



Integrating Pedagogical Innovation in School Basketball: Comparing Tactical Training and Flipped Learning among Adolescent Female Students

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Article Info	Abstract
Article type: Research Article Review Article Article history: Received 22 February 2026 Received in revised form 25 May 2026 Accepted 10 June 2026 Available online 29 June 2026 Keywords: Tactical Training, Flipped Learning, Basketball, Physical Education, Adolescent Girls, Tactical Knowledge, Skill Performance.	Introduction: Innovative pedagogical approaches are increasingly emphasized in physical education to enhance students' tactical understanding and sport performance. However, limited evidence exists comparing tactical training and flipped learning in school basketball settings, particularly among adolescent female students. Objective: This study compared the effects of tactical training and flipped learning on tactical knowledge and basketball skill performance among adolescent female students. Method: A randomized controlled trial with a parallel-group design was conducted among 180 female students (aged 13-17 years) in Karaj, Iran. Participants were randomly assigned to tactical training (n=60), flipped learning (n=60), or control (n=60). The intervention lasted 8 weeks. Tactical knowledge was assessed using a standardized test (0-100), and basketball skill performance was measured using an observational rating scale (0-25). Data were analyzed using ANCOVA controlling for baseline scores. Results: Significant group effects were found for tactical knowledge, $F(2,164)=48.72$, $p<0.001$, $\eta^2=0.37$, and skill performance, $F(2,164)=41.56$, $p<0.001$, $\eta^2=0.34$. Both tactical training and flipped learning groups outperformed the control group in tactical knowledge (71.4 ± 7.9 ; 66.2 ± 8.1 vs. 45.8 ± 8.2) and skill performance (19.8 ± 2.9 ; 18.3 ± 3.0 vs. 13.1 ± 3.1 ; all $p<0.001$). The tactical training group showed significantly greater improvements than the flipped learning group in both tactical knowledge ($p=0.02$) and skill performance ($p=0.03$). Conclusions: Both tactical training and flipped learning effectively enhanced tactical knowledge and basketball skill performance in adolescent female students. However, tactical training demonstrated superior effects, suggesting that game-based pedagogical approaches may be more effective for developing sport competence in school basketball programs. Cite this Article: Bagheri, S. (2026). Integrating Pedagogical Innovation in School Basketball: Comparing Tactical Training and Flipped Learning among Adolescent Female Students. <i>Physical Activity in Children</i> , 3(1), 116-125. https://doi.org/10.22034/pach.2026.588292.1097

1. Introduction

Physical education plays a critical role in promoting lifelong physical activity, developing motor competence, and fostering cognitive and social skills among children and adolescents (1). Within school-based physical education programs, team sports provide unique opportunities for students to acquire not only technical skills but also tactical understanding, decision-making abilities, communication skills, and collaborative competencies (2). Basketball, one of the most widely practiced team sports worldwide, is particularly well suited for promoting these multidimensional learning outcomes due to its dynamic nature, rapid transitions, and continuous interaction among players (3).

Traditional approaches to basketball instruction in school settings have predominantly emphasized the repetitive practice of isolated technical skills, such as dribbling, passing, and shooting (4). Although these methods can improve fundamental motor execution, they often fail to adequately develop students' tactical awareness and their ability to apply acquired skills

effectively during game situations (5). As a result, students may demonstrate proficiency in controlled practice environments but struggle to make appropriate decisions and adapt their actions during actual gameplay. This discrepancy has prompted researchers and educators to advocate for learner-centered pedagogical approaches that integrate technical skill development with tactical understanding.

Tactical knowledge refers to an individual's ability to perceive, interpret, and respond effectively to game situations (6). It encompasses both declarative knowledge, which involves understanding game rules, strategies, and principles, and procedural knowledge, which relates to applying this understanding in real-time decision-making contexts (7). Tactical performance, in turn, reflects the effective execution of skills and decisions during gameplay. The development of tactical competence is increasingly recognized as a central objective of contemporary physical education because it enables students to



become more autonomous, engaged, and successful participants in sport (8).

In response to the limitations of traditional skill-based instruction, tactical training approaches have gained considerable attention in sport pedagogy. Models such as Teaching Games for Understanding (TGfU), Game Sense, and Tactical Games Approach emphasize learning through modified games and problem-solving activities that replicate authentic game situations (9). Rather than teaching technical skills in isolation, these approaches encourage students to explore tactical challenges, make decisions, and apply skills within meaningful contexts (10). Evidence suggests that tactical training can improve decision-making, game intelligence, motivation, and transfer of learning more effectively than conventional teaching methods (11).

The effectiveness of tactical training may be particularly relevant during adolescence, a developmental period characterized by significant cognitive, social, and physical changes (12). Adolescents develop enhanced capacities for abstract reasoning, strategic thinking, and metacognitive processing (13), making them more receptive to instructional approaches that require analysis, reflection, and problem-solving. Moreover, student-centered pedagogies that promote active engagement and autonomy may align more closely with adolescents' developmental needs and preferences (14), potentially increasing participation and enjoyment in physical education.

