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A multimodal physical activity training program to improve motor competence in college students: evidence from a controlled 12-week trial

Cahyo Wibowo[ABCDE], Dennys Christovel Dese[BCDE]

Satya Wacana Christian University, Indonesia

Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim: College students often exhibit low levels of movement competence despite participating in physical education programs. This limitation is partly due to monotonous and insufficiently challenging physical activity routines. Multimodal physical activity programs that integrate gymnastics, dance, and sport-based games offer promising alternatives for enhancing fundamental movement skills. This study aims to evaluate the effectiveness of a 12-week multimodal physical activity learning program in enhancing the movement competence of physical education students.

Material and Methods: The study used a quasi-experimental pre-test and post-test design. Sixty students enrolled in a physical education program were divided into two groups: the experimental group and the control group. Both groups followed the intervention program for 12 weeks. Movement competence was assessed using the Movement Competency Screen (MCS), which included five skill tests: squat, lunge and twist, bend and pull, push-up, and single-leg squat. Collaborative learning, peer teaching, and peer assessment were applied in the experimental group. Data were analyzed quantitatively using descriptive statistics and a paired-sample t-test.

Results: The descriptive analysis and paired-sample t-test results showed statistically significant improvement in all movement competence indicators in the experimental group ($p < 0.05$). In contrast, the control group showed no significant improvement ($p > 0.05$). These findings suggest that a varied and collaborative physical activity training approach is more effective in improving movement competence.

Conclusions: Integrating multimodal physical activities and collaborative learning strategies into physical education can improve college students' movement competence. This study emphasizes the importance of adaptive and interactive approaches in higher education physical education programs.

Keywords: movement competence, multimodal physical activity, collaborative learning, physical education

Introduction

Movement competence refers to an individual's ability to perform various motor tasks efficiently, in a coordinated and adaptive manner across different physical activity contexts. Research indicates that movement competence encompasses elements of stability, locomotion, coordination, and functional ability, all conceptually embedded within the framework of physical literacy [1, 2, 3]. It is widely recognized that movement competence supports lifelong participation in physical activity and is closely linked to psychosocial factors such as self-confidence, motivation to be active, and overall quality of life [4, 5]. However, several studies have shown that university students, particularly those in higher education, experience a significant decline in physical activity levels, physical fitness, and motor function. Contributing factors include increased academic demands, sedentary lifestyles, and limited engagement in physical activities [6, 7, 8]. When opportunities to develop movement skills are not optimized, the impact extends beyond the physical domain and affects emotional, social, and cognitive dimensions essential to students' holistic development.

A preliminary study conducted among students of the Physical Education Study Program at Satya Wacana Christian University revealed that most students still demonstrated low levels of movement competence. An evaluation of the teaching practices indicated that the primary cause was a monotonous and repetitive instructional approach with minimal cognitive challenge. The lack of activity variation and the absence of problem-solving or group work integration also contributed to decreased motivation and reduced effectiveness in physical education learning.

One approach that has begun to gain attention is multimodal physical activity learning programs that integrate various activities into a progressive framework. This approach provides more diverse physical stimuli and creates opportunities for

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social and cognitive development [9, 10]. Research has shown that multimodal approaches combining physical activities with academic or social components, such as cooperative learning, can foster the development of positive social attitudes in both adolescents and educators [11, 12]. Although several previous studies have explored multimodal physical activity interventions, they are generally limited in scope and have not integrated pedagogical elements such as peer teaching and collaborative learning, particularly in the context of physical education students in higher education [13, 14].

In line with the theoretical frameworks of social constructivism and physical literacy, physical activity learning is not merely seen as a process of motor skill transmission but also as a social experience that shapes learners' understanding, attitudes, and values through active interaction with their environment and peers [15, 16]. Social constructivism emphasizes the importance of social engagement and collaboration in knowledge construction, positioning students as active agents in the learning process rather than passive recipients of information [17, 18]. This approach can be realized in physical education through group work and reflective discussions that encourage students to learn from one another, provide feedback, and develop skills within meaningful contexts [19]. Meanwhile, the concept of physical literacy views movement competence as part of holistic individual development, integrating physical, cognitive, and affective elements to foster sustained and active participation in physical life [20].

