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Methodology of Assessment of Athletes' Jumping Skills Using Electronic Equipment

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Abstract

Background and Study Aim. Vertical jump performance is a critical factor in volleyball, significantly influencing actions like spiking, blocking, and serving. Accurate assessment of jump height is essential for optimizing training strategies, especially at the elite level. **Purpose:** The aim of this study was to evaluate the validity and reliability of a novel computerized diagnostic equipment (CDE-A, Patent No. 001144) designed for precise measurement of vertical jump height in volleyball players.

Material and methods. The study involved the development and validation of the CDE-A system to assess vertical jump performance. Participants included elite volleyball players from the Uzbekistan national team, various club teams, and students from the State University of Physical Education and Sports of Uzbekistan. The system's accuracy and reliability were tested through rigorous procedures, including data storage and analysis capabilities for maximum jump height and functional performance. The research involved developing and testing a specialized device (CDE-A) to evaluate elite volleyball players' vertical jump capabilities. Participants included 18 athletes aged 13–14, 16 athletes aged 15–16, and 50 students from the Uzbekistan State University of Physical Education and Sports. Measurements were conducted across age groups and educational levels. A pedagogical experiment compared traditional training (control group, CG) with specialized exercises for agility and jumping endurance (experimental group, EG).

Results. The CDE-A device demonstrated high reliability and precision in measuring vertical jump height. Key features include the capability to store maximal jump data in computer memory and analyze its functional significance for training and performance evaluation. The device enables coaches to monitor and enhance athletes' jump performance with greater efficiency and accuracy.

Conclusions. This research highlights the utility of the CDE-A system for assessing and improving vertical jump capabilities in volleyball players across all age groups. The study underscores its potential to revolutionize training methodologies by providing coaches with reliable, evidence-based insights into athletes' performance. The findings offer a foundation for further advancements in jump height measurement technologies and their application in sports science. This study establishes the CDE-A as a valuable tool for sports performance evaluation, with implications extending to volleyball and other sports requiring explosive jump abilities.

Key words: computerized diagnostic equipment, vertical jumping, test construction, reproducibility, jumping abilities, position differences.

Анотація

Методика оцінки стрибкової підготовки спортсменів із застосуванням електронного обладнання

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Передумови та мета дослідження. Вертикальні стрибки є критично важливим фактором у волейболі, суттєво впливаючи на такі дії, як напад, блокування та подача. Точна оцінка висоти стрибка має значення для оптимізації стратегій тренувань, особливо на елітному рівні. Мета: метою даного дослідження була оцінка валідності та надійності нового комп'ютерного діагностичного обладнання (CDE-A, патент № 001144), призначеного для точного вимірювання висоти вертикального стрибка у волейболістів.

Матеріал і методи. Дослідження включало розробку та валідацію системи CDE-A для оцінки вертикальних стрибків. Учасниками були елітні волейболісти з національної збірної Узбекистану, різних клубних команд та студенти Державного університету фізичної культури та спорту Узбекистану. Точність та надійність системи були перевірені за допомогою суворих процедур, включаючи можливості зберігання та аналізу даних для максимальної висоти стрибка та функціональної продуктивності. Дослідження включало розробку та тестування спеціалізованого пристрою (CDE-A) для оцінки вертикальних стрибкових можливостей елітних волейболістів. Учасниками були 18 спортсменів віком 13–14 років, 16 спортсменів віком 15–16 років та 50 студентів Узбецького державного університету фізичної культури та спорту. Вимірювання проводилися за віковими групами та рівнями освіти. Педагогічний експеримент порівнював традиційне тренування (контрольна група, КГ) зі спеціалізованими вправами на спритність та витривалість у стрибках (експериментальна група, ЕГ).

Результати. Пристрій CDE-A продемонстрував високу надійність та точність при вимірюванні висоти вертикального стрибка. До основних функцій відноситься можливість зберігати дані про максимальний стрибок у пам'яті комп'ютера та аналізувати їх функціональну значущість для навчання та оцінки результатів. Пристрій дозволяє тренерам контролювати та покращувати результати стрибків спортсменів з більшою ефективністю та точністю.

Висновки. Це дослідження наголошує на корисності системи CDE-A для оцінки та поліпшення можливостей вертикального стрибка у волейболістів усіх вікових груп. Дослідження наголошує на потенціал для революційних змін у методологіях навчання, надаючи тренерам надійні, засновані на фактичних даних відомості про результати спортсменів. Результати пропонують основу для подальшого розвитку технологій вимірювання висоти стрибка та їх застосування у спортивній науці. Це дослідження встановлює CDE-A як цінний інструмент для оцінки спортивних результатів з наслідками, що поширюються на волейбол та інші види спорту, що вимагають вибухових стрибкових здібностей.

Ключові слова: комп'ютеризоване діагностичне обладнання, вертикальні стрибки, побудова тесту, відтворюваність, стрибкові здібності, відмінності у положенні.

Introduction

Volleyball is an intermittent sport, characterized by alternating periods of intense activity and brief recovery. It requires a blend of technical, tactical, and physical skills, with explosive movements such as vertical jumps, powerful strikes, and rapid directional changes being essential for success [1]. The vertical jump is critical in volleyball, particularly for actions like spiking, blocking, and executing various serves [3]. According to Ashby and Heegaard, jumping involves intricate coordination between the upper and lower body, making it a fundamental human movement [2]. As noted by Lidor and Ziv, evaluating and improving vertical jump capabilities is essential for athletes to excel in higher levels of competition [4]. Thus, vertical jump performance is a key focus for both coaches and players [5].

