Bridging Coaching Knowledge and AI Feedback to Enhance Motor Learning in Basketball Shooting Mechanics Through a Knowledge-Based SOP Framework

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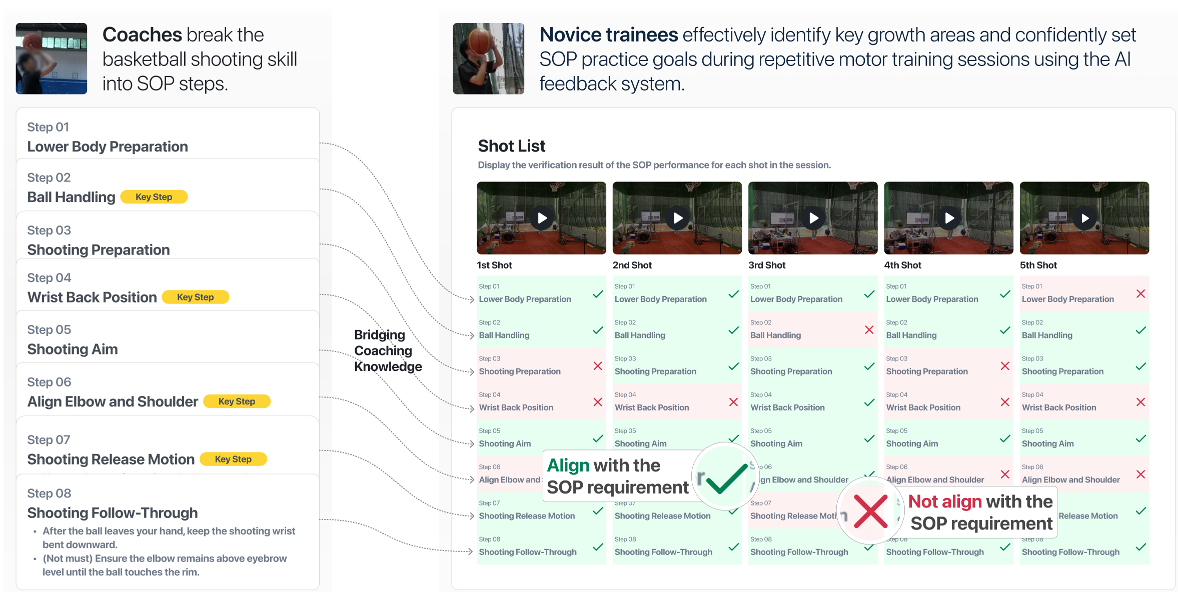

Figure 1: Our proposed SOP methodology enhances basketball shooting through expert comparisons and structured AI feedback.

Abstract

We present a methodology for designing an AI feedback system aimed at assisting basketball beginners in refining their shooting techniques during independent practice sessions. Mastering shooting mechanics requires consistent, precise repetition, which traditionally depends on coaching feedback and the breakdown of movements into steps during the early stages. However, due to limited coaching resources, this guidance is often unavailable, leading to ineffective and even detrimental motor learning. To bridge this gap, we propose a Standard Operating Procedure (SOP) framework grounded in expert human knowledge, or knowledge-based SOP, which allows our AI-driven system to verify and guide players' movements in real-time. Through a formative study involving interviews with 13 coaches and players, we identified key challenges faced by beginners, such as uncertainty in movement correctness and lack of guidance during unsupervised practice. Our AI system addresses these issues by providing immediate, actionable feedback using SOP tailored to individual players. In a study with 28 participants, we confirmed that our system improves shooting form, increases confidence in adjustments, and enhances self-awareness during practice. This work highlights the potential of integrating coaching expertise with AI to empower athletes with more effective tools for self-directed practice.

Keywords

Sports/Exercise, Visualization, Empirical study that tells us about how people use a system

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1 Introduction

Repetitive motor training is essential for learning new sports skills, particularly for beginners in basketball shooting. Consistent repetition helps players internalize proper motor patterns, which are critical for developing a stable and accurate shooting form [24, 26]. However, as our formative study (cf. Section 3) reveals, current training methods often fail to support independent practice outside formal coaching sessions sufficiently. Due to limited coaching resources, coaches often cannot monitor and guide players effectively during these sessions. Some coaches utilize video recordings as a supplementary tool, sharing instructional clips or encouraging players to film their practice. However, this approach has limitations, such as delayed feedback and challenges in diagnosing posture errors [6, 7, 12]. Despite evidence showing that progressive methods (i.e., mastering small parts before advancing to more complex movements) enhance learning outcomes [15], trainees have a hard time ensuring their motions align with the coach's standards during unsupervised practice sessions, leading to ineffective motor training for beginners.

Researchers seek automated methods to provide feedback and enhance unsupervised motor training. However, delivering effective posture feedback in an automatic system without a coach's presence poses significant challenges. First, the 3D nature of movements complicates accurate assessment. Feedback must support analyzing detailed spatial movements involved in shooting mechanics. Second, real-time adjustments are necessary to help players correct their form as they practice, but automated feedback systems often struggle to accurately identify errors and offer clear, actionable advice. Third, motor learning relies heavily on proprioception, which can be difficult to cultivate without direct guidance. Furthermore, individual variations in muscle movements mean that feedback must go beyond simple metrics like shot percentage, requiring an understanding of the subtleties of posture that are challenging to quantify.

Popular approaches like digital video modeling (VM), such as Kinovea [18] and Dartfish [23], attempt to address these challenges by mapping movements onto videos, allowing players to observe and analyze their posture after practice. However, VM has limited capability to provide real-time feedback and does not effectively foster proprioception or account for individual muscle variations without coaches' input, limiting its overall impact in improving motor skills such as basketball shooting form [15, 31]. On the other hand, tools like NOAH [13] offer real-time feedback on shot trajectories but fail to address the complexity of 3D movements. This simplified feedback limits trainees' ability to develop proprioception and hinders their ability to make nuanced posture corrections. AR feedback systems enhance self-awareness through real-time 3D feedback, which improves proprioception and spatial awareness. However, they still fall short in delivering personalized, detailed feedback on more complex shooting mechanics, as shown in [22].

Despite advancements in existing tools, our review reveals a significant gap in delivering effective posture feedback during self-practice, which is crucial for developing motor skills. Specifically, there is a gap in providing posture feedback that enhances self-awareness and addresses individual posture variations. This gap highlights the need for a more comprehensive approach to posture analysis that goes beyond basic metrics and provides actionable guidance tailored to the unique requirements of each learner, particularly beginners.

To address this gap, we proposed a knowledge-based SOP framework to deliver posture feedback, which integrates coaching insights and system feedback into step-by-step posture motion breakdowns. Our study seeks to understand the requirements for designing an effective automatic posture feedback system. While previous studies focus on *what* feedback [31] and *where* [22] to present this motor feedback, our study focuses on *how* to present such

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AI-generated feedback to bridge the gap between human expert insights and AI measurements. Specifically, through our user-centered study, we aim to answer three research questions:

- *RQ1. "What are the key user needs and considerations for designing a fully automatic AI system that improves posture alignment between basketball coaches and beginner players during self-practice sessions?"*
- *RQ2. "How can we design an effective feedback system to support progressive learning and enhance self-awareness and confidence for basketball beginners during self-practice sessions?"*
- *RQ3. "How does the progressive learning system affect the basketball beginner's self-learning experience and the accuracy of their posture alignment with their coach?"*

Based on in-depth interviews with professional basketball coaches, we identified three design goals for an AI SOP posture feedback system: providing real-time comparisons of individual movement segments against coaching standards, enabling motion replays to observe incremental adjustments, and offering guidance on prioritizing posture modifications (RQ1). Our SOP framework derives each step of shooting motion mechanics based on coaches' insights. Each step includes a posture explanation and is accompanied by a detailed video comparison to deliver precise, real-time posture feedback. Our framework further breaks down AI feedback into steps and provide summaries across sessions to allow actionable insights for trainees to develop self-awareness during training (RQ2).

To evaluate whether a structured AI feedback system based on our SOP framework can truly help beginners enhance their self-awareness and training outcomes (RQ3), we developed a prototype to provide posture feedback using the Wizard of Oz method. We conducted a controlled user study with 28 basketball beginners, comparing the traditional video modeling approach with our knowledge-based SOP approach. Our results show that the knowledge-based SOP method can deliver precise posture feedback, significantly enhancing trainees' self-awareness and alignment with training goals. Participants using the SOP system demonstrated increased awareness of their posture performance, with higher scores and more accurate posture error recognition than the baseline group. The structured feedback based on the SOP framework further enabled an effective personalized goal-setting and error-correction loop, allowing participants to identify specific errors and make targeted adjustments. By providing structured, real-time feedback, the SOP method not only improved the accuracy of trainees' movements but also boosted their confidence by fostering a deeper understanding of their own posture performance. These results validate our system design's potential to support effective motor learning, leading to consistent progress and greater satisfaction among trainees.

In summary, our study explores a knowledge-based SOP method to bridge the gap between human knowledge and automatic feedback for enhancing motor learning in basketball shooting. Our contributions are fourfold: 1) a formative study that identifies the key challenges beginners face in aligning their basketball shooting form with coaching standards, 2) an SOP approach to designing a posture feedback system that incorporates coaching knowledge with real-time video and textual feedback, 3) a user study assessing the impact of our AI SOP Posture feedback system design on beginner players across key metrics in confidence, self-awareness, and effectiveness, and 4) insights for designing future AI-driven feedback systems targeting effective human-AI partnerships in sports motor training.

2 Related Work

2.1 Video Annotation Tools

Several existing market solutions, such as Kinovea [18], Dartfish [23], Coach's Eye [33], and Kaia Health [10], offer robust video annotation capabilities that provide detailed visual feedback through frame-by-frame deconstruction of movements. These tools partially address the challenge of capturing the 3D nature of movements by allowing users to analyze posture and technique in detail. However, their reliance on post-training analysis limits their ability to provide real-time adjustments, which are critical for immediate form correction during practice sessions. Additionally, these tools often require users to have a certain level of expertise and familiarity with the software, which can overwhelm less experienced athletes and coaches, impeding their ability to develop proprioception and interpret feedback that addresses individual variations in muscle movements and posture nuances. Our system addresses these gaps by delivering intuitive, actionable feedback in real-time, directly during training, enhancing the accessibility and effectiveness of posture correction.

2.2 Trajectory-Based Basketball Training Solutions

The Noah Shooting System [13] is a widely recognized trajectory-based solution endorsed by NBA professionals and implemented in various elite training facilities. It uses pre-installed cameras to track shot angles and trajectories, providing numerical data on the ball's path and offering real-time feedback on shot outcomes. However, Noah falls short in addressing the 3D complexity of body movements, fostering proprioceptive development, and providing personalized, detailed posture feedback. These limitations often leave players and coaches to infer the necessary adjustments from the arc data, which may lead to oversimplified and less effective training interventions.

In contrast, augmented reality (AR) systems, such as the one developed by Lin et al. [22], build upon prior work [16] by integrating 3D visualizations of ideal shot trajectories, aiming to improve real-time feedback and players' self-awareness of their performance. While these systems improve on trajectory visualization, they still lack comprehensive posture guidance and often depend on wearable devices that can cause discomfort and limit usability due to their weight and restricted field of view. Focusing solely on trajectory overlooks the critical need for posture alignment, which may inadvertently reinforce improper movements and result in inconsistent performance or even injury. Our system differentiates itself by integrating both posture and movement standards, providing comprehensive feedback that supports balanced skill development in posture alignment and shooting accuracy, all without requiring cumbersome wearables.

