

Design and Evaluation of 3-in-1 Volleyball Self-Training Machine

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Abstract

Volleyball training often requires specialized equipment to enhance skill development. However, existing self-training tools are limited in functionality and accessibility, making comprehensive training challenging for individual players. This project aims to develop a 3-in-1, setter, spike and digging volleyball self-training machine to provide a cost-effective and efficient solution for individual training. The methodology involves a systematic review of existing training tools, followed by a structured design and development process. The design was refined through simulations to validate theoretical functionality. The performance tests including oscillation, accuracy, and stability assessments were conducted to evaluate effectiveness. The results demonstrate that the proposed device significantly improves skill acquisition by enabling repetitive and controlled practice of multiple volleyball techniques. The stability test confirms the machine can support up to 20kg, ensuring safe usage. In conclusion, the developed 2-in-1 volleyball self-training machine enhances training efficiency and accessibility by integrating multiple functions into a single device.

1. Introduction

Volleyball is a fast-paced and exciting sport that requires players to master several skills, including passing, serving, setting, spiking, and blocking. To perform well in matches, players must train regularly and develop good techniques. Training helps improve coordination, reaction time, strength, and decision-making [1]. A well-trained player can move quickly, react to the ball efficiently, and work better with teammates [2]. However, effective training requires the right equipment, and many training tools are expensive. Because of this, not all players, especially those in schools and local clubs, have the opportunity to use these tools. This makes it harder for them to improve their skills and compete at a higher level.

There are several types of volleyball training machines designed to help players practice specific techniques. Spike training machines allow players to adjust the speed, height, and angle of the ball so they can improve their spiking ability [3]. These machines are useful for outside hitters and middle blockers, as they need to develop powerful and accurate spikes. Serving machines help players practice different types of serves, such as float, topspin, and jump serves. These machines can also be used for reception training, as they allow players to practice defending against strong serves [4]. Blocking trainers help players improve their blocking skills by simulating an opponent's attack. This is useful for players who play at the net, such as middle blockers and

outside hitters [5]. Passing and digging machines are designed to make players react to unpredictable ball movements, helping them improve their defensive skills [6]. Setting trainers allow setters to develop accuracy and control when delivering the ball to hitters. Some advanced machines can perform multiple functions, allowing players to practice several skills using one device [7].

Although these machines offer great benefits, they are very expensive, which makes them difficult for many players to afford. Most training machines use advanced technology, such as sensors, automated ball delivery, and adjustable settings, which increase their cost [8]. Because each machine focuses on only one skill, a player would need several different machines to get complete training. This adds to the financial burden, making it almost impossible for amateur players, school teams, and community clubs to access these tools [9]. As a result, only well-funded organizations or professional teams can afford these machines. The high cost of training equipment creates an unfair advantage, where players from wealthier backgrounds receive better training, while others struggle to improve due to a lack of resources [10].

Since most players cannot afford these expensive machines, they often rely on traditional training methods. Traditional training involves practicing with teammates and receiving coaching from trainers. While this method can be effective, it has several limitations. One major issue is scheduling conflicts. Players may not always have access to a coach or teammates when they want to train [11]. This can lead to inconsistent training and slower skill development. Another issue is the lack of personalized feedback. In a group training session, a coach may not be able to give individual attention to every player. This means that some players may continue making the same mistakes without knowing how to fix them. Additionally, traditional training may not always provide the high-intensity repetitions needed for fast improvement [3]. Without proper training equipment, athletes may take longer to develop their skills, which can affect their confidence and overall performance in matches.

For school players, beginners, and amateur athletes, having access to affordable and effective training equipment is very important. Many schools and community sports clubs have limited budgets, which makes it difficult for them to purchase expensive training machines. Because of this, young players often do not get the opportunity to practice properly or refine their basic volleyball skills [2]. This lack of access to quality training puts them at a disadvantage when competing against better-trained players. To solve this problem, it is necessary to create low-cost training tools that still provide proper skill development opportunities. These budget-friendly training tools would allow more players to improve, regardless of their financial background [6].