Alongside advances in sport-specific pedagogies, educational technologies have transformed teaching and learning across disciplines. One instructional innovation that has received growing attention is flipped learning. In the flipped learning model, students engage with instructional content, such as videos, demonstrations, and digital resources, outside the classroom, allowing in-class time to be dedicated to active learning, discussion, and application (15-18). This approach shifts the focus from teacher-centered instruction to student-centered learning, encouraging greater responsibility, autonomy, and engagement.

Within physical education and sport contexts, flipped learning offers several potential advantages. By accessing instructional materials before class, students can learn at their own pace, review content as needed, and arrive better prepared for practical activities (19,20). Consequently, class time can be used more efficiently for skill practice, tactical discussions, feedback, and collaborative learning experiences. Flipped learning may also facilitate differentiated instruction by accommodating diverse learning styles and prior knowledge levels (21,22).

Emerging evidence suggests that flipped learning can enhance students' motivation, knowledge acquisition, self-efficacy, and skill performance in physical education settings (23-25). Nevertheless, research examining its application in sport-specific contexts, particularly team sports such as basketball, remains limited (19,20). Furthermore, existing studies have produced mixed findings regarding the effectiveness of flipped learning compared with more established pedagogical approaches. While some investigations have reported significant improvements in cognitive and performance outcomes, others have

found limited or inconsistent effects, highlighting the need for further research.

Despite the growing body of literature supporting both tactical training and flipped learning, important questions remain unanswered regarding their relative educational value. Most previous investigations have examined each instructional approach separately, typically comparing it with traditional teacher-centered instruction. Consequently, current evidence demonstrates that both approaches can improve selected learning outcomes, but provides limited guidance regarding which pedagogical model is more effective for promoting tactical understanding and game performance when implemented under comparable school conditions. Direct comparisons between these learner-centered approaches are therefore necessary to assist teachers in selecting instructional strategies that best align with curriculum objectives and available teaching time.

Another important limitation of previous research is that many studies have evaluated either cognitive outcomes (e.g., tactical knowledge) or motor performance outcomes (e.g., technical skill execution) in isolation. Because effective basketball performance depends on the integration of tactical decision-making with skill execution during authentic game situations, simultaneously examining both domains provides a more comprehensive evaluation of instructional effectiveness. Such multidimensional assessment is particularly relevant for contemporary physical education, which increasingly emphasizes game competence rather than isolated technical proficiency.

Furthermore, evidence remains limited for adolescent female students, who have historically been underrepresented in sport pedagogy research despite potential differences in sport participation opportunities, motivational factors, and learning experiences. Most available studies have also been conducted in extracurricular or competitive sport settings rather than compulsory school physical education, where instructional time, class size, and student ability are substantially more heterogeneous. Evaluating innovative pedagogical models within regular school classes therefore enhances the ecological validity and practical relevance of the findings for physical education teachers.

Addressing these gaps is particularly important in the context of Iranian schools, where physical education curricula are increasingly encouraging student-centered instructional practices while simultaneously seeking practical approaches that can be implemented within the constraints of regular class schedules. However, empirical evidence comparing contemporary pedagogical models in this educational context remains scarce. Consequently, it remains unclear whether tactical training or flipped learning provides greater educational benefits for adolescent female students learning basketball in school-based physical education.

Therefore, the present study aimed to compare the effects of tactical training and flipped learning on tactical knowledge and basketball skill performance among adolescent female students in Karaj, Iran. Unlike previous studies that have evaluated either pedagogical approach independently against traditional instruction, the present randomized

controlled trial directly compared two innovative learner-centered instructional models delivered within the same school-based educational context. By examining both tactical knowledge and basketball skill performance simultaneously among adolescent female students, this study seeks to address an important gap in the sport pedagogy literature and provide evidence that may assist physical education teachers in selecting instructional approaches appropriate for regular school settings. It was hypothesized that both instructional approaches would improve tactical knowledge and basketball skill performance; however, the magnitude and pattern of these improvements were expected to differ because tactical training and flipped learning emphasize distinct instructional processes, levels of contextualized game practice, and opportunities for tactical decision-making. Rather than assuming the superiority of either approach, the study was designed to determine their comparative effectiveness under the specific conditions of the present investigation. The findings of this study may contribute to the growing evidence base on innovative pedagogical practices in physical education and inform the development of more effective and engaging basketball instruction for adolescent girls.