In light of the importance of vertical jump performance, there has been increased interest in strength and neuromuscular training interventions aimed at enhancing the capabilities of developing athletes [6,7]. This has driven the demand for cost-effective, accessible, and reliable tools for assessing performance before and after training interventions [8]. Research has compared the vertical jump heights measured with gold-standard tools, like force platforms, against those derived from more practical field-based methods, such as mobile devices [9–13], high-speed video analysis [14], and linear position transducers [15]. These studies generally show that field-based tools can reliably assess countermovement jump (CMJ) and drop jump (DJ) heights, demonstrating strong agreement with gold-standard instruments [8].

The standing long jump (SLJ) test is another commonly used method to assess explosive lower-limb strength. It provides a straightforward and reliable measure of muscle power [16] and requires minimal equipment, with the jump distance measured using a standard measuring tape [17]. Given its simplicity and ease of use, SLJ is widely employed in sports testing.

Recent advancements in wearable technology have further transformed the monitoring and measurement of training loads in both practice and competition [18]. These tools, which incorporate magnetometers, gyroscopes, and accelerometers, offer precise quantification of performance metrics, without significant interference with athletic movement. Compact, affordable sensors now allow athletes to monitor various aspects of their performance, and wearable devices can be easily attached to different body regions, such as the arms, waist, or quadriceps [19,20].

Despite the growing body of literature on jump-related parameters, research focusing specifically on wearable technologies in volleyball remains limited. While recent reviews highlight the increasing use of wearable devices, video analysis systems, and training software in volleyball, a comprehensive evaluation of these technologies and their application in volleyball performance assessment is still lacking. This gap necessitates further research to inform coaches and researchers about the variables and instruments used to monitor, evaluate, and improve volleyball performance.

Vertical jump performance assessments involve various testing protocols and measurement tools, including force platforms, video systems, contact mats, and photoelectric cells. These tests measure different jump modalities (e.g., squat jumps, CMJs, DJ, and repeated jumps) and employ performance calculations like vertical take-off velocity, flight time, mechanical power output, and body center of mass displacement [21]. However, limited attention has been given to positional differences in jumping ability within volleyball-specific research.

Hypothesis. This study hypothesizes that systematic training and positional demands in volleyball will result in observable differences in vertical jump performance across player positions. Additionally, it is expected that there will be anthropometric variations among players in different positions due to selection criteria.

The primary objectives of this research are to: The aim of this study was to evaluate the validity and reliability of a novel computerized diagnostic equipment designed for precise measurement of vertical jump height in volleyball players.

Materials and Methods

Participants

This study was conducted between September 2021 and June 2022, involving 18 participants aged 13–14, 16 participants aged 15–16, and 50 students and athletes from the Uzbekistan State University of Physical Education and Sports. Among them were elite volleyball players who were also students enrolled in pedagogical skill improvement groups. Each group of volleyball players was examined three times, resulting in the following number of measurements: 13–14-year-old volleyball players: n = 54; 15–16-year-old volleyball players: n=48; 1st-year volleyball players: n=36; 2nd-year volleyball players: n=39; 3rd-year volleyball players: n=33; 4th-year volleyball players: n=42.

Procedure

The pedagogical experiment spanned from September 2022 to June 2023. It included skilled volleyball players divided into 13 control (CG) and 13 experimental (EG) groups, each matched in physical and technical–tactical training. Both groups included students. The CG underwent traditional training during the specified period. In contrast, the EG incorporated specialized exercises and movement games to enhance agility and jumping endurance, which were conducted independently every morning in addition to regular training sessions.

All experiments were structured into four stages. During the 1st stage (January–June 2020), bibliographic sources, regulatory and legal documents, and statistical data pertinent to the selected topic were studied and comparatively analyzed. Additionally, visual observations of training sessions involving young and elite volleyball players, in-depth examination of their experience, official pedagogical observations, interviews with elite volleyball players–students and teachers–coaches, and surveys were conducted.

The 2nd stage (September 2020–June 2021) involved 13–14 and 15–16-year-old volleyball players from children's and youth sports schools and students from the Uzbek State University of Physical Education and Sports engaged in developing their sports pedagogical skills. Traditional tests designed to assess jumping height or jumping endurance were selected. A pedagogical experiment plan was devised during the 3rd stage (September 2021–June 2022), and CGs and EGs were identified and organized. According to the plan, research was conducted twice in both groups—before and after the experiment. The results obtained during the 4th stage (July–December 2022) were compared using mathematical statistical methods in a classified and grouped manner. Subsequently, articles and theses were published based on the research findings, and practical recommendations were formulated and implemented in educational processes.

Evaluation of vertical jump abilities using computerized electronic measuring equipment

The objective was to use computer software-based electronic measuring equipment to estimate vertical jump height. This includes presenting a schematic view of the measuring equipment (depicted in Figure 1), providing its technical specifications, and outlining the procedure for its use.

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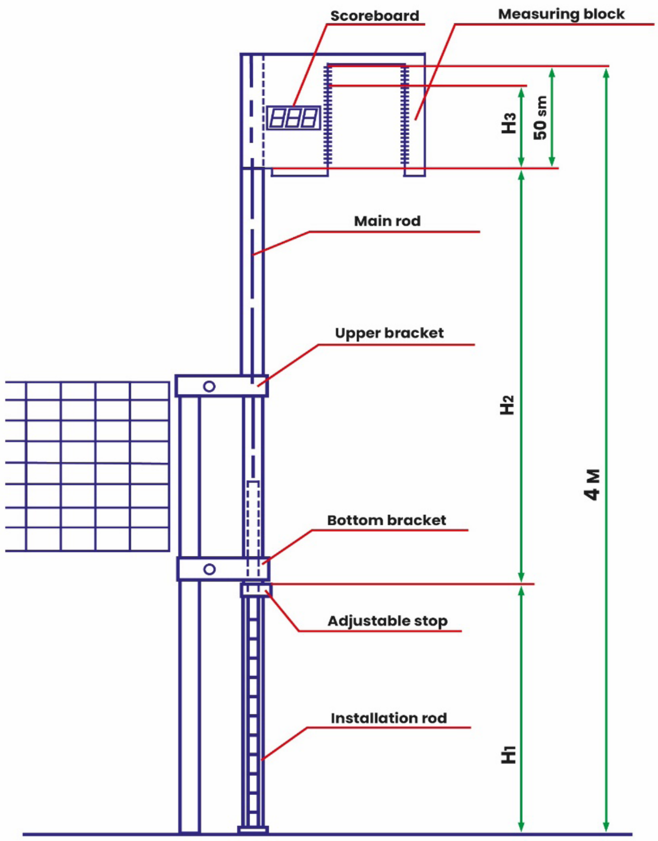

