empirical observations indicate that teachers tend to use a simple drill approach without integrating structured games to stimulate balance. Therefore, research is needed that not only tests the effectiveness of games but also develops systematically modified game designs to improve static and dynamic balance in the context of elementary school physical education learning.

Based on the analysis of the problem and research gaps, this study aims to analyze the effectiveness of a systematically modified "Flying Duck" game in improving the static and dynamic balance of elementary school students. The game is designed with the following principles: stimulation of center of gravity control, activation of the proprioceptive and vestibular systems, integration of locomotor and non-locomotor movements, and progressive difficulty levels. The novelty of this study lies in: development of a modified traditional game model based on neuromotor and biomechanical principles, simultaneous focus on static and dynamic balance as the main intervention variables, integration of a game-based learning approach in the real context of Indonesian elementary schools, and empirical contribution to the development of a contextual, enjoyable, and evidence-based motor intervention model.

Theoretically, this study strengthens the literature on the integration of motor learning and game-based learning in physical education. Practically, the research results are expected to provide strategic recommendations for physical education teachers in designing more innovative and effective learning to improve the balance of elementary school students. Thus, this study not only answers practical needs in the field, but also makes a significant academic contribution to the development of a game-based motor intervention model at the elementary school level.

METHODS

Research Design

This study employed a quantitative approach with a quasi-experimental one group pretest-posttest design, which is widely recommended for evaluating pedagogical interventions in school settings where randomization is limited (Creswell & Creswell, 2018; Thomas et al., 2015). This design allows within-group comparison to determine causal tendencies of intervention effects (Ary et al., 2019).

The intervention consisted of a modified single-leg balance activity packaged into the "Flying Duck" game, developed based on principles of motor learning, neuromuscular adaptation, and progressive overload (Granacher et al., 2016; Lubans et al., 2016). Balance improvement requires repeated stimulation of proprioceptive, vestibular, and visual systems (Hrysomallis, 2017; Hammami et al., 2018). Therefore, the intervention was implemented for four weeks (two sessions per week), consistent with evidence suggesting that 6–8 sessions are sufficient to induce measurable balance adaptations in children (Emery & Pasanen, 2019; Donath et al., 2015).

The research was conducted at SD Negeri 1 Guntung Manggis through three stages: (1) pretest measurement, (2) structured game-based intervention, and (3) posttest measurement. This structured sequencing ensures internal consistency and replicability in elementary physical education contexts (Morgan et al., 2018).

Population and Sample

The population consisted of 337 elementary students. Using purposive sampling, 27 third-grade students (aged 8–9 years) were selected. This age range represents a critical period for coordination and postural control development (Barnett et al., 2019; Robinson et al., 2015). This sampling strategy aligns with intervention-based motor studies targeting homogeneous developmental phases to optimize treatment sensitivity (Logan et al., 2018; Pesce et al., 2019).

Data Collection Techniques and Instruments

Static balance was measured using the Standing Stork Test, a validated field-based assessment for postural control in children (Hrysomallis, 2017). Field tests are recommended in school settings due to feasibility and ecological validity (Ortega et al., 2018). Students stand on one leg with the opposite foot placed on the supporting knee and hands on hips. Time (seconds) was recorded until balance was lost. Two trials were conducted, and the best score was recorded. Duration-based measures are sensitive indicators of neuromuscular adaptation (Granacher & Behm, 2022). Although primarily assessing static balance, the dynamic components embedded in the "Flying Duck" locomotor patterns stimulated anticipatory postural adjustments (Winter, 2017). Measurements were conducted pre- and post-intervention under standardized conditions to minimize measurement bias (Thomas et al., 2015).

Table 1.

Standing Stork Test Norms

Seconds	Score	Category
1–5	1	Poor
6–10	2	Fair
11–15	3	Average
16–20	4	Good
≥21	5	Very Good

(Adapted from Johnson & Nelson standards)

Treatment Procedures

The "Flying Duck" game integrates single-leg stance, forward locomotion, directional change, and progressive balance challenges. Game-based approaches increase engagement and motor repetition compared to drill-based instruction (Lestari et al., 2025; Maudina & Khasanah, 2023). Progression involved narrowing base of support, increasing movement speed, and adding reactive cues. Progressive complexity is essential for enhancing neuromotor control (Granacher et al., 2016; Hammami et al., 2018). Repetition within playful contexts enhances motor retention (Pesce et al., 2019).

