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A boccia-based adaptive physical education model for supporting gross motor skill development in students with quadriplegia

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ABSTRACT

Background: Students with quadriplegia often encounter significant barriers to participation in physical education due to limited mobility and the lack of structured adaptive learning models. Despite the potential of boccia as an inclusive sport, its use as a pedagogical tool in school-based physical education remains underexplored. **Objectives:** This study aimed to develop and evaluate a modified boccia-based learning model to support gross motor skill development among students with quadriplegia in special education settings. **Methods:** A research and development (R&D) approach based on the Borg and Gall model was implemented in six stages. Participants were recruited from a special education school in Surakarta, Indonesia, involving five students in the small-group trial and 20 students in the field trial. The intervention was conducted over eight sessions. Data were collected using expert validation sheets and a modified version of the Test of Gross Motor Development–Second Edition (TGMD-2). Pre–post differences were analysed using paired-samples t-tests, and effect size was calculated using Cohen's d. **Results:** The developed model demonstrated acceptable content validity (CVR = 0.50-1.00; mean = 0.60) and satisfactory reliability ($r > 0.50$; $p < 0.05$). Gross motor skill scores increased from 48.78 (pretest) to 85.78 (posttest), with a statistically significant difference ($p < 0.001$) and a very large effect size ($d = 3.70$). However, these findings should be interpreted cautiously due to the absence of a control group and the small sample size. **Conclusion:** The modified boccia-based learning model shows potential as a feasible and practical approach for supporting motor skill development in students with quadriplegia. Further research using controlled experimental designs is required to confirm its effectiveness.

Keywords: Boccia; adaptive physical education; gross motor skills; quadriplegia; learning model

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INTRODUCTION

Adaptive physical education (APE) plays a crucial role in ensuring meaningful participation for students with physical disabilities, supporting the development of

motor, cognitive, and social competencies (An et al., 2024; Jariono et al., 2025). For students with quadriplegia, structured PE activities stimulate essential motor domains such as object control, eye–hand coordination, and postural stability (Cornejo et al., 2023). However, research shows that PE programmes in many schools still rely heavily on passive, individualised exercises with minimal opportunities for game-based engagement (Azlan et al., 2021; Ferraz et al., 2024). This creates a need for adaptive PE models that are active, participatory, and developmentally appropriate.

Boccia, an official Paralympic precision sport, is widely recognised for its suitability for individuals with severe motor impairments, particularly those with cerebral palsy and quadriplegia (Koper et al., 2020; Suárez-Iglesias et al., 2020). Studies indicate that boccia supports fine-motor control, tactical decision-making, and functional movement patterns relevant to educational settings (Roldan et al., 2017; Shieh et al., 2025). Although primarily used in rehabilitation and elite sports, its task characteristics—grasping, reaching, aiming, and releasing—align directly with curricular motor-skill outcomes, making it highly adaptable as a school-based learning medium (Huang et al., 2014; Sufitriyono et al., 2025).

Despite its potential, most global research focuses on boccia from competitive or therapeutic perspectives. Previous studies have examined athlete classification, biomechanical performance, and intervention-rehabilitation outcomes (Ferreira et al., 2025; Shieh et al., 2025). However, very few studies have explored boccia as a structured pedagogical tool within school-based PE, especially for students with severe impairments (Fazari et al., 2023). In addition, existing educational models emphasise general motor play rather than game-specific, goal-directed models such as boccia (Barus et al., 2025). This highlights a major research gap in the development of boccia-based instructional frameworks for improving basic motor skills among quadriplegic students.

This gap becomes more critical in the Indonesian context. According to the Ministry of Education, Culture, Research, and Technology (Habibah, 2024), more than 330,000 students are identified as having special educational needs, with 12-15% experiencing physical impairments requiring adaptive PE. Studies show that PE in Indonesian special schools remains dominated by static drills, limited motor tasks, and teacher-centred instruction (Mahendra et al., 2020; Nugrohowati & Raharjo, 2023). Meanwhile, research indicates that boccia can enhance coordination, ball-handling accuracy, and social interaction in children with severe motor limitations (Andamarisa et al., 2025; Sufitriyono et al., 2025). Although boccia has been explored in rehabilitation and sport performance contexts, evidence concerning structured pedagogical models for its integration into school-based physical education, particularly within Indonesian special education settings, remains limited.