Figure 1. Schematic diagram of the measuring equipment

Technical specifications of the equipment include the following components:

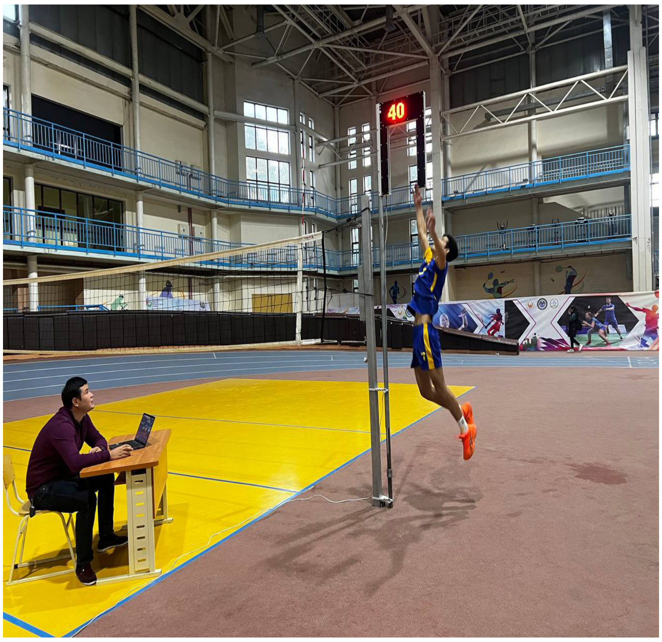

Figure 2. Vertical jumping

- The main bar positioned parallel to the volleyball post
- Lower and upper brackets for support
- Electronic display board for information presentation
- Height adjustment mechanism
- Programmed mechanism for displaying and transmitting data to a computer in sensor mode.

The measuring unit comprises a rectangular sensing panel housing 2 cm 'sensor–receivers' designed to detect infrared light via photocells placed at a specific distance. These 'sensor–receivers,' positioned on the upper section of the main bar, accurately capture and transmit information regarding jump height to the computer in a sensor mode. A bracket is attached to a volleyball post. The bar measuring the height of the jump is marked in centimeters.

The operating procedure of the equipment. The absolute height of the vertical jump, denoted as NA (measured from the field surface to where the leading hand's fingers touch), is determined by the sum of the following parameters: NA = N1 + N2 + N3 (refer to the picture). Specifically, N1 represents the distance from the field surface to the boundary where the leading hand's fingers initiate the touch mode, recorded in the computer; N2 is the distance from the lower main bar's border to the photocells in the lower section of the measuring block; N3 is the distance from which the volleyball player, in a stationary position, jumps from the border of the leading hand's fingers marked along the main bar to the place where the fingers of the leading hand touch again. Relative values of vertical jump height (Nn) are displayed on both the scoreboard and computer monitor, measured in centimeters from the border of the standing hand's leading fingers to the place of touch by the leading hand's fingers. This indicator represents the vertical jump height of a volleyball player, whether from a standing or running position.

Procedure for assessing vertical jump height in volleyball players using equipment:

Ensure that volleyball players have not engaged in other physical activities (training, competitions, etc.) before the assessment to obtain the original (true) vertical jump height or agility indicator. Before evaluating vertical jump height, it is recommended that players perform brief warm-up exercises, such as "warm up". Provide the examinee with information and guidance on the technique, rules, and procedure for performing a standing or running vertical jump. Assess the height of the jump following these steps:

- **Vertical jump from a stationary position:** The test taker begins by standing in front of the equipment and aligning the fingers of the leading hand along the bracket, marked with dimensions in centimeters, on the main bar. The height is then displayed on both the scoreboard and computer monitor. Subsequently, the test taker bends his legs to an optimal angle, executes a jump with active arm movement, and reaches

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to touch the fingers of the leading hand to the measurement marks on the bracket at maximum height. Information regarding vertical jump height is displayed on the scoreboard and computer monitor and stored in memory for future reference.

- **Running and vertical jump:** After accelerating with 2–3 maximum-speed steps, the subsequent actions are performed in the same sequence as executing the vertical jump from a stationary position.

- **Jumping endurance** – evaluated in the following order:

Statistical analysis

Methods of Mathematical Processing of Results and Their Interpretation

T-Student Formula. The t-Student formula is used to calculate the t-statistic, which helps determine if there is a significant difference between the means of two groups, especially when the sample sizes are small and the population standard deviations are unknown.