2.3 Posture-Based Suggestion Solutions

Recent advancements in posture-based feedback systems, such as those employing lightweight real-time models like MoveNet [1], provide 2D joint angle calculations and real-time rule-based audio feedback for activities like workouts and yoga [2]. However, these activities are typically governed by well-established SOP and do not involve the complex coordination and kinetic chains seen in sports like basketball shooting. Moreover, such systems often overlook individual biomechanical variations, which limits their efficacy in enhancing complex motor skills, such as a basketball set shot. In this work, we investigate how to decompose intricate motor skills like the basketball set shot and develop methods for presenting feedback that bridges the gap between human expert insights and AI measurements. Our approach aims to provide personalized, context-sensitive feedback that captures the intricate biomechanical nuances of shooting mechanics, addressing the limitations of current feedback systems by aligning feedback guidance more closely with expert coaching standards.

Existing basketball posture studies, such as those by Nakai et al. [27] and Chen et al. [4], have explored the relationship between posture and shooting success using 2D pose estimation algorithms like OpenPose [3]. While these works contribute valuable insights into how posture affects performance, they primarily rely on 2D data and do not provide comprehensive real-time feedback, thus failing to capture the 3D complexities of shooting movements and the necessity for immediate posture adjustments. Furthermore, although these systems highlight skill-level discrepancies, they often lack the personalized feedback needed to accommodate individual muscle movement variations, leaving players to interpret and adjust based only on 2D joint angle data.

In other sports, studies on 3D visualization tools, such as table tennis [20, 34] and badminton [21], demonstrating the potential of monocular 3D human pose estimation models in enhancing posture analysis. However, these approaches often provide visual tutorials of sports movement without offering clear, real-time feedback that users can immediately act upon, limiting their ability to effectively foster proprioception and guide personalized improvements. By contrast, our system adopts a human-AI interaction design that not only enhances self-awareness but also delivers specific, actionable insights aligned with expert coaching, ensuring that players receive feedback that builds confidence and supports consistent progress in their training.

3 Formative Study

To gain a comprehensive understanding of the challenges faced by novice basketball players during independent practice sessions, we conducted a formative study involving basketball beginners and experienced coaches. Based on interview results, we summarized three key challenges that need to be addressed in the system design in Section 4.

3.1 Study Setup

3.1.1 Participants.

We recruited five beginner basketball players (P1-P5; M=1, F=4; Age: 18-24), with less than two years of training experience and limited knowledge of the sport, and eight professional basketball coaches (C1-C8, M=5, F=3; Age: 30-55; Teaching experience: 8-20), with experience in mentoring students across various levels, from primary school to university. To gain realistic insights into basketball shot training, we paired each player with a coach. In total, we observed 5 training groups. Three more coaches (C6-C8) were interviewed separately. Table 1 shows how participants are divided in our formative study.

Group	ID	Role	Sex	Experience
1	C1	Coach	M	18 years of teaching
	P1	Player	F	<1 year in training
2	C2	Coach	F	5 years of teaching
	P2	Player	F	<1 year in training
3	C3	Coach	M	20 years of teaching
	P3	Player	F	1.5 years in training
4	C4	Coach	F	17 years of teaching
	P4	Player	F	<1 year in training
5	C5	Coach	M	9 years of teaching
	P5	Player	M	<1 year in training
N/A	C6	Coach	M	8 years of teaching
N/A	C7	Coach	M	20 years of teaching
N/A	C8	Coach	F	25 years of teaching

Table 1: Background of formative study participants.

3.1.2 Procedure.

To observe how beginners learn complex movements like shooting a basketball in their self-practice, we adopted the common practice of using video recordings as supplementary supports in our study. Each training group consisted of a coaching phase, a self-practice phase, and a post-training feedback phase, and concluded with a semi-structured interview with both the coach and player.

Coaching phase: The coach provided foundational teaching on executing a basketball set shot, 2.5m from the hoop. Both the coach's and player's postures were recorded from the side using a mobile phone positioned 3 meters away to capture full-body views.

Self-practice phase: The player began practice shooting without the coach's feedback. After each shot, they can review their posture videos and compare them with the coach's demonstration. This process was repeated ten times.

Post-training feedback phase: After observing the player training on their own, the coach offered targeted feedback through verbal explanations, physical demonstrations, and video replays to help improve the player's shooting techniques.

Post-study interview: At the end of the study, we interviewed the player on their challenges during self-practice and their needs for additional guidance. Players were also shown examples of 2D [18, 33] and 3D pose analysis tools [20], commonly used in sports training for movement evaluation. Later, we solicited the coach's feedback and ideas on mechanisms to improve their coaching procedures.

3.2 Identifying User Challenges in Self-Training

We identified three key challenges that beginners face in practicing shooting techniques independently, followed by our design goals for a basketball shot training AI SOP posture feedback system to address these issues.

Pain Points	Design Requirements
01: Uncertainty in meeting coaching standards	**01**: Providing real-time comparisons of individual movement segments against coaching standards
02: Unnoticed misalignment between perceived and actual posture	**02**: Enabling motion replays to observe incremental adjustments
03: Not confident in prioritizing posture adjustment	**03**: Offering guidance on prioritizing posture modifications

Table 2: Pain points and corresponding design requirements.

3.2.1 *Pain Point 01: Uncertainty in Meeting Coaching Standards*.

When a technique is broken down into multiple steps, trainees often miss key training points during self-practice, frequently expressing the need to see the posture video replay. Without the coach's video guidance, these omissions could significantly reduce the effectiveness of self-training. As Coach C4 noted, *"We emphasize five key points in the movement, but if a student only executes two, their posture won't receive the proper feedback, leading to frustration over time and eventually causing them to doubt their own learning ability."* Furthermore, through interviews with both coaches and players, we found that even when players replayed their own videos, they still overlooked critical aspects. This is largely due to the complexity of shooting techniques and the beginners' lack of a solid knowledge framework to identify errors. As C5 mentioned, *"During the coaching phase, the students may only partially understand the movements but hesitate to seek clarification. As coaches, we often assume they've grasped the concept, but when they struggle to perform the actions correctly, we realize they've missed important details in the video."*

3.2.2 *Pain Point 02: Unnoticed Misalignment Between Perceived and Actual Posture*.

All participants realized during practice that the movements they thought they were performing were different from what they saw in their recorded videos. For example, as P1 remarked, *"I thought I played like a professional athlete, but the video showed something different."* This discrepancy may be attributed to beginners' limited experience and understanding of basketball techniques. Additionally, as Coach C6 pointed out, it could also be due to beginners' muscles and fascia still adapting to the new physical demands, making immediate adjustment difficult. Learner P3, after reviewing videos of both themselves and the coach, realized that the body might need some time to catch up with the mind: *"When I played the coach's video in slow motion, I noticed there should have been a slight pause here. The flow of the movement was different from what I did. I might not be able to replicate it right away, but now I understand how to correct it."*

3.2.3 *Pain Point 03: Not Confident in Prioritizing Posture Adjustment*.

We found that beginners, after reviewing their shooting practice videos, often notice discrepancies in their movements but struggle to make all the necessary adjustments at once due to the high cognitive load. They tend to rely on the coach's guidance to prioritize which corrections to focus on. P1 illustrated this by comparing their uncertainty in adjusting basketball techniques to their confidence in other sports: *"In basketball, I don't have enough knowledge, so I want the coach to review my performance and prioritize the corrections for me. With weight training, I have enough experience to know what adjustments to make, so I don't need someone to sort it out for me."*

3.3 Design Requirements

During post-study interviews, we discovered that novice players encountered significant challenges with existing 2D and 3D training tools. The primary obstacles stemmed from the players' limited understanding of basketball techniques and their inability to effectively interpret the visual data presented by these advanced systems, leaving them uncertain about their next steps. In response to these identified pain points and the shortcomings of current solutions, we proposed three key design requirements for designing an effective posture training system to address the primary challenges beginners face during independent practice.

3.3.1 *Design Requirement 01: Evaluate Real-Time Compliance with Step-by-Step Coaching Standards*.

All interviewed coaches agreed that while there is no absolute standard for every breakdown of the shooting motion, general principles apply. Coaches adapt these principles based on their teaching style and areas of focus. As coaches C3, C6, C7, and C8 mentioned, many key aspects of shooting technique can be visually assessed during instruction to identify students' posture errors. They also expressed a desire for a system that allows coaches to input personalized teaching points, enabling the system to quickly determine whether students' movements align with these points. As C7 explained, *"Beginners often don't know what the ideal shooting posture looks like. This scoring mechanism could provide them with immediate feedback. It can provide benefits to both parties: students can identify areas for improvement during self-practice, and coaches can use the system to highlight key posture requirements."* Additionally, coaches suggest that instructional steps should be sequenced according to the movement chain, with clear and simple explanations to aid memory. Several coaches recommend incorporating percentage and trend changes for each breakdown of the movements. This approach not only helps students track their progress but also fosters trust between the student and the coach. As C6 emphasized, *"Students can see their own improvement and trust the validation of the coach's expertise."*

3.3.2 *Design Requirement 02: Clearly Replay and Compare Correct and Incorrect Movements*.

To enhance beginners' awareness of their postures, we recommend, based on interview findings, that player postures be replayed in alignment with each step of the process. Coaches noted that beginners often struggle to identify movement issues from videos due to their unfamiliarity with proper form. Coaches C4, C6, and C7 have recorded videos of their own shooting motions and shared them online with trainees to demonstrate necessary adjustments during routine training. As C8 mentioned, *"I previously recorded my students' video clips and directly pointed out the lack of muscle extension in their movements."* The system should also emphasize both correct and incorrect movements, along with the coach's instructional videos at each step, to allow students to quickly compare their actions for fine-tuning. As C4 stated, *"You need to show students which movement details to maintain, which areas are weak and need improvement... or use video comparisons between the instructional video and the student's performance."*

3.3.3 *Design Requirement 03: Provide Clear Guidance on Prioritizing Posture Modifications.*

After students complete their shooting practice, the system should clearly indicate which specific movement breakdown should be prioritized for correction. Our observations of coach-student interactions during teaching and correction revealed that all coaches recommend focusing first on hand movements, as their accuracy has a direct impact on shooting performance. As Coach C7 explained, *"When practicing hand movements, don't worry about the feet. Once the hand movements are correct, we can then address the feet. Later, it's crucial to ensure stability in feet, and then focus on generating power from the heels and hips."* From a beginner's perspective, knowing the order of corrections is equally important. Ideally, the system should provide a mechanism that allows coaches to rank corrections, helping students focus on key areas for improvement. As P1 mentioned, *"I'm not sure if the coach can see the system's recommendations, but ultimately, the coach needs to evaluate and tell me what to fix first since they are familiar with my performance."*

3.4 Summary

In summary, beginners often face challenges maintaining training quality without a coach, and existing methods, like side-view recording, fail to fully capture movement issues. We identified three design requirements that address critical challenges as a basis for feature development in the next section.