2. Methods

2.1. Study Design

This study employed a randomized controlled trial with a parallel-group design to compare the effects of tactical training and flipped learning on tactical knowledge and basketball skill performance among adolescent female students. Participants were randomly assigned to one of three groups: (1) tactical training group, (2) flipped learning group, or (3) control group receiving usual physical education instruction. The intervention lasted 8 weeks, with assessments conducted at baseline (pre-test) and immediately after the intervention (post-test). The study was designed and reported in accordance with the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2.2. Setting and Participants

School principals first provided institutional permission, after which physical education teachers introduced the study to eligible students during regular physical education classes. Information sessions were subsequently held for students and their parents or legal guardians to explain the study objectives, procedures, potential benefits, and risks. A total of 236 female students were invited to participate. Twenty-two students declined participation and 14 did not meet the eligibility criteria. Consequently, 200 students underwent baseline screening, and 180 fulfilled all eligibility requirements, provided written informed consent and assent, and were enrolled in the study, representing an overall response rate of 76.3%. Participants were female students aged 13-17 years enrolled in regular physical education classes. Inclusion criteria were having no formal extracurricular basketball training in the past six months, possessing the physical capability to engage in activities, and providing written informed assent alongside parental or guardian consent. Conversely, individuals were excluded if they presented with musculoskeletal injuries or medical conditions that

limited physical activity, held prior competitive basketball experience at a club or regional level, maintained an attendance rate below 80% across intervention sessions, or expressed an unwillingness to continue their participation in the study.

2.2.1. Sample Size Determination

Sample size was estimated using G*Power version 3.1. The primary outcome of the study was tactical knowledge, which was selected as the basis for sample size estimation because it represented the principal educational outcome of interest. Although multiple dependent variables were analyzed, ANCOVA was chosen as the primary analytical approach because it provides greater statistical power by adjusting post-intervention scores for baseline differences while reducing unexplained variance. The calculation assumed a moderate effect size ($f = 0.25$), $\alpha = 0.05$, statistical power $(1-\beta) = 0.80$, and three independent groups. The selected effect size was based on previous school-based basketball pedagogy studies comparing innovative instructional approaches, which generally reported medium intervention effects on tactical learning and game performance. Under these assumptions, the minimum required sample size was 159 participants (53 per group). To compensate for an anticipated attrition rate of approximately 12%, the recruitment target was increased to 180 participants (60 per group).

2.2.2. Recruitment and Randomization, and Allocation Concealment

Following completion of baseline assessments, participants were randomly assigned in a 1:1:1 ratio to the tactical training, flipped learning, or control group. Randomization was performed using computer-generated block randomization with variable block sizes of six and nine to maintain balanced group allocation throughout recruitment while minimizing allocation predictability. No stratification was performed because baseline demographic characteristics were expected to be comparable within the relatively homogeneous school population. The random allocation sequence was generated by an independent researcher who was not involved in participant recruitment, outcome assessment, or intervention delivery. Eligible students were enrolled by the principal investigator, whereas group assignments were implemented by a research assistant who had no role in data collection. Allocation concealment was maintained using sequentially numbered, opaque, sealed envelopes prepared by the independent researcher. Envelopes remained sealed until completion of all baseline assessments and were opened individually after participant enrollment, thereby ensuring concealment throughout the allocation process.

2.2.3. Blinding

Because of the educational nature of the interventions, participants and instructors could not be blinded. However, all outcome assessors remained blinded to group allocation throughout baseline and post-intervention testing. Assessors were instructed not to discuss intervention procedures with participants, and students were reminded before each assessment not to disclose their group assignment. Data analysts also remained blinded until completion of the primary statistical analyses.

2.3. Intervention Procedures

The intervention lasted 8 weeks, with two 60-minute physical education sessions per week (16 sessions). Prior to study initiation, all instructors completed a two-day standardized training workshop covering intervention protocols, instructional procedures, and fidelity requirements. Each instructor received a detailed intervention manual describing lesson objectives, teaching strategies, session progression, and expected learning outcomes. Intervention fidelity was monitored using standardized observation checklists completed by independent observers during approximately 20% of randomly selected sessions. Fidelity items assessed adherence to lesson objectives, instructional sequence, teaching strategies, student engagement, and time allocation. Mean protocol adherence exceeded 93% across intervention groups. Weekly meetings were also held with instructors to reinforce protocol consistency and address implementation issues.

2.3.1. Tactical Training Group

Participants assigned to the tactical training group underwent an intervention based on the TGfU framework, with each 60-minute session consisting of a 10-minute warm-up, 15 minutes of modified tactical games, 20 minutes of tactical problem-solving activities, and 15 minutes of game application and reflection. The instructional sequence was progressive, beginning with Weeks 1–2 focused on maintaining possession and creating space via 3-versus-3 games, advancing in Weeks 3–4 to passing options, support play, and off-the-ball movement, transitioning in Weeks 5–6 to offensive and defensive transitions through 4-versus-4 games, and culminating in Weeks 7–8 with the integration of tactical principles in complex scenarios mirroring formal basketball. Throughout this process, instructors utilized guided-discovery questioning—such as inquiring about available space or optimal passing lanes—to stimulate tactical thinking, encouraging students to discuss and immediately test solutions during modified gameplay, while addressing specific tasks such as offensive width, numerical superiority, defensive switching, fast-break decision-making, and transition defense.