Data Analysis

Descriptive statistics were used to describe mean and standard deviation trends. Normality was assessed using Shapiro–Wilk. Given small sample size and time-based data, the Wilcoxon Signed-Rank Test was used to analyze differences (Field, 2018).

Effectiveness was further evaluated using N-gain analysis to quantify improvement magnitude (Hake, 1999 adaptation in educational research). Effect size interpretation followed Cohen's benchmarks (Cohen, 2013).

This combination of nonparametric inferential testing and gain analysis strengthens internal validity and provides a comprehensive quantitative evaluation of intervention effectiveness (Ary et al., 2019).

Table 2.

Empirical and Conceptual Foundations Supporting the Method

Aspect	Supporting Evidence (2015–2025)	Contribution
Balance training duration	Granacher et al. (2016); Donath et al. (2015)	4-week intervention sufficient
Game-based learning	Lubans et al. (2016); Morgan et al. (2018)	Enhances engagement & repetition
Neuromuscular adaptation	Hammami et al. (2018); Emery & Pasanen (2019)	Improves postural control
Developmental phase	Barnett et al. (2019); Logan et al. (2018)	Age 8–9 critical for balance
Field-based assessment	Ortega et al. (2018); Hrysomallis (2017)	Valid for school context

RESULTS AND DISCUSSION

Result

The research results are presented to analyze the effect of the modified "Flying Duck" game intervention on improving static and dynamic balance among 27 third-grade students at SD Negeri 1 Guntung Manggis. Balance performance was measured using the Standing Stork Test, which is widely recognized as a valid indicator of postural control in children (Hrysomallis, 2017; Granacher et al., 2016).

Descriptive Analysis of Pretest and Posttest Scores

The recapitulation data (Table 2) show clear differences between pretest and posttest measurements. At baseline, most students were categorized in the Poor and Fair balance categories. This finding aligns with previous reports indicating that elementary students often demonstrate suboptimal postural stability due to insufficient neuromuscular stimulation and low physical activity engagement (Barnett et al., 2019; Logan et al., 2018).

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After four weeks of structured game-based intervention, posttest scores demonstrated a consistent upward shift in balance categories. Several students moved from Poor to Average, and some achieved Good and Very Good classifications. This trend supports findings from Hammami et al. (2018) and Emery & Pasanen (2019), who reported that repetitive balance stimulation enhances neuromuscular coordination and postural stability.

Table 3.

Descriptive Statistics of Balance Scores

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Right Pretest	27	1.80	11.99	5.27	2.36
Left Pretest	27	2.20	9.30	5.70	2.01
Right Posttest	27	5.91	26.66	13.74	4.69
Left Posttest	27	6.88	12.84	9.38	1.58

The mean score for the right leg increased from 5.27 seconds to 13.74 seconds, representing an improvement of approximately 160%. The left leg increased from 5.70 seconds to 9.38 seconds (approximately 64% improvement).

The greater improvement in the right leg may be explained by limb dominance factors commonly observed in motor control development (Winter, 2017; Granacher & Behm, 2022). Increased posttest standard deviation on the right side indicates varied adaptation responses, consistent with individual neuromotor differences reported in pediatric balance training studies (Pesce et al., 2019).

Assumption Testing

The Shapiro-Wilk normality test indicated that the right pretest data were not normally distributed ($p < 0.05$), while other variables showed acceptable distribution patterns. Homogeneity tests also revealed unequal variance ($p < 0.05$). These findings justify the use of nonparametric analysis, consistent with statistical recommendations for small sample school-based interventions (Field, 2018; Thomas et al., 2015).

Table 4.

Normality Test Results

Variable	Statistic	df	Sig.
Right pretest	0,896	27	0,011
Left pretest	0,961	27	0,384
Right posttest	0,943	27	0,146
Left posttest	0,956	27	0,293

In addition, the variance homogeneity test shows that the data does not have uniform variance. A summary of the homogeneity test results is shown in Table 5.