4 System Design

To address the challenges identified in the formative study, we designed and built a prototype of AI SOP posture feedback system to test its effectiveness for beginners. The prototype was refined through a pilot study, incorporating feedback from four professional coaches (C4, C6, C7, C8) and iterative brainstorming among our research team.

4.1 Breakdown of the SOP for Basketball Set Shot and SOP Tutorial Video

To address Design Requirement 01, we collaborated with coach C4 to design an SOP for basketball set shot summarized in Table 3 based on her domain knowledge backed up by relevant shooting biomechanics literature. Key steps are marked by the ⋆ symbol. Checkmarks (✓) indicate verification points, enabling both trainees and coaches to assess whether each step has been correctly executed. This ensures that trainees receive continuous feedback and maintain alignment with coaching standards.

Based on this SOP, we recorded videos of the coach demonstrating each step, along with an additional clip that combines all the steps into a complete sequence. These videos feature the coach's explanations, enhanced with subtitles and visual aids such as arrows to highlight key movements and instructions. This tutorial aims to provide clear, step-by-step guidance, making it easier for trainees to understand and replicate the shooting technique.

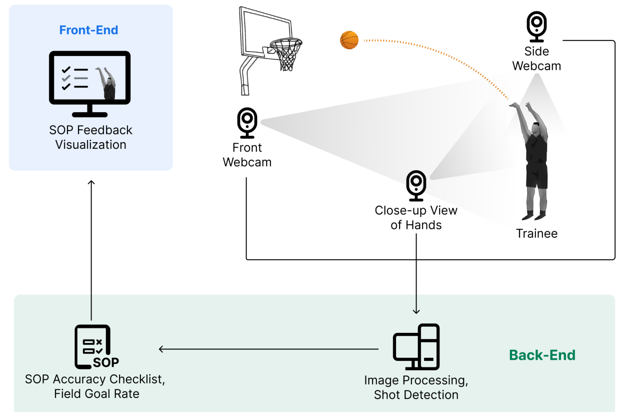

Figure 2: AI posture SOP feedback system design framework.

4.2 System Design Framework and Prototype

The framework of our proposed prototype for the AI SOP posture feedback system is illustrated in Figure 2. We implemented a front-end interface using ReactJS and a back-end server with NodeJS to manage video streaming, storage, AI processing, and feedback visualization. The system processes video streams from cameras using the AI-based method developed by Kao et al. [17] to automatically detect basketball shots and segment continuous footage into concise clips capturing each shot from start to finish. These clips were stored in the server's database and accessed by a remote coach, who evaluated the shot performance using an SOP checklist on Google Sheets, employing a Wizard of Oz approach to simulate AI-generated feedback. The completed evaluations were then downloaded and integrated with the videos, enabling the system to present participants with specific, actionable feedback on their shooting performance. Each set of annotated shot videos, paired with the SOP results, was accessible via unique URLs, providing trainees with a structured and user-friendly interface to review their feedback.

4.3 SOP Posture Performance Data Visualization

To help beginners effectively evaluate their practice alignment with coaching standards (Design Requirement 01), enhance their self-awareness (Design Requirement 02), and boost their confidence in setting training goals (Design Requirement 03), we developed a system with User Interface (UI) illustrated in Figure 3, which includes key features such as Session SOP Performance (F1), Shot List (F2), SOP Posture Video Clip Comparison (F3), Shot Replay (F4), Coach SOP Posture Tutorial (F5), and SOP Posture Session Overview Trend (F6).

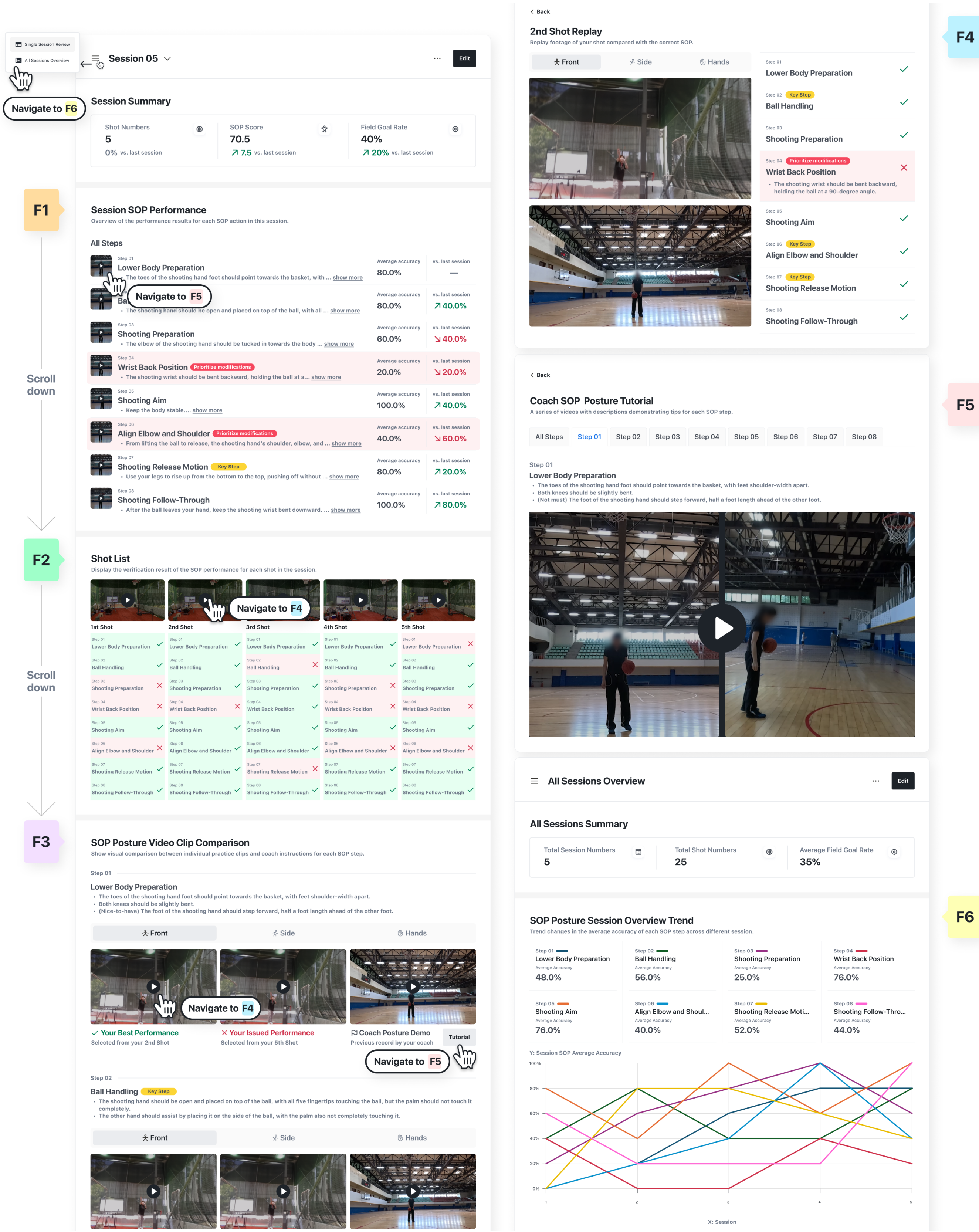

Figure 3: The AI feedback SOP system. Key features include Session SOP Performance (F1), Shot List (F2), SOP Posture Video Clip Comparison (F3), Shot Replay (F4), Coach SOP Posture Tutorial (F5), and SOP Posture Session Overview Trend (F6).

Step	Description
1. Lower Body Preparation	✓ The toes of the shooting hand foot should point towards the basket, with feet shoulder-width apart. [8, 19, 25, 29, 30] ✓ Both knees should be slightly bent. [14, 19, 30] ⋆ The foot of the shooting hand should step forward, half a foot length ahead of the other foot. [8, 11, 19]
⋆2. Ball Handling	✓ The shooting hand should be open and placed on top of the ball, with all five fingertips touching the ball, but the palm should not be completely touching it. [29] ✓ The other hand should assist by placing it on the side of the ball without contacting it with your palm. [14, 28, 32]
3. Shooting Preparation	✓ The elbow of the shooting hand should be tucked in towards the body. [19, 25] ✓ As the ball is brought back, the hips should slightly squat backward. [30]
⋆4. Wrist Back Position	✓ The shooting wrist should be bent backward, holding the ball at a 90-degree angle. [19, 28]
5. Shooting Aim	✓ Keep the body stable. ✓ Raise the ball to the front of the shooting hand's forehead. [28, 30] ✓ Lean slightly forward, eyes focused on the front edge of the rim. [25, 28, 30, 32]
⋆6. Align Elbow and Shoulder	✓ From lifting the ball to release, the shooting hand's shoulder, elbow, and wrist should extend forward in a straight line, aligned with the basket. [11, 28]
⋆7. Shooting Release Motion	✓ Use your legs to rise up from the bottom to the top, pushing off without jumping. [28–30] ✓ Extend the shooting hand, snap the wrist downward, and follow through with the fingers in a straight line toward the basket. [9, 14, 19, 25, 28, 29] ⋆ The left hand should not apply force. [9, 14, 19, 25, 28, 29]
8. Shooting Follow-Through	✓ After the ball leaves your hand, keep the shooting wrist bent downward. [25, 28–30] ⋆ Ensure the elbow remains above eyebrow level until the ball touches the rim. [25, 28–30]

Table 3: Standard Operating Procedure (SOP) Steps for Basketball Shooting: This table outlines the SOP steps derived from interviews with professional basketball coaches, supplemented by findings from shooting-related research papers. The steps are organized to guide beginners through the shooting process, emphasizing key techniques and best practices. The symbol ⋆ denotes particularly important steps, while the checkmark (✓) shows instructions to be verified for each action.

4.3.1 ***Session SOP Performance***. Based on Design Requirement 01, Session SOP Performance (F1) in the Figure 4 was crafted to provide trainees with a clear view of performance metrics for each SOP step during a session. Steps are listed sequentially according to the coach's SOP, displaying current session accuracy and changes from the previous session, allowing trainees to track their performance in a structured and intuitive manner.

Each SOP step is paired with a tutorial video to enhance trainees' understanding through visual guidance. A visualization of 'Average Accuracy' and percentage changes from the previous session are provided to enable trainees to monitor their progress at a glance. To prevent cognitive overload for beginners, critical steps are marked as 'Key Step,' emphasizing essential actions to support a smoother learning process, as recommended by coaches. If performance on these key steps falls below a pre-defined threshold (e.g., 50% as determined by coaches), the system dynamically updates the label to 'Prioritize Modifications,' highlighted with a red block to draw attention. This adaptive feedback mechanism helps trainees focus on areas for improvement and guides their priorities for future sessions, fulfilling Design Requirement 03.

Insights from the pilot study suggested that reducing the emphasis on field goal rate would help trainees concentrate on posture. As a result, following discussions with coaches, the field goal rate was discreetly positioned in a less prominent area of the interface. This subtle adjustment directs trainees' attention towards posture practice, minimizing distractions from less critical metrics and enhancing training effectiveness.