One solution is to design training equipment that is simple, affordable, and easy to use. Instead of relying on expensive automated systems, these tools can use mechanical or manual mechanisms. For example, a manually adjustable spiking target could help players practice hitting with precision without needing a high-tech spike machine [5]. A basic serving trainer could allow players to practice serving accuracy without needing an advanced serving machine. Similarly, a blocking aid made of lightweight materials could help blockers practice their hand positioning and timing at a much lower cost [4]. These low-cost alternatives would still provide valuable training benefits while being accessible to a wider range of players.

In addition to being affordable, these manual training tools would be especially useful for schools and beginner players. Many young athletes are still learning the basics of volleyball, and they do not need complex machines with advanced technology [7]. Simple equipment would allow them to practice fundamental skills in a structured way, helping them build a strong foundation before moving on to more advanced techniques. Schools could benefit from these budget-friendly training aids by providing their students with better practice opportunities, ensuring that more young players develop an interest in the sport and continue to improve.

In conclusion, while advanced training machines can help volleyball players refine their skills, their high cost makes them difficult for many athletes to access. Traditional training methods, although effective, can sometimes be inconsistent and may not provide enough individual feedback. To make training more accessible, it is important to develop affordable training tools that allow players to practice fundamental skills like passing, serving, and digging. These budget-friendly training solutions would help school teams, amateur players, and community clubs gain the training they need to compete at a higher level. By making volleyball training more accessible to everyone, we can create more opportunities for young athletes to develop their skills and enjoy the sport, regardless of their financial situation.

2. Methodology

Fig. 1 (a), (b) and (c) shows three concepts of self-training volleyball machines. All concepts are manual gravity-based feeders to help players practice passing, setting, and digging without the need for electricity. Concept (1) has a curved track that regulates ball speed, making it useful for passing and digging drills, but friction may cause inconsistent ball movement, and it requires frequent reloading. Concept (2), the selected design, features a straight inclined track for controlled and adjustable ball delivery, ensuring consistency in passing and reception training while remaining simple and easy to use. However, it has a fixed trajectory and limited hopper capacity. Concept (3) is a compact drop feeder that delivers balls straight down, making it effective for setting and digging drills, but its lack of trajectory variation limits its training applications. Among these, Concept (2) is the best

choice due to its consistent ball delivery, adjustability, and ease of use, making it a practical and efficient solution for volleyball training. Fig. 1 (d) shows the orthographic drawing of the model of Concept (b).

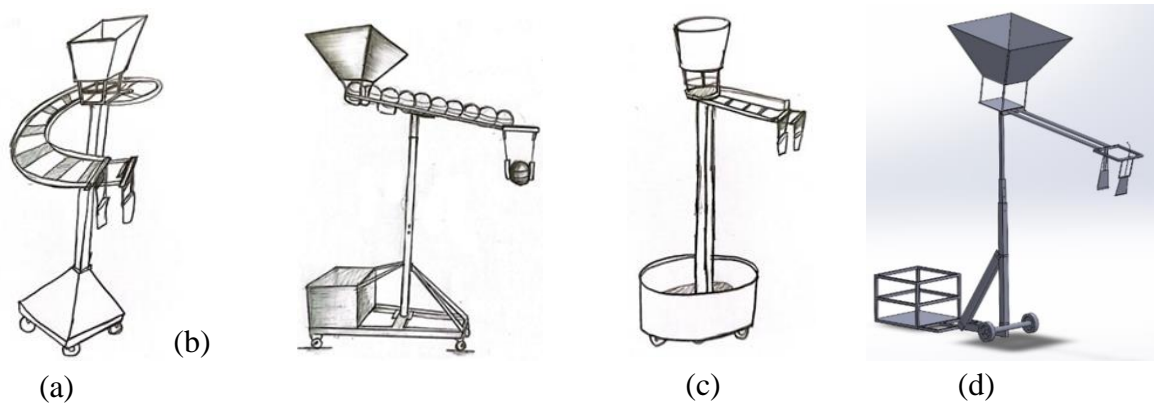


Fig. 1 Concept design and model (a) Concept (1); (b) Concept (2); (c) Concept (3); (d) CAD modelling of concept (2)

The volleyball training equipment was constructed using a robust steel frame, primarily composed of durable hollow section steel to ensure stability and longevity. The main structure consists of a vertical support pole with adjustable height settings, allowing flexibility for different training drills. A funnel-shaped ball feeder was fabricated from metal sheets, ensuring a smooth and consistent ball release. The base was reinforced with a sturdy metal frame and fitted with wheels for easy mobility. To enhance stability, weight plates of varying sizes (5kg, 10kg, 15kg, and 20kg) were incorporated at the base, ensuring balance during use. The ball release mechanism consists of a simple manual lever system, allowing precise control over ball delivery. The equipment's design prioritizes ease of use, stability, and accuracy, making it a reliable tool for volleyball training and skill development. Fig. 2 show the prototype of the volleyball self-training equipment.



