

Android-assisted gymnastics learning media to improve backward roll skills: A comparative analysis

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Abstract

Problem Statement and Purpose. Performing gymnastics movements correctly is important in physical education. However, improving gymnastics skills, including the backward roll, is technically complex and remains a major challenge. One factor is the lack of interesting and interactive learning media. To address this issue, recent scholars have introduced more interactive tools, such as Android-assisted gymnastics learning media. This study analyzes the effectiveness of this media compared to conventional methods, particularly in improving backward roll skills. **Materials and Methods.** An experimental design with a pretest and posttest was employed, involving 80 junior high school students. These students were recruited randomly and divided into two groups: an experimental group ($n_1=40$; age= 13.57 ± 0.54 years; and BMI= 21.98 ± 0.93) and a control group ($n_2=40$; age= 13.79 ± 0.65 years; and BMI= 22.03 ± 0.93). Participants in the experimental group learned using the Android-assisted gymnastics learning media. Meanwhile, the control group used conventional learning methods, including explanations and direct demonstrations for ± 8 weeks. The assessment was conducted in three phases of the backward roll skill: preparation, implementation, and completion. The data were analyzed using paired and independent-sample t-tests. Then, the effect sizes were reported using Cohen's d. **Result.** The results showed that the mean score of the experimental group increased from 59.600 to 70.142, moving the category from poor to adequate. In contrast, the conventional group increased only approximately 4 points from 59.558 to 63.400, and remained in the poor category. The paired-samples t-test showed a significant increase in both groups ($p=0.001$), with a larger increase in the experimental group ($t=26.234$; MD=10.542). The independent-sample t-test also showed a significant difference between the two groups in the posttest ($t=10.471$; $p=0.001$; and Cohen's $d=2.342$). **Conclusions.** These findings conclude that Android-assisted gymnastics learning media is more effective visually and interactively in helping students understand and practice gymnastics movements. The integration of such a technology is important as it promotes a more interactive and adaptive learning environment. Further research is needed to examine the effectiveness of similar learning media across various types of gymnastics skills. Studies investigating other relevant variables and a larger sample size are also highly recommended.

Keywords: Mobile-assisted learning; motor skill acquisition; backward roll technique; visual-interactive learning; physical education pedagogy; experimental learning design.

Introduction

Gymnastics is an important discipline in physical education because it requires complex, coordinated fundamental movement skills and integrates strength, agility, balance, and postural control (Haywood & Getchell, 2024; Pehkonen, 2010). It is characterized by rapid transitions between dynamic and static elements, changes in body orientation, and a high demand for movement accuracy, making it technically more difficult than other physical activities (Coelho, 2010; Novak et al., 2008). Success in performing gymnastics movements is not only determined by students' physical capacity but also depends heavily on the quality of the learning process, including teaching methods, the clarity of demonstrations, and the effectiveness of feedback provided by educators (Pehkonen, 2010).

In schools gymnastics, the application of appropriate pedagogical approaches is important to improve learning effectiveness. Kovač et al. (2008) emphasize the importance of using a variety of tasks, clear movement descriptions, and adequate trial opportunities. This approach not only improves physical skills but also contributes to students' overall physical fitness and motor skills (Culjak et al., 2014; Pei et al., 2023). In this

regard, artistic gymnastics serves as a strategic means to develop movement coordination, body awareness, and fundamental movement skills through a series of structured movements (Maceiras et al., 2023).

One of the basic skills in artistic gymnastics, commonly taught at various levels of school education, is the backward roll skills. This movement contributes significantly to increasing core muscle strength, agility, balance, and postural control (Invernizzi et al., 2020; Mitchell et al., 2002; Rudd et al., 2015). It also plays a crucial role in developing the sensorimotor system and fundamental movement skills, which are essential for protecting the body during collisions and preventing falls-related injuries (De Meester et al., 2016; Komaini et al., 2023). However, mastering the backward roll skill is relatively difficult for students because it requires precise movement coordination, understanding of the correct sequence of movements, and the courage to rotate the body backward, making it a frequent challenge in conventional gymnastics instruction (Invernizzi et al., 2020).