4.3.2 ***Shot List and Shot Replay***. Shot List (F2) and SOP Replay (F4) in the in the Figure 5 provide shot performance and video views aiming at enhancing beginners' ability to assess their adherence to coaching standards and improve posture awareness. Each shot

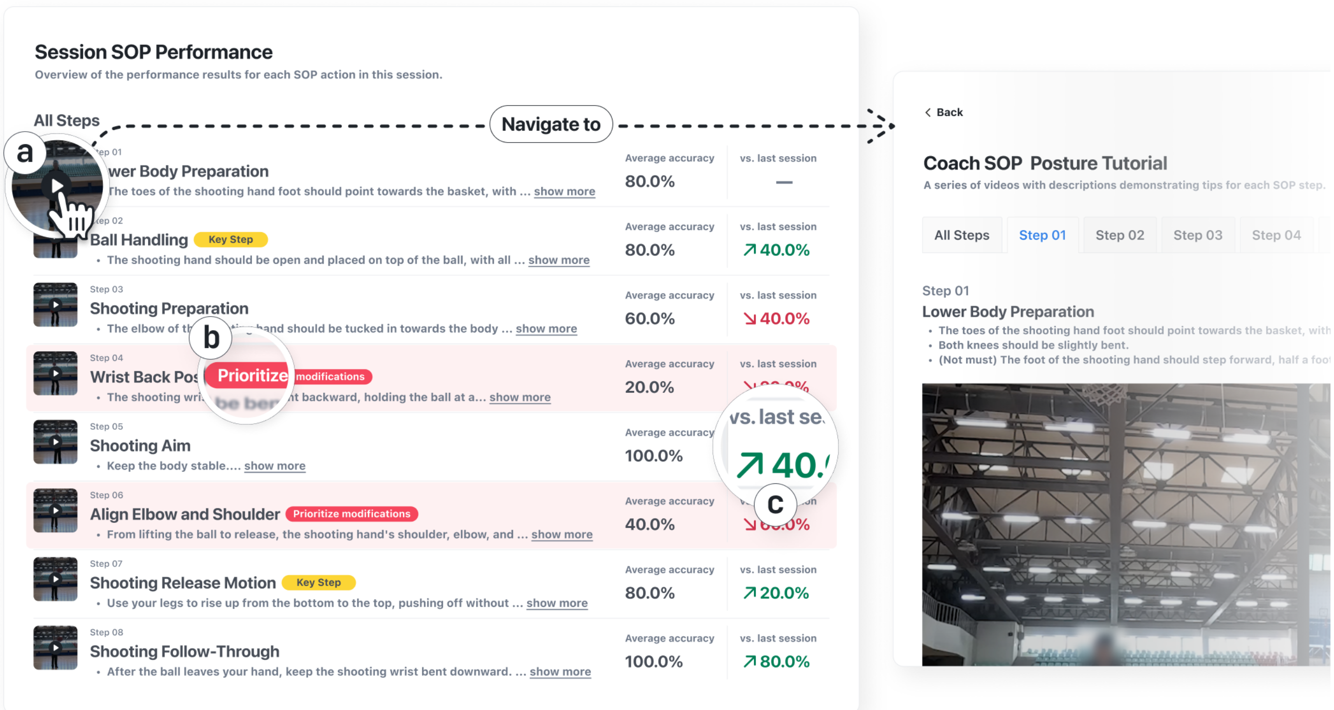

Figure 4: SOP Session Performance (F1) allows users to overview the performance results for each SOP steps in the current session. Users can click the video thumbnail (a) to review a specific SOP step tutorial in Coach SOP Posture Tutorial (F5). The "Prioritize Modifications" label (b) helps users gain clarity on which SOP step to prioritize next. Users can track their progress for all steps compared to the last session (c).

taken during a session is documented with a snapshot and replay option, along with a detailed performance breakdown against predefined SOP steps. To highlight areas for improvement, steps are visually marked: "✔" (correct) with a light green background color denotes compliance, and "✘" (incorrect) with a light red background color signals deviations. This intuitive use of color coding, paired with bold fonts, allows users to swiftly pinpoint errors and make targeted adjustments (Design Requirement 01).

4.3.3 *SOP Posture Session Overview Trend*.

The SOP Posture Session Overview Trend (F6) in the in the Figure 6 visually tracks changes in average accuracy for each SOP step across multiple sessions, providing trainees with a clear view of their performance trends. By plotting performance trajectories for each predefined step, the graph highlights patterns of improvement and SOP steps needing further attention, guiding beginners to focus on specific techniques that require additional practice (Design Requirement 03). This intuitive design, shaped by coach feedback, emphasizes the use of clear visual indicators such as line charts to simplify the understanding of performance trends, making it easier for beginners to quickly grasp their progress and adjust their training priorities accordingly. Additionally, the "All Session Summary" in F6 offers a comprehensive overview of key metrics, including the total number of sessions, shots, and the average field goal rate, providing users with a holistic view of their overall progress (Design Requirement 01). This combination of detailed trend analysis and summary metrics ensures that trainees have a complete understanding of their development throughout their training journey.

4.3.4 *SOP Posture Video Clip Comparison*.

SOP Posture Video Clip Comparison (F3) in the Figure 7 interfaces are designed to boost players' self-awareness by encouraging a focus on the finer details of their performance. To fulfill Design Requirement 02, it highlights the player's best execution of each SOP step among a session in the "Your Best Performance" panel, helping them identify and replicate correct postures. Trainees can select different camera viewing angles (including front, side, and close-up view of hands) to make more comprehensive observations for analyzing their postures. If players are uncertain about a specific step or do not have a correct execution recorded in the "Your Best Performance" panel, they can click the "tutorial" button to review the Coach SOP Posture Tutorial (F5), which presents a coach-led video demonstration of the step. This video-based feedback approach, combined with SOP-based comparison, helps players observe and accurately mimic movements, reinforcing proper techniques through clear visual guidance.

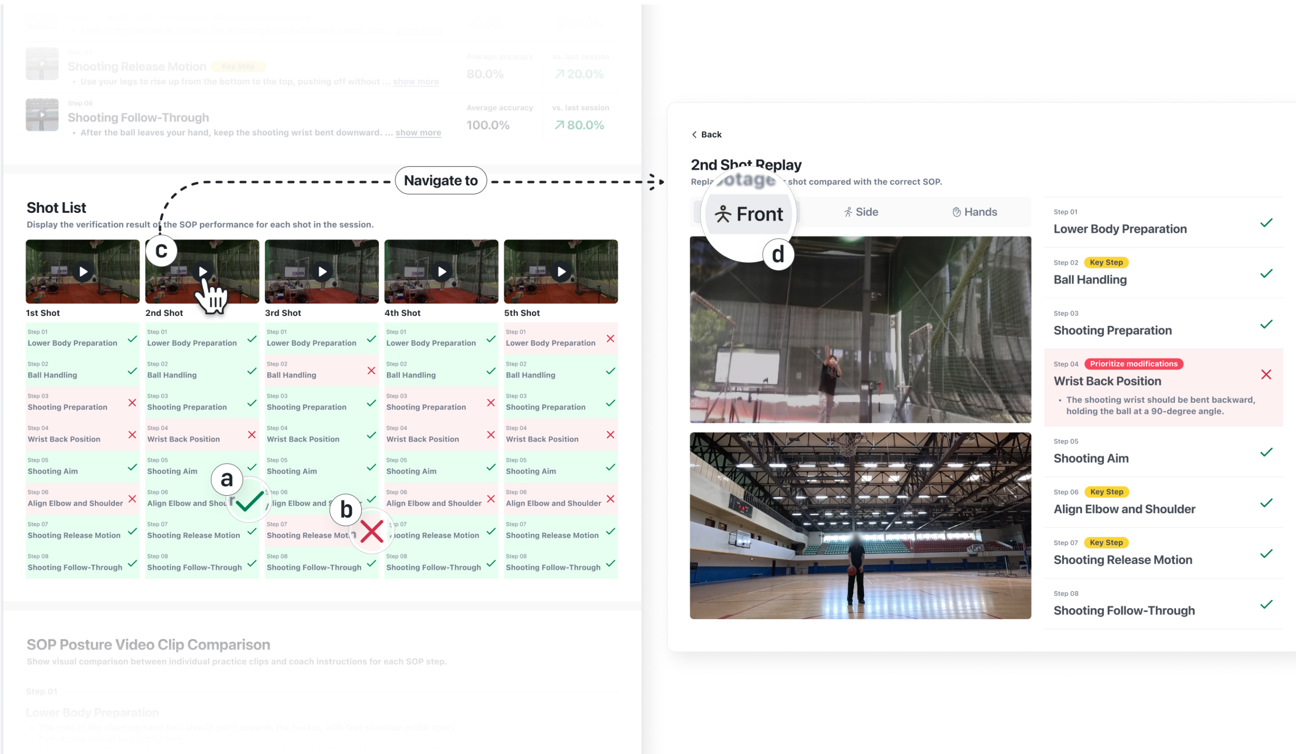

Figure 5: Shot List (F2) displays the verification result of the SOP performance for each shot in the session. The automatically generated signals (ab) indicate whether the trainees' posture aligns with the SOP requirement. To review footage of specific shots side-by-side with the correct SOP video, the trainees can click the video thumbnail (c) to access Shot Replay (F4) and switch between different camera angles using the toggle (d).

5 Experiment

Our study aims to verify whether SOP-based feedback can achieve better outcomes in shooting posture training compared to traditional video feedback methods. We conducted a controlled user study, collecting both qualitative user feedback and quantitative data on SOP posture correctness. We compare participant's performance and feedback with and without the use of our designed system prototype, assessing its impact on improving shooting form.

5.1 Participants and Setup

We targeted individuals with limited basketball experience who are eager to improve their shooting form. A total of 28 participants (A1-A14 & B1-B14; M = 15, F = 13; Age: 18-44) were recruited. To achieve a more gender-balanced and diverse age range among beginners, we utilized online forums to find qualified participants from the Hsinchu city area. All participants reported having *"no prior professional shooting learning"* with *"low shooting accuracy and poor shooting mechanics"*. Participants were evenly distributed into two groups based on the conditions mentioned in Section 5.2: Group A (Video Feedback / without SOP feedback) and Group B (SOP Feedback). Each participant received a compensation of 10 USD for taking part in the study. Additional details about each participant information can be found in the supplementary material.

To simulate AI feedback, we employed the Wizard of Oz method, where a coach (an experienced former national basketball player and current university team coach), was positioned in a separate room to assess the participants' shooting posture correctness using a predefined SOP checklist. This approach allowed the coach to provide real-time evaluations that mimicked the functionality of an AI-driven SOP feedback system.

The study took place in an indoor laboratory, with a designated shooting area separated from the working and resting areas by safety nets. The basketball hoop was installed at the regulation height of 3.05 meters. Participants were instructed to shoot the ball from a marked spot 2.5 meters away from the hoop. Cameras were mounted at three angles: one in front of the participant, capturing the entire body, and two at the sides (one providing a full-body view and the other offering a close-up view of the player's hands) to capture comprehensive footage from different perspectives. The coach then used the recorded videos to evaluate shooting correctness based on the SOP checklist. A 65-inch LG Touch Screen Monitor was placed next to the shooting area to display the SOP feedback system. Participants were asked to review the system feedback via the touchscreen monitor after completing each shooting session .