Fig. 2 Prototype of the volleyball self-training equipment

Three test were conducted to evaluate machine performance. The test are oscillation, accuracy, and stability. Five players participated by hitting the ball while we measured the number of oscillations on the beam rod and recorded the time taken for movement to stop at three different pole heights (1m, 2m, and 3m). The accuracy test involved 20 throws per player to the setter's position, where we recorded successful and failed throws at different pole heights to assess the equipment's precision. Lastly, the stability test examined the effect of different weights (5kg, 10kg, 15kg, and 20kg) on the machine's stability at varying heights. All tests were conducted systematically, with data recorded for analysis.

3. Results

The performance of the volleyball self-training machine was evaluated through oscillation, accuracy, and stability tests. These tests examined the machine's dynamic response to external forces, its ability to track and return the ball with precision, and its capacity to remain balanced under varying loads. The findings provide a basis for assessing the machine's effectiveness in supporting self-training while identifying areas for further refinement.

3.1 Oscillation Test

The oscillation test measures how much the machine moves after impact and the time required for stabilization. Oscillation is influenced by the strength of the impact, the mechanical properties of the structure, and the height at which the force is applied. The results as shown in Figure 3 indicate that at a height of 1 meter, Player D produced the highest oscillation with 71 movements, requiring 30.12 seconds to stabilize, whereas Player C had the lowest oscillation at 50, stabilizing in 24.07 seconds. This suggests that Player D applied a stronger force, causing greater instability, while Player C's impact was comparatively weaker.

At 2 meters, oscillation values varied significantly. Player C recorded the highest oscillation at 32, while Player E had the lowest at 20. The stabilization time followed a similar pattern, with Player C taking the longest to settle at 40 seconds. These variations imply that different players generate distinct impact forces, which in turn affect the machine's movement. It is also possible that variations in player technique influenced the consistency of oscillations.

At 3 meters, oscillation values became more uniform across players, with Player B exhibiting the highest oscillation at 40. Stabilization times were also more consistent, suggesting that at higher heights, the mechanical response of the machine becomes more predictable. This could be due to the reduction in variability of impact forces at longer distances, leading to more stable oscillation patterns. As shown in Fig. 3, the findings indicate that while the machine can effectively absorb impact forces at different heights, improvements in damping mechanisms could further enhance stability, particularly at lower heights where oscillation variations are more pronounced.

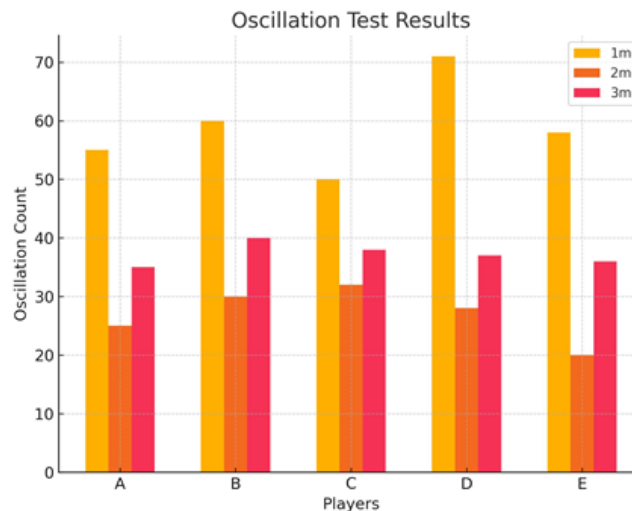


Fig. 3 Oscillation test results

3.2 Accuracy Test

Accuracy is a critical factor in assessing the machine's effectiveness in responding to player actions. The results as shown in Fig. 4, demonstrate that at 1 meter, the machine performed well, with Players A, B, and D achieving high success rates of above 85%. This suggests that at shorter distances, the tracking mechanism is highly responsive and able to adjust to player input effectively. However, Player E showed a notably lower success rate, with only 5 successful throws, which indicates a possible inconsistency in tracking.