Along with the development of digital technology, the use of Android-assisted applications in physical education learning is becoming increasingly relevant. It is a mobile technology that makes the presentation of learning materials more interactive, flexible, and easy to access. The application also supports the visualization of movements and provides real-time, more personalized feedback (Handayani et al., 2023a; 2023b; Jastrow et al., 2022; Martín-Rodríguez & Madrigal-Cerezo, 2025). Such characteristics allow students to learn movements more accurately and make corrections more independently (Alnedral et al., 2023; Handayani et al., 2023a; 2023b; Potdevin et al., 2018; Zulfahri et al., 2023).

Besides pedagogical benefit, Palička et al. (2016) show that using mobile applications in physical education can increase student motivation and physical performance. These studies confirm the strong potential of mobile applications in supporting the learning of gymnastics skills.

Recent studies have developed and introduced Android-assisted gymnastics learning media as an innovative solution in physical education learning. For example, Mulyana et al. (2022) developed the Android-assisted gymnastics learning application, called "GYMBASTECH", using the ADDIE model. They showed that the media was feasible for use based on expert validation and system usability testing. However, this study still focused on the product development stage and media feasibility, without experimentally testing its effectiveness in improving specific gymnastics skills. A more recent study was conducted by Handayani et al. (2023a), who developed Android-assisted gymnastics learning media for handstand skills. Their study was based on the R&D design using the Plomp model, which involved a pre-experimental test.

The results showed that the media was effective in significantly improving junior high school students' handstand skills. However, this study emphasized the product's validity, reliability, and effectiveness in a single-group design without a comparison group, limiting the generalizability of the findings and the strength of causal inference. In addition, the skill studied was the handstand, which has biomechanical characteristics and risk levels different from those of the backward roll skill. Furthermore, Handayani et al. (2023b) reported that the use of Android-assisted gymnastics learning media can improve junior high school students' cartwheel skills using a one-group pretest and posttest pre-experimental design. The results confirm the potential of mobile technology in improving gymnastics skills that require coordination, strength, and balance. However, their study did not include a control group or conventional learning methods as a comparison, so it did not provide a strong picture of the relative advantages of Android-assisted media compared to conventional learning.

Although various studies have shown the potential of Android-assisted gymnastics learning media to improve gymnastics skills, research specifically examining backward roll skills is still very limited. In fact, backward roll skills are basic gymnastics skills that are technically complex, requiring accurate visual perception, systematic mastery of movement stages, and strict adherence to safety principles in order to be learned effectively and safely (Invernizzi et al., 2020; Mitchell et al., 2002). Furthermore, previous studies rely heavily on non-experimental or pre-experimental single-group designs. Empirical evidence on the effectiveness of Android-assisted learning media compared to conventional methods is not yet strong.

This study aims to address the challenges of teaching backward rolls, which students still find difficult to master. As argued earlier, conventional teaching methods tend to rely on direct demonstrations and verbal instructions. In contrast, this study integrates mobile technology into gymnastics teaching as an alternative to improve the quality of teaching complex skills. In particular, it examines the effectiveness of Android-assisted gymnastics learning media compared to conventional learning using a pretest-posttest experimental design, thereby enabling an objective analysis of changes in students' skills before and after treatment. This study is expected to provide stronger evidence of the relative advantages of using mobile technology in gymnastics skill learning, while expanding theoretical and practical contributions to the development of technology-assisted physical education learning.

Our hypotheses are as follows: (a) Android-assisted gymnastics learning can significantly improve students' backward roll skills between the pretest and posttest; (b) conventional gymnastics learning also significantly improves backward roll skills; and (c) there is a significant difference in posttest backward roll skills between the two groups, with a higher improvement in the group using Android-assisted gymnastics learning media.

Materials & Methods

Study design & participants

This was an experimental study involving 80 junior high school students who voluntarily participated. The students studied in the seventh and eighth grades in a combined physical education class and participated in extracurricular gymnastics activities. They were recruited randomly and divided into two groups: an experimental group ($n_1=40$; age= 13.57 ± 0.54 years; weight= 49.60 ± 1.84 kg; height= 147.18 ± 2.01 cm; and BMI= 21.98 ± 0.93) and a control group ($n_2=40$; age= 13.79 ± 0.65 years; weight= 47.63 ± 2.03 kg; height= 147.05 ± 1.88 cm; and BMI= 22.03 ± 0.93). The experimental group learned using Android-assisted gymnastics learning media, while the control group used conventional teaching methods. Both groups received different treatments but were measured using the same instruments and procedures, at both the pretest and posttest stages (see Figure 1).