2.3.2. Flipped Learning Group

Students in the flipped learning group engaged in a hybrid instructional model where pre-class preparation involved viewing 10–15-minute instructional videos—covering techniques, tactical concepts, and game scenarios—via an online platform, with compliance verified through learning management system tracking and short, mandatory pre-class quizzes that achieved an average completion rate exceeding 90%. Each practical session was structured around a 10-minute discussion of these materials, 15 minutes of instructor clarification, 30 minutes of practical application, and a 5-minute reflection, during which students participated in technical drills, small-sided games, tactical exercises, and peer assessments. Throughout these sessions, the instructor functioned primarily as a facilitator who prioritized individualized feedback and peer discourse, shifting the pedagogical focus away from traditional direct instruction toward collaborative learning and application.

2.3.3. Control Group (Usual Instruction)

Participants in the control group received traditional physical education instruction based on the standard school curriculum. Instruction primarily consisted of teacher-led demonstrations followed by repetitive skill practice (e.g., passing, dribbling, shooting drills), with limited emphasis on tactical understanding or game-based learning.

2.4. Measurements

2.4.1. Tactical Knowledge

Tactical knowledge was assessed using the Basketball Tactical Knowledge Test, previously validated for adolescent basketball players. The questionnaire consists of 25 multiple-choice items assessing declarative and procedural tactical knowledge across offensive and defensive game situations. Scores range from 0 to 100, with higher scores indicating greater tactical understanding. Previous studies have reported satisfactory construct validity and internal consistency (Cronbach's $\alpha = 0.87$). In the present study, Cronbach's α was 0.89.

2.4.2. Basketball Skill Performance

Basketball performance was evaluated during standardized small-sided games using a structured observational instrument. The assessment consisted of five performance domains: passing accuracy, dribbling control, shooting execution, tactical decision-making, and off-ball movement. Each domain was scored from 1 (very poor) to 5 (excellent), yielding total scores ranging from 5 to 25. Higher scores reflected superior basketball performance. Previous investigations have demonstrated acceptable content validity and inter-rater reliability. Internal consistency in the present sample was high (Cronbach's $\alpha = 0.91$). Performance evaluations were conducted independently by two experienced basketball coaches who each possessed more than five years of coaching experience and completed a standardized assessor training workshop before data collection. Both assessors remained blinded to participant group allocation throughout the study. Inter-rater reliability was excellent (intraclass correlation coefficient [ICC] = 0.93).

2.5. Data Collection Procedures

Pre-test assessments were conducted one week before the intervention, and post-test assessments were conducted within one week after completion of the 8-week program. All assessments were administered during physical education classes by trained evaluators blinded to group allocation.

2.6. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 29. Descriptive statistics are presented as means $\pm$ standard deviations. Prior to conducting ANCOVA, statistical assumptions were examined. Normality of residuals was assessed using the Shapiro-Wilk test and Q-Q plots. Homogeneity of variances was evaluated using Levene's test, while homogeneity of regression slopes was examined by testing the interaction between baseline scores and group membership. Independence of observations was ensured through the randomized study design. All assumptions were satisfactorily met before the primary analyses. One-way ANCOVA was used to compare post-test scores among the three groups while adjusting for corresponding baseline values. Adjusted post-test means (estimated marginal means),

adjusted mean differences, 95% confidence intervals, F statistics, p-values, and partial eta squared (η^2p) are reported. Bonferroni-adjusted pairwise comparisons were performed following significant overall group effects. Cohen's d values for pairwise comparisons were calculated using adjusted post-test means divided by the pooled post-test standard deviation to facilitate interpretation of intervention magnitude. Statistical significance was established at $p < 0.05$.

3. Results

3.1. Participant Flow and Retention

A total of 214 female students from the four participating secondary schools were assessed for eligibility (Figure 1). Of these, 22 students declined participation, and 12 did not meet the inclusion criteria

because of previous competitive basketball experience or medical conditions limiting participation. Consequently, 180 eligible students completed baseline assessments and were randomly allocated to the tactical training group ($n = 60$), flipped learning group ($n = 60$), or control group ($n = 60$). During the 8-week intervention, 12 participants (6.7%) were lost to follow-up because of prolonged absenteeism ($n = 7$) or school transfer ($n = 5$). Attrition occurred in the tactical training ($n = 4$), flipped learning ($n = 5$), and control ($n = 3$) groups. No statistically significant differences were observed in dropout rates among the three groups ($p = 0.81$). Accordingly, the final analyses included 168 participants, comprising 56 students in the tactical training group, 55 in the flipped learning group, and 57 in the control group, representing an overall retention rate of 93.3% (Figure 1).