As the height increased to 2 meters, accuracy began to decline, with success rates dropping across all players. Player A maintained relatively high accuracy, with 14 successful throws, while the remaining players showed moderate performance with success rates between 8 and 13. The decline in accuracy at this height suggests that the machine encounters difficulties in tracking movements over a longer distance. Possible

contributing factors include sensor limitations, mechanical response delays, or variations in player technique that introduce inconsistencies in how the machine interprets movement.

At 3 meters, accuracy dropped further, particularly for Player E, who had the lowest success rate with only 3 successful throws. Players A and B, however, maintained moderate accuracy with 10 and 9 successful throws, respectively. The significant decline in accuracy at this height, indicating that the machine's tracking system struggles to maintain precision as distance increases. The likely causes could be sensor calibration issues, reduced response time, or mechanical inconsistencies in adjusting to rapid player movements. To improve performance at longer distances, enhancements in sensor resolution and tracking algorithms may be necessary to maintain accuracy across varying heights.

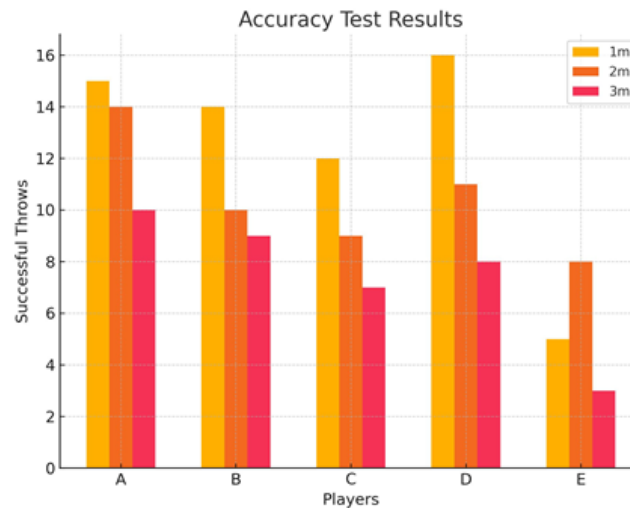


Fig. 4 Accuracy test results

At 2 meters, oscillation values varied significantly. Player C recorded the highest oscillation at 32, while Player E had the lowest at 20. The stabilization time followed a similar pattern, with Player C taking the longest to settle at 40 seconds. These variations imply that different players generate distinct impact forces, which in turn affect the machine's movement. It is also possible that variations in player technique influenced the consistency of oscillations.

3.3 Stability Test

The stability test evaluates how well the machine maintains balance under different weight loads. As shown in Fig. 5, at 5 kg, minimal instability was observed, suggesting that while the machine could hold the weight, it was not entirely stable. As the weight increased to 10 kg, the machine showed improved stability, particularly at 1 meter, where oscillations were significantly reduced. This indicates that additional weight contributed to enhanced balance by minimizing unintended movements.

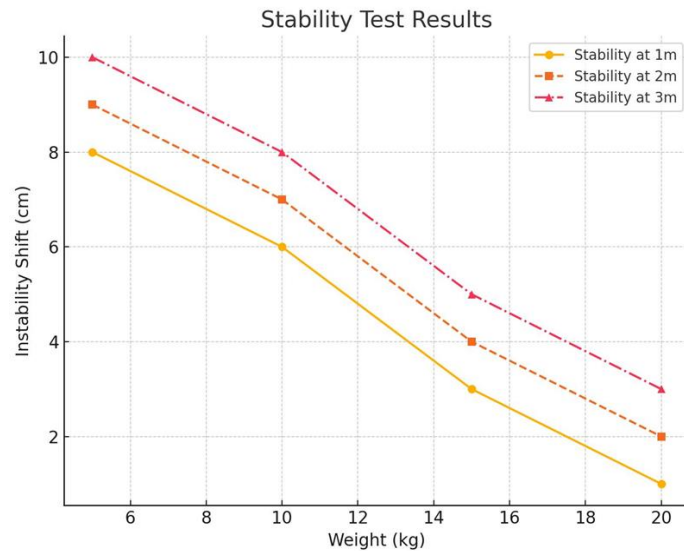


Fig. 5 Stability test results

At 15 kg, stability was further improved across all tested heights, demonstrating that the machine is capable of handling moderate weights without significant tipping. However, at this level, minor shifts were still recorded at 3 meters, suggesting that higher positioning may introduce slight instability under certain conditions.

