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Original Article

A 10-WEEK LARGE LANGUAGE MODEL-GENERATED (LLM) VERSUS HUMAN-MADE VOLLEYBALL TRAINING PROGRAM ON THE JUMPING PERFORMANCE OF COLLEGIATE VOLLEYBALL ATHLETES

UM PROGRAMA DE TREINAMENTO DE VOLEIBOL DE 10 SEMANAS GERADO MODELO DE LINGUAGEM EM LARGA ESCALA (LLM) VERSUS PRODUZIDO POR HUMANOS SOBRE O DESEMPENHO DE SALTO DE ATLETAS UNIVERSITÁRIOS DE VOLEIBOL

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RESUMO
O estudo comparou a eficácia de programas de treinamento de voleibol gerados por IA e por humanos na melhoria do desempenho de salto vertical e horizontal entre 43 atletas-estudantes. Os participantes foram divididos em um grupo de treinamento de voleibol gerado por IA (23 participantes) e um grupo de treinamento feito por humanos (20 participantes), cada um seguindo um programa de 10 semanas, com três sessões por semana. Os desempenhos de salto vertical e horizontal foram medidos antes e depois dos programas de treinamento usando testes de salto vertical e em distância. Testes t pareados foram usados para comparações dentro do grupo, e testes t independentes analisaram as diferenças pós-teste. O programa gerado por IA melhorou os saltos verticais e horizontais unilaterais direitos, mas não afetou significativamente os saltos bilaterais ou unilaterais esquerdos. Atletas femininas mostraram melhorias nos saltos verticais bilaterais e unilaterais direitos. O programa feito por humanos melhorou os saltos verticais bilaterais e unilaterais direitos, especialmente em mulheres, mas não afetou significativamente o desempenho do salto horizontal. O estudo concluiu que os programas gerados por IA têm potencial, mas ainda não são um substituto para programas de treinamento projetados profissionalmente. Recomenda-se mais pesquisas para expandir o estudo e incluir habilidades específicas do voleibol.
Palavras-chave: Inteligência artificial, LLM, Desempenho de salto, Voleibol.

ABSTRACT
The study compared the effectiveness of AI-generated and human-generated volleyball training programs in enhancing vertical and horizontal jumping performance among 43 student-athletes. Participants were divided into an AI-generated volleyball training group (23 participants) and a human-made training group (20 participants), each following a 10-week, three-session-per-week program. Vertical and horizontal jumping performances were measured before and after the training programs using vertical and standing broad jump tests. Paired t-tests were used for within-group comparisons, and independent t-tests analyzed post-test differences. The AI-generated program improved right unilateral vertical and horizontal jumps but did not significantly affect bilateral or left unilateral jumps. Female athletes showed improvements in bilateral and right unilateral vertical jumps. The human-made program enhanced bilateral and right unilateral vertical jumps, especially in females, but did not significantly affect horizontal jumping performance. The study concluded that AI-generated programs have potential but have yet to be a substitute for professionally designed training programs. Further research is recommended to expand the study to include volleyball-specific skills.
Keywords: Artificial intelligence, LLM, Jumping performance, Volleyball.

Introduction

Artificial intelligence (AI) involves the science and engineering of creating systems that exhibit human-like characteristics and behaviors. These systems replicate human intelligence, such as logical reasoning, learning, and problem-solving[1]. AI finds extensive application in fields like medicine[2], human biology[3], nutrition[4], and education[5]. Beyond these structured disciplines, AI also plays a significant role in social life and economic activities, contributing to solving various social problems through robotic technologies[6]. AI can even perform tasks that require empathy[7]. Despite its many applications, AI faces limitations based on the information it is provided[8]. Additionally, AI has the potential to replace human jobs[7]. While AI demonstrates remarkable capabilities across various domains, including medicine, human biology, nutrition, education, and social problem-solving, it is crucial to consider and manage its limitations and impact on human employment.

Meanwhile, jumping performance is crucial for volleyball players as it impacts essential actions like spiking, blocking, and serving. Studies show that vertical jump (VJ) performance is vital for game success and varies across playing positions, with middle blockers typically exhibiting higher jump frequencies and heights[9]. The reliability and validity of jumping tests are well-documented, showing high reliability across different playing positions[10]. Body composition significantly influences jumping ability, with better body composition leading to improved jump heights[11]. Neuromuscular performance, including upper-body horizontal power, differentiates elite from sub-elite players, with elite players generally performing better[12]. Proper training and conditioning, including specific jump training and electromyostimulation (EMS), can enhance jumping performance and prevent injuries[13]. Motor coordination, alongside jumping height and body stature, is a key factor in achieving elite status in volleyball[14]. Fatigue impacts jumping performance differently based on players' experience and conditioning, with elite players potentially showing a decline due to fatigue[15]. Coordination significantly influences spiking ability, as effective jumping allows players to reach optimal heights for successful spikes[16]. Incorporating jumping exercises into training regimens is essential for developing young volleyball players, leading to significant improvements in-game performance[17]. Continuous focus on improving jumping ability is essential for maintaining peak performance and overall game effectiveness. Jumping performance is a critical determinant of success in volleyball, influencing key actions and overall game effectiveness, making continuous improvement in this area essential for players at all levels.

Artificial intelligence (AI) exercise prescription involves using AI to create tailored training programs based on user inputs. AI-generated training programs are becoming increasingly popular in the fitness industry, leveraging neural networks and logistic regression to provide personalized recommendations[18] through methods like evolutionary computation and swarm intelligence[19]. These programs have been shown to effectively improve leg power, agility, vertical pulling movements, and squat movement[20]. They can generate highly specific training regimens that enhance physical fitness[21] and can simulate opponents by mimicking fundamental athletic movements, thereby improving training quality[22]. Additionally, AI can offer feedback on movement patterns during weight training[23]. Research indicates that AI-generated training programs from ChatGPT 3.5 and ChatGPT 4.0 are equally effective across genders and can be used for training with human supervision[24]Also, an Artificial Intelligence-generated calisthenics training program was found to be effective in improving flexibility and muscular endurance[24]. However, it is also argued that AI in exercise prescription should be a supplementary tool and cannot replace personalized, progressive, and health condition-specific training programs provided by healthcare and fitness professionals[25]. Consequently, studies have developed AI systems to support professionals in exercise prescription for therapeutic purposes[26,27]. While AI-generated training programs offer efficient and effective fitness solutions and can mimic natural athletic movements, they should complement, not replace, the personalized guidance of healthcare and fitness professionals.