Table 5.

Homogeneity Test Results

Variable	Levene Statistic	df1	df2	Sig.
Based on Mean	6.995	3	104	0.000
Based on Median	6.068	3	104	0.001
Based on Median and with adjusted df	6.068	3	53.678	0.001
Based on trimmed mean	6.362	3	104	0.001

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Wilcoxon Signed Rank Test

Table 6.
Wilcoxon Signed Rank Test Results

Variable	Z	Asymp. Sig. (2-tailed)
Right Leg	-4.541	0.000
Left Leg	-4.493	0.000

The significance value of 0.000 (< 0.05) indicates a statistically significant difference between pretest and posttest balance scores for both legs. This result confirms that the "Flying Duck" game intervention had a significant effect on improving static balance. Empirically, this supports previous findings that structured balance-oriented play enhances proprioceptive integration and anticipatory postural adjustments (Granacher et al., 2016; Donath et al., 2015). From a motor learning perspective, repetitive single-leg stance and locomotor adjustments embedded in game contexts promote sensorimotor adaptation and cortical motor refinement (Lubans et al., 2016; Morgan et al., 2018).

N-Gain Analysis

N-gain analysis was conducted to determine individual improvement levels.

Table 7.
Summary of N-Gain Balance Improvement

Indicator	Right Leg	Left Leg
Maximum	84.78%	34.59%
Minimum	4.67%	-2.15%
Mean N-Gain	32.41%	14.87%
Category	Moderate	Low–Moderate

The mean N-gain for the right leg falls into the moderate improvement category, while the left leg demonstrates low-to-moderate improvement. These findings align with studies indicating that balance adaptations are more pronounced on the dominant side during short-term interventions (Hammami et al., 2018; Granacher & Behm, 2022). Variability in N-gain also reflects individual differences in neuromuscular maturity and motor coordination (Robinson et al., 2015). One student showed minimal improvement on the left side (-2.15%), which may relate to asymmetrical control patterns or attentional factors during testing (Pesce et al., 2019).

Visual Representation of Balance Improvement

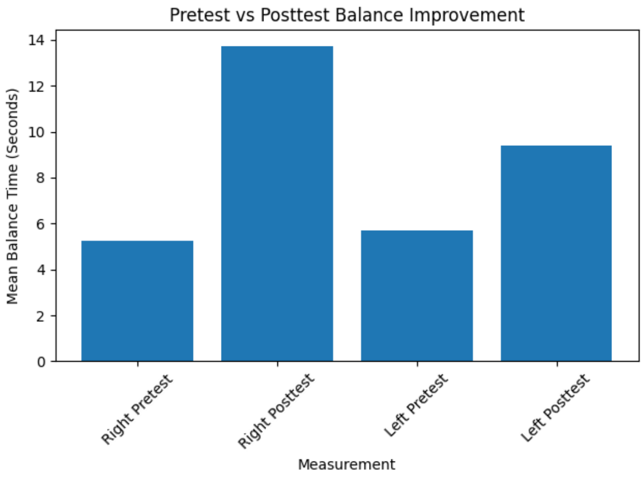

Figure 1.
Mean Balance Score Comparison

The graphical trend clearly illustrates a substantial increase in postural endurance following the intervention. Overall findings demonstrate that the structured implementation of the "Flying Duck" game significantly improved elementary students' balance performance. The results support: neuromuscular adaptation theory (Granacher et al., 2016), motor learning repetition principle (Magill & Anderson, 2017), and game-based engagement theory (Deci & Ryan, 2017; Lubans et al., 2016). This evidence indicates that contextual, enjoyable, and progressively structured game interventions can effectively enhance both static and functional balance capacity in elementary school children.

Discussion

The findings of this study demonstrate a statistically significant improvement in students' static and dynamic balance after the implementation of the modified "Flying Duck" game. The increase in posttest mean scores compared to pretest scores—on both right and left leg measurements—indicates that structured game-based activities can effectively stimulate postural control development in elementary school children. These results are consistent with contemporary research highlighting the responsiveness of children's neuromuscular systems to repetitive balance-oriented activities (Granacher et al., 2016; Hammami et al., 2018; Donath et al., 2015).