At 20 kg, the machine exhibited the highest level of stability, with no signs of tipping at any height. Fig. 3 illustrates that the machine can reliably support up to 20 kg without compromising balance. The findings suggest that the addition of weight enhances structural stability, likely due to a lower center of gravity reducing unintended movement. This is an important consideration for real-world use, as stability under different loads ensures that players can train without concerns about machine tipping. The results indicate that while the current design effectively maintains balance, further structural reinforcements could enable even greater weight tolerance, expanding the machine's usability in various training scenarios

3.4 Discussion

The results from the three tests provide a comprehensive understanding of the machine's performance in real-world training conditions. The oscillation test highlights variations in movement stability, demonstrating that while oscillations are more controlled at higher heights, there is still room for improvement in minimizing excessive movement at lower levels. Incorporating improved damping mechanisms or structural reinforcements could enhance stability, particularly when responding to stronger impact forces.

The accuracy test reveals that the machine performs well at shorter distances but struggles with consistency as distance increases. This suggests that the tracking system requires optimization to maintain responsiveness at longer distances. Potential solutions include improving sensor calibration, enhancing mechanical response speed, or integrating more advanced tracking algorithms to minimize accuracy loss over extended ranges. Addressing these issues would allow for more effective player-machine interactions and improve the reliability of training feedback.

The stability test confirms that the machine can support weights up to 20 kg without tipping, indicating that it is structurally sound for training purposes. The findings suggest that adding weight enhances stability, reinforcing the importance of a balanced design. However, minor instability was observed at lower weight levels, implying that further structural modifications could improve balance under lighter loads. These insights can be used to refine the machine's design, ensuring greater adaptability across different training conditions.

In conclusion, the evaluation of oscillation, accuracy, and stability provides valuable information on the machine's capabilities and limitations. The results indicate that while the machine effectively supports self-training for volleyball players, enhancements in tracking precision, oscillation control, and weight distribution could further improve performance. Future iterations of the machine could incorporate adaptive tracking algorithms, enhanced damping systems, and structural reinforcements to optimize stability and accuracy. These improvements would enhance the machine's usability, ensuring that it provides consistent and reliable training feedback across different conditions.

4. Conclusion

The evaluation of the volleyball training machine through oscillation, accuracy, and stability tests highlights its effectiveness in facilitating self-training while identifying areas for improvement. The oscillation test reveals

that while the machine absorbs impact forces well, excessive movements at lower heights suggest the need for enhanced damping mechanisms. The accuracy test shows strong performance at shorter distances but a decline at greater heights, indicating the necessity for improved sensor calibration, faster response times, and optimized tracking algorithms. The stability test confirms that the machine can support up to 20 kg without tipping, with additional weight improving balance, though minor instability at lower weights suggests a need for structural reinforcements. Overall, the results demonstrate the machine's viability for volleyball training, but enhancements in tracking precision, oscillation control, and structural stability are essential for optimizing performance. Future improvements should focus on refining tracking accuracy, minimizing oscillations, and increasing weight tolerance to ensure consistent and reliable training feedback for players of all skill levels.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: **study conception and design:** Nur Hazwanie Jusoh, NurFatin Anisa Rusdan, Nurul Syawani Abd Hamid; **data collection:** Nur Hazwanie Jusoh, NurFatin Anisa Rusdan, Nurul Syawani Abd Hamid; **analysis and interpretation of results:** Nur Hazwanie Jusoh, NurFatin Anisa Rusdan, Nurul Syawani Abd Hamid; **draft manuscript preparation:** Abdullah Wagiman. All authors reviewed the results and approved the final version of the manuscript.

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