Integrating AI into sports training represented an innovative approach to optimizing athletic performance, particularly in volleyball, where jumping ability was crucial. Given AI's ability to replicate human intelligence and provide tailored recommendations, its application in exercise prescription rapidly gained traction in the fitness industry. In the context of volleyball, where vertical jump performance significantly impacted essential actions like spiking, blocking, and serving, AI-generated training programs offered substantial benefits. These programs not only improved key physical attributes such as leg power and agility but also demonstrated how AI can be utilized in volleyball training. However, it was important to evaluate the effectiveness of AI-generated training programs against traditional training methods to determine which approach yielded superior results. This study aimed to investigate the effect of a 10-week AI-generated volleyball training program on jumping performance, specifically in terms of both vertical and horizontal jumping. Additionally, it examined the impact of an adopted volleyball training program. A comparative analysis was conducted between AI-generated and human-generated volleyball training programs regarding their effectiveness in improving the aforementioned jumping performance components. Finally, the study employed a sex-specific approach to investigate the relationships between the independent and dependent variables.

Methods

Design

The study utilized a quasi-experimental design. Specifically, it used a group pretest-post-test design on the within-group comparison. As for the between-group comparison, a two-group pretest-posttest design was utilized. The experimental design was implemented to fully understand the causal relationship between the independent variables (Human-made and Artificial Intelligence Volleyball training programs) and dependent variables (horizontal and vertical jumping performance).

Sample

The study's participants were 43 collegiate student-athletes selected using a purposive sampling. The inclusion criteria were set, which are (1) a bonafide student of the locale of the study, (2) having formal or habitual volleyball training, and (3) having no medical issues that can be worsened or triggered by moderate to vigorous activity. Table 1 shows the distribution of the participants based on group and sex. The Artificial Intelligence-Generated Volleyball training program group (AIGVTP) was the group that administered the 10-week Artificial Intelligence-generated volleyball training program. The said training program was generated using ChatGPT 3.5. The group comprises 12 females, who constitute 27.91% of the participants. There are 11 male participants, making up 25.58% of the participants. In total, the group consists of 53.48% of the AIGVTP group. The Human-made Volleyball Training Program group (HMVTP) was administered by an adopted volleyball training program from a study. This group had the remaining 46.51% of the participants, comprising 20 members. Female participants comprised 10, which is 23.26% of the participants. Male participants also comprised 10, making up 23.26% of the participants. The HMVTP group comprises 46.51% of the participants, with 20 participants. The study had a total of 43 participants.

Table 1. Distribution of sex of the participants per group

	Female	**Male**	**Total**
AIGVTP	12(27.91%)	11(25.58%)	23(53.48%)
HMVTP	10(23.26%)	10(23.26%)	20(46.51%)
TOTAL	22(51.16%)	21(48.84%)	43(100%)

Source: Authors

Table 2 shows the body composition of both groups. The AIGCTP group had a mean height of 174.97±6.61 cm and a mean weight of 63.91±9.70 kg. In totality, the body mass index of the group was 23.79±3.56. On the other hand, the HMCTP group had a mean height of 174.51±6.08 cm and a mean weight of 66.63±10.88 kg. This constitutes the mean body mass index of 24.91±4.21. Despite the groupings, the participants had a mean height of 174.74±6.31

cm and a mean weight of 63.28±10.33 kg, contributing to the mean body mass index of 24.36±4.01.

Table 2. Distribution of the body composition of the participants per group

	AIGCTP	HMCTP	Total
HEIGHT	174.97±6.61	174.51±6.08	174.74±6.31
WEIGHT	63.91±9.70	66.63±10.88	63.28±10.33
BMI	23.79±3.56	24.91±4.21	24.36±4.01

Source: Authors

Instrument

Vertical jump test

As for the bilateral vertical jumping performance, the vertical jump test[28] was utilized. Mainly, it assesses the lower extremities' power in delivering simultaneous extension of the hip, knee, and ankle joints. A vertical jump test was performed using the jump and reach method. To perform the method, the participant marks the highest standing reach on a wall, then jumps as high as possible to make a second mark. The vertical jump height is determined by measuring the distance between these two marks, with the test repeated three times for accuracy. The method was used because of its practicality. However, the validity of the testing was not compromised as the method was found to be highly correlated to the motion analysis system (r=.906)[29].

Single-leg vertical jump test

As for the unilateral vertical jumping performance, a single-leg vertical jump was utilized. The test was designed to assess the functional performance of the unilateral lower extremity, focusing on strength, power, and balance[30]. It was also used as a test for the functionality of athletes post-ACL reconstruction and to determine readiness to return to sport[31]. The same as the vertical jump test, the test was done using the jump and reach method. It had the same protocol as the vertical jump test. However, the jump was done using one leg for three trials. After this, the other leg was also tested. The reliability of the test was established by having high reliability with intraclass correlation coefficients (ICC) greater than 0.85, indicating consistency in trials and sessions[32]. Also, it has a low coefficient of variation[33] and moderate-to-excellent test-retest reliability[34].

Standing broad jump test

The bilateral horizontal jumping performance was quantified using the standing broad jump test. It was a widely used valid instrument to assess leg power, involving jumping forward as far as possible from standing[35]. The participant stands behind a starting line with feet shoulder-width apart, swings their arms back and forward while bending their knees, and jumps forward as far as possible, landing on both feet. The distance from the starting line to the back of the closest heel is measured, with typically three trials conducted and the best jump recorded[36]. The instrument's reliability was established as it had an intraclass correlation coefficient of .96 for male raters and .99 for female raters[37]. Also, the test-retest reliability of the instrument was established by having r=96 among males and r=.90 for females[37]. Lastly, it can discriminate elite from non-elite athlete's horizontal jumping performance[37].