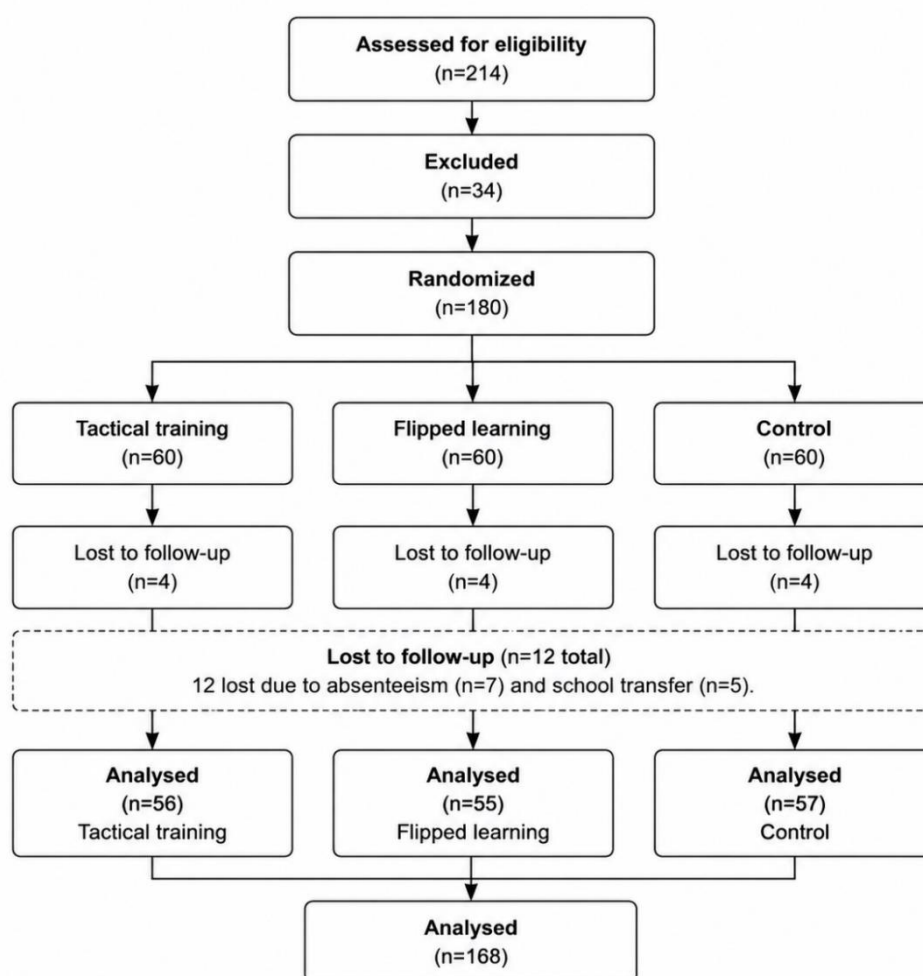


Figure 1. CONSORT Flow Diagram of Participant Recruitment, Randomization, Follow-up, and Analysis.

3.2. Baseline Characteristics

Baseline demographic characteristics and outcome measures are presented in Table 1. No statistically significant differences were observed among the three

groups for age, previous basketball experience, tactical knowledge, or basketball skill performance (all $p > 0.05$), indicating that randomization successfully produced comparable groups before the intervention.

Table 1. Baseline Characteristics of Participants

Variable	Tactical Training (n = 60)	Flipped Learning (n = 60)	Control (n = 60)	p
Age (years), mean $\pm$ SD	15.2 $\pm$ 1.1	15.1 $\pm$ 1.2	15.3 $\pm$ 1.0	0.74
Tactical Knowledge (0-100)	41.8 $\pm$ 8.6	42.1 $\pm$ 8.3	41.5 $\pm$ 8.4	0.96
Skill Performance (0-25)	12.4 $\pm$ 3.2	12.6 $\pm$ 3.1	12.3 $\pm$ 3.0	0.93
Prior basketball experience (months)	3.1 $\pm$ 2.0	3.3 $\pm$ 2.2	3.2 $\pm$ 2.1	0.88

3.3. Intervention Adherence and Fidelity

Attendance was high across all study groups. Mean attendance rates were 92.3% for the tactical training group, 90.8% for the flipped learning group, and 94.1% for the control group. Independent fidelity observations indicated high adherence to the intervention protocols, with instructors implementing 93.6% of the planned tactical training components and 94.2% of the planned flipped learning components. Compliance with pre-class video viewing in the flipped learning group exceeded 90% according to the online learning platform records. No intervention-related adverse events were reported.

3.4. Effects on Tactical Knowledge

Descriptive characteristics and outcome measures of tactical knowledge are presented in Table 2 and Figure 2. After adjustment for baseline tactical

knowledge scores, the one-way ANCOVA demonstrated a statistically significant effect of group on post-intervention tactical knowledge, $F(2,164) = 48.72$, $p < 0.001$, partial $\eta^2 = 0.37$, indicating a large intervention effect. The adjusted post-test means (estimated marginal means) were 71.2 (95% CI: 69.3–73.1) for the tactical training group, 66.0 (95% CI: 64.1–67.9) for the flipped learning group, and 45.9 (95% CI: 44.1–47.8) for the control group. Bonferroni-adjusted post hoc comparisons demonstrated that both intervention groups achieved significantly higher tactical knowledge scores than the control group (both $p < .001$). Furthermore, participants receiving tactical training demonstrated significantly greater tactical knowledge than those receiving flipped learning (adjusted mean difference = 5.2 points, 95% CI: 1.8 to 8.6, $p = 0.02$).