Formula for the t-statistic

For two independent samples, the t-statistic is calculated using the following formula:

$$t = (\bar{X}_1 - \bar{X}_2) / (s_p \sqrt{(1/n_1 + 1/n_2)})$$

Where:

$\bar{X}_1$ = mean of the first sample

$\bar{X}_2$ = mean of the second sample

n_1 = size of the first sample

n_2 = size of the second sample

s_p = pooled standard deviation, calculated as:

$$s_p = \sqrt{[((n_1 - 1) s_1^2 + (n_2 - 1) s_2^2) / (n_1 + n_2 - 2)]}$$

Where:

s_1 = standard deviation of the first sample

s_2 = standard deviation of the second sample

Steps to Calculate t-Statistic

1. Calculate the means ($\bar{X}_1$ and $\bar{X}_2$) for both samples.

2. Calculate the standard deviations (s_1 and s_2) for both samples.

3. Calculate the pooled standard deviation (s_p).

4. Plug values into the t-statistic formula to find t.

5. Determine degrees of freedom (DF) using: $DF = n_1 + n_2 - 2$.

Results

Vertical jump abilities (standing and running vertical jump height and jump endurance) are essential in contemporary volleyball practice. However, both CG and EG displayed considerably lower performance levels compared to the officially established normative requirements and model indicators for elite volleyball players before the commencement of the experiment, as outlined in Table 1.

Table 1. **Dynamics of jumping abilities among elite volleyball players in the CG (n = 13 × 2 = 26) and EG (n = 13 × 2 = 26) during the pedagogical experiment**

Graded jumping qualities	EM	Group	At the beginning of the experiment $\bar{X}$	σ	At the end of the experiment $\bar{X}$	Σ	AG	RI	t	P
Vertical jump from place, cm.	Traditional test	CG	66.13	4.41	68.32	4.24	2.19	3.31	1.83	>0.05
		EG	66.84	4.64	71.18	4.39	4.34	6.49	3.45	<0.01
	Electronic measuring equipment	CG	68.61	5.23	71.56	5.14	2.95	4.30	2.05	<0.05
		EG	69.13	5.52	75.41	5.38	6.30	9.11	4.17	<0.001
Running vertical jump, cm.	Traditional test	CG	71.26	6.12	74.17	6.06	2.91	4.08	1.72	>0.05
		EG	70.66	6.34	76.69	6.22	6.03	8.53	3.46	<0.01
	Electronic measuring equipment	CG	74.48	5.02	76.48	4.73	2.36	3.17	1.74	>0.05
		EG	75.52	5.27	80.24	4.93	4.72	6.25	3.34	<0.01
Jumping endurance, times	Traditional test	CG	31.24	2.69	32.76	2.66	1.52	4.87	2.05	<0.05
		EG	30.79	2.76	34.16	2.78	3.37	10.95	4.39	<0.001
	Electronic measuring equipment	CG	32.51	2.47	33.91	2.42	1.40	4.31	2.06	<0.05
		EG	31.93	2.55	35.02	2.51	3.09	9.68	4.40	<0.001
					average	relative	CG	4.01	%	
							EG	8.50	%	

Note: CG – control group; EG – experimental group; GJQ – Graded jumping qualities; VJP – Vertical jump from a stationary position; RVJ – Running vertical jump; JE – Jumping endurance; TT – traditional test; EME – Electronic measuring equipment; AG – Absolute growth; RI – Relative (compared to the indicator at the beginning of the experiment) increase, %

For example, based on the research conducted on traditional tests, the vertical jump height before the experiment was determined to be 66.13 ± 4.41 cm. In comparison, the running and vertical jump height reached 71.26 ± 6.34 cm, with a maximum endurance of jumping recorded at 31.24 ± 2.69 times. Interestingly, these indicators observed in the experimental group did not significantly differ from the average indicators noted in the control group. However, by the end of the experiment, the vertical jump height in the control group showed a slight increase from 66.13 ± 4.41 to 68.32 ± 4.24 cm (with an absolute growth rate of 2.19 cm and a relative growth

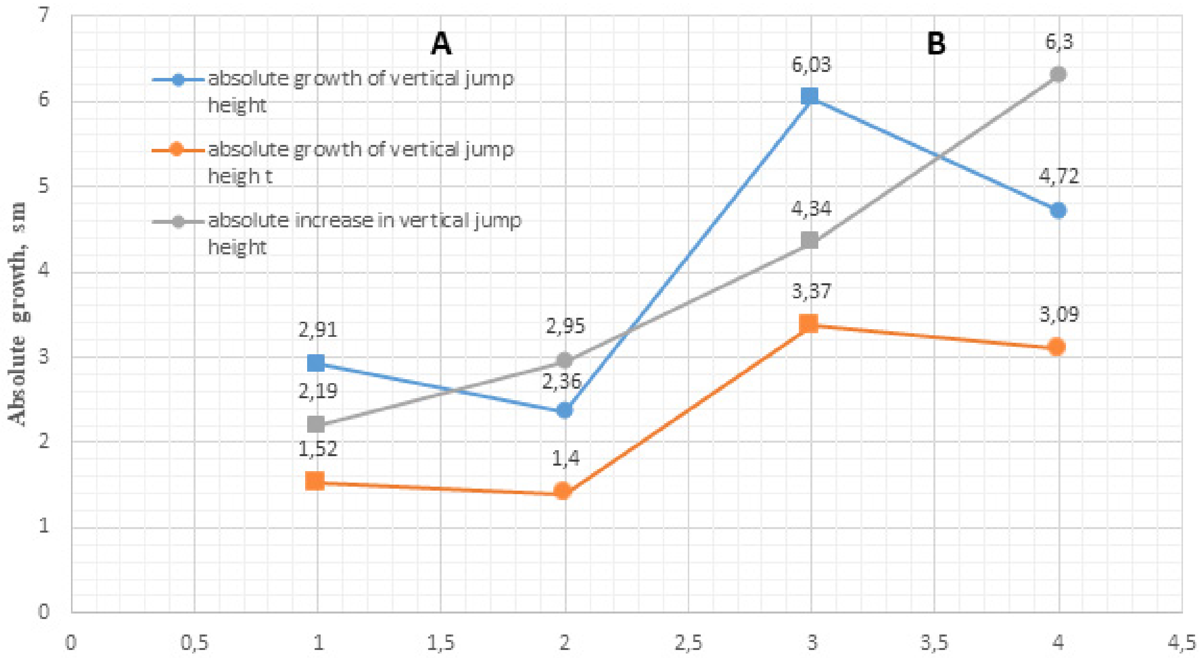

Figure 3. The absolute growth of vertical jump abilities in the CGs and EGs by the end of the experiment