To address these gaps, this study develops and evaluates a modified Boccia learning model tailored to the needs of quadriplegic students in special education settings. The model follows structured instructional stages and uses simplified rules and adaptive equipment to ensure accessibility and skill progression. Its effectiveness is measured with the Test of Gross Motor Development-2 (TGMD-2), widely validated for children with disabilities (Capio et al., 2016; Houwen et al., 2010). This study is among the first to systematically develop and empirically evaluate a boccia-based instructional model within school-based adaptive physical education settings for students with quadriplegia.

This study offers both theoretical and practical contributions. Theoretically, it expands the adaptive PE framework by integrating game-based learning with inclusive sports adaptation. Practically, it produces an evidence-based model that is easy for teachers to apply, enhances participation, and supports measurable improvements in motor

development. Therefore, the aim of this research is to develop and test a modified boccia game model to improve basic motor skills among quadriplegic students in special schools.

METHOD

Research Design

This study employed a research and development (R&D) design adapted from Borg and Gall's educational product development framework (Gall, 2007), streamlined into six major stages: (i) needs analysis, (ii) initial product development, (iii) expert validation, (iv) revision, (v) small-group try-out, and (vi) field trial. This simplified model was adopted to ensure practical implementation within a school-based adaptive physical education setting while maintaining the essential components of systematic product development and evaluation.

The first stage (needs analysis) involved observations and informal interviews with teachers and students to identify existing limitations in adaptive physical education practices. The second stage focused on designing the initial prototype of the boccia-based learning model based on literature review and contextual needs. The third stage involved expert validation to assess content relevance and feasibility. Based on expert feedback, revisions were made in the fourth stage. The fifth stage consisted of a small-group trial to evaluate feasibility, safety, and practicality, while the final stage (field trial) aimed to examine the preliminary effectiveness of the developed model in improving students' gross motor skills.

Participants

Participants were recruited from a special education school for students with physical disabilities (SLB D YPAC Surakarta), Indonesia. The study involved two groups reflecting early-phase R&D procedures in adaptive physical education. A small-group trial included five students, followed by a field trial involving 20 students aged 8-12 years. All participants were diagnosed with quadriplegia and were enrolled in the school's adaptive physical education programme. Purposive sampling was applied using the following inclusion criteria: (i) ability to participate in modified boccia activities with minimal assistance; (ii) regular attendance in physical education sessions; and (iii) confirmation of medical readiness from the school. Students with progressive neurological disorders, recent musculoskeletal injuries, or limited ability to follow instructions were excluded. The sample size reflects the limited and specialised nature of the target population in adaptive physical education research. Descriptive characteristics of participants are presented in **Table 1**.

Table 1. Participant Characteristics in the Small-Group and Field Trials

Characteristic	Small-Group Trial (n = 5)	Field Trial (n = 20)	Total (N = 25)
Age (years), Mean ± SD	10.2 ± 1.1	10.4 ± 1.3	10.3 ± 1.2
Gender (Male/Female)	3/2	12/8	15/10
Grade Level	3-5	3-6	3-6
Type of Disability	Quadriplegia	Quadriplegia	Quadriplegia

Instrument

Data were collected using three instruments: (i) expert validation sheets, (ii) observation checklists, and (iii) a modified version of the Test of Gross Motor Development–Second Edition (TGMD-2). The TGMD-2 was selected due to its widespread use in assessing gross motor skills and its strong psychometric properties across diverse child populations (Ulrich, 2000; Aliriad et al., 2024; Tun et al., 2023).

Considering the limited locomotor abilities of students with quadriplegia, the original TGMD-2 tasks were adapted to ensure feasibility and measurement fairness. The adaptation followed a simplified framework consisting of domain review, task modification, expert consultation, and pilot feasibility testing. Locomotor tasks that required independent lower-limb movement (e.g., running, hopping, and galloping) were removed or replaced with seated balance and upper-body coordination activities. Object-control tasks were retained but modified using assistive devices such as boccia ramps and lightweight balls.

The preliminary instrument was reviewed by four experts in adaptive physical education, physiotherapy, child motor development, and special education. Content validity was assessed using the Content Validity Ratio (CVR) and Content Validity Index (CVI). A pilot test involving five students was conducted to examine task feasibility and scoring clarity. Items that were considered impractical for students with quadriplegia were excluded, while the remaining indicators were mapped conceptually to the original TGMD-2 domains. Consequently, the adapted instrument was treated as a modified TGMD-2 framework rather than a direct replication of the original scale. Inter-rater reliability was evaluated during the small-group trial and showed high agreement (ICC = 0.87). A summary of the modified TGMD-2 indicators is presented in Table 2.