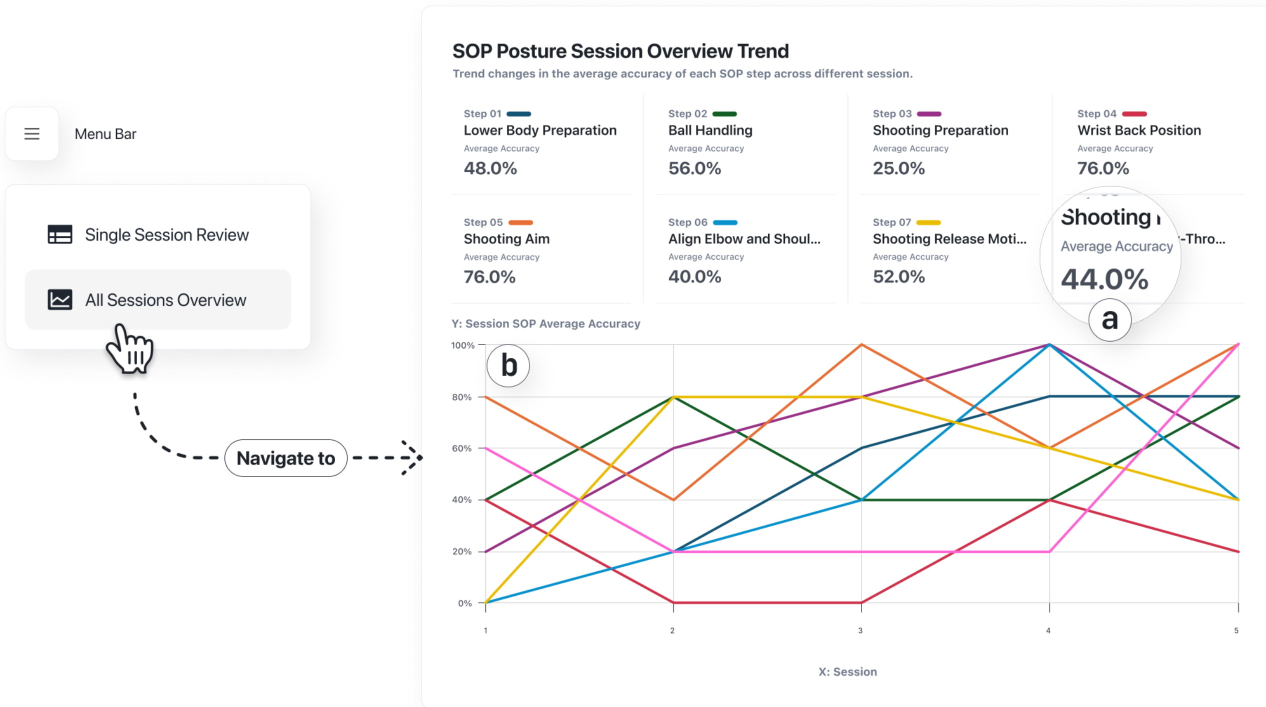

Figure 6: SOP Posture Session Overview Trend (F6). Users can monitor each step's SOP average accuracy rate over practice sessions (a) and track changes in the average scores of different SOP steps (b) over practice sessions.

5.2 Experimental Conditions

Video Feedback: Participants were provided with a webpage that first displayed the coach's step-by-step SOP tutorial video clips, followed by their own session recordings for comparison and review. The system did not offer any analysis of the participants' step-by-step posture performance.
SOP Feedback: Participants accessed our designed feedback system through a touchscreen monitor, allowing them to navigate the provided features (from F1 to F6) and identify which steps to focus on for improvement.

5.3 Design and Procedures

Figure 8 illustrates our experimental procedure, which consisted of the following phases for each group.
Introduction (5 minutes): The study began with an overview of experiment motivation, objectives, and protocol of the research. Then, all participants were required to review and sign a formal consent document before advancing to the subsequent stages.
Pretest & Learning (10 minutes): All participants were asked to take five shots to establish a baseline for measuring performance improvements. They then watched an Coach SOP Posture Tutorial (F5) based on Table 3, which demonstrated proper shooting mechanics.
Training Session (40 minutes): At each training session, participants completed a standardized assessment by retaking 5 shots to evaluate skill progression. Group A engaged with raw video replays and the Coach SOP Posture Tutorial (F5) without additional annotations, while Group B utilized our SOP feedback system, receiving simulated AI coaching guidance. Post-session interviews systematically assessed participants' movement performance self-awareness and their confidence in establishing subsequent practice objectives.
Final Survey (5 minutes): All participants completed a post-study questionnaire to provide subjective feedback on the overall system. Group B, which received SOP feedback, conducted additional targeted feature rankings of the AI feedback posture SOP system.

5.4 Objective Evaluation

We collected video data and user inputs from our system. As introduced in Section 3.2, key objectives for enhancing training effectiveness include clear comparisons of correct and incorrect movements, prioritization of posture modifications, and real-time evaluation of compliance with coaching standards. To assess participants' performance, we measured movement accuracy, posture adjustment consistency, adherence to coaching guidelines, and shot percentage. Below, we define the performance metrics used in the quantitative analysis.
Initial Baseline: To evaluate how user performance is impacted by the given system, we established a baseline by measuring posture correctness as their shot accuracy during the pretest.

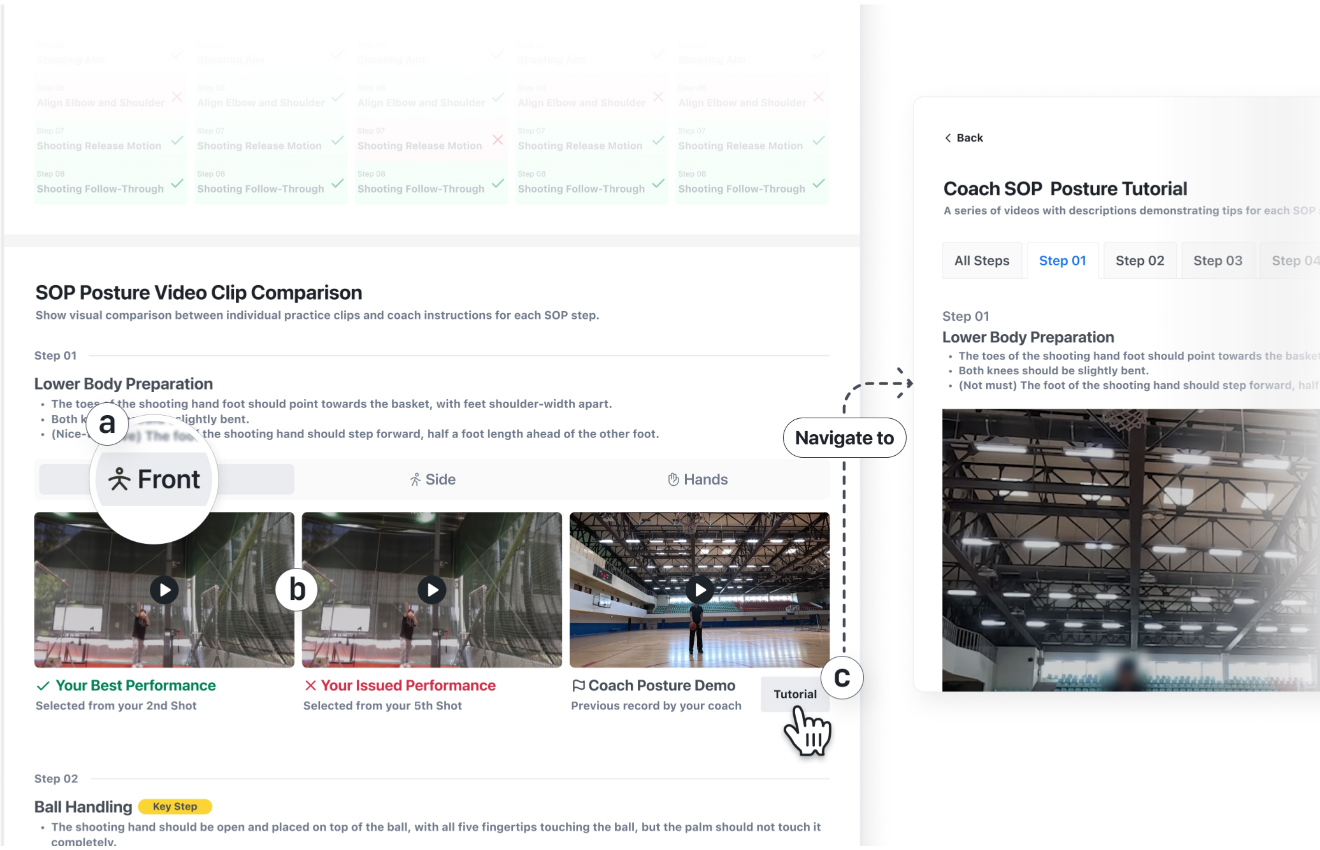

Figure 7: SOP Posture Video Clip Comparison (F3) enables beginners to (a) switch camera angles of videos (b) for a specific SOP step to identify posture issues or replicate their previously correct posture. If they need to revisit the SOP requirement details, they can click (c) to navigate to Coach SOP Posture Tutorial (F5).

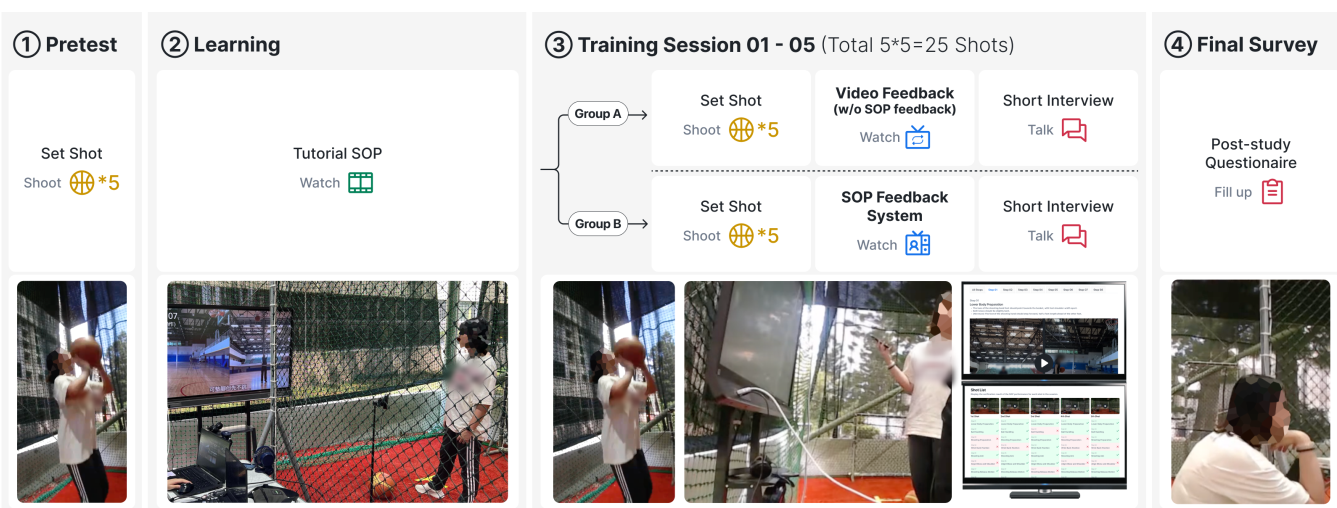

Figure 8: Experimental procedure. Participants were split into two groups: Group A and Group B.