An analysis of previous research findings has shown that multimodal physical activity interventions can positively influence motor competence and psychosocial development. The authors have drawn attention to the importance of integrating pedagogical strategies such as peer teaching, cooperative learning, and reflective practice. These elements should be incorporated into physical education curricula. The authors have also emphasized the need to address cognitive and social aspects in addition to physical development. At the same time, there is a clear need for further research. It should focus on evaluating the effectiveness of multimodal training programs that include collaborative and problem-based learning. This is particularly relevant for physical education students in higher education.

Although previous studies have addressed the benefits of multimodal physical activity programs, few have systematically examined their application in higher education settings using a student-centered approach. In particular, there is a lack of quasi-experimental research that integrates collaborative learning strategies within an outcome-based education (OBE) curriculum in physical education programs.

To address this gap, this study aims to evaluate the effectiveness of a 12-week multimodal physical activity learning program in enhancing the movement competence of physical education students.

Materials and Methods

Participants

The participants in this study were 60 male students from the Physical Education Study Program at Satya Wacana Christian University. They were aged between 18 and 22 years and enrolled in academic cohorts from 2022 to 2024. All participants were in good physical health, with no history of musculoskeletal injuries, cardiovascular disorders, or other medical conditions that could hinder active participation in the program. The inclusion criteria were: (a) current enrollment as an active student in the Physical Education Study Program; (b) age between 18 and 22 years; and (c) willingness to participate in all phases of the intervention. The exclusion criteria were: (a) presence of injury or health issues during the initial screening process; (b) more than 30% absence during the intervention period; and (c) failure to provide written informed consent for participation. Group assignment was conducted using purposive sampling based on class grouping. This resulted in two groups: an experimental group (n = 30) and a control group (n = 30).

Although this study was not registered with an institutional ethics committee, all procedures adhered to established ethical research principles, including voluntary informed consent and data privacy protection. Participants received detailed information about the research objectives, procedures, potential benefits, and risks. Written informed consent was obtained prior to the commencement of the study. Participant confidentiality was strictly maintained, with data access limited to the principal investigator. All collected data were securely stored and used exclusively for the purposes of this research.

Research Design

This study employed a quasi-experimental design with a pre-test and post-test control group structure, involving both experimental and control groups. The experimental group participated in a 12-week multimodal physical activity program conducted twice a week, with each session lasting 110 minutes. The program was designed to integrate various types of physical activities, including gymnastics, dance, and sports games, and to incorporate elements of problem-solving and peer-based learning strategies. The control group followed the standard physical education curriculum without any intervention modifications.

Instrument

Both groups underwent movement competence assessments before and after the intervention. The

evaluation was conducted using the Movement Competency Screen (MCS), which consists of five items: squat, lunge and twist, push-up, bend and pull, and single-leg squat [21]. The MCS instrument has been psychometrically validated and demonstrates high inter-rater reliability (ICC = 0.88, 95% CI: 0.81–0.93) [22].

During the intervention period, all participants in both groups received equal treatment regarding session duration, access to facilities, and physical environmental conditions in order to minimize potential bias. The MCS was selected for its relevance in evaluating the movement competence of students following the multimodal physical activity intervention. It is designed to assess fundamental functional movement patterns that serve as key indicators of motor competence.

The MCS also offers practical advantages, as it can be administered in group settings with minimal time and equipment requirements. A detailed overview of the MCS items used in this study is presented in Table 1.

