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Development and Effectiveness of a Wrist Flick Training Device to Enhance Volleyball Hitting Performance

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Abstract

Studi purpose: This study aimed to develop and evaluate the effectiveness of a wrist flick training device (Wrist Muscle Flick Training Device /WMFT-Volly) in improving volleyball hitting performance, particularly in enhancing wrist speed and ball control during overhead skills.

Materials and Methods: The study employed a research and development approach followed by a pretest–posttest control group experimental design. Thirty university volleyball athletes were randomly assigned to an experimental group ($n = 15$), which trained using the wrist flick device, and a control group ($n = 15$), which followed conventional training. The intervention lasted four weeks (12 sessions). Hitting performance (ball speed and accuracy) was measured before and after the intervention. Data were analyzed using the Shapiro–Wilk test for normality, Levene's test for homogeneity, paired sample t-test, independent sample t-test, and effect size (Cohen's d).

Results; The data were normally distributed and homogeneous ($p > 0.05$). The experimental group showed a significant improvement in hitting performance ($p < 0.05$), while the control group did not demonstrate significant changes ($p > 0.05$). Independent sample t-test revealed a significant difference in gain scores between groups ($p = 0.001$). The effect size was large (Cohen's $d = 1.20$), indicating a substantial practical impact of the intervention.

Conclusions: The wrist flick training device is valid, practical, and effective in enhancing volleyball hitting performance. The findings support the importance of specific wrist-focused training as part of an integrated volleyball training program to optimize technical performance.

Keywords: Wrist flick training, Volleyball, Hitting performance, Training device development, Biomechanics

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Introduction

Achievement in modern volleyball is no longer determined solely by mastery of fundamental techniques such as serving, passing, and spiking, but also by the optimization of an efficient biomechanical kinetic chain extending from the lower extremities to the distal segments of the upper extremities (Suhairi & Dewi, 2021). Based on the kinetic chain theory, force production in spike and serve actions results from a coordinated transfer of energy from proximal to distal segments, in which the wrist functions as the terminal segment that determines the final ball velocity and direction (Slovák et al., 2023). Within this framework, the quality of wrist mechanics (flexion, extension, stabilization, and “flick”) serves as the final determinant of performance output, including ball velocity, spin, and directional accuracy (Daulian Hrp, Sunarno, Supriadi, & Indrakasih, 2021).

Previous research has shown that in spike and topspin serve actions, upper arm velocity, handeye coordination, and upper limb stability contribute significantly to performance (Slovák et al., 2023). However, most of these studies have focused on proximal segments (the shoulder and elbow), while the wrist, as the distal segment in the kinetic chain, has not been thoroughly analyzed as a specific point of intervention. Biomechanically, increasing angular velocity in the distal segment amplifies the ball’s linear velocity at contact and influences spin through changes in release angle and timing (Suhairi, Rahmat, & Rusmita, 2023).

Empirical findings indicate a relationship between wrist flexion and lower limb explosive power in relation to spiking ability (Sistiasih, Nurrohman, Rumpoko, & Sholeh, 2024). These findings support the assumption that the wrist is an integral component of a synergistic force-production system. However, the study was correlational in nature and did not examine a training intervention that directly targeted wrist mechanics as an experimentally manipulated independent variable.

Within the framework of the principles of overload and training specificity, optimal neuromuscular adaptations occur when training is purposefully designed to target specific movement segments that are the focus of performance improvement (Vecchio;, Enoka;, and Farina 2024; Fredriksen and van den Tillaar 2025). These changes primarily occur during the final phase of ball release, characterized by increased wrist flexibility and control (Karisman & Supriadi, 2022). Nevertheless, this evidence has not yet been tested in the context of volleyball, with performance variables such as spike velocity, accuracy, and wrist stability as measurable outcomes.