The adapted instrument underwent expert review by four specialists (adaptive physical education, physiotherapy, child motor development, and PE teachers). Content validity was assessed using the Content Validity Index (CVI) and Content Validity Ratio (CVR), with all items meeting acceptable thresholds (CVI ≥ 0.80; CVR ≥ 0.75). Item validity was further examined using item–total correlation analysis (Pearson correlation), comparing each item score with the overall scale score based on expert ratings. Items with correlation coefficients above 0.30 were considered acceptable indicators of construct validity. Inter-rater reliability was tested during the small-group trial and yielded high agreement (ICC = 0.87), indicating that the scoring rubric was consistent and dependable for use in special school settings. A summary of the adapted TGMD-2 indicators used in this study is presented in **Table 2**.

Table 2. Modified TGMD-2 Indicators for Students with Quadriplegia

No	Domain	Skill Indicator	Performance Description	Score Range
1	Balance / Postural Control	Seated or supported balance	Maintains a stable position during play	0–2
2	Body Adjustment	Positional shifting	Adjusts body or chair orientation to prepare for throwing	0–2
3	Non-locomotor	Trunk rotation	Rotates trunk or adjusts direction in a controlled manner	0–2
4	Manipulative	Ball release toward target	Initiates throw manually or using assistive ramp	0–2
5	Manipulative	Force control	Adjusts throwing force to prevent over/under shooting	0–2
6	Assistive tool use	Ramp manipulation	Uses ramp independently or with minimal assistance	0–2
7	Affective (Adaptation)	Engagement	Shows interest and participation during the game	0–2
8	Social (Adaptation)	Cooperative interaction	Communicates or collaborates with peers during activity	0–2

Notes: Each item was scored on a 3-point scale (0 = not performed, 1 = partially performed, 2 = performed correctly).

Procedures

This study followed six stages of the research and development (R&D) process adapted from the Borg and Gall model (Gall et al., 2007). The stages included: (i) needs analysis conducted through observations and interviews with teachers and students at a special education school for students with physical disabilities (SLB D YPAC Surakarta), Indonesia; (ii) literature review and initial product development, resulting in the first prototype of the modified boccia learning model; (iii) expert validation involving four specialists in adaptive physical education, physiotherapy, motor development, and special education teaching; (iv) product revision based on expert feedback; (v) a small-group trial with five students to evaluate feasibility, safety, and instructional practicality; and (vi) a field trial with 20 students to examine intervention effectiveness.

The intervention during the field trial lasted eight weeks and was integrated into the school's physical education schedule. Students participated in two sessions per week, each lasting 30-40 minutes. Each session consisted of: (i) a 5-minute warm-up adapted for seated or assisted participation; (ii) a 20-25-minute modified boccia activity incorporating adapted equipment, adjustable throwing distances, and optional assistive ramps; and (iii) a 5-10-minute cool-down focusing on breathing and relaxation.

All sessions were supervised by a physical education teacher and supported by the researcher to ensure fidelity of implementation and participant safety. Motor skill assessments were conducted before and after the intervention using the modified TGMD-2 instrument. Two trained observers independently scored performance, and inter-rater discrepancies were resolved through consensus discussion to maintain scoring consistency. While the small-group trial primarily focused on feasibility and safety evaluation, the field trial followed identical instructional procedures to assess intervention effectiveness.

Data Analysis

Quantitative pretest and posttest data were analysed using parametric procedures. Normality of difference scores was assessed with the Shapiro–Wilk test ($p > 0.05$), indicating that assumptions for paired-samples analysis were met. Differences in motor skill scores were examined using paired-samples t-tests, with statistical significance set at $p < 0.05$. Effect size was calculated using Cohen's d to estimate the magnitude of change. Content validity of the instrument was evaluated using the Content Validity Index (CVI) and Content Validity Ratio (CVR) based on expert judgements (CVI ≥ 0.80, CVR ≥ 0.75). Item validity was assessed using item–total correlation ($r > 0.30$), and inter-rater reliability showed high agreement (ICC = 0.87). All analyses were conducted using SPSS version 26.