Experimental Group Design

Students in the experimental group participated in a 12-week physical activity program designed to enhance movement competence through a multimodal approach. The program integrated three primary types of physical activities: gymnastics, dance, and sport-based games. Each component was systematically implemented to stimulate various dimensions of movement competence. The program emphasized both individual responsibility and group collaboration. During the intervention, students were actively engaged in collaborative learning through small-group activities. The learning process was supported by peer teaching and peer assessment strategies, conducted twice per week.

In the peer assessment sessions, each student was assigned to observe a peer performing a movement task using an observation sheet. This sheet contained indicators such as stability, coordination, movement alignment, and technical accuracy. After the observation, students provided both verbal and written feedback, followed by a brief reflective discussion facilitated by the instructor. The results of the peer assessments were collected and used as formative evaluation tools by both students and instructors to monitor progress and improve performance. Within this student-centered approach, the instructor served as a facilitator, observing, providing guidance, and ensuring the validity and fairness of the assessment process.

Control Group Design

The control group participated in a conventional physical education program based on the existing curriculum, which focused on a single type of sport and the mastery of basic tactics. To ensure treatment equivalence with the experimental group, the program was conducted twice per week over twelve weeks. It was supported by learning media such as practicum modules, instructional videos, and structured assignments. The program adopted a teacher-centered, demonstrative approach, in which the instructor played a central role in delivering content and guiding practice sessions. The learning emphasis was placed on improving individual performance, particularly in the development of fundamental motor skills and physical fitness.

Evaluations were conducted periodically using standardized instruments and direct observation to assess students' fitness and motor abilities. Pre-test and post-test data were collected to evaluate the effectiveness of the conventional program. These results were then compared with those of the experimental group to assess the impact of the

Table 1. Movement Competency Screen (MCS)

Movement	Instructions
Squat	Perform a bodyweight squat with fingertips placed on the sides of the head. Lower the body as far as is comfortable while maintaining balance and upright posture.
Lunge & Twist	Cross the arms and rest the hands on the shoulders, keeping the elbows pointed forward. Step into a forward lunge and rotate the torso toward the front knee. After completing the rotation, return to the center and rise to a standing position. Alternate legs with each repetition.
Bend & Pull	Begin with the arms extended overhead. Bend forward, allowing the arms to drop beneath the torso. Pull the hands toward the body in a motion similar to a barbell row. Then return to the starting position with the arms fully extended overhead.
Push-Up	Begin in a high plank position with hands placed shoulder-width apart and the body forming a straight line from head to heels. Lower the body by bending the elbows, keeping them close to the torso. When the chest is just above the floor, push back to the starting position. Maintain core engagement.
Single-Leg Squat	Stand on one leg with fingertips on the sides of the head and the other leg extended slightly behind the body. Keep the chest lifted and back straight. Slowly lower into a squat as far as is comfortable, maintaining balance and control. Return to the starting position and repeat on the opposite leg.

instructional approach.

Statistical Analysis

This study employed multiple data analysis techniques to evaluate the effectiveness of the intervention. Descriptive statistics were used to report the mean, standard deviation, and score distribution for each movement competency variable. A paired-sample t-test was conducted to examine within-group changes in the experimental group from pre-test to post-test. The use of the paired-sample t-test was justified by the study's focus on evaluating changes within the same group before and after the intervention. In addition, to complement the interpretation of statistical significance, effect size was calculated using Cohen's *d* to provide insight into the magnitude of the intervention's impact on movement competency. The analysis aimed to assess both the statistical significance of the differences and the practical strength of the intervention effects.

Results

Table 2 displays the pre-test and post-test means and standard deviations for the experimental group across five movement tasks. These data were used to evaluate changes in performance following the multimodal physical activity program.