From the perspective of motor learning theory, the development of stable movement patterns requires repeated practice with specific feedback on critical movement segments (Jaszczur-Nowicki et al., 2021). Latihan berulang dapat meningkatkan kinerja (Faozi, Irawan, Sundari, Setia, & Syamsul, 2026). Various volleyball training tools have been developed for passing and spiking (Suhairi, Asmawi, Tangkudung, Hanif, & Dlis, 2020); Haryanto, Dwiyogo, and Sulistyorini (2015), however, most have focused on global coordination or macro-level technique. To date, no training tool has been systematically designed to isolate and train the “flick” mechanics of the wrist muscles as the distal component in the hitting kinetic chain.

Theoretically, wrist mechanics in volleyball strikes can be explained through a conceptual framework that positions wrist movements including flexion, extension, stabilization, and flick as the primary determinants of increased angular velocity in the distal segments of the upper extremities Slovák et al. (2024); Liu et al. (2024). The increase in angular velocity subsequently contributes to higher ball velocity and improved spin control at ball contact, ultimately directly impacting performance outcomes such as accuracy, spike effectiveness, and hitting consistency (Liu, Chen, & Peng, 2025). Thus, the quality of wrist mechanics functions not merely as a complementary movement component but as a key factor in determining the final performance outcome of volleyball striking techniques (Kohmura et al., 2019). This model illustrates that the wrist is not just an auxiliary movement segment but the terminal determinant of energy transfer within the volleyball hitting system.

Although the literature has acknowledged the importance of the wrist in volleyball striking performance, a significant and specifically identified scientific gap remains—conceptually, methodologically, and practically. Conceptually, no experimental model has yet explicitly tested the causal relationship between wrist mechanics training and improvements in ball velocity and hitting accuracy within the context of volleyball. Methodologically, most existing studies are correlational or conducted in other sports, limiting the direct empirical basis for generalizing findings to volleyball striking performance. Practically, there is still no standardized training tool designed to provide specific, measurable, and systematic stimulus to the wrist "flick" movement in accordance with the principles of overload and training specificity. Consequently, a measurable gap exists between the theoretical recognition of wrist mechanics' importance in the hitting kinetic chain and the absence of experimentally tested, tool-based interventions specifically developed for volleyball.

Based on this gap, the present study is formulated around the primary research question: can the development and implementation of a wrist-flick training device significantly improve hitting velocity, accuracy, and wrist stability among university student-athletes participating in volleyball student activity units compared to conventional training? In line with this question, the study hypothesizes that athletes who undergo training using the wrist-flick device will demonstrate a significant increase in hitting velocity compared to the control group; athletes in the intervention group will exhibit greater improvements in hitting accuracy than those in the control group; and the use of the device will significantly enhance wrist stability and control.

To the best of the authors' knowledge, this study is the first to develop, validate, and examine the effectiveness of a wrist-flick training device in volleyball by integrating kinetic chain biomechanics, the principles of overload, and motor learning theory into a measurable intervention design. This study provides a conceptual contribution through a model linking wrist mechanics to hitting performance, as well as a practical contribution in the form of a training protocol and device design applicable to athlete development programs. Therefore, this study is expected to bridge the gap between biomechanical theory and volleyball hitting training practice while enriching the sport biomechanics literature.

Materials and methods

Study participants

This study involved active athletes from the Volleyball Student Activity Unit (UKM) at Universitas PGRI Pontianak who participated in a regular training program at least three times per week. Participants were selected using purposive sampling, with the following inclusion criteria: (1) athletes aged 18–23 years, (2) having a minimum of one year of volleyball training experience, (3) no upper extremity injuries in the past three months, and (4) willingness to participate in the entire research intervention protocol (Etikan, 2016).

Overall, the study involved three participant groups corresponding to the stages of product development. The validation phase included three expert validators: a sports equipment specialist, a certified volleyball coach, and a lecturer with expertise in volleyball instruction. The small group trial involved 10 athletes to evaluate the practicality and safety of the training device. The main field testing involved 30 athletes, divided into an experimental group (n = 15) and a control group (n = 15). Group allocation was performed using simple random assignment to minimize selection bias.