Note: A – CG indicators; B – EG indicators; ■– traditional test results; ● – test results obtained using electronic measuring equipment

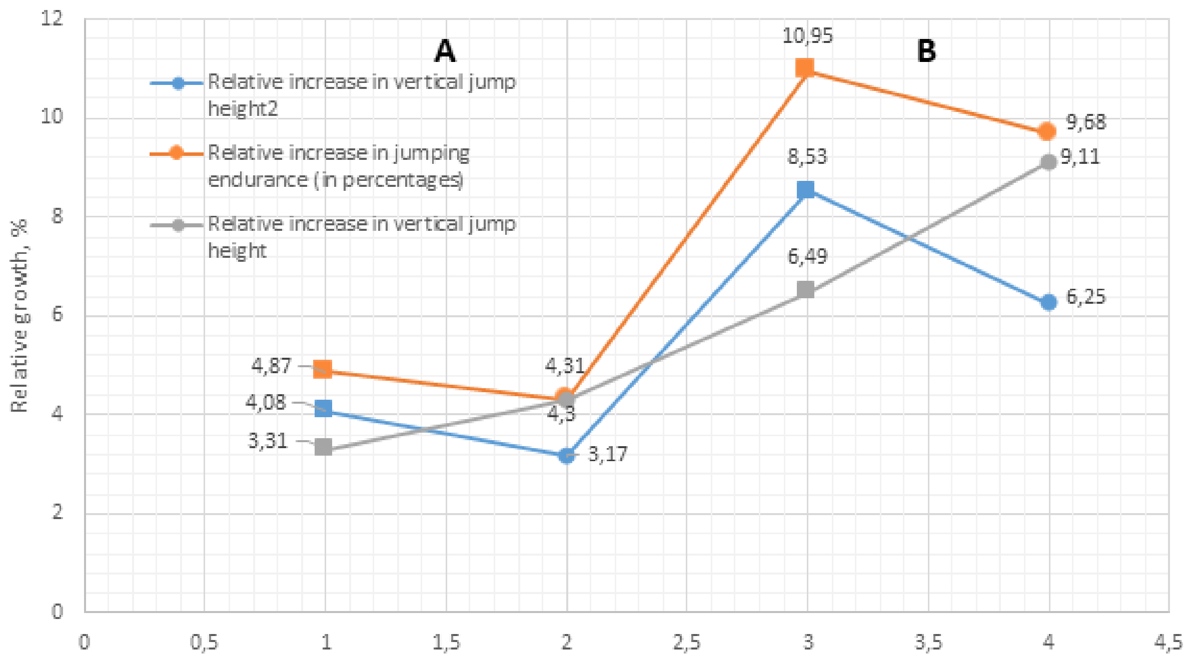

Figure 4. The relative growth of vertical jump abilities in the CGs and EGs by the end of the experiment

A – Indicators for the CG; B – Indicators for the EG; ■– indicators obtained using traditional tests; ●– indicators obtained using electronic rate of 3.31%, indicating no significant difference with p > 0.05). Similarly, the height of running and vertical jump slightly increased from 71.26 ± 6.12 to 74.17 ± 6.06 cm (with an absolute growth of 2.91 cm and a relative growth of 4.08%, also showing no significant difference with p > 0.05). However, the jump endurance only marginally increased from 31.24 ± 2.69 to 32.76 ± 2.66 times (with an absolute increase of 1.52 times and a relative increase of 4.87%, showing a significant difference with p < 0.05). In contrast, the experimental group, consistently performing the recommended experimental jump exercises, demonstrated more pronounced improvements. Their vertical jump height increased significantly from 66.84 ± 4.67 to 71.18 ± 4.39 cm (p < 0.01), with an absolute growth of 4.34 cm and a relative growth of 6.49%. Similarly, the running and vertical jump height showed a notable rise from 71.66 ± 6.34 to 76.69 ± 6.22 cm (p < 0.05), with an absolute increase of 6.03 cm and a relative growth of 8.53%. Additionally, jump endurance considerably improved, increasing from 30.79 ± 2.76 times to 34.16 ± 2.78 times (p < 0.001), with an absolute increase of 3.37 times and a relative increase of 10.95%.

The results from assessing the growth rates of standing and running vertical jump heights and jump endurance, using computerized measuring equipment during the experiment, align closely with the growth dynamics observed in corresponding indicators from traditional tests. The original accuracy indicators obtained using this equipment (before the experiment, without loading effects) range from 2.5 to 4.5 cm. Further, it was revealed that this accuracy has improved significantly. Therefore, it can be asserted that evaluating volleyball players' agility and jumping endurance through electronic measurement equipment provides objective and reliable information. Through experimental investigation, we aimed to ascertain the consistent development of standing and running vertical jump heights (jumping capacity), including jump endurance, concerning the repeated high-speed running loads typical in volleyball practice.