Based on Table 2, the results of the descriptive analysis for the experimental group demonstrated an overall increase in mean scores across all indicators of movement competence following the implementation of the 12-week multimodal physical activity training program. In the squat test, the average score increased from 1.27 (SD = 0.521) on the pre-test to 1.60 (SD = 0.621) on the post-test. Similarly, the lunge and twist indicator showed a rise in mean scores from 2.30 (SD = 0.702) to 3.40 (SD = 1.102). The bend and pull test also demonstrated substantial improvement, with scores increasing from 2.63 (SD = 0.850) to 3.87 (SD = 0.819) after the intervention. Furthermore, performance in the push-up test improved from a mean score of 1.30 (SD = 0.535) to 1.67 (SD = 0.606), while the single-leg squat test score rose from 1.13 (SD = 0.434) to 1.33 (SD = 0.547). These findings suggest that the multimodal physical activity training intervention had a positive impact on college students' movement competence across multiple motor skill domains.

Descriptive statistics for the control group's movement competence scores before and after the

Table 2. Experimental group design descriptive analysis score

Criteria	Groups	N	Min	Max	Sum	Mean	Std. deviation
Squat	Pretest	30	1	3	38	1.27	.521
	Posttest	30	1	3	48	1.60	.621
Lunge and Twist	Pretest	30	2	4	69	2.30	.702
	Posttest	30	2	6	102	3.40	1.102
Bend and Pull	Pretest	30	2	5	79	2.63	.850
	Posttest	30	2	6	116	3.87	.819
Push Up	Pretest	30	1	3	39	1.30	.535
	Posttest	30	1	3	50	1.67	.606
Single Leg Squat	Pretest	30	1	3	34	1.13	.434
	Posttest	30	1	3	40	1.33	.547

Table 3. Control group design descriptive analysis scores

Criteria	Groups	N	Min	Max	Sum	Mean	Std. deviation
Squat	Pretest	30	1	3	45	1.50	.731
	Posttest	30	1	3	53	1.77	.817
Lunge & Twist	Pretest	30	2	6	128	4.27	1.172
	Posttest	30	2	6	130	4.33	.959
Bend & Pull	Pretest	30	2	6	100	3.33	1.093
	Posttest	30	2	5	102	3.40	.932
Push Up	Pretest	30	1	3	49	1.63	.718
	Posttest	30	1	5	53	1.77	.728
Single Leg Squat	Pretest	30	1	3	47	1.57	.679
	Posttest	30	1	5	46	1.53	.730

intervention are presented in Table 3. The table summarizes the mean and standard deviation for each movement skill, allowing comparison of pre-test and post-test performance within the control group.

Based on the descriptive analysis results for the control group, as presented in Table 3, the average movement competence scores showed only minor improvements following participation in the conventional physical activity program. The mean score for the squat indicator increased from 1.50 (SD = 0.731) at the pre-test to 1.77 (SD = 0.817) at the post-test. In the lunge and twist task, a marginal increase was observed, with the mean score rising slightly from 4.27 (SD = 1.172) to 4.33 (SD = 0.959), indicating minimal change. Similarly, the bend and pull indicator showed a slight improvement, with the mean score increasing from 3.33 (SD = 1.093) to 3.40 (SD = 0.932). A comparable trend was found in the push-up assessment, where the mean score increased from 1.63 (SD = 0.718) to 1.77 (SD = 0.728). In contrast, performance on the single-leg squat indicator slightly declined, with the average score decreasing from 1.57 (SD = 0.679) to 1.53 (SD = 0.730). These findings suggest that the conventional program had a limited effect on improving students' movement competence compared to the experimental group.

Paired-sample t-test results for both the experimental and control groups are presented in Table 4. The table shows the statistical significance of pre-test and post-test differences in movement competence scores across five assessed motor skill indicators.