Ethical Considerations

Ethical approval was obtained from the relevant institutional review body. Written informed consent was secured from parents/guardians, and assent was obtained from participating students. All procedures complied with ethical standards for research involving vulnerable populations.

RESULTS AND DISCUSSION

Results

Content Validity of the Boccia-Based Learning Model

Content validity was assessed using the Content Validity Ratio (CVR) based on expert judgement from four specialists in adaptive physical education. According to Lawshe's criteria, items with CVR values below the minimum threshold (0.75 for N = 4) were considered for revision.

Table 3. Content Validity Ratio (CVR) Results

Item	CVR	Decision
1	1.00	Valid
2	0.50	Needs revision
3	0.50	Needs revision
4	0.50	Needs revision
5	0.50	Needs revision
6	1.00	Valid
7	1.00	Valid
8	1.00	Valid
9	0.50	Needs revision
10	0.50	Needs revision
Mean CVR	0.60	Acceptable

As shown in **Table 3**, four items achieved full expert agreement (CVR = 1.00), indicating strong relevance. However, six items fell below the minimum threshold (CVR = 0.50), suggesting the need for refinement. The overall mean CVR of 0.60 indicates moderate content validity, meaning that while the model is generally acceptable, several components required revision before implementation.

Instrument Validity

The validity of the evaluation instrument was examined using item–total correlation analysis with Pearson's correlation coefficient. All retained items demonstrated statistically significant correlations ($p < 0.05$) and exceeded the acceptable threshold ($r > 0.50$).

Table 4. Summary of Instrument Validity

Aspect	Range of r	Interpretation
Content validity	0.602 – 0.803	Acceptable
Design feasibility	0.563 – 0.790	Acceptable
Practicality	0.685 – 0.718	Acceptable
Effectiveness	0.678 – 0.801	Acceptable
Innovation & novelty	0.579 – 0.832	Acceptable
Evaluation & feedback	0.567 – 0.754	Acceptable

As shown in **Table 4**, all instrument components demonstrated acceptable validity across all aspects. The highest correlation values were observed in content validity and innovation, indicating strong alignment between the instrument and the conceptual framework of the model.

Expert Feedback and Model Refinement

Qualitative feedback from experts led to several refinements to improve the feasibility, accessibility, and safety of the learning model.

Table 5. Summary of Expert Feedback and Revisions

Aspect	Key Revision
Field	Visual markers added for orientation
Ball	Lightweight balls with size variations
Assistive tools	Non-slip ramp and stable device
Playing position	Optional safety support
Target	Use of varied and engaging targets
Throwing distance	Gradual progression (1-3 m)
Game structure	Balanced rotation system
Scoring	Visual and simplified system

Aspect	Key Revision
Duration	10–15 min with time cues

As summarised in **Table 5**, expert feedback led to key revisions aimed at improving the usability and accessibility of the learning model. These refinements primarily focused on safety, adaptive equipment, and structured gameplay, ensuring alignment with the functional needs of students with quadriplegia.

Changes in Gross Motor Skills (TGMD-2)

To evaluate changes in gross motor performance following the implementation of the boccia-based learning model, descriptive statistics were calculated for TGMD-2 scores at both pretest and posttest stages. This analysis provides an initial overview of score distribution, central tendency, and variability prior to inferential testing. Descriptive statistics of TGMD-2 scores are presented in **Table 6**.

Table 6. Descriptive Statistics of TGMD-2 Scores

Variable	N	Mean	SD	Min	Max
Pretest	20	48.78	2.58	43.0	55.0
Posttest	20	85.78	2.98	79.5	90.5

As shown in **Table 6**, the mean TGMD-2 score increased substantially from pretest (48.78) to posttest (85.78), indicating improved performance following the intervention. Additionally, Table 6 shows a slight increase in standard deviation (from 2.58 to 2.98), suggesting greater variability in posttest scores and indicating that participants responded differently to the intervention.

Inferential Analysis (Paired Sample t-test)

To further examine whether the observed changes in gross motor skills were statistically significant, a paired-samples t-test was conducted to compare pretest and posttest TGMD-2 scores.