Under the influence of this load, the indicator was 62.14 ± 5.32 cm initially and 65.18 ± 5.3 cm by the end of the experiment (p < 0.05), indicating an absolute growth of 0.90 cm and a relative growth of 3.04%. In the EG, these indicators were as follows: before the running load—65.34 ± 5.21 cm, increasing to 71.26 ± 5.08 cm (p < 0.001) with an absolute growth of 2.20 cm and a relative growth of 5.92%; under the influence of the loading—63.27 ± 5.69 cm, increasing to 69.94 ± 5.68 cm (p < 0.001) with an absolute growth of 2.70 cm and a relative growth of 6.67%. Evaluating these indicators using electronic measuring equipment revealed trends consistent with the abovementioned dynamics in both the CGs and EGs. By the end of the experiment, it became evident that vertical jump height and jumping endurance in the experimental group, before and under the influence of the "Running in the spruce configuration," exhibited significant and steady improvement compared to the CG. The diagram in Figure 5 and the data analysis illustrate that the standing and running vertical jump heights and jumping endurance significantly increased in the EG participants, who regularly engaged in the meaningful jumping exercises developed during the experiment, even before undertaking the "Star" running. It is clear that these metrics have improved and are approaching established regulatory standards. The average relative growth rates

Table 2. **Dynamics of changes in the vertical jump height of skilled volleyball players in the CG (n = 13 × 2 = 26) and EG (n = 13 × 2 = 26) at the beginning and the end of the pedagogical experiment**

EM	RL	Group	At the beginning of the experiment		At the end of the experiment		AG	RI	t	P
			X̄	σ	X̄	σ				
Traditional test	before	CG	64.72	4.89	67.51	4.81	1.50	4.31	2.07	<0.05
		EG	65.34	5.21	71.26	5.08	2.20	9.06	4.15	<0.001
	after	CG	62.14	5.32	65.18	5.3	0.90	4.89	2.06	<0.05
		EG	63.27	5.69	69.94	5.68	2.70	10.54	4.23	<0.001
Electronic measuring equipment	before	CG	65.74	4.29	67.76	4.16	1.20	3.07	1.72	>0.05
		EG	65.13	4.54	69.34	4.24	3.60	6.46	3.46	<0.01
	after	CG	64.54	5.51	67.66	5.49	1.20	4.83	2.05	<0.05
		EG	65.18	5.86	71.97	5.86	2.70	10.42	4.18	<0.001

Note: CG – control group; EG – experimental group; EM – evaluation methodology; RL – running load; TT – traditional test; EME – Electronic measuring equipment; AG – Absolute growth; RI – Relative (compared to the indicator at the beginning of the experiment) increase, %; VJP – Vertical jump from a stationary position.

of these indicators, expressed as a percentage compared to their baseline values at the beginning of the experiment, were 9.44% ($p < 0.001$) and 8.70% ($p < 0.001$) for vertical jump height and jumping endurance, respectively.

However, the improvements in the performance of the CG participants, who continued training using traditional tools and methods during the experimental process, are lower and statistically insignificant compared to the corresponding indicators in the EG.

In modern volleyball, particularly in long 4–5 set matches or competition cycles lasting 7–8 months, maintaining jumping skills (standing and running vertical jump height and jumping endurance) under intense loads and attacking maneuvers is critical for enhancing performance efficiency. However, after a single application of this running load (average running duration of 26.9 s), this metric decreased to 66.5 ± 2.37 cm. Moreover, the vertical jump height decreased from 74.5 ± 2.81 to 71.9 ± 2.18 cm under the influence of this running load, and jumping endurance decreased from 31.7 ± 2.23 to 27.8 ± 2.03 times. These results underscore a deficiency in the jumping reserve of elite volleyball players and highlight the instability of their jumping height.

During the 10-month pedagogical study, it was observed that the vertical jump height in the CG participants, who adhered to traditional training methods, only marginally increased from 66.13 ± 4.41 to 68.32 ± 4.24 cm ($p > 0.05$), resulting in an absolute growth rate of 2.19 cm and a relative growth rate of 3.31%. Similarly, the

Table 3. **Dynamics of vertical jump height changes among elite volleyball players in the CG (n = 13 × 2 = 26) and EG (n = 13 × 2 = 26) at the beginning and end of the pedagogical experiment**

EM	RL	Group	At the beginning of the experiment		At the end of the experiment		AG	RI	t	P
			$\bar{X}$	σ	$\bar{X}$	σ				
Traditional test	before	CG	71.61	6.34	75.07	6.09	3.46	4.83	2.04	<0.05
		EG	72.36	6.48	79.93	6.49	7.57	10.46	4.21	<0.001
	after	CG	69.34	5.24	71.28	5.11	2.48	3.58	1.73	<0.05
		EG	71.56	5.73	76.69	5.47	5.39	7.53	3.48	<0.01
Electronic measuring equipment	before	CG	72.87	6.24	76.41	6.21	3.54	4.86	2.05	<0.05
		EG	72.28	6.49	79.98	6.51	7.70	10.65	4.27	<0.001
	after	CG	70.56	5.35	73.58	5.24	3.02	4.28	2.06	<0.05
		EG	71.27	5.58	77.97	5.56	6.70	9.40	4.30	<0.001

Note: CG – control group; EG – experimental group; EM – Evaluation methodology; RL – running load; TT – traditional test; EME – Electronic measuring equipment; AG – Absolute growth; RI – Relative (compared to the indicator at the beginning of the experiment) increase, %; RVJ – running vertical jump.