Single-leg standing broad jump test

A single-leg standing broad jump test was utilized for the unilateral variation of horizontal jumping. It was a variation of the traditional standing broad jump test[38]. However, the test was performed using one lower extremity at a time. With the non-jumping leg bent, the participant stands on one leg behind a starting line, then swings their arms and performs a countermovement jump, landing on the same leg while maintaining balance. The distance from the starting line to the heel of the landing leg is measured, with typically three trials conducted for each leg to ensure accuracy and the best jump recorded[37]. The instrument was established to have an acceptable absolute reliability with bilateral standing broad jump test on mean velocity, peak force, peak velocity, and impulse (CV range = 3.65-9.81%)[38].

Procedures

Adherence to the training programs

The participants engaged in an extensive deliberation about the training program. This entails the elucidation and exhibition of every activity integrated within the programs. In addition, participants were provided with guidelines that outlined the training requirements, including preliminary exercises, instructions on how to perform workouts, and cooldown exercises. Finally, the participants were instructed to rigorously comply with the training regimen by abstaining from all other kind of physical activity for a duration of 10 weeks. Protocols were implemented to mitigate any risks to internal validity.

Sequence of the field test administration

The study instruments were administered to the participants deliberately to avoid any cumulative impact on subsequent examinations. At first, the participants' bodies were prepared by doing a warm-up that involved exercises for the entire body and dynamic stretching. Initially, the vertical jump tests were performed. This encompassed the utilization of the vertical leap test to assess bilateral jumping ability and the single-leg vertical jump test to evaluate unilateral jumping ability. Following this, the horizontal leap tests were conducted, including the standing broad jump test for bilateral jumping and the single-leg standing broad jump test for unilateral jumping. The tests were conducted with a one-hour break between each test to guarantee complete recovery of the participants' phosphagen and anaerobic glycolytic energy systems[39,40]. Jumping necessitates a forceful utilization of strength in the lower extremities, so the phosphagen energy system was employed and this recovery period also guaranteed that subsequent tests were devoid of the cumulative impacts of the previous examinations.

Pretesting

The participants underwent the respective field tests for bilateral and unilateral vertical jumping performance and bilateral and unilateral horizontal jumping performance, following the sequence of tests religiously.

Implementation of the training programs

A day after the pretesting, the implementation of the respective volleyball training programs per group commenced. The AIGVTP group was administered by the 10-week artificial intelligence-generated Volleyball training program, created using ChatGPT 3.5. The prompt includes the specifics of the training program using the principles of frequency, intensity, time, and type. Below is the exact prompt inputted in the ChatGPT 3.5.

Prompt: Please create a 10-week volleyball training program with three times sessions per week. Each session should last for 60-90 minutes. The intensity should be tailored to increase the jumping performance of collegiate volleyball players.

Using this prompt, a training program was created. Below is the tabular version of the 10-week AI-generated Volleyball Training Program for student-athletes. Table 3 shows a comprehensive 10-week volleyball training program designed to improve vertical jump performance, strength, and overall explosive power. The program was structured into three phases: Foundation and Strength Development (Weeks 1-4), Power and Explosiveness (Weeks

5-8), and Peak Performance and Maintenance (Weeks 9-10). Each week consists of three sessions focusing on different aspects of physical conditioning and skill development.

Table 3. 10-week Artificial Intelligence-generated Volleyball Training program

		Week 1-4: Foundation and Strength Development	
Session 1	**Warm-up (15 min):** Dynamic stretching, jogging, light volleyball drills.	**Strength Training (30 min):** • Squats (3 sets of 8-10 reps) • Lunges (3 sets of 10 reps per leg) • Calf raises (3 sets of 15 reps) • Box jumps (3 sets of 5 reps, focusing on explosive power)	**Jumping Technique (15 min):** Vertical jump technique drills and form practice.
Session 2	**Warm-Up (15 min):** Dynamic stretching, agility ladder drills, short sprints.	**Plyometric Training (30 min):** • Depth jumps (3 sets of 5 reps) • Bounds (3 sets of 30 meters) • Plyometric push-ups (3 sets of 10 reps)	**Cooldown and Stretching (15 min):** Static stretching focusing on legs and core.
Session 3	**Warm-Up (15 min):** Dynamic stretching, light jogging, volleyball-specific footwork drills.	**Power Circuit (30 min):** • Medicine ball slams (3 sets of 10 reps) • Single-leg box jumps (3 sets of 5 reps per leg) • Kettlebell swings (3 sets of 15 reps)	**Core Strength (15 min):** Planks, leg raises, and rotational core exercises.
		Week 5-8: Power and Explosiveness	
Session 1	**Warm-Up (15 min):** Dynamic stretching, agility drills, short sprints.	**Explosive Power (30 min):** Power cleans (3 sets of 5 reps) • Split jumps (3 sets of 10 reps) • Depth jumps onto platform (3 sets of 5 reps)	**Jumping Technique (15 min):** Fine-tuning vertical jump mechanics.
Session 2	**Warm-Up (15 min):** Dynamic stretching, agility ladder drills, light volleyball drills.	**Plyometric Circuit (30 min):** • Box jumps (3 sets of 5 reps) • Depth drops (3 sets of 5 reps) • Hurdle hops (3 sets of 10 reps)	**Cooldown and Stretching (15 min):** Full-body stretching with focus on legs and core.
Session 3	**Warm-Up (15 min):** Dynamic stretching, light jogging, volleyball-specific footwork drills.	**Power Endurance (30 min):** • Continuous jumps (3 sets of 20 seconds) • Tuck jumps (3 sets of 10 reps) • Medicine ball rotational throws (3 sets of 10 reps each side)	**Core Stability (15 min):** Plank variations, Russian twists, and stability ball exercises.

Week 9-10: Peak Performance and Maintenance			
Session 1	**Warm-Up (15 min):** Dynamic stretching, agility drills, short sprints.	**High-Intensity Power (30 min):** • Olympic lifts (power snatch or power clean, 3 sets of 3-5 reps) • Depth jumps with reactive jumps (3 sets of 5 reps) • Continuous jumps with quick turnover (3 sets of 20 seconds)	**Jumping Technique and Cool Down (15 min):** Review of technique and thorough stretching.
Session 2	**Warm-Up (15 min):** Dynamic stretching, agility ladder drills, light volleyball drills.	**Game Simulation (45 min):** Incorporate simulated game situations focusing on explosive movements and jumps.	**Cooldown and Stretching (15 min):** Full-body stretching with emphasis on recovery.
Session 3	**Warm-Up (15 min):** Dynamic stretching, light jogging, volleyball-specific footwork drills.	**Active Recovery (45 min):** Light volleyball drills, low-intensity plyometrics, and stretching.	**End-of-Program Review (15 min):** Discuss progress, techniques learned, and future training goals.