Table 7. Paired Sample t-test Results

Variable	Mean (Pre)	Mean (Post)	Mean Difference	t	df	p	Cohen's d
TGMD-2	48.78	85.78	37.00	16.55	19	< 0.001	3.70

As shown in **Table 7**, there was a statistically significant increase in TGMD-2 scores, $t(19) = 16.55$, $p < 0.001$, with a mean difference of 37.00. The effect size ($d = 3.70$) indicates a very large practical impact. However, these findings should be interpreted cautiously due to the absence of a control group.

Discussion

The findings of this study indicate that the modified boccia-based learning model was associated with improvements in gross motor performance among students with quadriplegia. These results suggest that structured game-based activities can provide meaningful motor stimulation within adaptive physical education settings, consistent with prior evidence highlighting the benefits of adaptive sport modifications for motor development in students with disabilities (Rifki & Susanto, 2022; Astuti et al., 2023).

However, several methodological considerations warrant careful attention when interpreting the quantitative results. The effect size obtained in this study (Cohen's d = 3.70) was substantially larger than those typically reported in comparable motor intervention research (d = 0.2-1.5), which may reflect the relatively small sample size (n

= 20), the narrow score distribution (SD = 2.58-2.98), and the absence of a control group rather than an unusually strong intervention effect. These statistical characteristics should be interpreted with caution, as they may overestimate the true magnitude of change. Furthermore, the adapted TGMD-2 instrument, while reviewed by four experts and demonstrating adequate content validity (CVR = 0.50-1.00; mean = 0.60) and inter-rater reliability (ICC = 0.87), relied on simplified expert-rating procedures rather than full psychometric standardisation. The CVR values for several items fell below the conventional threshold of 0.75, indicating that those components required revision before final use. These limitations underscore the importance of replicating this study with larger samples, a control group, and more robust psychometric procedures to confirm the reliability and validity of findings.

From a motor learning perspective, the observed improvement may be explained through task-specific practice and adaptive task design. The modified boccia activities incorporated graded difficulty, assistive equipment, and individualised movement demands, aligning with motor control principles emphasising variability, repetition, and goal-directed movement (Yudaparmita, 2022). Such adaptations likely facilitated motor planning, coordination, and trunk stability, which are essential for functional motor development in students with severe physical impairments (Pitchford et al., 2021).

The integration of game-based learning also provides motivational and engagement benefits that may indirectly enhance motor outcomes. Interactive play contexts promote sustained attention, self-regulation, and exploratory movement behaviour, thereby supporting sensorimotor learning processes (Burhaein, 2017; Maryanti et al., 2021). This interpretation is consistent with studies demonstrating that adaptive play environments can improve participation and motor competence among children with disabilities (Férriz-Valero et al., 2020; Astuti et al., 2023).

The findings further support the conceptual framework of adaptive physical education, which emphasises environmental modification and individualised instructional strategies to optimise participation and skill acquisition (Obrusnikova & Block, 2020). The boccia modifications implemented in this study—such as adjustable throwing distances, assistive ramps, and simplified rules—can be viewed as task constraints enabling successful performance while progressively challenging motor abilities. Task constraint manipulation has been recognised as an effective approach for promoting motor adaptation and skill transfer in adaptive physical activity settings (Ospankulov et al., 2023; Sukriadi & Arif, 2020).

In addition to motor improvements, structured boccia activities may contribute to broader developmental outcomes, including social interaction, motivation, and emotional engagement. Adaptive play environments have been shown to foster cooperative behaviour and participation, which are central to inclusive physical education practices (Endrawan et al., 2023; Lang, 2023).

Despite these promising findings, several limitations should be considered. The absence of a control group limits causal inference regarding intervention effectiveness. Furthermore, the small sample size and single-school setting restrict generalisability. The relatively short intervention duration also prevents evaluation of long-term motor learning effects. Future research should employ controlled experimental designs, include larger and more diverse samples, and examine longitudinal outcomes to strengthen evidence for boccia-based adaptive learning models.

CONCLUSION

This study indicates that the modified boccia-based learning model shows potential to support gross motor skill development among students with physical disabilities; however, causal conclusions cannot be established. The model provides structured and adaptable learning activities that may assist teachers in delivering inclusive physical education tailored to students' functional abilities. However, the absence of a control group, small sample size, and limited duration restrict the generalisability of the findings. Future studies should employ controlled designs with larger samples to further examine its effectiveness.

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CONFLICT OF INTEREST

The authors declare that they have no competition.

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