Posture Correctness: To measure improvements in shooting posture throughout a training session, the coach marked if each SOP step is correct or not for each shot in the session.
Field Goal Performance: To provide an objective assessment of shooting performance, we compared the field goal percentage after each session for both experiment groups.

5.5 Subjective Evaluation

To assess user experience and system effectiveness, we gathered subjective feedback through post-study surveys and semi-structured interviews. For the interviewed response, three independent coders analyzed the data using qualitative coding, focusing on confidence, self-awareness, and system usability. In the post-study surveys, each aspect was rated by participants based on a 7-point Likert scale.
Confidence: This metric aimed to evaluate the extent to which the system boosted participants' confidence by offering detailed, actionable feedback that guided their performance improvements during training.
Self-awareness: The system's ability to enhance participants' self-reflection was measured by examining how effectively it helped them recognize their own errors, make informed adjustments, and gain a deeper understanding of their training process. Self-evaluations were validated through a post-study survey and by comparing interview responses with a professional coach's feedback on posture performance.
System Usability: Usability was assessed based on indicators such as usefulness, ease of use, intention to use, and overall satisfaction. These metrics offered a comprehensive evaluation of how well the system supported participants in achieving their training goals and their overall satisfaction with the its features and functionality.

6 Results and Discussion

In this section, we present the study results based on quantitative shot measurements and subjective performance evaluations. Key insights are outlined in each subsection, along with detailed supporting evidence and corresponding discussions.

6.1 The AI Feedback SOP System Improves Trainees' Posture Awareness, Ensuring Better Alignment with Training Goals

6.1.1 *Participants Demonstrated Greater Self-awareness of Their Posture Performance When Using AI Posture SOP Feedback System.*

In the middle of the Figure 9 illustrates the subjective ratings in awareness. Group B participants (with SOP feedback) reported significantly higher ratings than Group A (without SOP feedback), as indicated by ANOVA analysis (α = 0.05, where α refers to the significance level).

Based on qualitative user feedback, the structured SOP feedback allowed participants in Group B to precisely identify specific errors. The Figure 10 also indicates the Session SOP Performance (F1) and Shot List (F2), participants were able to pinpoint specific parts of incorrect body movements and explain personal observations. For example, B03 in his session 03 described: *"Aftering reading the score, this time I remembered to maintain wrist extension while holding the ball. Previously, in Step 06, my elbow and shoulder weren't aligned, but this time I improved by 60%. I didn't do this instinctively before, but I made a conscious effort to adjust during the first two rounds. However, my elbow still wasn't above my eyebrows during the follow-through (pointing to Step 08) [...] Also, in the preparation phase, my elbow didn't tuck in toward my body, and I didn't bend my knees before shooting."* This clarity led several participants to uncover previously unnoticed mistakes in their practice. Shot Replay (F4) further improved trainees' understanding of their posture misalignment. Participants were able to make direct comparisons between their actions and SOP closely, and identify discrepancies in incorrect postures. For instance, participant B5 recognized that their foot placement was off, deriving deeper insights beyond the provided guidance. In total, 10 out of 14 participants using both SOP Posture Video Clip Comparison (F3) and Coach SOP Posture Tutorial (F5) were able to accurately identify and infer the reasons behind their errors. The bar chart in Figure 10 illustrates that participants heavily relied on these two features (F3 and F5) to learn new posture movements during their training sessions.

Conversely, Group A (without SOP feedback) participants, who trained only with video feedback, displayed tendencies toward overconfidence in their posture performance, leading to misjudging their posture alignment and making counterproductive adjustments. 7 out of 14 participants wrongly believed they had fully corrected their movements to align with the coach's form, despite their scores indicating otherwise. For example, participant A11 assumed their SOP posture accuracy was between 80-90% after reviewing their video, while the actual accuracy was below 40%. Another type of misjudgment was observed when participants mistakenly modified correct movements into incorrect ones, demonstrated by four participants in Group A. This pattern of misjudgment observed in Group A underscores the challenges faced by trainees when structured, targeted feedback was not provided.

Taken together, Group B demonstrated higher self-awareness and greater clarity in describing their posture errors while Group A participants could only describe general problems in body posture or overall fluidity with difficulties discerning specific problems.

6.1.2 *Using AI Posture SOP Feedback System Enables Participants to Better Align Postures with the Coach's Training Requirements.*

Figure 11 shows the participants' posture SOP accuracy compared to the coach's training requirements throughout the user study. Group A (without SOP feedback) showed a modest average improvement of 29% with higher variability in performance (σ=22%), while Group B (with SOP feedback) demonstrated a more substantial average improvement of 48% with a lower variability (σ= 18%), reflecting more consistent and substantial progress. This comparison demonstrates that incorporating SOP feedback into training accelerates improvement and enhances the consistency of performance outcomes, emphasizing the value of SOP-driven feedback in refining posture accuracy and stability among trainees.

Despite the SOP feedback's positive impact on self-awareness and posture alignments, it is worth noting that **focusing on posture performance may not lead to immediate field goal improvement.** As shown in Figure 12, neither Group A (without SOP feedback) nor Group B (with SOP feedback) showed notable

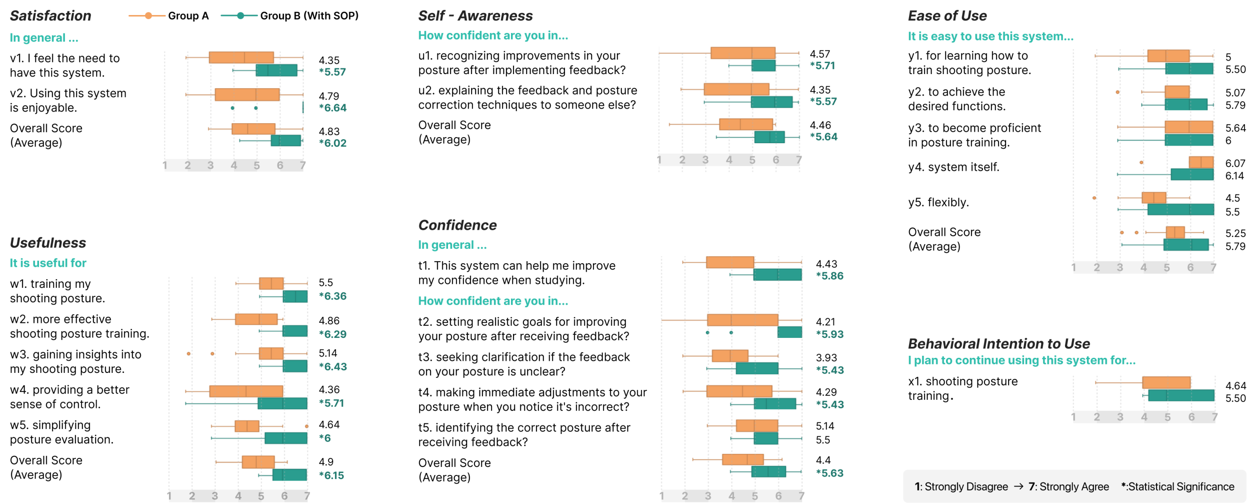

Figure 9: Comparison of confidence and awareness levels between Group A (without SOP feedback) and Group B (with SOP feedback), alongside user scores for Satisfaction, Usefulness, Behavioral Intention to Use, and Ease of Use.

Figure 10: The charts illustrate Group B participants' rankings of the various SOP features displayed in Figure 3. These features were evaluated based on their perceived usefulness in understanding movement, setting goals, and learning correct posture. The Y-axis represents the cumulative percentage of rankings provided by the 14 participants. Each bar is segmented by color, corresponding to rankings from 1st to 6th place, providing a clear visual representation of participants' prioritization of these features.

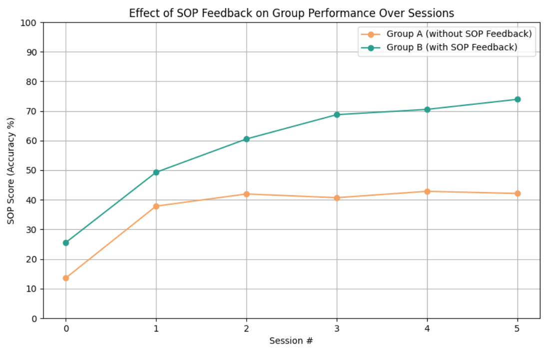

Figure 11: Session-wise SOP average scores (%) between Group A (without SOP feedback) with Group B (with SOP feedback) across sessions. Group B shows significant improvement in SOP accuracy across sessions, demonstrating the benefit of SOP feedback.

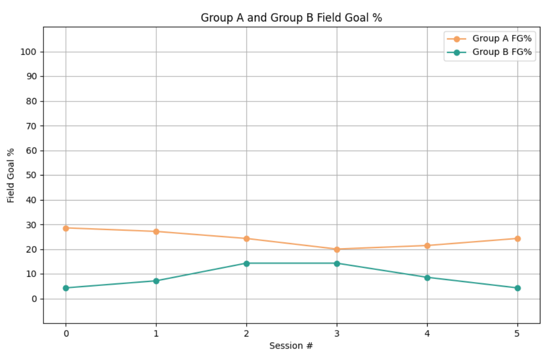

Figure 12: Field goal percentage for Group A (without SOP feedback) and Group B (with SOP feedback) across sessions. Neither group significantly improved field goal percentages, which was expected given the short training period.

improvement in field goal percentages over the short-term training period of the user study. As motor skills like basketball shooting require a longer training period with more repetitions [5, 35, 36] to achieve substantial improvements, ensuring athletes obtain timely feedback and make necessary adjustments to posture movements are essential to enhance performance over time. In fact, during our formative study, coaches actually recommended that beginners prioritize movement correctness over shooting accuracy and that accuracy information should be de-emphasized to prevent distractions. By improving posture awareness and ensuring consistent, precise repetition, SOP feedback could offer a solid basis for long-term performance gains, helping bridge the gap between novice execution and professional standards.

6.2 The AI Posture SOP Feedback System Enables Precise Goal-Setting and Enhances Error Correction for More Effective Training

6.2.1 ***AI Posture SOP Feedback System Boosts Trainees' Confidence in Setting and Executing Their Training Goals.*** Figure 9 revealed that Group B (with SOP feedback) consistently reported higher ratings than Group A (without video feedback) on questions regarding confidence levels in goal setting, seeking clarity, making adjustments, and identifying correct posture, with statistically significant differences for t1 through t4 (ANOVA, α = 0.05). The "Overall Confidence Rate" across all questions confirmed that Group B had a higher confidence distribution compared to Group A, suggesting a positive impact of the SOP system despite the smaller margin in question a5.