Prior to the commencement of the study, all participants signed an informed consent form. The study received ethical approval from the authorized institutional review board within the researchers' institution (Creswell; & Creswell, 2018).

Study organization

This study employed a Research and Development (R&D) approach using a modified Borg and Gall model consisting of seven stages: (1) preliminary research and information gathering, (2) product design planning, (3) initial product development, (4) small group trial, (5) first-stage product revision, (6) main field testing, and (7) final product revision (Sugiyono, 2020). This approach was selected because the study aimed to develop, validate, and test the effectiveness of a wrist-flick training device for volleyball athletes.

In the preliminary research stage, a needs analysis was conducted through training observations and interviews with coaches to identify issues in developing wrist-flick mechanics. The planning stage involved designing the technical specifications of the device based on the principles of the biomechanical kinetic chain, overload, and training specificity. The initial product was then validated by three experts to assess content feasibility, design, safety, and biomechanical appropriateness.

The small group trial was conducted over a two-week period to identify technical constraints and gather user feedback. Following the first-stage revision, the main field testing was carried out over six weeks with a training frequency of three sessions per week. The experimental group incorporated the wrist-flick training device as part of their striking technique sessions, while the control group underwent conventional training without any additional device.

The experimental design employed was a pretest–posttest control group design, commonly applied in sports training research (J. Dankel 2020; Skvarc and Fuller-Tyszkiewicz 2024). Measurements were taken before and after the intervention period for the following variables: (1) hitting velocity, measured using a radar gun/speed device Palao and Valades (2009); (Krzysztofik, Kalinowski, Filip-stachnik, Wilk, & Zajac, 2021), (2) hitting accuracy, assessed using a target score test (Luciano et al., 2024), and (3) wrist stability, evaluated through an observation checklist based on a biomechanical assessment rubric.

The research instruments included: (1) expert validation sheets (assessing content feasibility, design, and safety); (2) athlete and coach questionnaires (evaluating practicality and applicability); (3) wrist movement technique observation sheets; and (4) volleyball performance tests. All instruments underwent content validation by three experts. Reliability testing was conducted using Cronbach's Alpha coefficient, with $\alpha \geq 0.70$ considered reliable. The training device was deemed feasible and effective if it met the following criteria: (1) expert validation score ≥ 80% (categorized as highly feasible), (2) practicality level ≥ 80%, and (3) a statistically significant improvement ($p < 0.05$) in volleyball striking performance variables following the intervention.

Statistical analysis

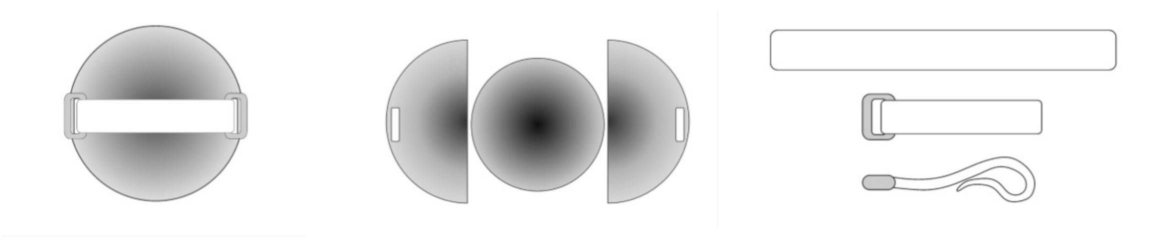
Quantitative data were analyzed using the latest version of IBM SPSS Statistics Version 26 (Pallant, 2020). The analysis was conducted in several steps. First, the assumptions of normality were tested using the Shapiro–Wilk test, and homogeneity of variances was assessed using Levene's test. Second, expert validation data and user responses were analyzed descriptively using means and percentages to determine feasibility and practicality categories. To examine the effectiveness of the training device, (1) a paired sample t-test was conducted to analyze pretest–posttest differences within each group, and (2) an independent sample t-test was used to compare score changes between the experimental and control groups. Effect sizes were calculated using Cohen's d to interpret the magnitude of the intervention's impact. The significance level was set at α = 0.05.