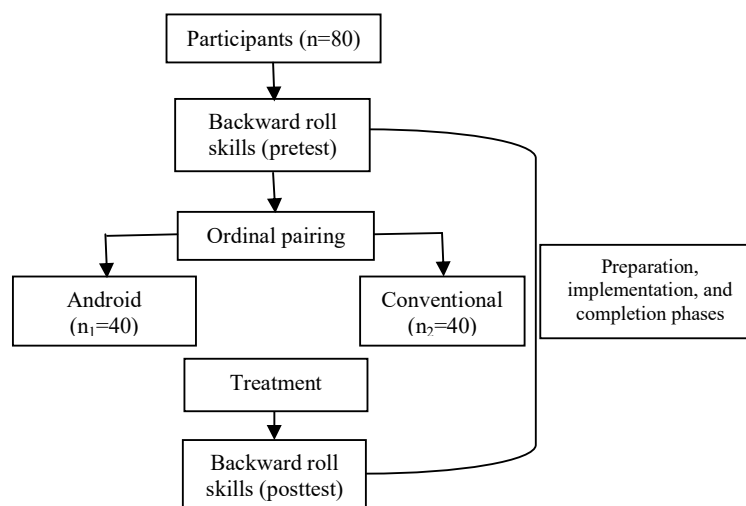


Figure 1. Research flowchart

Procedures and instruments

The study began with a pretest administered to both groups to measure their initial backward roll skills. Furthermore, the experimental group learned using the developed Android application, while the control group used conventional learning methods through explanations and direct demonstrations by the teacher. After the treatment, both groups were given a posttest using the same instrument to measure the improvement in backward roll skills.

The Android-assisted learning media is one of the training materials developed by Handayani et al. (Handayani et al., 2023a). Previous research merely focused on handstand skills. This study employed another training material in the application, which focused on backward roll skills. In particular, it examined its effectiveness (see Figure 2). The learning media were tested and found to be feasible, with an average V-index of 0.87 (high) and an ICC of 0.88 (very high). The procedures of this study were performed as follows: (1) collecting pretest data via a backward roll skills test before using the Android-assisted gymnastics learning media, (2) providing treatment to students via the aforementioned media on backward roll material for a duration of ± 8 weeks, and (3) collecting posttest data via a backward roll skills test. The instrument used was a backward roll test consisting of preparation, implementation, and completion phases, as shown in Table 1. The backward roll skills in this study were classified into five categories: very poor (0-29), poor (30-64), fair (65-79), good (80-89), and very good (90-100).

Table 1. Backward roll skills instrument

Phase	Information
Preparation	Stand up straight with your hands raised straight above your head. Then, bend both knees into a half-squat position while lowering your hands straight down. Keep your gaze forward, in a squat position, both feet together, and heels raised.
Implementation	Drop your buttocks back until your body forms a curved position, with your knees and chin close to your chest. Place your palms beside your ears, and pull both knees back toward your head as your back touches the mat. Press the mat with both palms as your toes touch the mat. Make sure your hands remain straight, and your head is lifted.
Completion	Squat with your arms straight out in front of you and your gaze looking straight ahead. Make sure your body is balanced, then stand up straight.