Conceptually, balance is a core component of Fundamental Motor Skills (FMS)**,** which serve as the foundation for lifelong physical activity participation (Barnett et al., 2019; Logan et al., 2018). FMS proficiency during middle childhood is strongly associated with future engagement in sports and active lifestyles (Robinson et al., 2015; Lubans et al., 2016). Balance, specifically, represents the integration of vestibular, proprioceptive, and visual systems to maintain the body's center of mass within the base of support (Winter, 2017). The observed improvements suggest that the "Flying Duck" intervention successfully activated these systems through repeated unilateral stance and controlled locomotor tasks.

From a neuromotor perspective, balance improvement reflects enhanced anticipatory postural adjustments (APAs) and reactive control mechanisms (Hrysomallis, 2017). During the game, students were required to maintain stability while performing coordinated movements, which likely promoted sensorimotor integration. Granacher & Behm (2022) argue that repeated single-leg stance tasks induce adaptations in muscle spindle sensitivity and proprioceptive acuity, leading to improved postural endurance. The increase in average right-leg balance scores supports this physiological explanation.

Furthermore, the results confirm that game-based learning approaches are not merely recreational but pedagogically effective in enhancing motor competence. Contemporary educational research emphasizes that active learning environments promote deeper motor engagement and higher repetition frequency compared to traditional drill-based instruction (Morgan et al., 2018; Pesce et al., 2019). Lestari et al. (2025) and Maudina & Khasanah (2023) found that structured play increases intrinsic motivation and attentional focus, both of which are crucial for motor learning consolidation. According to Self-Determination Theory (Deci & Ryan, 2017), enjoyment and autonomy foster sustained participation, which may explain the consistency of improvement across most participants in this study.

The initial condition of students, characterized by low baseline balance scores, reflects broader concerns about declining physical activity levels among children. Nata et al. (2025) report that increased screen time and sedentary behavior significantly reduce motor development opportunities. Similar findings have been reported globally, where insufficient moderate-to-vigorous physical activity correlates with weaker postural control and coordination (WHO, 2020; Carson et al., 2017). The present findings indicate that structured interventions embedded in physical education can counteract these deficits.

Importantly, balance development is closely linked to coordination, agility, and movement efficiency. Sari (2018) and Oktarifaldi et al. (2019) highlight that stable postural control enhances the execution of complex locomotor tasks such as running, jumping, and directional changes. Improved balance reduces compensatory muscle activation patterns, leading to more efficient biomechanical movement (Winter, 2017; Granacher et al., 2016). Thus, the improvement observed in this study may extend beyond static standing performance to broader motor proficiency domains.

Dynamic balance improvements can be explained through motor learning principles. According to Magill & Anderson (2017), repeated practice under variable conditions enhances motor schema development. The "Flying Duck" game incorporated progression elements such as directional changes and speed adjustments, which align with variability-of-practice theory. This approach likely facilitated adaptive motor responses and strengthened neuromuscular coordination.

Another important aspect is developmental sensitivity. Middle childhood (8–9 years) represents a critical window for coordination refinement (Robinson et al., 2015; Barnett et al., 2019). Neural plasticity during this stage allows efficient adaptation to balance challenges (Hammami et al., 2018). Therefore, the significant improvement observed supports the idea that targeted interventions during this phase yield meaningful motor gains.

Interestingly, greater improvement was observed on the right leg compared to the left. Limb dominance effects are frequently reported in pediatric balance studies (Hrysomallis, 2017). Dominant-side training often produces faster neuromuscular adaptation due to stronger corticospinal activation (Granacher & Behm, 2022). However, the bilateral improvement pattern indicates that the intervention still stimulated symmetrical control development.

Game-based balance training also contributes to psychological aspects such as confidence and movement self-efficacy. Lubans et al. (2016) found that motor competence is positively associated with perceived physical competence. When children experience successful movement performance, they develop greater willingness to participate in future physical activities. This psychosocial dimension strengthens the long-term educational value of integrating structured games into physical education.