Based on the results of the paired-sample t-test presented in Table 4, statistically significant differences were found between the pre-test and post-test scores in the experimental group across all measured components of movement competence. A significant improvement was observed in the squat assessment, with scores increasing from 1.27 ± 0.521 to 1.60 ± 0.621 (t = –3.340, p = 0.002). A similar pattern was found for lunge and twist, with scores rising from 2.30 ± 0.702 to 3.40 ± 1.102 (t = –6.279, p < 0.001), and for bend and pull, which increased from 2.63 ± 0.850 to 3.87 ± 0.819 (t = –6.713, p < 0.001). The push-up indicator also showed a statistically significant increase, from 1.30 ± 0.535 to 1.67 ± 0.606 (t = –4.097, p < 0.001). Finally, performance in the single-leg squat test improved from 1.13 ± 0.434 to 1.33 ± 0.547 (t = –2.693, p = 0.012).

In contrast, the control group showed no statistically significant differences across most movement competence indicators. For example, although squat scores increased from 1.50 ± 0.731 to 1.77 ± 0.817, this change was not statistically significant (p = 0.133). Similar nonsignificant results were found for lunge and twist (p = 0.690), bend and pull (p = 0.712), push-up (p = 0.326), and single-leg squat (p = 0.573). These findings underscore the effectiveness of the multimodal physical activity intervention implemented in the experimental group, which significantly improved students' fundamental movement competence compared to the conventional program. To complement the statistical significance testing, effect size was calculated using Cohen's *d*. The analysis showed that the multimodal training program had a moderate effect on squats (*d* = 0.576) and push-ups (*d* = 0.647), and a large effect on lunges and twists (*d* = 1.191) as well as bends and pulls (*d* = 1.486). In contrast, single-leg squats demonstrated a small to moderate effect size (*d* = 0.405).

Discussion

This study aimed to evaluate the effectiveness of a 12-week multimodal physical activity program implemented through a collaborative, student-centered learning approach in improving students' movement competence. The results indicate that the experimental group experienced statistically significant improvements in all aspects of movement

Table 4. Paired sample t-test scores of the experimental and control groups

Criteria	Groups	Pre-test M±SD	Post-test M±SD	t	p	Cohen's d
Squat	Experiment	1.27 ± 0.521	1.60 ± 0.621	-3.340	.002	0.576
	Control	1.50 ± 0.731	1.77 ± 0.817	-1.547	.133	
Lunge and Twist	Experiment	2.30 ± 0.702	3.40 ± 1.102	-6.279	.000	1.191
	Control	4.27 ± 1.172	4.33 ± 0.959	-.403	.690	
Bend and Pull	Experiment	2.63 ± 0.850	3.87 ± 0.819	-6.713	.000	1.486
	Control	3.33 ± 1.093	3.40 ± 0.932	-.372	.712	
Push Up	Experiment	1.30 ± 0.535	1.67 ± 0.606	-.4097	.000	0.647
	Control	1.63 ± 0.718	1.77 ± 0.728	-1.000	.326	
Single Leg Squat	Experiment	1.13 ± 0.434	1.33 ± 0.547	-2.693	.012	0.405
	Control	1.57 ± 0.679	1.53 ± 0.730	.571	.573	

competence after completing the program. Previous studies have shown that collaborative and active learning approaches can effectively stimulate the development of motor skills and teamwork abilities [23]. The multimodal physical activity approach facilitates the activation of various neuromuscular systems, supporting improvements in coordination, strength, and body control [24]. Consistent with the findings of this study, other research has also demonstrated that incorporating a diverse range of physical activities within physical education contributes positively to movement competence [25, 26].

Although the participants in this study were students enrolled in a physical education program, the pre-test results revealed that their initial level of movement competence was relatively low. This outcome may be attributed to a monotonous approach to physical education that emphasizes direct instruction and repetitive movements, without sufficient cognitive and affective engagement. Previous research supporting the findings of this study suggests that cooperative learning in physical education can enhance student motivation, self-confidence, and sense of relatedness. These are affective outcomes that contribute to meaningful learning. Cooperative learning can also promote knowledge acquisition, problem-solving abilities, and cognitive development [27, 28, 29]. Several studies have also demonstrated that limited variation and lack of adaptation in physical activity programs may hinder the development of movement competence [30, 31].