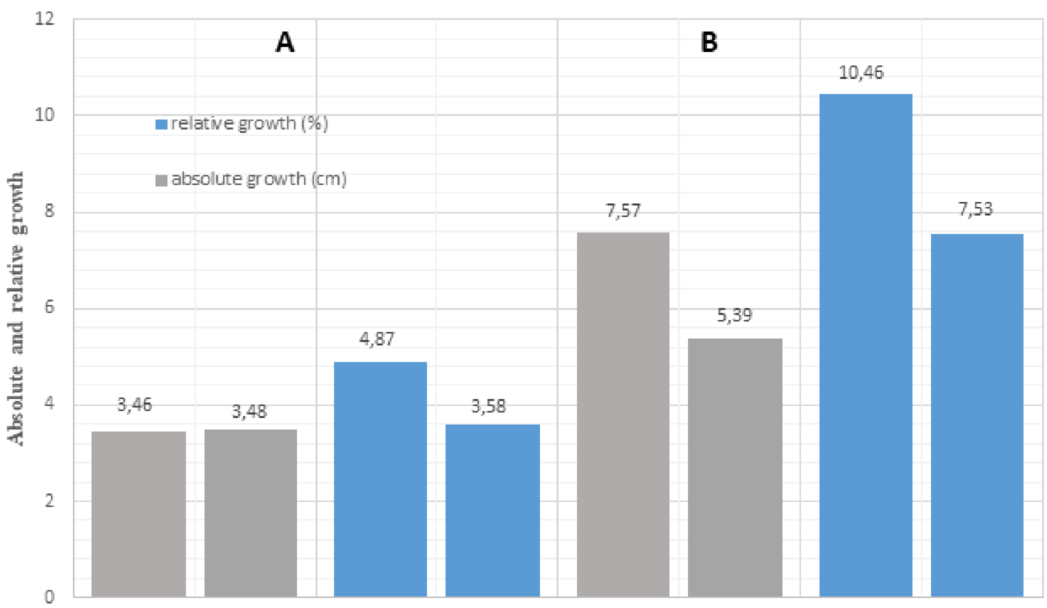

Figure 5. **Comparison of the relative growth in the mean vertical jump height among elite volleyball players in the CG (n = 13 × 2 = 26) and EG (n = 13 × 2 = 26) during the pedagogical experiment**

running and vertical jump height saw a modest increase from 71.26 ± 6.12 to 74.17 cm (absolute growth – 2.91 cm, relative growth – 4.08%; p > 0.05), while jumping endurance increased from 31.24 ± 2.69 to 32.76 ± 2.66 times (absolute increase—1.52 times, relative increase—4.87%; p < 0.05). In contrast, the EG participants, who regularly engaged in the recommended experimental jumping exercises, exhibited rapid and consistent improvements in these indicators. For instance, the vertical jump height significantly increased from 66.84 ± 4.67 to 71.18 ± 4.39 cm (absolute growth—4.34 cm, relative growth—6.49%; p < 0.01). Similarly, the running and vertical jump height increased from 70.66 ± 6.34 to 76.69 ± 6.22 cm (absolute growth—6.03 cm, relative growth—8.53%; p < 0.05), while jumping endurance increased from 30.79 ± 2.76 times to 34.16 ± 2.78 times (absolute increase—2.37 times, relative increase—10.95%; p < 0.001). Furthermore, when these indicators were evaluated using computerized measuring equipment, the results showed a 15–20% increase, suggesting the emergence of emotionally charged motivation among the athletes during the assessment of quality indicators on objective and reliable electronic measuring devices.

The findings from the investigation into the growth rate of the assessed jumping abilities under intense running loads have shed light on the potential for their sustainable development. For instance, in the EG following traditional testing under loading conditions (absolute growth—2.20 cm, relative growth—5.92%; p < 0.001). Similarly, the running vertical jump height increased from 72.38 ± 6.45 to 79.93 ± 6.49 cm (absolute growth—7.57 cm, relative growth—10.46%; p < 0.001), while jump endurance increased from 30.38 ± 2.42 to 33.79 ± 2.37 times (absolute growth – 2.91 times, relative growth – 9.58%; p < 0.001). When evaluating these indicators on electronic measuring equipment, their growth rates (before and after load) were recorded with relatively higher results. However, such positive trends were not observed in the CG participants, who adhered to traditional training methods during the experiment. For example, in this group, the absolute growth difference in standing vertical jump height was 1.5 cm, with a relative growth rate of 8.79% (p < 0.05). Similarly, the running and vertical jump height increased in terms of absolute growth by 3.46 cm and in terms of relative growth by 4.83% (p < 0.05), while jump endurance exhibited an absolute increase of 1.28 times and a relative increase of 4.33%.

When subjected to loading using 68.4-m running in the «star» configuration, the standing vertical jump height in the EG increased significantly from 64.53 ± 5.80 to 70.02 ± 5.68 cm (absolute growth—5.49 cm, relative growth—8.51%; p < 0.01). Similarly, the height of the running vertical jump increased from 70.78 ± 5.65 to 76.09 ± 5.42 cm (absolute growth—5.31 cm, relative growth—7.50%; p < 0.01), while jump endurance increased from 29.50 ± 2.65 to 32.63 ± 2.67 times (absolute growth—3.13 times, relative growth—10.61%; p < 0.001). Although the trends observed with electronic measuring equipment aligned with these dynamics, the actual indicators of learning abilities, along with their absolute and relative growth rates, were higher. Additionally, it was noted that the rate of growth of these indicators was slower in the CG. For example, the absolute growth rate of standing vertical jump height was 2.61 cm, with a relative growth difference of 4.10% (p > 0.05); the height of running and vertical jump exhibited absolute growth of 2.5 cm and relative growth of 3.57% (p > 0.05); whereas jump endurance showed an absolute increase of 1.4 cm and a relative increase of 4.85% (p < 0.05).