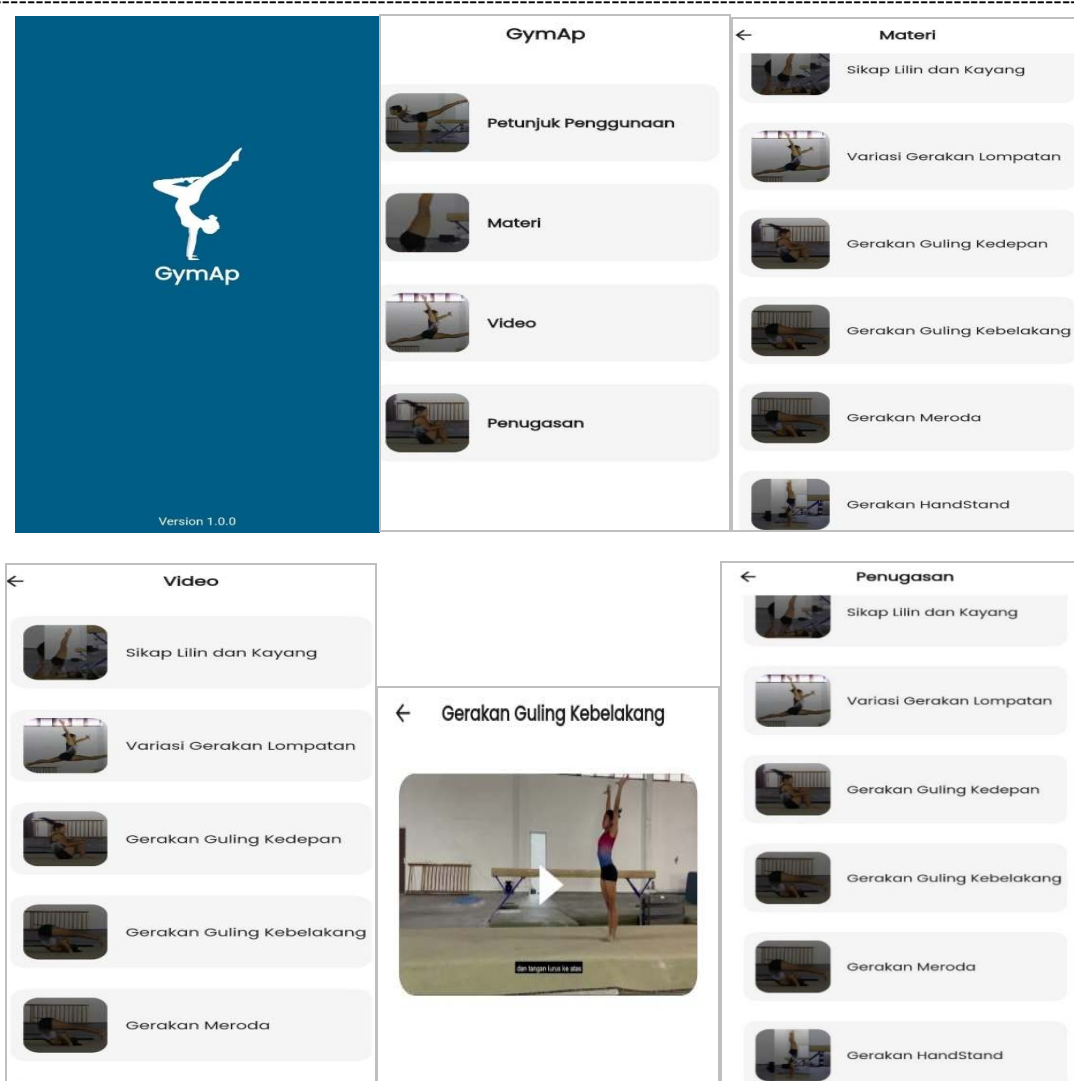


Figure 2. Menus on Android-assisted gymnastics learning media

Statistical analysis

The data were analyzed using descriptive statistics to determine the mean and categories of backward roll skills for each movement phase. The normality and homogeneity prerequisites were tested using the Kolmogorov-Smirnov, Shapiro-Wilk, and Levene tests. A paired-samples t-test was used to determine differences in pretest and posttest results within each group. Meanwhile, an independent-samples t-test was used to assess differences in posttest results between the experimental and control groups. In addition, Cohen's d was used to measure the effect size or difference between the experimental and control groups, with $d=0.2$ indicating a small effect, $d=0.5$ indicating a moderate effect, and $d \geq 0.8$ indicating a large effect. All analyses were performed at the 0.05 significance level using SPSS version 26.

Result

Descriptive analysis

A descriptive analysis of backward roll skills is presented in Table 2. Among students who used Android-assisted gymnastics learning media, the mean pretest score for backward roll skills was 59.600, which fell into the poor category. This score then increased significantly to 70.142 in the posttest, placing it in the fair category. The increase occurred consistently across all three phases of the movement, namely the preparation phase (from $M=60.550$ to 70.950), the implementation phase (from $M=57.950$ to 68.825), and the completion phase (from $M=60.300$ to 70.650) (see Figure 3). Meanwhile, in the conventional group, the mean score for backward roll skills also improved, though not as much as in the group that used Android-assisted gymnastics learning media. The overall average for the pretest was 59.558, which increased to 63.400 in the posttest. However, it was still in the poor category. Improvements in each phase were also observed, but were smaller than those in the group that used Android-assisted gymnastics learning media.