Qualitative data from observations and participant comments were analyzed using data reduction, thematic categorization, and conclusion drawing techniques to reinforce the interpretation of the quantitative results.

Results

The initial phase of the study was conducted through training observations at volleyball clubs in Pontianak, interviews with coaches, and a review of previous research. The data collection revealed that the majority of coaches and athletes did not have specialized training equipment for wrist movements, even though nearly all coaches considered wrist-flick movements to be crucial for increasing ball speed and direction during serves and spikes. Furthermore, based on a needs questionnaire completed by 15 athletes, 80% reported difficulty maintaining wrist flexibility during powerful hits, and 73% of coaches indicated the need for a training device that can stimulate the wrist flexor–extensor muscles. These findings provided the basis for developing a wrist-flick training device aimed at enhancing strength, flexibility, and fine motor control of the wrist joint.

The initial design of the training device was created as an elastic strap with light resistance, worn on the athlete's forearm and connected to a small rubber ball grip. The primary function of the device is to generate a recoil force when the athlete performs the flicking motion, allowing controlled, repeated activation of the wrist muscles. The device's design components include: (1) Main material: latex elastic cord approximately 30 cm in length, (2) Fastening strap: neoprene fabric comfortable on the skin, (3) Grip: small rubber ball with a diameter of approximately 9 cm, with a weight of 0.5 kg, and (4) Joint support: a small metal ring connecting the cord to the strap. The initial prototype was named the "Wrist Flick Trainer."



(a) (b) (c)

Figure 1. Overall Design of the Wrist-Flick Muscle Training Device: (a) design of the wrist-flick training device; (b) ball component (inside and outside view); and (c) strap and hook components of the wrist-flick training device.

Validation was conducted by three experts: a sports equipment specialist, a volleyball technique expert (coach), and a volleyball pedagogy expert (lecturer). Each expert evaluated three aspects: device design, safety, and training functionality.

Table 1. Validation Results Conducted by Three Experts (Sports Equipment Specialist, Volleyball Technique Expert [Coach], and Volleyball Pedagogy Expert [Lecturer]).

Assessed Aspect	Average (%)	Category
Media Design	87.50	Highly Feasible
Safety and Comfort	85.00	Highly Feasible

Training Function and Applicability	88.33	Highly Feasible

The overall average validation score was 86.94%, indicating that the device was deemed suitable for use without major revisions. Feedback from the validators was mainly technical, such as reinforcing the elastic connections and adding foam padding to the strap to enhance user comfort.

The small group trial involved 10 athletes participating in the Volleyball Student Activity Unit (UKM) at Universitas PGRI Pontianak. Observations indicated that the device could be used safely and was easy to attach. Results from the user response questionnaire were as follows:

Table 2. Small Group Trial Results of the Wrist-Flick Training Device Development for Volleyball Athletes.

Indicator	Average (%)	Category
Ease of Use	85.71	Highly Practical
Training Comfort	82.14	Highly Practical
Benefits for Hitting Technique	84.28	Highly Practical
Training Appeal and Motivation	87.85	Highly Practical

The average user response score was 84.99% (categorized as highly practical). In addition, coaches suggested that the device be made available in multiple resistance levels (light, medium, heavy) to accommodate athletes' varying abilities.

Based on feedback from experts and users, the first-stage product revision included: (1) adding a foam layer to the ball strap, (2) creating three levels of strap elasticity (low, medium, high), (3) labeling installation directions and providing a usage guide, and (4) adjusting the rubber layer on the outer surface of the ball/device. After these revisions, the product was internally retested and deemed ready for the main field trial.

The main field trial involved 30 athletes (15 in the experimental group and 15 in the control group) over four weeks (12 training sessions). The experimental group used the wrist-flick training device, while the control group performed conventional training without the device. Volleyball hitting performance tests (ball speed and direction) were conducted before and after the training period.