Many observations of traditional training methods with elite volleyball players in club and national teams, including those involved in our research, have highlighted shortcomings in exercises targeting standing and running vertical jumps, which are crucial for height and jumping endurance development. Particularly, a discrepancy is noted in exercise selection and application, their volume, intensity, and alignment with jumping game methodologies. Neglecting factors such as the angle of leg bending during jumps, coordination of arm and body movements, and the generation of inertial force during liftoff suggests a disregard for proper jumping technique. Consequently, these issues may lead to a divergence from international standard requirements, indicating inadequate agility and jumping endurance development.

Discussion

The significant improvements observed in the experimental group (EG) highlight the superiority of specialized training regimens over traditional methods. Notably, the EG exhibited an absolute increase in vertical jump height (4.34 cm, *p* < 0.01) and a remarkable relative growth in jumping endurance (10.95%, *p* < 0.001), compared to the control group (CG), whose progress was statistically insignificant in most metrics. This discrepancy underscores the inadequacy of conventional training methods in addressing the dynamic and multi-faceted demands of modern volleyball, a sport characterized by rapid transitions and sustained high-intensity play (Borràs et al., 2011). The results align with prior research indicating that sport-specific training tailored to biomechanical and physiological demands yields superior outcomes (Sattler et al., 2012).

The structured exercises employed in the experimental group not only targeted the physical attributes critical for jumping performance but also introduced an element of neuro-muscular conditioning that traditional methods lack. For instance, the exercises were designed to enhance the coordination of arm and body movements, the optimization of takeoff angles, and the generation of inertial forces, all of which are critical in achieving higher and more stable jumps. Such an approach echoes findings by Ashby and Heegaard (2002), who emphasized the integration of biomechanical principles to maximize jump efficiency.

Moreover, the rapid and sustained improvements in jumping endurance among EG participants suggest that the inclusion of high-intensity interval jumping drills effectively simulates competitive conditions. This strategy appears to mitigate fatigue-induced declines in performance, a common challenge in extended matches or prolonged competition cycles (Bergeron et al., 2015).

The modest progress observed in the CG participants reflects the limitations of traditional training, which often fails to address the specific performance needs of elite volleyball players. The results reveal inadequacies in exercise intensity, volume, and specificity, which are critical for developing explosive power and endurance. For instance, the CG's absolute increase in running vertical jump height (2.91 cm) and relative improvement in jumping endurance (4.87%, $p < 0.05$) were significantly lower than the gains in the EG. These results support findings by Lidor and Ziv (2010), who highlighted the need for volleyball training to evolve beyond general fitness exercises to incorporate targeted skill development.

Additionally, traditional training often neglects technical refinements, such as optimal knee flexion angles and coordinated arm swing during jumps. These deficiencies contribute to suboptimal biomechanical efficiency and hinder the development of maximal jump height and endurance. This observation aligns with Forthomme et al. (2017), who reported that technical execution is a key determinant of jumping performance in volleyball.

The integration of CDE in assessing jumping performance introduced a level of precision and objectivity absent in traditional methods. The observed 15–20% higher sensitivity in detecting improvements highlights the transformative potential of technology in sports science. By providing real-time feedback and reliable data storage, CDE facilitates a more nuanced understanding of athletes' performance dynamics, aligning with the findings of Balsalobre-Fernández et al. (2015) and Camomilla et al. (2018). Moreover, the motivational boost observed in EG athletes during CDE assessments suggests that the psychological benefits of objective feedback should not be underestimated.

The results have profound implications for long-term athlete development frameworks. Incorporating experimental training methods and advanced diagnostic tools can enhance not only jumping performance but also broader athletic attributes, such as agility, power, and resilience to fatigue. These insights align with the International Olympic Committee's consensus on youth athletic development, which advocates for evidence-based, individualized training approaches (Lloyd et al., 2016).

Furthermore, the significant improvements in the EG under intense running loads suggest that the training regimen effectively develops a "jumping reserve," crucial for maintaining performance under competitive conditions. This finding is particularly relevant for volleyball, where players must repeatedly execute high-intensity jumps over prolonged periods (Bartlett et al., 2017).

While this study provides compelling evidence for the efficacy of experimental training, it is not without limitations. The sample size and the specific demographic focus on elite volleyball players may limit the generalizability of the findings to other sports or competition levels. Future research should explore the applicability of these methods across diverse athletic populations and age groups.

Additionally, the study did not examine the long-term retention of performance improvements or their impact on match outcomes. Longitudinal studies investigating the sustainability of these gains and their correlation with game-specific metrics, such as spike velocity and block success rates, would provide a more comprehensive understanding.

Conclusion

Utilizing dependable tools like computerized diagnostic equipment (CDE) outside the sports laboratory setting is crucial for acquiring real-time performance variables. In conclusion, it is suggested that the CDE employed in this study be leveraged to measure and track changes in vertical jump performance among athletes over time. However, it is essential to exercise caution when reporting and interpreting jump heights obtained from different measurement systems.

In addition to traditional testing methods, it is recommended to incorporate computerized measuring equipment capable of providing objective and reliable data and storing it for reference. This approach proves invaluable when assessing the speed of development in jumping skills, including standing and running jump height and jumping endurance. These insights can greatly assist coaches and trainers seeking to effectively monitor their athletes' or clients' vertical jump ability in a valid and cost-effective manner.

Highlights:

The study confirms the reliability and accuracy of the CDE-A device (patent No. 001144) for measuring vertical jump height in volleyball players.

A method for storing maximal jump data and evaluating its functional significance was developed, offering insights into performance.

Specialized exercises significantly enhanced agility and vertical jump ability, as demonstrated through rigorous pre- and post-experiment measurements.

The CDE-A device is applicable to athletes at all levels, supporting personalized training to optimize jump performance.

The study utilized advanced statistical methods to validate findings and provide actionable recommendations for enhancing training strategies.

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Supplementary Information

Article details

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Conflict of interest
The authors declare that there is no conflict of interest.

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