Notes:			
Progression: Increase intensity gradually throughout the weeks to avoid overtraining.	**Rest:** Ensure adequate rest between sets and sessions to optimize recovery and performance gains.	**Nutrition and Hydration:** Emphasize proper nutrition and hydration for energy and muscle recovery.	**Monitoring:** Track progress with regular assessments of vertical jump height and overall performance.

Source: ChatGPT 3.5

On the other hand, the human-made volleyball training program was made by adopting a volleyball specific plyometric training program of a study. Initially, the training program was designed for 12 weeks. For the purpose of similarity of training duration, it was compressed into 10 weeks. The HMVTP group participated in a 10-week upper and lower extremities training program involving three sessions per week[41]. The table 4 provides a 10-week volleyball training program that focuses on both upper and lower-extremity plyometric exercises. Each week includes a set of exercises for both the upper and lower body, designed to improve explosive strength and power, which is crucial for volleyball athletes. Each session consists of carefully selected plyometric exercises that alternate between upper and lower body, ensuring a balanced development of strength and power throughout the training program.

Table 4. 10-week Human-generated Volleyball Training program adopted from Idrizovic et al.[41]

Week	Upper Extremities	Lower Extremities
Week 1	• Explosive push-ups (from knees): 5x3 • Jumping spider (from knees): 5x3 • Clapping push-ups (from knees): 5x3	• Stiff knee leg hops (2-leg): 5x5 • Maximal vertical jumps (2-leg): 5x5 • Maximal tuck jumps (2-leg): 5x5
Week 2	• Explosive medicine ball presses (1-kg med ball): 5x4	• Maximal lateral/diagonal jumps (2-leg): 5x3 • Maximal broad jumps (2-leg): 5x3

	• Alternating rotational throws (1-kg med ball): 5x4 • Explosive push-ups (from knees): 5x3	• Obstacle jumps (2-leg; 30 cm high): 5x3
Week 3	• Explosive chest passes (1-kg med ball): 5x2 • Explosive chest passes (3-kg med ball): 5x3 • Explosive overarm throws (2-handed: 1-kg med ball): 5x3	• Box jumps (2-leg; 40 cm high): 5x3 • Box shuffles (40 cm high): 5x4 • Drop jumps (2-leg; 40 cm depth): 5x3
Week 4	• Explosive push-ups (from knees): 5x3 • Jumping spider (from knees): 5x4 • Clapping push-ups (from knees): 5x3	• Drop jumps (2-leg; 60 cm depth): 5x2 • Drop jump ± max vertical jump (2-leg; 40 cm depth): 5x1 • Lateral/diagonal jumps (1-leg): 6x1
Week 5	• Explosive medicine ball presses (1-kg med ball): 5x4 • Alternating rotational throws (1-kg med ball): 5x4 • Explosive push-ups (from knees): 5x3	• Broad jumps (1-leg): 6x1 • Obstacle jumps (1-leg; 20 cm high): 6x1 • Box jumps (1-leg; 20 cm high): 6x1
Week 6	• Explosive chest passes (1-kg med ball): 6x3 • Explosive chest passes (3-kg med ball): 5x5 • Explosive overarm throws (2-handed: 1-kg med ball): 5x3	• Stiff knee leg hops (2-leg): 4x4 • Maximal vertical jumps (2-leg): 5x2 • Maximal tuck jumps (2-leg): 5x3
Week 7	• Explosive push-ups (from knees): 5x3 • Jumping spider (from knees): 5x3 • Clapping push-ups (from knees): 5x3	• Maximal broad jumps (2-leg): 5x3 • Obstacle jumps (2-leg; 30 cm high): 5x3 • Box jumps (2-leg; 40 cm high): 5x3
Week 8	• Explosive medicine ball presses (1-kg med ball): 5x4 • Alternating rotational throws (1-kg med ball): 5x4 • Explosive push-ups (from knees): 5x3	• Box shuffles (40 cm high): 5x4 • Drop jumps (2-leg; 40 cm depth): 5x3 • Drop jumps (2-leg; 60 cm depth): 5x3
Week 9	• Explosive chest passes (1-kg med ball): 5x2 • Explosive chest passes (3-kg med ball): 5x3 • Explosive overarm throws (2-handed: 1-kg med ball): 5x3	• Drop jump ± max vertical jump (2-leg; 40 cm depth): 5x1 • Lateral/diagonal jumps (1-leg): 6x1 • Broad jumps (1-leg): 6x1
Week 10	• Explosive push-ups (from knees): 5x3 • Jumping spider (from knees): 5x4 • Clapping push-ups (from knees): 5x3	• Obstacle jumps (1-leg; 20 cm high): 6x1 • Box jumps (1-leg; 20 cm high): 6x1 • Maximal broad jumps (2-leg): 5x3

Source: Idrizovic et al.[41]

Post testing

The participants underwent the same testing protocol after 48 to 72 hours of recovery. This recovery period was set in order to minimize the compounding effect of the last training session on the components that need to be measured[42].

Statistical analysis

The study utilized a paired t-test for the within-group comparison of each volleyball training program on the jumping performance. As for the between-group comparison, an independent sample t-test was used. The significance level was set to $p<.05$ for discrepancies to be categorized as significant. The statistical analysis was done using SPSS version 26. Furthermore, a normality test was not performed, since according to the Central Limit Theorem, when the sample of the study is sufficiently large ($n > 30$), the distribution of sample means approaches normality, thereby allowing the use of parametric tests. Additionally, parametric tests are robust to deviations from normality when sample sizes are large, making them appropriate for this study.

Ethical statement

The participants were given a comprehensive briefing on the study, which included a discussion about their rights within the study context. Afterwards, individuals were asked to provide informed consent by completing a consent letter. Subsequently, a Physical Readiness Questionnaire was administered to ascertain the presence of any concealed medical conditions among the subjects. To conclude, it is essential to emphasize that the acquired data was handled with utmost confidentiality and disclosed to the owner upon their request.