Table 3. Measurement Results of Volleyball Athletes' Hitting Performance.

Group	Pre-test mean	Post-test mean	Improvement (%)	Sig. (p)
Experiment	62.40	78.60	25.9	0.000*
Control	63.10	67.20	6.5	0.071

Note: Significant at $p < 0.05$

The effectiveness data were analyzed using a paired sample t-test to examine significant differences between pre- and post-intervention measurements, as well as between the experimental and control groups, as shown in the following figure 1.

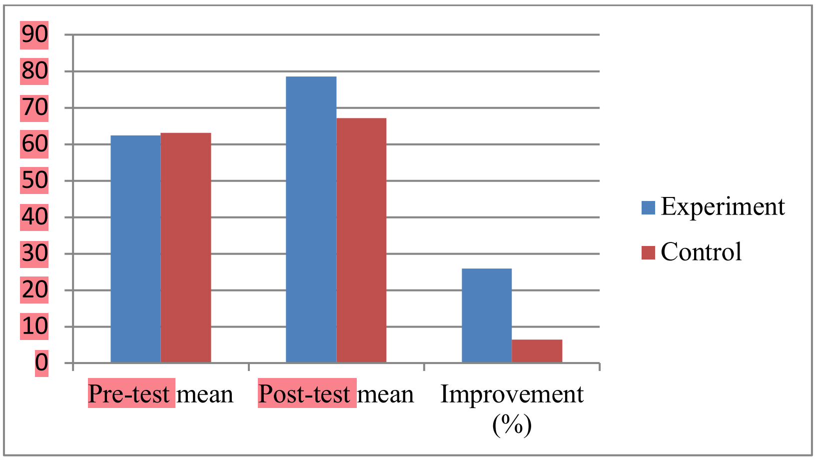


Figure 1. Bar Chart of Volleyball Athletes' Hitting Performance Measured Using the Wrist-Flick Muscle Training Device.

The paired sample t-test results showed a significant improvement in volleyball hitting performance in the experimental group, whereas the control group did not exhibit any significant increase. Thus, the use of the wrist-flick training device was proven to be more effective than conventional training methods.

In addition to improved test results, movement technique observations indicated enhancements in the athletes' wrist biomechanics, namely: a more stable flexion–extension angle during ball contact, faster and more controlled flicking motion, and easier ball direction control through precise hand rotation. Coaches also reported that athletes appeared more focused on hand movements during training, and the adaptation period to the device lasted only during the first two training sessions.

Before conducting hypothesis testing, the data were first subjected to assumption tests, including normality and homogeneity tests. Normality was assessed using the Shapiro–Wilk test to determine whether the data were normally distributed. The results showed that all pre-test and post-test data for both groups had significance values (p) > 0.05. Therefore, it can be concluded that the data were normally distributed and met the requirements for parametric analysis.

Homogeneity of variances was tested using Levene's Test, which yielded a significance value of $p = 0.312$ ($p > 0.05$), indicating that the variances of the two groups were homogeneous. With the assumptions of normality and homogeneity satisfied, the analysis could proceed using the parametric independent sample t-test.

Table 4. Results of the paired sample t-test

Group	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)	Interpretation
Experiment	16.20	5.34	11.74	14	0.000*	Significant
Control	4.10	6.02	1.98	14	0.071	Not Significant

The paired sample t-test results indicated that the experimental group experienced a significant improvement ($p < 0.05$), whereas the control group did not show a significant increase ($p > 0.05$).

To examine the difference in improvement between the experimental and control groups, an independent sample t-test was conducted on the gain scores (post-test minus pre-test). The results showed a significance value of $p = 0.001$ ($p < 0.05$), indicating a significant difference in hitting performance improvement between the experimental and control groups. Thus, the use of the wrist-flick training device was proven to be more effective than conventional training methods.