Table 2. Descriptive statistics of backward roll skills

Group	Data	n	Phase	Min	Max	M±SD		Category
						Per phase	All phases	
Android	Pretest	40	Preparation	52.000	66.000	60.550±2.900	59.600±1.842	Poor
			Implementation	51.000	65.000	57.950±2.438		
			Completion	55.000	68.000	60.300±2.462		
	Posttest	40	Preparation	62.000	78.000	70.950±3.522	70.142±3.365	Fair
			Implementation	60.000	75.000	68.825±3.304		
			Completion	60.000	77.000	70.650±3.984		
Conventional	Pretest	40	Preparation	52.000	66.000	60.475±2.891	59.558±2.119	Poor
			Implementation	52.000	65.000	58.000±2.542		
			Completion	55.000	68.000	60.200±2.574		
	Posttest	40	Preparation	58.000	70.000	64.450±2.459	63.400±2.292	Poor
			Implementation	57.000	68.000	62.325±2.411		
			Completion	56.000	69.000	63.425±2.480		

Note- Backward roll skills.

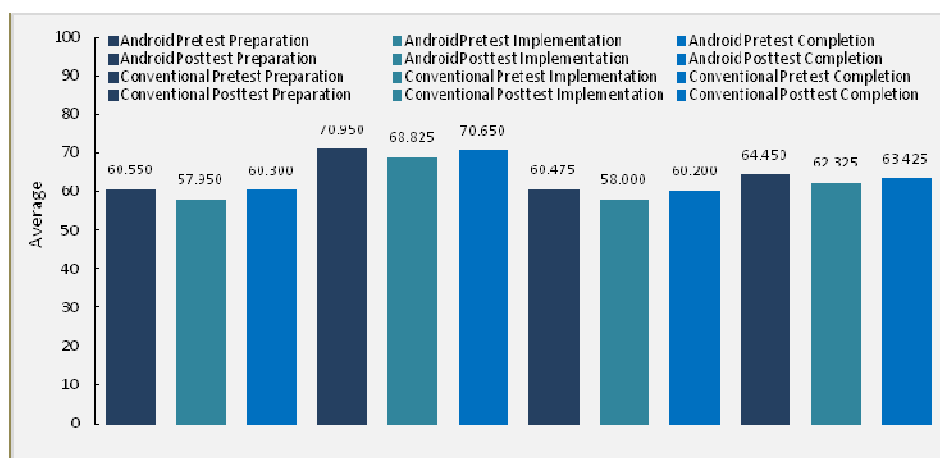


Figure 3. Average per phase of backward roll skills for both groups

Analysis requirements

The results of normality and homogeneity tests are presented in Table 3. Based on these results, both pretest and posttest scores meet the requirements for parametric analysis. This is indicated by the significance values of the Kolmogorov-Smirnov and Shapiro-Wilk normality tests, as well as the results of the Levene test for variance homogeneity ($p > 0.05$).

Table 3. Summary of analysis requirements testing

Group	Data	n	Normality test		Levene's	
			K-S (p)	S-W (p)	Pretest (p)	Posttest (p)
Android	Pretest	40	0.057	0.083	0.520	0.164
	Posttest	40	0.065	0.059		
Conventional	Pretest	40	0.081	0.333		
	Posttest	40	0.200	0.902		

Note- Backward roll skills; K-S is Kolmogorov-Smirnov, S-W is Shapiro-Wilk, the homogeneity test used is Levene's; significance ($p > 0.05$).

Hypothesis testing

Paired samples t-test

The results of the paired-samples t-test are summarized in Table 4. There was a significant increase in the pretest and posttest data results in both groups. Among students who used Android-assisted gymnastics learning media, the average score increased from 59.600 to 70.142 with an average difference of 10.542 and a t-value of 26.234 ($p = 0.001$). Meanwhile, in the conventional group, the average increased from 59.558 to 63.400, yielding an average difference of 3.842 with a t-value of 12.863 ($p = 0.001$). These results indicate that both groups were effective in improving backward roll skills, but the increase was greater in the group that used Android-assisted gymnastics learning media.