Results

Table 4 shows the pretest and post-test results of vertical jumping performance within the Artificial Intelligence-Generated Volleyball Training Program (AIGVTP). Interestingly, there was no significant improvement in the participants' overall bilateral vertical jumping performance (Vertical Jump test ^{pretest}=60.46±11.69, Vertical Jump test post-test=62.42±11.97, t=0.87, p=0.40). However, significant improvements were observed in the unilateral vertical jumping for the right lower extremity (Single-leg Vertical Jump test (right) ^{pretest}=48.30±11.97, Single-leg Vertical Jump test (right) $^{post\text{-}test}$=55.44±11.71, t=3.02, p=0.00). In comparison, no significant improvement was seen for the left lower extremity (Single-leg Vertical Jump test (left) ^{pretest}=51.07±14.39, Single-leg Vertical Jump test (left) post-test=56.32±11.69, t=1.59, p=0.13). Within comparison was also done with sex specificity, females showed significant improvement in the bilateral vertical jumping performance (Vertical Jump test ^{pretest}=50.01±6.41, Vertical Jump test $^{post\text{-}test}$=58.56±9.06, t=4.83, p=0.00) and the unilateral vertical jumping for the right lower extremity (Single-leg Vertical Jump test (right) ^{pretest}=47.49±11.94, Single-leg Vertical Jump test (right) $^{post\text{-}test}$=54.68±11.49, t=2.28, p=0.04), but no significant improvement in the left lower extremity (Single-leg Vertical Jump test (left) ^{pretest}=52.71±15.56, Single-leg Vertical Jump test (left) $^{post\text{-}test}$=53.30±12.48, t=0.12, p=0.90). For males, no significant improvement was found in the bilateral vertical jumping performance (Vertical Jump test ^{pretest}=70.21±4.90, Vertical Jump test $^{post\text{-}test}$=65.99±10.68, t=1.24, p=0.24) or in the unilateral vertical jumping for the right (Single-leg Vertical Jump test (right) ^{pretest}=49.06±12.36, Single-leg Vertical Jump test (right) $^{post\text{-}test}$=56.16±12.27, t=1.73, p=0.11) and left lower extremities (Single-leg Vertical Jump test (left) ^{pretest}=49.54±13.58, Single-leg Vertical Jump test (left) $^{post\text{-}test}$=59.13±10.53, t=2.05, p=0.06).

Meanwhile, the pretest and post-test results of vertical jumping performance within the Human-generated Volleyball Training Program (HGVTP). Significant improvement was observed in the participants' overall bilateral vertical jumping performance (Vertical Jump test pretest=61.12±11.71, Vertical Jump test post-test=68.18±11.79, t=2.76, p=0.02). Additionally, significant improvements were also seen in the unilateral vertical jumping for the right lower extremity (Single-leg Vertical Jump test (right) ^{pretest}=46.78±10.91, Single-leg Vertical Jump test (right) $^{post\text{-}test}$=54.28±12.49, t=2.29, p=0.04). In comparison, no significant improvement was noted for the left lower extremity (Single-leg Vertical Jump test (left) ^{pretest}=54.94±10.45, Single-leg Vertical Jump test (left) $^{post\text{-}test}$=58.30±11.40, t=1.06, p=0.30). Within comparison was also done with sex specificity, females showed significant improvement in the bilateral vertical jumping performance (Vertical Jump test ^{pretest}=50.68±6.47, Vertical Jump test $^{post\text{-}test}$=67.08±12.49, t=4.34, p=0.00). Still, no significant improvement in the unilateral vertical jumping for both the right (Single-leg Vertical Jump test (right) ^{pretest}=47.72±11.68, Single-leg Vertical Jump test (right) post-test=56.80±12.20, t=1.68, p=0.13) and left lower extremities (Single-leg Vertical Jump test (left) ^{pretest}=56.76±8.86, Single-leg Vertical Jump test (left) $^{post\text{-}test}$=58.55±12.07, t=0.44, p=0.67). For males, no significant improvement was found in the bilateral vertical jumping performance (Vertical Jump test ^{pretest}=70.86±49.61, Vertical Jump test $^{post\text{-}test}$=69.21±11.44, t=0.67, p=0.051) or in the unilateral vertical jumping for the right (Single-leg Vertical Jump test (right) ^{pretest}=45.93±10.47, Single-leg Vertical Jump test (right) $^{post\text{-}test}$=51.93±11.76, t=1.36, p=0.20) and left lower extremities (Single-leg Vertical Jump test (left) ^{pretest}=53.25±11.80, Single-leg Vertical Jump test (left) $^{post\text{-}test}$=58.07±11.16, t=0.95, p=0.35).

Table 5. Within-group comparison of AIGVTP and HGVTP on Vertical Jumping Performance

Jumping Test	Pretest	Post-test	t-value	p-value
AIGVTP				
		All		
Vertical Jump test	60.46±11.69	62.42±11.97	.87	.40
Single-leg vertical jump test (R)	48.30±11.97	55.44±11.71	3.02	.00
Single-leg vertical jump test (L)	51.07±14.39	56.32±11.69	1.59	0.13
		Female		
Vertical Jump test	50.01±6.41	58.56±9.06	4.83	.00
Single-leg vertical jump test (R)	47.49±11.94	54.68±11.49	2.28	.04
Single-leg vertical jump test (L)	52.71±15.56	53.30±12.48	.12	.9
		Male		
Vertical Jump test	70.21±4.90	65.99±10.68	1.24	.24
Single-leg vertical jump test (R)	49.06±12.36	56.16±12.27	1.73	.11
Single-leg vertical jump test (L)	49.54±13.58	59.13±10.53	2.05	.06
HGVTP				
		All		
Vertical Jump test	61.12±11.71	68.18±11.79	2.76	.02
Single-leg vertical jump test (R)	46.78±10.91	54.28±12.49	2.29	.04
Single-leg vertical jump test (L)	54.94±10.45	58.30±11.40	1.06	.30
		Female		
Vertical Jump test	50.68±6.47	67.08±12.49	4.34	.00
Single-leg vertical jump test (R)	47.72±11.68	56.80±12.20	1.68	.13
Single-leg vertical jump test (L)	56.76±8.86	58.55±12.07	.44	.67
		Male		
Vertical Jump test	70.86±49.61	69.21±11.44	.67	.051
Single-leg vertical jump test (R)	45.93±10.47	51.93±11.76	1.36	.20
Single-leg vertical jump test (L)	53.25±11.80	58.07±11.16	.95	.35