Table 2. Tactical Knowledge Before and After the Intervention

Group	Pre-Test	Post-Test	Mean Change	Adjusted Post-test Mean (95% CI)
Tactical Training	41.8 ± 8.6	71.4 ± 7.9	+29.6	71.2 (69.3–73.1)
Flipped Learning	42.1 ± 8.3	66.2 ± 8.1	+24.1	66.0 (64.1–67.9)
Control	41.5 ± 8.4	45.8 ± 8.2	+4.3	45.9 (44.1–47.8)

3.5. Effects on Basketball Skill Performance

Descriptive characteristics and outcome measures of basketball skill performance are presented in Table 3 and Figure 2. After adjustment for baseline skill performance scores, ANCOVA revealed a significant group effect for basketball skill performance, $F(2,164) = 41.56$, $p < 0.001$, partial $\eta^2 = 0.34$, also representing a large effect. Adjusted post-test means were 19.7 (95% CI: 19.0–20.4) for the tactical training group, 18.2 (95% CI: 17.5–18.9) for the flipped learning group, and 13.2 (95%

CI: 12.5–13.9) for the control group. Bonferroni-adjusted comparisons showed that both intervention groups significantly outperformed the control group (both $p < 0.001$). In addition, students receiving tactical training achieved significantly higher basketball skill performance scores than those receiving flipped learning (adjusted mean difference = 1.5 points, 95% CI: 0.2 to 2.8, $p = 0.03$).

Table 3. Basketball Skill Performance Before and After the Intervention.

Group	Pre-Test	Post-Test	Mean Change	Adjusted Post-Test Mean (95% CI)
Tactical Training	12.4 ± 3.2	19.8 ± 2.9	+7.4	19.7 (19.0–20.4)
Flipped Learning	12.6 ± 3.1	18.3 ± 3.0	+5.7	18.2 (17.5–18.9)
Control	12.3 ± 3.0	13.1 ± 3.1	+0.8	13.2 (12.5–13.9)

3.6. Pairwise Comparisons of Adjusted Post-Test Scores

Bonferroni-adjusted pairwise comparisons are presented in Table 4. For tactical knowledge, the tactical training group demonstrated significantly higher adjusted scores than the flipped learning group (mean difference = 5.2 points, 95% CI: 1.8–8.6, $p = 0.02$, Cohen's $d = 0.64$) and the control group (mean difference = 25.3 points, 95% CI: 21.7–28.9, $p < 0.001$, $d = 2.01$). The flipped learning group also outperformed the control group (mean difference = 20.1 points, 95%

CI: 16.5–23.7, $p < 0.001$, $d = 1.58$). Similarly, for basketball skill performance, the tactical training group achieved significantly higher adjusted scores than both the flipped learning group (mean difference = 1.5 points, 95% CI: 0.2–2.8, $p = 0.03$, $d = 0.52$) and the control group (mean difference = 6.5 points, 95% CI: 5.2–7.8, $p < 0.001$, $d = 2.08$). The flipped learning group also demonstrated significantly greater skill performance than the control group (mean difference = 5.0 points, 95% CI: 3.7–6.3, $p < 0.001$, $d = 1.63$).

Table 4. ANCOVA Results and Adjusted Pairwise Comparisons.

Outcome	F(2,164)	p	Partial η^2
Tactical Knowledge	48.72	< 0.001	0.37
Basketball Skill Performance	41.56	< 0.001	0.34
Comparison	Adjusted Mean Difference (95% CI)	p	Cohen's d
Tactical Knowledge			
Tactical vs Control	25.3 (21.7, 28.9)	< 0.001	2.01
Flipped vs Control	20.1 (16.5, 23.7)	< 0.001	1.58
Tactical vs Flipped	5.2 (1.8, 8.6)	0.020	0.64
Basketball Skill Performance			
Tactical vs Control	6.5 (5.2, 7.8)	< 0.001	2.08
Flipped vs Control	5.0 (3.7, 6.3)	< 0.001	1.63
Tactical vs Flipped	1.5 (0.2, 2.8)	0.030	0.52