To determine the magnitude of the device's effect on hitting performance improvement, the effect size was calculated using Cohen's d. The calculation yielded a value of Cohen's d = 1.20. According to Cohen's criteria—0.20 = small, 0.50 = medium, 0.80 = large—the value of 1.20 falls into the large effect category. This indicates that the use of the wrist-flick training device had a strong impact on improving volleyball hitting ability.

In addition to quantitative test improvements, observations of movement technique revealed enhancements in the wrist biomechanics of the experimental group, namely: (1) more stable flexion–extension angles during ball contact, (2) faster and more controlled flicking motion, and (3) easier ball direction control through precise hand rotation. Coaches also reported that athletes were more focused on hand movements during training and were able to adapt to the device within the first two training sessions.

Based on the effectiveness test results and field feedback, the final product was refined as follows: (1) adjustment of the elastic cord length to be more flexible (25–35 cm), (2) addition of a logo and safety instructions, and (3) covering metal components with protective rubber. The final product, named the Wrist-Flick Muscle Training Device for Volleyball (WMFT-Volly), is ready for use.

Based on expert validation (86.94%), user responses (84.99%), and effectiveness testing ($p < 0.05$), the wrist-flick training device was concluded to be: (1) Feasible for use in volleyball training, (2) Practical for implementation by coaches and athletes, and (3) Effective in improving volleyball hitting performance through enhanced wrist strength and control.

These results reinforce that the development of movement-specific training devices can serve as an innovative approach in sports technique training, particularly in volleyball. The final product was designated as the Wrist-Flick Muscle Training Device for Volleyball (WMFT-Volly).

Discussion

The study results demonstrated that the use of the Wrist-Flick Muscle Training Device for Volleyball (WMFT-Volly) led to a significant improvement in volleyball hitting performance in the experimental group compared to the control group. This was confirmed by a paired sample t-test, which showed a significant increase in the experimental group ($p < 0.05$), while the control group did not show a significant improvement ($p > 0.05$). Furthermore, an independent sample t-test on the gain scores revealed a significant difference in improvement between the two groups ($p = 0.001$). The magnitude of the device's effect was further supported by the effect size value (Cohen's d = 1.20), classified as large. Therefore, both statistically and practically, the developed device proved to be effective in enhancing volleyball hitting performance.

From a biomechanical perspective, these findings align with studies showing that wrist flexion–extension movements are a critical component of the kinetic chain in overhead volleyball strikes Ozawa et al. (2021); Wissam et al. (2025). The study *Biomechanical Analysis of Volleyball Overhead Pass* found that skilled athletes utilize the stretch-shortening cycle (SSC) of the wrist flexor muscles during the 'pull' phase before ball contact, releasing the stored elastic energy during the 'push' phase. Therefore, the development of a training device that specifically targets the wrist-flick motion can provide mechanical stimulation that matches the demands of volleyball striking techniques (Ozawa et al., 2021). This mechanism allows for more efficient energy transfer from proximal to distal segments (Kumar & Kumar, 2020). Accordingly, a device that specifically trains the wrist-flick movement offers mechanically relevant stimulation for improving volleyball hitting performance.

The developed device emphasizes the “flick” or rapid wrist movement, aligning with the concept that the wrist joint absorbs and releases energy within a very short interval for example, studies have reported that the hand–ball contact time lasts only approximately 0.006–0.010 seconds (Engstrom; & Vint, 2000). This is supported by the study *Kinematics of Wrist Joint Flexion in Overarm Throws Made by Skilled Subjects* by Debicki et al., (2004) which demonstrated that during overarm throwing movements, higher throwing velocities were achieved while wrist flexion amplitude remained relatively constant (~27°), whereas flexion velocity increased significantly. Within this very short time interval, the wrist functions to both absorb and release energy explosively. In other words, increasing the wrist’s angular velocity is more critical than merely expanding its range of motion. Skilled athletes rely more on increasing wrist movement speed rather than simply enlarging the range of motion (Debicki et al., 2004). In addition, the device also enhances athletes’ engagement and motivation in performing the movement Effendi et al. (2023); Suhairi and Arifin (2024); Supriatna and Suhairi (2021) Therefore, the developed wrist-flick training device is able to facilitate adaptations in wrist movement speed and mechanical control rather than merely increasing the range of motion. These findings indicate that skilled athletes depend more on improving wrist movement speed than simply increasing wrist flexibility. In the context of this study, the WMFT-Volly provides elastic resistance that stimulates improvements in wrist movement speed and mechanical control rather than merely enhancing flexibility. This is consistent with observations in the experimental group, which demonstrated flicking movements that were faster, more stable, and better controlled.