In the training sessions, we discovered that nearly all participants in Group B could clearly articulate which step they needed to improve in the next session. They demonstrated solid understanding of their goals and the rationale behind their choices, often using Session SOP Performance (F1) to review their performance on previously set goals. Two strategies were applied by Group B to make adjustment plans. 7 participants in Group B **followed the system's recommendations**, prioritizing modifications suggested by the SOP. Another 4 participants focused on **correcting the lower-scoring steps sequentially** as they memorized the sequence. For example, B10 concentrated on key steps marked by the SOP feedback, prioritizing critical steps for making adjustments, such as Step 04 and 06, while ignoring less relevant steps. On the other hand, B5 focused on Step 02 and 03 from Session 02, increasing both scores from 0 to 100 by the last session 05. The strategic goal-setting by Group B led to all 14 participants showing improvements in their SOP scores over 32 sessions after setting specific goals. In addition, we observed that when Group B faced uncertainty about certain SOP steps, 6 participants adjusted their movements between shots to compare with the SOP Checklist provided by Shot List (F2), showing the AI posture SOP feedback system's ability to guide effective self-correction.

In contrast, Group A participants (without SOP feedback) often set vague or irrelevant goals and exhibited a lack of direction in their training. For instance, A10, in Session 03, set an overly broad goal, *"I think I just need to be more fluid and coordinated,"* Some Group A members even ceased to set goals after a few shots, as seen with A7, *"I actually don't know what I'm doing. I am aimlessly shooting the ball."*, and A11 by Session 04, felt there were no goals left to pursue. Despite clear experimental instructions to focus on learning and adjusting movements in the beginning, 5 of 14 participants from Group A shifted their goals to aspects unrelated to shooting form in later sessions. For example, A4 in Session 05 redirected focus to whether the ball was spinning, and A5, distracted from movement adjustments, began concentrating on shooting accuracy after noticing an increase in made shots. Similar patterns were observed with A6, A8, and A7, who discussed the muscle force of their shooting rather than focusing on form corrections.

Taken together, Group B (with SOP feedback) participants were able to monitor their SOP performance effectively and strategically set their training goals based on SOP feedback, allowing more effective training compared to Group A.

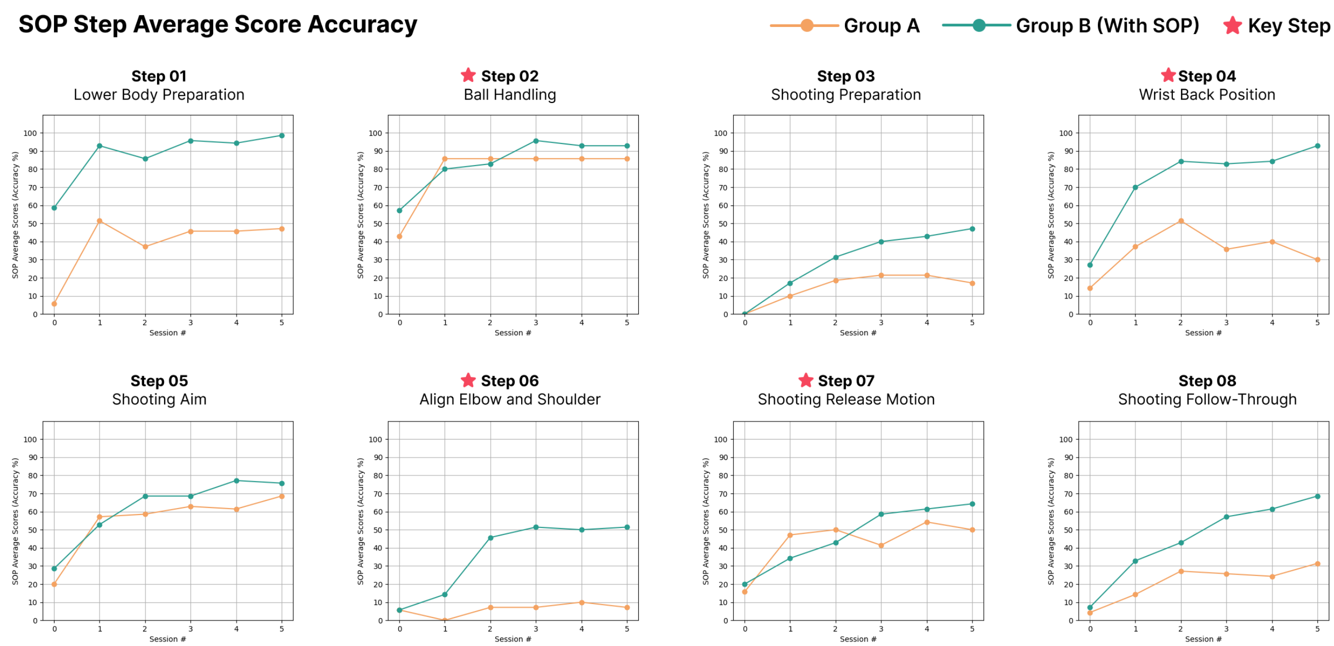

Figure 13: Average SOP Step Accuracy Scores for Group A (without SOP feedback) and Group B (with SOP feedback) across sessions. Group B consistently outperforms Group A, especially in key steps (⋆), showing the effectiveness of SOP feedback in improving shooting accuracy and posture alignment.

6.2.2 *Trainees Using the AI Posture SOP Feedback Found it Easier to Maintain Proper Posture Alignment and Correct Their Posture Errors.*

Figure 13 presents individual SOP step scores for participants in Group A (without SOP feedback) and Group B (with SOP feedback) across sessions. Group B shows a consistent upward trend in SOP scores, while Group A's performance has a higher variable and lacks a consistent improvement, particularly in Steps 03, 04, 05, and 08. These results suggest that SOP feedback facilitates continuous improvement and self-correction of posture errors in sessions, allowing trainees to align their posture more effectively with the coach's SOP requirements. Conversely, relying solely on training tutorials and replay videos may partially improve posture alignment, but trainees are likely to demonstrate inconsistent improvement and reach a plateau more quickly compared to those using the AI posture SOP feedback system.

Despite these benefits, **trainees using AI posture SOP feedback system may occasionally overlook some corrections after setting new goals; however, these oversights can be addressed easily once identified**. Seven participants in Group B experienced drops in scores when shifting their focus to new goals, inadvertently neglecting previously corrected steps. However, all these participants were able to identify the missed steps in the following session using Session SOP Performance (F1) and SOP Posture Session Overview Trend (F6) and subsequently adjusted their goals to correct the oversight. For example, B2 noted after reading the system in her Session 03, *"I thought I was focusing on the basket earlier, but now I see that I wasn't. In the previous round, I made corrections in Step 05 and was properly aiming at the basket, but in this round, Step 05 reverted back to how it was in the first session."*. Moreover, two SOP high-scoring participants in Group B who had nearly perfected their movements by Session 03 or 04 temporarily shifted their goals to getting more balls in. This change led to noticeable drops in SOP scores in subsequent sessions. However, they recognized this issue and reverted their focus back to movement accuracy instead of shot frequency. For instance, B11 commented, *"I rushed through the shots in that session, likely missing key posture details. My field goal percentage didn't improve, but my posture score dropped. I realized I should focus on stabilizing my movements before targeting accuracy."* In contrast, three participants in Group A faced similar oversight issues, but after changing their goals, they failed to correct their dropped scores, reflecting the lack of structured feedback to guide them back on track.

6.3 The AI Posture SOP Feedback System Helps Trainees Build Appropriate Confidence through Consistent Feedback While Maintaining Motivation Throughout Motor Training

In addition to the subjective confidence ratings in Figure 9, qualitative feedback revealed that **trainees felt more confident and motivated to correct their posture alignment when using AI posture SOP feedback system**. Initially, most participants experienced a decline in shot accuracy, leading to questions about the correlation between SOP scores and performance. However, Group

B (with SOP feedback) participants showed increased motivation as they noticed improvements in posture after setting and executing clear SOP training goals. 10 participants noted that rising SOP scores encouraged continued refinement (e.g., B2: *"I did feel that I improved a little with each round [...] Initially, with my preset form, the shots were going in, but after adjusting my posture, I missed in the following sessions. This made me question whether I should revert to my original shooting form. However, seeing my SOP score improve gave me the motivation to keep working on it."*). Meanwhile, three participants attributed their initial decline in accuracy to being in the modification phase, believing long-term practice would eventually lead to improvement, drawing parallels to their experiences in other sports like badminton and table tennis. Like what B9 mentioned after her Session 04, *"I believe that in any competitive sport, there are moments when things happen by luck, and consistency may not always be guaranteed. However, if you're aiming for professional-level performance, you must continuously refine these small details to achieve consistent results."*

In contrast, **without the SOP feedback, trainees are more prone to overconfidence in their SOP.** Group A, who trained without the SOP feedback, exhibited two extreme behaviors: diminished confidence or overestimation of their performance. Some participants lost confidence entirely, questioning the purpose of certain SOP steps and the value of their practice. For example, in Session 04, A13 complaint *"I can see that there's already a difference. [...] I know my hands position didn't actually reach the required height, but I don't think I should adjust it further. (Why?) I feel that the height is more related to personal habits, and I don't really like using my wrist to control the ball."*). On the other hand, several participants overestimated their progress, with six believing their performance in the fifth session was their best. However, the actual SOP scores indicated otherwise, as some participants even recorded their lowest SOP scores during this session. This overconfidence, akin to the Dunning-Kruger effect, led them to prematurely assume mastery (For example, A14 said *"I think I'm perfect now; I can focus on field goal rate."*).

Overall, with the AI posture SOP feedback, trainees were more confident and motivated to correct their posture alignment. The system provided objective feedback that corrected misconceptions and fostered realistic self-assessment, sustaining motivation through visible improvements. As the post-survey result showed in the Figure 9, such differences made participants rate the AI posture SOP feedback system as more useful and satisfying in assisting their motor training.

6.4 Players with Previous Training in Other Sports Show a Faster Learning Pace and Greater Confidence in Adapting to the AI Posture SOP Feedback System

Five from Group A and three participants from Group B mentioned their prior experience in other sports, respectively, including fitness training (A5), volleyball (A6, A14), rock climbing (A11), and ceremonial rifle drills (A5) in Group A, and kendo (B12), cheerleading/gymnastics/taekwondo (B11), and badminton/volleyball (B3) in Group B. Based on analyzing participants' qualitative feedback, we found that players with previous sports experiences demonstrated greater confidence in using the SOP system and a faster learning pace. This advantage is likely attributed to their ability to quickly memorize detailed steps and incorporate feedback into their practice more easily. For example, B12 shared that his sports experience in Kendo and Kyudo was similar to learning our SOP basketball set shot, leading to his improvement from 0% in the pretest to over 80% by Session 03. Similarly, B11, who nearly achieved 100% SOP accuracy by Session 03 said: *"I consider myself someone who learns and corrects movements relatively quickly, thanks to my previous sports experiences. [...] Cheerleading, in particular, demands an even greater understanding of movement accuracy compared to ball sports."* Participants with sports backgrounds in Group A, as detailed in the supplementary material, demonstrated an average SOP improvement of 51.88%, whereas those in Group B, who received SOP feedback, achieved a significantly higher average improvement of 70.63%. This likely transferable learning experience suggests that the AI SOP posture feedback system could offer benefits beyond basketball shot training, with potential applications in other areas of sports skill development. However, to further validate the system's effectiveness in leveraging existing skills for performance alignment, additional data from different experimental settings will be required.