Source: Authors

Table 5 shows the pretest and post-test results of horizontal jumping performance within the Artificial Intelligence-Generated Volleyball Training Program (AIGVTP). Interestingly, there was no significant improvement in the participants' overall standing long jump performance (Standing long jump test $^{\text{pretest}}$=206.60±1.96, Standing long jump test $^{\text{post-test}}$=229.31±43.5, t=1.96, p=0.07). However, significant improvements were observed in the unilateral standing long jump for the right lower extremity (Single-leg Standing long jump test (right) $^{\text{pretest}}$=147.87±28.08, Single-leg Standing long jump test (right) $^{\text{post-test}}$=163.15±26.43, t=2.42, p=0.03). In comparison, no significant improvement was seen for the left lower extremity (Single-leg Standing long jump test (left) $^{\text{pretest}}$=144.97±28.74, Single-leg Standing long jump test (left) $^{\text{post-test}}$=158.70±29.20, t=1.92, p=0.078). A within-group comparison was also conducted with sex specificity. Females showed significant improvement in the bilateral standing long jump performance (Standing long jump test $^{\text{pretest}}$=198.34±33.06, Standing long jump test $^{\text{post-test}}$=229.47±47.48, t=2.22, p=0.05) but no significant improvement in the unilateral standing long jump for both the right (Single-leg Standing long jump test (right) $^{\text{pretest}}$=144.58±30.25, Single-leg Standing long jump test (right) $^{\text{post-test}}$=162.81±26.21, t=1.86, p=0.08) and left lower extremities (Single-leg Standing long jump test (left) $^{\text{pretest}}$=134.89±21.76, Single-leg Standing long jump test (left) $^{\text{post-test}}$=145.05±28.28, t=1.00, p=0.34). For males, no significant improvement was found in the bilateral standing long jump performance (Standing long jump test $^{\text{pretest}}$=215.45±53.67, Standing long jump test $^{\text{post-test}}$=229.14±40.64, t=0.67, p=0.51) or in the unilateral standing long jump for both the right (Single-leg Standing long jump test (right) $^{\text{pretest}}$=151.39±26.12, Single-leg Standing long jump test (right) $^{\text{post-test}}$=163.52±27.64, t=1.30, p=0.22) and left lower extremities (Single-leg Standing long jump test (left) $^{\text{pretest}}$=155.76±32.05, Single-leg Standing long jump test (left) $^{\text{post-test}}$=173.34±23.02, t=1.55, p=0.14).

Meanwhile, it also shows the pretest and post-test results of horizontal jumping performance within the Human-generated Volleyball Training Program (HGVTP). Interestingly, there was no significant improvement in the participants' overall standing long jump performance (Standing long jump test $^{\text{pretest}}$=214.33±36.96, Standing long jump test $^{\text{post-test}}$=221.87±36.67, t=0.69, p=0.50). Although there was a trend towards improvement in the unilateral standing long jump for the right lower extremity, it was not statistically significant (Single-leg Standing long jump test (right) $^{\text{pretest}}$=154.02±28.40, Single-leg Standing long jump test (right) $^{\text{post-test}}$=167.20±30.72, t=2.10, p=0.06). No significant improvement was observed for the left lower extremity (Single-leg Standing long jump test (left) $^{\text{pretest}}$=146.12±28.83, Single-leg Standing long jump test (left) $^{\text{post-test}}$=148.02±26.77, t=0.26, p=0.80). Within comparison was also done with sex specificity. Females showed no significant improvement in the bilateral standing long jump performance (Standing long jump test $^{\text{pretest}}$=206.72±37.17, Standing long jump test $^{\text{post-test}}$=212.72±39.70, t=0.36, p=0.72) or in the unilateral standing long jump for both the right (Single-leg Standing long jump test (right) $^{\text{pretest}}$=150.27±31.05, Single-leg Standing long jump test (right) $^{\text{post-test}}$=163.32±30.92, t=1.42, p=0.18) and left lower extremities (Single-leg Standing long jump test (left) $^{\text{pretest}}$=147.07±29.07, Single-leg Standing long jump test (left) $^{\text{post-test}}$=150.11±24.66, t=0.31, p=0.76). For males, no significant improvement was found in the bilateral standing long jump performance (Standing long jump test pretest=222.48±36.27, Standing long jump test $^{\text{post-tes}}$t=231.67±31.80, t=0.62, p=0.54) or in the unilateral standing long jump for both the right (Single-leg Standing long jump test (right) $^{\text{pretest}}$=158.04±25.79, Single-leg Standing long jump test (right) $^{\text{post-test}}$=171.35±31.90, t=1.35, p=0.19) and left lower extremities (Single-leg Standing long jump test (left) $^{\text{pretest}}$=145.12±29.64, Single-leg Standing long jump test (left) $^{\text{post-test}}$=145.79±29.64, t=0.06, p=0.96).

Table 5. Within-group comparison of AIGVTP and HGVTP on Horizontal Jumping Performance

Jumping Test	Pretest	Post-test	t-value	p-value
	AIGVTP			
		All		
Standing long jump test	206.60±1.96	229.31±43.5	1.96	.07
Single-leg Standing long jump test (R)	147.87±28.08	163.15±26.43	2.42	.03
Single-leg Standing long jump test (L)	144.97±28.74	158.70±29.20	1.92	.078
		Female		
Standing long jump test	198.34±33.06	229.47±47.48	2.22	.05
Single-leg Standing long jump test (R)	144.58±30.25	162.81±26.21	1.86	.08
Single-leg Standing long jump test (L)	134.89±21.76	145.05±28.28	1.00	.34
		Male		
Standing long jump test	215.45±53.67	229.14±40.64	.67	.51
Single-leg Standing long jump test (R)	151±39±26.12	163.52±27.64	1.30	.22
Single-leg Standing long jump test (L)	155.76±32.05	173.34±23.02	1.55	.14
	HGVTP			
		All		
Standing long jump test	214.33±36.96	221.87±36.67	.69	.50
Single-leg Standing long jump test (R)	154.02±28.40	167.20±30.72	2.10	.06
Single-leg Standing long jump test (L)	146.12±28.83	148.02±26.77	.26	.80
		Female		
Standing long jump test	206.72±37.17	212.72±39.70	.36	.72
Single-leg Standing long jump test (R)	150.27±31.05	163.32±30.92	1.42	.18
Single-leg Standing long jump test (L)	147.07±29.07	150.11±24.66	.31	.76
		Male		
Standing long jump test	222.48±36.27	231.67±31.80	.62	.54
Single-leg Standing long jump test (R)	158.04±25.79	171.35±31.9	1.35	.19
Single-leg Standing long jump test (L)	145.12±29.64	145.79±29.64	.06	.96