The analysis of the control group revealed no statistically significant results, and even showed a slight decline in the single-leg squat indicator. This finding is consistent with previous research suggesting that teacher-centered methods may reduce student enthusiasm, engagement, and the development of essential skills, as students tend to participate passively. As a result, lower levels of physical fitness and a weaker understanding of movement concepts are frequently observed [32, 33]. Reporting the findings in the control group is important, as null or negative results are often underrepresented in experimental studies. However, such data can provide valuable insights into the limitations of conventional instructional approaches.

Over the past few decades, physical education research has primarily focused on elementary and secondary education levels, with an emphasis on early motor skill development [34, 25, 36]. In contrast, populations in early adulthood, such as college students, have rarely been the focus of such interventions, even though this phase is a critical transitional period for establishing long-term physical activity patterns that are essential to health and well-being [37]. Several studies have reported a statistically significant decline in physical activity participation once students enter higher education [38, 39]. Therefore, pedagogical approaches that are both relevant and adaptive are urgently needed to promote an active and healthy lifestyle. Supporting the findings of the present study, previous research has shown that diverse fitness programs can enhance motor memory and coordination skills, and that such approaches are effective in developing movement competence among university students [40].

Unlike previous studies that tend to examine single types of physical activity in isolation [41], the findings of this study are supported by existing research indicating that integrating varying intensities and forms of physical activity within a multimodal program is more effective in enhancing multiple aspects of movement competence [2, 7, 31]. Game-based collaborative learning has also been shown to increase students' motivation, engagement, and motor skill development [42, 43]. However, controlled experimental designs, particularly quasi-experiments with pre-test and post-test measures in higher education contexts, remain limited.

Limitations

This study has several limitations that should be acknowledged. First, the participant sample was limited to male students from a single academic program at one university. This homogeneity restricts the generalizability of the findings to broader populations, including female students, individuals from other academic disciplines or institutions, and participants with diverse cultural and fitness backgrounds. Second, the study did not include affective variables such as intrinsic motivation, self-confidence, or the quality of social interaction, despite the recognized importance of these factors in holistic physical education.

Future research is recommended to involve more diverse participant groups, extend the duration of the intervention, and incorporate measures of affective domains. Such efforts would contribute to a more comprehensive understanding of the effectiveness of physical activity-based interventions and enhance the applicability of findings across varied educational contexts.

Conclusions

The findings of this study indicate that a 12-week multimodal physical activity program is effective in improving movement competence among physical education students. Significant improvements were observed in five fundamental movement skills: squat, lunge and twist, bend and pull, push-up, and single-leg squat, compared to the control group. These results underscore the value of a varied and collaborative approach to physical activity-based

learning. The study supports the integration of multimodal strategies into higher education physical education curricula, emphasizing collaboration, active engagement, and movement exploration to enhance student outcomes.

Conflict of Interest

The authors declare no conflict of interest.

AI Tools Usage

In preparing this manuscript, the authors made limited use of several artificial intelligence (AI)-based tools to enhance the efficiency and quality of academic writing. ChatGPT was used to assist with sentence restructuring, grammar correction, and language refinement in accordance with academic standards. Additionally, Consensus was used as a search tool to identify and select scientific references relevant to the research topic. DeepL Translator supported the translation process, while Grammarly was employed to check and improve grammar in the final version of the manuscript. All data analyses and statistical procedures were conducted independently using SPSS software.

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Information about the authors:

Cahyo Wibowo; (Corresponding author); https://orcid.org/0009-0002-5249-1238; cahyo.wibowo@uksw.edu; Satya Wacana Christian University; Salatiga, Indonesia.

Dennys Christovel Dese; https://orcid.org/0000-0002-0168-3486; dennys.christovel@uksw.edu; Satya Wacana Christian University; Salatiga, Indonesia.

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