Table 4. Summary of paired sample t-test

Group	Data	n	M	r	p	MD	Std. EM	t	p
Android	Pretest	40	59.600	0.666	0.000	10.542	0.401	26.234	0.001
	Posttest		70.142						
Conventional	Pretest	40	59.558	0.636	0.000	3.842	0.298	12.863	0.001
	Posttest		63.400						

Note- Backward roll skills; M is the mean for pretest and posttest data; r is the correlation value for pretest and posttest data; MD is the mean difference between pretest and posttest data; Std. EM is the Standard Error Mean; significance ($p < 0.05$).

Independent samples t-test

The results of the independent-sample t-test on the posttest data show a significant difference in the two groups ($p < 0.05$; Cohen's $d = 2.342$) (see Table 5). Students who used Android-assisted gymnastics learning media had a higher posttest average ($M = 70.142$) than those in the conventional group ($M = 63.400$), with an average difference of 6.742. The t-test result was 10.471 ($p = 0.001$), indicating that this difference is statistically significant. Thus, it can be inferred that the use of Android-assisted gymnastics learning media has a greater effect on improving backward roll skills than conventional methods (Cohen's $d = 2.342$).

Table 5. Summary of independent sample t-test

Group	Data	N	M	MD	t	Std. EM	Cohen's d	p
Android	Posttest	80	70.142	6.742	10.471	0.643	2.342	0.001
Conventional			63.400					

Note- Backward roll skills; M is the posttest data mean; MD is the difference between posttest data means; Std. EM is Standard Error Mean; significance ($p < 0.05$); effect size: Cohen's $d = (M_2 - M_1) / SD_{pooled}$.

Discussion

The study found a significant increase in backward roll skills among the group that used Android-assisted gymnastics learning media compared with the group that used conventional learning methods. The Android group increased both mean scores and categories from the "poor" category in the pretest ($M = 59.600$) to the "fair" category in the posttest ($M = 70.142$). In contrast, the conventional group remained in the "poor" category despite an increase in scores ($M = 63.400$). These findings indicate that Android applications can be an effective tool for improving backward roll skills in gymnastics. The paired-samples t-test confirmed this difference by showing a significant increase in both groups, but the t-value and mean difference were greater in the Android group ($t = 26.234$; $MD = 10.542$) than in the conventional group ($t = 12.863$; $MD = 3.842$). Independent samples t-test also confirmed a significant difference in posttest scores between groups ($p < 0.05$), reinforcing the argument that the Android application provides an advantage in backward roll skills in gymnastics (Cohen's $d = 2.342$).

The results of this study align with previous studies that examined the impact of technology in physical education. For example, the use of smartphone applications in physical education has been shown not only to improve teaching quality but also to promote student engagement in physical activities. Thus, it has a positive effect on learning outcomes (Gil-Espinosa et al., 2022). The use of Android-assisted applications allows students to visualize movements repeatedly, helping them better internalize each stage of the movement. This finding supports the research by Mulyana et al. (2022), which shows that Android-assisted gymnastics applications such as "GYMBASTECH" can increase student engagement in gymnastics learning and yield better results than traditional, more static learning methods.

Meanwhile, conventional methods that rely on verbal instructions and teacher demonstrations do not provide sufficient visual stimuli to help students understand and practice movements effectively, especially for complex motor skills such as backward rolls. The Android application provides immediate visual feedback, allowing students to correct technical errors independently. This is in line with Potdevin et al. (2018), who found that the use of video feedback (VFB) in gymnastics learning can improve students' motor skill mastery and motivation. In this case, Android applications offer more useful direct feedback than conventional methods that rely on verbal instructions, which often do not provide students with opportunities to directly assess their movements (Potdevin et al., 2018). Thus, although conventional learning has value in introducing basic movements, technologies such as Android-assisted applications offer significant improvements in learning more complex motor skills.

In addition to improving skills, the use of Android applications also increases student motivation in physical education. As stated by Varga & Révész (2023), technological devices in physical education can improve student performance and create a more positive motivational climate. In this study, Android applications enabled students to learn more independently, giving them a sense of achievement as they saw their skill development in real time (Varga & Révész, 2023). Conversely, in the group that used conventional methods, although skills improved, student motivation did not increase in proportion to the skills. Android applications provide a stronger motivational boost because they allow students to learn in a more interactive way and focus on personal achievement (Handayani et al., 2023a; 2023b).