7 Design Implications

We discuss the design implications for future AI SOP feedback posture systems for sports skill training, including the timing and type of AI feedback based on our knowledge-based SOP framework.

7.1 Timing of Technological Interventions in the Teaching Workflow

7.1.1 *Adopt SOP System During and After Initial Learning Phases to Enhance Comprehension and Reinforce Self-Training*.

Our evaluation of the SOP system revealed that following the initial coaches' instructions with the SOP framework significantly enhanced trainees' understanding of each step in the shooting mechanics, leading to effective self-assessment and error correction, as discussed in Section 6.1 and Section 6.2. As the biggest challenge for beginner learners was ensuring their training meets coaching standards, introducing the SOP during initial training provides a structured approach to understanding the nuances of motor skills. Furthermore, structured feedback provided according to these SOP steps, initially guided by coaches and later supported by AI-driven feedback, helps learners obtain familiar training insights as they transition to independent practice.

Participants B4 and B6, for example, struggled with Step 02 in the initial training phase, specifically with how their left hand should interact with the ball, despite multiple attempts to adjust their positioning. Receiving initial in-person guidance from a coach would help them understand the correct posture more quickly, reducing trial and error before using the AI SOP posture feedback system. Providing AI feedback that aligns with coaches' training goals could also save time for coaches after they have provided hands-on instructions. As Coach 05 noted, *"In large group classes, providing individualized attention can be time-consuming. A detection system that allows students to practice independently and identifies* *where their posture needs adjustment could significantly reduce the time required for corrections."* By categorizing coaches' instructions into SOP steps followed by structured AI feedback, such an AI feedback system can enhance overall learning efficiency for both learners and coaches while maintaining training quality.

7.1.2 *Provide Staged Evaluations to Improve Memorability of Motion Sequence and Training Effectiveness*.

Although the SOP provides a structured approach as learners familiarize themselves with a new motor skill, we found that beginners often struggle to memorize all the steps at once. During the experiment with both Group A and Group B, none of the participants were able to memorize all the steps after watching the coach's SOP tutorial in their initial attempt. Several participants frequently referred to the monitor to review the SOP step sequence before shooting, highlighting the challenge of retaining all steps simultaneously. Participant B7 noted that learning would be more manageable if she could focus on mastering a few steps at a time rather than all at once.

In particular, steps that involved multi-joint coordination movements, such as Step 06 in Figure 13, posed significant difficulties. Many participants had difficulty mastering it, with progress plateauing after Session 03 despite the SOP system's support. Conversely, steps involving simpler single-joint movements, such as Steps 01, 02, 04, and 05, were more easily accomplished after following the SOP tutorial.

These findings suggest the effectiveness of using a staged evaluation approach in our SOP framework, where challenging SOP steps are tackled progressively, allowing learners to target small parts as they develop a better control of muscle movement for each body part over time[15]. By focusing on a few steps at a time, this method can facilitate more effective learning and continuous improvement, better aligning with the needs of beginners who may find the full sequence overwhelming when introduced all at once.

7.1.3 *Provide Personalized, Interactive Feedback in Real-Time to Enhance Immediate Error Correction*.

Obtaining real-time feedback was perceived helpful by all participants across Group A and B. Moreover, with the support of SOP feedback, learners demonstrated an increased level of self-awareness, often requesting personalized feedback to further enhance their learning experience. Eight participants in Group B suggested incorporating targeted visual aids, such as indicators that pinpoint problematic body parts, which would facilitate them to make focused adjustments faster. Participants also expressed a desire for immediate feedback on their own performance with video replay, including step-by-step scores after each shot and the ability to view full-body videos of their shooting motion directly on the screen. Participant B5 proposed to extend feedback beyond binary "✔" (correct) or "✖" (incorrect) indicators, requesting a percentage-based evaluation that reflects the accuracy improvement for each movement. This more nuanced feedback approach could alleviate the complexities of steps involving multiple movement requirements, such as Step 06.

Additionally, voice interaction was deemed helpful to get timely feedback for sports motor training. During our study, participants B12–14 explored the use of voice commands during training sessions, requesting specific sections from the researcher without needing to touch the screen. This feedback suggests that integrating voice commands into the SOP system may significantly enhance user interaction by providing faster access to desired information. Typical commands included reviewing progress on previous goals via Session SOP Summary (F1), diagnosing poorly performed steps, and refining objectives using SOP Posture Video Clip Comparison (F3) along with the Coach SOP Posture Tutorial (F5) for the next session. Future systems can integrate these enhancements and create a more responsive training experience, empowering trainees' with more immediate, actionable feedback.

7.2 Types of AI Feedback for Personalized Motor Training

7.2.1 *Adjust Posture Tolerance to Addresses Individual Variations in SOP Training*.

Both coaches and participants recommended that the SOP checklist detection should include customizable tolerance ranges to account for individual physical differences. This design consideration is crucial for future AI SOP posture feedback systems, as body movements can vary significantly between individuals. Without this flexibility, inaccurate feedback could not only result in ineffective training but also increase the risk of injury.

During later training sessions, participants B6 and B11 reported wrist discomfort when attempting to meet the requirements of Step 04, which involved holding the ball with a wrist bent at a 90-degree angle. Consequently, despite not achieving higher scores in this step, they chose to stop making further adjustments. Similarly, Coach C4 suggested that increasing the tolerance range could help reduce frustration, noting, *"Because everyone's physical makeup, flexibility, learning ability, and coordination vary, it may not be realistic for all participants to meet the exact same SOP requirements. Being classified as incorrect might feel discouraging or disengaging for some participants."* Therefore, future research is needed to develop methods for generating personalized feedback grounded in scientific or empirical knowledge of motor skill learning.

7.2.2 *Correlate Performance Metrics with SOP Posture to Derive Deeper Training Insights*.

From a coaching perspective, an essential goal beyond achieving mechanical repetition in motor training is to foster personalized understanding and develop individualized training plans that support athletes' unique strengths. All coaches (C1–C8) emphasized that correlating SOP movements with shooting accuracy and incorporating larger datasets over time would enable coaches to guide trainees in discovering their unique strengths. C7 highlighted how variations in natural strength and preferred movements influence player roles: *"Some players have significant overall strength and don't need to rely on their legs for power; focusing on aiming with their hand and core strength can effectively propel the ball. Others excel in free throws due to the minimal leg movement required, but struggle with mid-range shots. Identifying these strengths and weaknesses can help tailor training to individual needs."*

Additionally, several coaches (C3, C7, C8) also noted that integrating field goal percentage data with SOP training could make their guidance more persuasive and motivating. As C3 noted, tracking data can clearly show athletes how specific adjustments improve their success rates, thus fostering engagement and improvement.

By correlating training data with performance, coaches can not only monitor progress and gain deeper insights, but also provide more effective, data-driven coaching.

7.2.3 *Provide Proactive Training Support to Improve Goal Setting and Execution under Plateau Phase.*

Trainees developing sports motor skills may experience a plateau phase after a period of time. Several participants in Group B experienced challenges in advancing their SOP performance on specific steps, suggesting that physical limitations, rather than a lack of understanding, were the primary barriers. Participants (B4, B5, B6, B8, and B12) particularly struggled with complicated steps like Step 06, where they found it difficult to execute the required movements despite recognizing the issues.

To address this, the AI SOP posture feedback system should offer options or reminders for trainees to seek expert insights, helping to identify specific areas for improvement and refine training goals, thereby keeping progress on track. Coaches C6 and C7 emphasized that participants often experience plateaus not because of conceptual misunderstandings of the SOP, but rather due to the need for further development in physical strength or coordination. As C6 articulated, *"Initially, we guide them through simpler, short-range exercises, such as improving single-hand support strength to help achieve a 90-degree elbow angle. [...] Although students can visually mimic wrist extensions, physical constraints often hinder their ability to perform the movements correctly. When the system lacks tailored recommendations or standard troubleshooting techniques, my intervention becomes crucial in addressing such challenges."*

Additionally, C4 observed that even when participants had technically mastered SOP movements, some still struggled with successful shot execution due to insufficient strength. To enhance learner engagement, the system could dynamically suggest adaptive modifications based on expert advice, such as adjusting shooting distance, to ensure training effectiveness and maintain motivation. This approach would better align the training process with individual needs and capabilities, ensuring an AI SOP posture feedback system can provide a more personalized and effective learning experience.

8 Limitations and Future Work

While our designed AI feedback posture SOP system shows promise in enhancing posture alignment and error correction, several limitations of the current study must be acknowledged. First, the scope of the training was limited to a relatively short duration and a small number of shots per session. To better understand the system's long-term efficacy, future work should include more extensive training periods with a higher volume of shots. This would provide insights into how sustained use of the system impacts both field goal percentages and posture alignment over time.

Another limitation of the current system is its reliance on coaches' input for posture correction feedback, which can introduce subjectivity and variability. To address this, future work could explore the collection of instructional language from various coaches to create a more objective feedback mechanism. By designing and fine-tuning large language models (LLMs) on a dataset with coaching instructions, we could develop an AI-driven system capable of generating precise feedback with less human input. This approach aims to standardize feedback, minimize human error, and ensure that posture correction aligns with established best practices. By enhancing the reliability and scalability of the SOP system, it also opens the door for applications in other training contexts using SOP, such as baseball swings, batting techniques, and boxing movements, which are part of the future work we are currently exploring.

Additionally, the study focused on a single shooting distance, limiting the generalizability of the findings across different shooting distances. Future research should explore the effects of the AI Feedback posture SOP system at varying shooting distances to better understand how posture alignment between basketball coaches and beginner players and field goal performance are influenced. Moreover, the study relied on coach assessments for performance validation, which may carry slight biases or inaccuracies. Future studies should incorporate more objective measures of performance, such as motion capture technology, biomechanical analysis or ball trajectories to validate the system's effectiveness more accurately.

Finally, while the current study primarily focused on posture alignment between basketball coaches and beginner players, it is essential to explore the correlation between posture alignment and field goal performance. Future work should examine how improvements in posture alignment directly correlate with field goal success rates, thereby providing a more holistic evaluation of the AI feedback posture SOP system's impact on basketball shooting performance. This approach will ensure a more integrated understanding of how posture correction contributes to overall skill enhancement in sports training.

9 Conclusion

This study introduces a methodology and framework for designing the AI feedback posture SOP system aimed at enhancing basketball motor learning by bridging coaching knowledge with independent practice. Results show that, first, the system effectively addresses key challenges for beginners, such as misalignment between proprioception and actual posture, uncertainty in corrections, and difficulties in goal-setting. Second, the structured SOP approach integrates coaching knowledge with real-time video and intuitive textual feedback, providing actionable and step-by-step guidance. Third, our user study demonstrates significant improvements in confidence, self-awareness, and effectiveness across training metrics. Lastly, the system offers a scalable and impactful framework that can be implemented on top of existing solutions for skill development, fostering better alignment with coaching standards and enriching the motor learning experience.

Our work presents a comprehensive framework that integrates expert coaching principles with AI-driven SOP feedback, establishing a foundation for future advancements in interactive sports training. To maximize the SOP framework's long-term impact on beginners' skill acquisition, we emphasize the importance of tailored AI feedback and strategically timed technological interventions, including advancements such as LLM implementations. These developments promise to improve system scalability, enhance training precision, and further advance motor learning research.

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