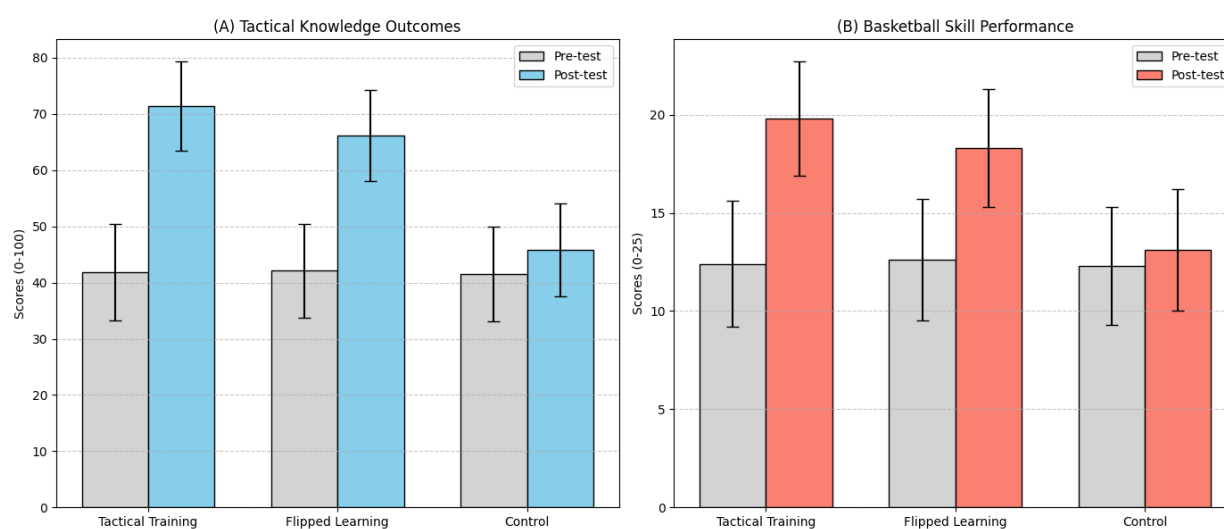


Figure 2. Changes in (A) Tactical Knowledge scores and (B) Basketball Skill Performance scores across pre-test and post-test. Data are presented as means with error bars representing standard deviation (SD). Abbreviations: TT, Tactical Training group; FL, Flipped Learning group; CG, Control group.

4. Discussion

The present randomized controlled trial compared the effects of tactical training and flipped learning on tactical knowledge and basketball skill performance among adolescent female students in school physical education settings. Consistent with the study hypotheses, both instructional approaches produced significant improvements in tactical knowledge and basketball skill performance compared with traditional physical education instruction. However, students who participated in the tactical training program demonstrated significantly greater improvements than those receiving flipped learning, even after controlling for baseline performance. These findings suggest that, within the educational context and population examined, game-based tactical instruction may provide greater benefits for developing basketball-specific cognitive and performance outcomes than a flipped learning approach alone.

The substantial improvement in tactical knowledge observed in the tactical training group is consistent with the theoretical foundations of game-centered pedagogical models such as TGfU and the Tactical Games Approach (26). These instructional models emphasize learning through modified game situations in which students are continuously required to perceive environmental cues, interpret tactical problems, make decisions, and execute appropriate responses within authentic performance contexts (10,26). Unlike traditional technique-centered instruction, tactical training promotes the simultaneous development of declarative and procedural knowledge by embedding technical skills within realistic decision-making situations. This integration encourages students to understand not only how to perform a skill but also when, where, and why it should be applied during gameplay. Consequently, repeated exposure to representative game scenarios may strengthen tactical awareness, anticipation, and strategic thinking more effectively than isolated practice. The present findings therefore support previous research demonstrating that game-based pedagogies enhance tactical understanding, decision-making, and game intelligence more

effectively than conventional instructional methods (10,11).

The superior basketball skill performance demonstrated by the tactical training group may also be explained by the contextual nature of the learning environment. Motor learning theory suggests that skills acquired under conditions resembling actual performance environments are more likely to transfer successfully to competitive play. Throughout the intervention, students repeatedly practiced passing, dribbling, movement, defensive positioning, and shooting while responding to changing game situations rather than rehearsing predetermined movement patterns. This continuous interaction between perception, decision-making, and skill execution likely strengthened functional movement adaptability, allowing students to perform more effectively during the observational assessments. Importantly, these improvements are educationally meaningful because they are likely to translate into better participation, teamwork, and decision-making during real basketball games rather than merely improving isolated technical drills.

Participants in the flipped learning group also exhibited significant improvements in tactical knowledge and basketball skill performance compared with the control group, supporting the growing evidence that technology-enhanced instructional approaches can positively influence learning in physical education. Flipped learning allowed students to review instructional videos, demonstrations, and tactical concepts before class, thereby increasing opportunities for active practice during physical education lessons (16,17,19). The flexibility to review learning materials repeatedly may have improved conceptual understanding, accommodated individual learning pace, and enhanced students' confidence before participating in practical activities. Furthermore, the increased classroom time available for teacher feedback and collaborative practice likely contributed to the observed improvements in both cognitive and motor outcomes.