In practical application to volleyball, the study The Relationship Between Wrist Flexion and Leg Muscle Explosive Power Against Volleyball Smash Ability demonstrated a connection between wrist flexion and leg explosive power in relation to smash performance. This means that the wrist is an integral part of the movement system. However, research by Sistiasih et al., (2024), states that wrist strength alone is not sufficient to significantly increase serve or smash velocity without the involvement of full-body technique and coordination. Similar findings were also reported by Aka et al., (2019), in the study *The Relationship of Wrist and Shoulder Joint Isokinetic Strength and Service and Spike Velocity in Elite Female Volleyball Players*, which showed that there was no significant correlation between wrist isokinetic strength alone and serve/spike velocity, but there was a relationship with shoulder strength. This emphasizes that the contribution of the wrist is complementary within the kinetic chain, rather than being the sole determinant of performance (Chu; et al., 2018). Mastery of these skills depends on careful planning and the coordination of all efforts to achieve success (Sakhi, 2026).

Thus, the results of this study demonstrate that the WMFT-Volly is effective in enhancing specific wrist-flick movements, particularly by increasing angular velocity and distal mechanical control. However, to achieve maximal impact on serve and spike performance, the use of this device should be integrated with comprehensive technical training, including strengthening of the shoulders, arms, core, and leg explosive power.

Overall, these findings reinforce the concept that specific movement-based training with elastic resistance can enhance neuromuscular adaptations relevant to sport-specific techniques. Supported by statistical results that meet normality and homogeneity assumptions, show significant differences between groups, and exhibit a large effect size, the WMFT-Volly can be recommended as an innovative training tool in volleyball technique programs, particularly for optimizing wrist-flick control and speed.

Conclusions

This study aimed to develop and test the effectiveness of the Wrist-Flick Muscle Training Device for Volleyball (WMFT-Volly) as an aid for volleyball hitting technique training. Based on expert validation results (86.94%; categorized as highly feasible), user responses (84.99%; categorized as highly practical), and effectiveness testing using a pretest–posttest control group experimental design, the developed device was proven to be feasible, practical, and effective. Statistical analysis indicated that the data met normality (Shapiro–Wilk) and homogeneity (Levene) assumptions, and there was a significant difference in improvement between the experimental and control groups ($p < 0.05$). The effect size value (Cohen's $d = 1.20$), classified as large, indicates that the intervention had a substantial impact on enhancing volleyball hitting performance.

Conceptually and biomechanically, these findings confirm that wrist flexion–extension and flick movements are critical components of the kinetic chain in volleyball strikes, particularly in overhead serves and smashes. Specific training that stimulates angular velocity and mechanical control of the wrist has been shown to enhance both hitting speed and accuracy. Therefore, this study reinforces the argument that targeted training of distal segments (the wrist) is a relevant and effective strategy for developing modern volleyball technique. Nevertheless, volleyball hitting is a complex movement that involves the integration of leg strength, core stability, shoulder–arm coordination, and precise ball contact timing. Therefore, the use of the WMFT-Volly is not recommended as a standalone training tool but should be integrated into a comprehensive training program that addresses strength, coordination, and technique holistically. This integrative approach is expected to maximize transfer of training effects to match performance. Practically, the developed device can be recommended as an innovative, cost-effective, and easily applicable training aid for various development levels, from beginner to advanced athletes, including in physical education classes and extracurricular activities.

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Conflict of interest

If the authors have any conflicts of interest to declare.

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