Source: Authors

Table 6 shows the comparison between AIGVTP and HGVTP vertical jumping performance post-test data of the participants. For the bilateral vertical jumping performance, there was a significant difference between the post-test data of both groups. HGVTP group (Vertical Jump test $^{post\text{-}test}$ = 68.18±11.79) was found to have a higher bilateral jumping performance (t=1.97, p= .05) in comparison to the AIGTVP group (Vertical Jump test $^{post\text{-}test}$ = 62.42±11.97). However, for the unilateral vertical jumping performance of both AIGVTP (Vertical Jump test (right) $^{post\text{-}test}$ 55.44±11.71, Vertical Jump test (left) $^{post\text{-}test}$=56.32±11.69) and HGVTP (Vertical Jump test (right) $^{post\text{-}test}$= 54.28±12.49, Vertical Jump test (left) $^{post\text{-}test}$=58.30±11.40), a significant difference was not observed. This was for both the right (t= .44, p= .66) and left (t= .66, p= .51) lower extremities. A sex-specific comparison between AIGVTP and HGVTP vertical jumping performance was also done. As for female participants, the bilateral vertical jumping performance had a significant difference between the post-test data of both groups. The HGVTP group (Vertical Jump test $^{post\text{-}test}$ = 67.08±12.49) was found to have a higher bilateral jumping performance (t=2.06, p=0.05) in comparison to the AIGVTP group (Vertical Jump test $^{post\text{-}test}$ = 58.56±9.06). However, for the unilateral vertical jumping performance of both AIGVTP (Single-leg Vertical Jump test (right) $^{post\text{-}test}$ = 54.68±11.49, Single-leg Vertical Jump test (left) $^{post\text{-}test}$ = 53.30±12.48) and HGVTP (Single-leg Vertical Jump test (right) $^{post\text{-}test}$ = 56.80±12.20, Single-leg Vertical Jump test (left) $^{post\text{-}test}$ =

58.55±12.07), a significant difference was not observed. This was for the right (t=0.45, p=0.65) and left (t=1.13, p=0.27) lower extremities. However, for the study's male participants, there was no significant difference between the bilateral vertical jumping performance and the post-test data of both groups. The HGVTP group (Vertical Jump test $^{post\text{-}test}$ = 69.21±11.44) did not significantly outperform the AIGVTP group (Vertical Jump test $^{post\text{-}test}$ = 65.99±10.68, t=0.80, p=0.43). Similarly, for the unilateral vertical jumping performance of both AIGVTP (Single-leg Vertical Jump test (right) $^{post\text{-}test}$ = 56.16±12.27, Single-leg Vertical Jump test (left) $^{post\text{-}test}$ = 59.13±10.53) and HGVTP (Single-leg Vertical Jump test (right) $^{post\text{-}test}$ = 51.93±11.76, Single-leg Vertical Jump test (left) $^{post\text{-}test}$ = 58.07±11.16), a significant difference was not observed. This was for the right (t=0.96, p=0.34) and left (t=0.27, p=0.79) lower extremities.

Meanwhile, it also shows the comparison between AIGVTP and HGVTP horizontal jumping performance post-test data of the participants. For the overall standing long jump performance, there was no significant difference between the post-test data of both groups. The AIGVTP group (Standing long jump test post-test = 229.31±43.5) did not significantly outperform the HGVTP group (Standing long jump test post-test = 221.87±36.67, t=0.70, p=0.48). Similarly, no significant differences were observed in the unilateral standing long jump performance for both the right (Single-leg Standing long jump test (right) post-test = 163.15±26.43 for AIGVTP and 167.20±30.72 for HGVTP, t=0.54, p=0.59) and left lower extremities (Single-leg Standing long jump test (left) post-test = 158.70±29.20 for AIGVTP and 148.02±26.77 for HGVTP, t=1.45, p=0.15). When comparing with sex-specificity, females in the AIGVTP group did not significantly outperform the HGVTP group in the bilateral standing long jump performance (Standing long jump test post-test = 229.47±47.48 for AIGVTP and 212.72±39.70 for HGVTP, t=0.18, p=0.86). No significant differences were observed in the unilateral standing long jump performance for the right lower extremity (Single-leg Standing long jump test (right) post-test = 162.81±26.21 for AIGVTP and 163.32±30.92 for HGVTP, t=0.70, p=0.49). However, a significant difference was observed for the left lower extremity, with the HGVTP group showing higher performance (Single-leg Standing long jump test (left) post-test = 150.11±24.66) compared to the AIGVTP group (Single-leg Standing long jump test (left) post-test = 145.05±28.28, t=2.74, p=0.01). For males, there was no significant difference in the bilateral standing long jump performance between the groups (Standing long jump test post-test = 231.67±31.80 for HGVTP and 215.45±53.67 for AIGVTP, t=1.05, p=0.30). Similarly, no significant differences were observed in the unilateral standing long jump performance for both the right (Single-leg Standing long jump test (right) post-test = 171.35±31.90 for HGVTP and 151.39±26.12 for AIGVTP, t=0.05, p=0.96) and left lower extremities (Single-leg Standing long jump test (left) post-test = 145.79±29.64 for HGVTP and 155.76±32.05 for AIGVTP, t=0.52, p=0.61).