Nevertheless, the present findings indicate that flipped learning alone did not produce improvements

equivalent to those achieved through tactical training. Several complementary mechanisms may explain this difference. First, although flipped learning effectively supports knowledge acquisition before class, it does not inherently guarantee that students will repeatedly experience the perceptual, cognitive, and motor demands encountered during authentic game play. In contrast, tactical training requires learners to solve tactical problems continuously while interacting with teammates and opponents, thereby strengthening perception-action coupling and contextual decision-making. Second, the immediate questioning, guided discovery, and adaptive feedback incorporated throughout the tactical training sessions may have facilitated deeper cognitive processing than independent pre-class learning. Third, tactical training encouraged students to construct knowledge through direct game experiences rather than primarily acquiring information before applying it in class (27,30). Collectively, these characteristics may explain why tactical training produced larger improvements than flipped learning in both tactical knowledge and skill performance.

Beyond statistical significance, the magnitude of the observed improvements has important educational implications. The approximately 30-point improvement in tactical knowledge and the substantial gains in basketball skill performance observed following tactical training suggest meaningful enhancement in students' ability to understand game situations, make appropriate decisions, and execute skills effectively during play. Such improvements are likely to increase students' confidence, enjoyment, and active participation during physical education lessons, which are important determinants of continued engagement in physical activity and sport throughout adolescence.

The findings also have important implications for physical education teachers and curriculum developers. Tactical training appears to be feasible for implementation within regular school lessons because it can be incorporated into existing class periods using modified games, small-sided activities, guided questioning, and structured reflection rather than requiring specialized facilities or expensive equipment. Teachers can progressively introduce tactical concepts by designing representative game scenarios that encourage students to identify tactical problems, discuss alternative solutions, and immediately apply these solutions during play. This learner-centered approach may improve engagement while simultaneously promoting cognitive, social, and motor development. Although flipped learning may require greater technological preparation, it remains a valuable complementary strategy, particularly when instructional videos can maximize limited classroom time or support students requiring additional review. Consequently, educators may also consider integrating selected flipped learning elements with game-based instruction to maximize both cognitive preparation and practical application.

The present findings may be particularly relevant for adolescent girls. Female students have historically reported lower participation rates and confidence in some team sports, often because physical education emphasizes technical proficiency over meaningful game involvement. By prioritizing decision-making,

cooperation, and problem-solving within supportive learning environments, tactical training may create more inclusive educational experiences that foster confidence, competence, and enjoyment. Such benefits may ultimately contribute to greater long-term participation in sport and physical activity among adolescent girls.

Several limitations should be considered when interpreting these findings. First, participants were recruited using convenience sampling from a limited number of public schools in Karaj, which may reduce the generalizability of the findings to adolescents from other educational systems, cultural contexts, or socioeconomic backgrounds. Second, the intervention lasted only eight weeks, preventing evaluation of whether the observed improvements are maintained over longer periods. Third, no long-term follow-up assessments were conducted, limiting conclusions regarding retention of tactical knowledge and skill performance. Fourth, participants and instructors could not be blinded because of the educational nature of the interventions, creating the possibility of expectancy and performance effects. Fifth, although standardized instructional protocols were implemented, differences in instructor teaching style, communication, or enthusiasm may have influenced student outcomes despite efforts to promote intervention consistency. Finally, basketball skill performance was evaluated using standardized observational ratings, which, although conducted by trained blinded assessors, may remain subject to some degree of measurement subjectivity.

Future research should address these limitations by conducting multicenter randomized trials involving more diverse student populations and longer intervention periods with extended follow-up assessments. Studies incorporating objective performance analysis systems, video-based movement tracking, or game analytics could further strengthen outcome assessment. Moreover, investigations examining hybrid pedagogical models that combine tactical training with flipped learning may determine whether integrating the strengths of both approaches produces greater educational benefits than either strategy alone. Additional research should also evaluate implementation feasibility, teacher professional development requirements, and curriculum integration to facilitate wider adoption within school physical education programs.

4.1. Conclusion

In conclusion, both tactical training and flipped learning were effective instructional approaches for improving tactical knowledge and basketball skill performance among adolescent female students compared with traditional physical education instruction. Within the conditions of the present randomized controlled trial, tactical training produced significantly greater improvements than flipped learning in both cognitive and performance outcomes. These findings suggest that instructional approaches emphasizing authentic game situations, decision-making, and contextual skill application may be particularly effective for developing basketball competence among adolescent girls in school settings.

Nevertheless, these findings should be interpreted within the context of the study design, participant

characteristics, and intervention duration. Rather than indicating that tactical training is universally superior across all educational settings, the results demonstrate greater effectiveness within this sample and under the conditions examined. Continued investigation across different populations, sports, and educational contexts is warranted before broader generalizations can be made. Overall, the present findings support the integration of evidence-informed, student-centered pedagogical approaches into school physical education to promote meaningful cognitive and motor learning while enhancing students' engagement and participation in sport.

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Data Availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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