Research conducted by Lin et al. (2023) shows that multiple feedback technologies are more beneficial for students with lower skill levels. Although technology provides many benefits, instructors still have a crucial role in providing direct correction and personal motivation. Corbett et al. (2025) emphasize that a combination of interactive feedback from mobile applications and face-to-face guidance will yield optimal learning outcomes. Therefore, even though Android applications provide many advantages for gymnastics learning, blending digital methods with face-to-face teaching remains necessary for maximum results. Kerner & Goodyear (2017) also emphasize that interactive feedback from mobile applications can improve mastery of movement techniques. This concept is supported by motor learning theory, which states that repetition with visual feedback is key to muscle memory formation (Schmidt et al., 2018).

However, the Android group's improvement was still considered "fair" in the posttest, indicating that there is room for improvement. This could be related to the limited duration of the intervention, the students' initial ability levels, or the application's suboptimal features. This finding corroborates the research by Chang et al. (2020), showing that learning applications with augmented reality and automatic motion-tracking features can significantly improve the effectiveness of motor learning. Therefore, the development of more sophisticated applications is recommended to maximize the learning outcomes of motor skills in the future.

This study shows that the use of Android-assisted learning media has a significant positive impact on backward roll skills in gymnastics, compared to conventional learning methods. Android applications not only improve students' motor skills but also increase their motivation and engagement in gymnastics learning. The advantage of this technology lies in its ability to provide immediate visual feedback, allowing students to correct technical errors independently and become more effective learners.

Although this technology offers various advantages, factors such as adequate teacher training and equal access to technology need to be considered to maximize its positive impact. Therefore, integrating technology into the physical education curriculum should be carried out with these factors in mind to ensure its successful implementation across various contexts. Several limitations in this study need to be acknowledged. First, the scope of the study was limited to one type of gymnastics skill (backward roll) and one level of education. The results cannot be generalized to other motor skills or different age groups. Second, the intervention lasted only 8 weeks and did not evaluate the long-term impact of using Android-assisted learning media. Third, non-instructional factors, such as student motivation and other variables that may affect the results of this study, have not been fully taken into account. Further research is needed to examine the role of motor skills at different educational levels, student involvement, and other variables. Additionally, an evaluation of long-term impacts is needed to provide a more comprehensive picture of the effectiveness of technology in physical education.

Conclusions

In conclusion, the use of Android-assisted gymnastics learning media is significantly more effective at improving backward roll skills than conventional learning ($p < 0.05$; Cohen's $d = 2.342$). The average skill score in the Android group increased by 10.542, while in the conventional group it only increased by 3.842. Analysis using paired-samples t-tests and independent-samples t-tests confirmed that the increase in skills was significant both intra-group and inter-group. The improvement in skills was consistent across all phases of the movement (preparation, execution, and completion), indicating that Android-assisted media can support the mastery of backward rolls in a comprehensive and systematic manner. These findings have important practical implications for physical education. Android-assisted learning media not only accelerates understanding of movements but also increases learning flexibility, ease of access, and student engagement in the learning process.

Educators may consider integrating this media into the curriculum, especially for complex gymnastics skills that require visual demonstrations and a gradual understanding of movement stages. Thus, Android-assisted media has the potential to be an innovative solution in teaching gymnastics skills, supporting independent learning, and improving the overall effectiveness of the teaching process. From a theoretical perspective, this study adds empirical evidence regarding the effectiveness of mobile technology in learning complex motor skills. The results of this study also show that the integration of digital media can strengthen understanding of movement concepts and skill mastery, thereby contributing to the development of technology-assisted learning theory in the field of physical education. Further research is recommended to evaluate the long-term effects of using Android-assisted learning media, including the impact on motivation, student engagement, and other supporting variables. In addition, it is necessary to explore other types of gymnastics skills and different levels of education, so that the results of this study serve as a basis for the development of more optimal, effective, and contextual digital learning media for various learning situations in the future.

Conflict of interest- The authors declare no potential conflicts of interest.

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