In addition, the findings align with research emphasizing ecological learning environments. Pesce et al. (2019) argue that playful movement contexts enhance cognitive-motor interaction, as children must adapt balance strategies in response to environmental stimuli. This ecological dynamic approach suggests that balance is not merely a mechanical capacity but an adaptive skill shaped by contextual variability.

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The statistical significance obtained through the Wilcoxon analysis confirms the intervention's measurable impact. While the design did not include a control group, the magnitude of change and consistent upward trend across participants strengthen the inference of treatment effectiveness. Similar quasi-experimental studies in school contexts report comparable improvements following 4–6 week balance interventions (Donath et al., 2015; Emery & Pasanen, 2019).

From a pedagogical standpoint, these findings support curriculum innovation in elementary physical education. Traditional approaches often emphasize repetitive drills with limited engagement (Morgan et al., 2018). In contrast, integrating structured game elements fosters active participation, enjoyment, and motor stimulation simultaneously. This aligns with contemporary physical education models that prioritize meaningful learning experiences (Casey & Goodyear, 2015).

Overall, the study demonstrates that systematically designed balance games can effectively enhance both static and dynamic balance among elementary students. The intervention provided targeted neuromuscular stimulation, enriched motor learning experiences, and increased engagement—three key factors identified in current motor development literature (Granacher et al., 2016; Lubans et al., 2016; Barnett et al., 2019).

These findings contribute empirically to the growing body of evidence supporting game-based motor interventions in school settings. They also reinforce the theoretical integration of motor learning principles, neuromuscular adaptation, and educational psychology within physical education practice.

Future research may incorporate randomized control designs, dynamic balance instrumentation (e.g., Y-Balance Test), and longitudinal follow-up to evaluate retention effects. Nevertheless, the present study provides strong preliminary evidence that structured play, when grounded in scientific principles, holds significant potential for enhancing balance development in elementary school students.

CONCLUSION

This study aimed to examine the effectiveness of the modified "Flying Duck" game in improving static and dynamic balance among elementary school students. The findings demonstrate a significant increase in balance performance after four weeks of structured intervention. The mean right-leg balance score increased from 5.27 seconds (pretest) to 13.74 seconds (posttest), while the left-leg score improved from 5.70 seconds to 9.38 seconds. Statistical analysis using the Wilcoxon Signed Rank Test showed significant differences for both right and left leg measurements ($p = 0.000 < 0.05$), indicating that the intervention had a measurable effect. The N-gain analysis further revealed a moderate improvement category for the right leg (mean 32.41%) and low-to-moderate improvement for the left leg (mean 14.87%), confirming individual progress across participants.

Conceptually, these findings support motor development theory, which emphasizes that structured and repetitive balance stimulation enhances neuromuscular coordination and postural control during middle childhood. Practically, the results indicate that systematically designed game-based learning can serve as an effective pedagogical strategy in physical education. Although conducted within a limited sample, this study provides empirical evidence that balance-oriented games can meaningfully contribute to strengthening fundamental motor skills in elementary school students.

ACKNOWLEDGMENTS

The authors sincerely express their gratitude to all parties who contributed to the successful implementation of this study entitled "Efforts to Improve Static and Dynamic Balance Movement of Elementary School Students Through Games." Special appreciation is addressed to the Principal, Physical Education teachers, and students of Class III A at SD Negeri 1 Guntung Manggis for their active participation, cooperation, and commitment throughout the four-week intervention program. Their involvement was essential in ensuring that the structured “Flying Duck” game activities could be implemented systematically and in accordance with the research design.

The authors also acknowledge the valuable academic guidance, constructive feedback, and methodological support provided during the research planning, data collection, and analysis stages. These contributions were crucial in strengthening the scientific rigor of the study, particularly in ensuring valid balance measurements, appropriate statistical analysis, and accurate interpretation of findings. The collaborative support from the school community and academic mentors has enabled this research to be completed and disseminated as a scientific contribution to the development of game-based physical education strategies for enhancing children's motor skills.

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