Table 6 . Between-group Comparison on Vertical and Horizontal Jumping Performance

Jumping Test	AIGVTP	HGVTP	t-value	p-value
Vertical Jumping Performance				
		All		
Vertical Jump test	62.42±11.97	68.18±11.79	1.97	.05
Single-leg vertical jump test (R)	55.44±11.71	54.28±12.49	.44	.66
Single-leg vertical jump test (L)	56.32±11.69	58.30±11.40	.66	.51
		Female		
Vertical Jump test	58.56±9.06	67.08±12.49	2.06	.05
Single-leg vertical jump test (R)	54.68±11.49	56.80±12.20	.45	.65
Single-leg vertical jump test (L)	53.30±12.48	58.55±12.07	1.13	.27
		Male		
Vertical Jump test	65.99±10.68	69.21±11.44	.80	.43

Single-leg vertical jump test (R)	56.16±12.27	51.93±11.76	.96	.34
Single-leg vertical jump test (L)	59.13±10.53	58.07±11.16	.27	.79
Horizontal Jumping Performance				
		All		
Standing long jump test	229.31±43.5	221.87±36.67	.70	.48
Single-leg Standing long jump test (R)	163.15±26.43	167.20±30.72	.54	.59
Single-leg Standing long jump test (L)	158.70±29.20	148.02±26.77	1.45	.15
			Female	
Standing long jump test	229.47±47.48	212.72±39.70	.18	.86
Single-leg Standing long jump test (R)	162.81±26.21	163.32±30.92	.70	.49
Single-leg Standing long jump test (L)	145.05±28.28	150.11±24.66	2.74	.01
			Male	
Standing long jump test	215.45±53.67	231.67±31.80	1.05	.30
Single-leg Standing long jump test (R)	151±39±26.12	171.35±31.9	.05	.96
Single-leg Standing long jump test (L)	155.76±32.05	145.79±29.64	.52	.61

Source: Authors

Discussion

The study participants were divided into two groups: AIGVTP and HGVTP. AIGVTP participants received an AI-generated Volleyball training program from ChatGPT 3.5. On the other hand, HGVTP received an adopted volleyball training program from a previous study. Each training program was done simultaneously for ten weeks. Pretest and post-tests were done before and after the training program.

Artificial intelligence-generated Volleyball training program on Vertical Jumping Performance

The within-group comparison was done with AIGVTP on their vertical jumping performance before and after the training program. The AI-generated volleyball training program was found to be effective in improving the unilateral vertical jumping performance of the right lower extremities. However, the bilateral vertical jumping and the unilateral vertical jumping performance of the left lower extremity were found to be insignificantly affected by the training program. The lack of specificity of the AI-generated training program can explain the no improvement seen in the unilateral vertical jumping performance. It was seen in the aforementioned training program that unilateral exercises were few in comparison to the bilateral plyometric exercises on the lower extremities. Training specificity is essential in training to promote desired adaptations[43]. Studies suggested that unilateral resistance training was more effective in improving unilateral jump performance, whereas bilateral training was more suitable for bilateral strength[44,45]. The training program should be created so that the prompt given on the AI specifically formed the training program in line with the training goal. For females, both the bilateral and right unilateral vertical jumping performance were significantly improved by the training program. However, the left unilateral vertical jumping performance was observed to be insignificantly affected. For males, both the unilateral and bilateral vertical jumping performance did not experience improvement after the implementation of the training program.

Human-generated Volleyball training program on Vertical Jumping Performance

HGVTP who underwent the human-generated volleyball training program, consisting of both lower and upper extremities plyometric exercises, were found to significantly improve bilateral and right unilateral vertical jump performance. However, the left unilateral jumping performance was observed to be insignificantly affected by the training program. The specificity of the adopted training program can explain the improvement in the bilateral vertical jumping performance and the insignificant performance change in the unilateral vertical jumps. The training program focused on the upper and lower extremities. Although there was a specific body part that the training program was designed for, the unilateral and bilateral exercises were poorly divided. Research indicates that unilateral resistance training is more effective for enhancing unilateral jump performance, whereas bilateral training is ideal for developing bilateral strength[46,47]. Training specificity and specific adaptations were met[43] for the female participants. Only the bilateral vertical jumping performance was observed to improve significantly. The administration of the training program insignificantly changed the unilateral vertical jumping performance. For the male participants, no improvement in all the variations in vertical jumping performance was observed after the training program.

AIGVTP versus HGVTP on Vertical Jumping Performance

A between-group comparison of AIGVTP and HGVTP in terms of its effect on vertical jumping performance was done. The participants who underwent the human-generated volleyball training program were found to have a higher bilateral vertical jumping performance. This was because of the significant difference between the two groups in terms of the jumping performance variation. However, the unilateral vertical jumping performance of both groups was found to be insignificantly different from each other. The superiority of the adopted volleyball training program over the AI-generated volleyball training program can be explained through several training principles. First is training specificity[43]. The adopted training program was seen to have a series of exercises that mainly focused on jumping using both lower extremities. By doing the same kind of exercises, the training program truly targeted bilateral vertical jumping performance. The AI-generated training program, although it exhibits a good periodization, which is a systematic, sequential, and phasic way to manipulate fitness[48] by dividing the 10-week training program into strategic training objectives, fails to address the exercises to be specific to bilateral vertical jumping. Only a bilateral vertical jumping performance difference was observed for female participants of the two groups. With this, the human-generated training program was superior in improving the vertical jumping performance of male-female participants. For male participants, significant differences were not observed among all of the vertical jump variations.

Artificial intelligence-generated Volleyball training program on Horizontal Jumping Performance

The within-group comparison was done with AIGVTP on their horizontal jumping performance before and after the training program. The participants who underwent the AI-generated Volleyball training program were found to have a significant increase in unilateral horizontal jumping performance. However, the bilateral horizontal and unilateral horizontal jumping performance of the left extremities was found to be insignificantly changed by the implementation of the training program. The AI-generated volleyball training program was seen to have plyometric exercises that aimed to treat the lower extremities. Numerous studies suggest that plyometric training, which lasts less than ten weeks, improves sprint performance[49,50]. Unilateral movements are performed with one limb without using the opposite limb. Sprinting and the movement of a single-leg standing broad jump are both unilateral movements. With this, an improvement in unilateral jumping performance can be connected to plyometric training. For female participants, the bilateral horizontal jumping performance improved after the training program's administration. However, the training program did not improve the unilateral horizontal jumping performance for both extremities. As for male participants, all of the variations of horizontal jumping performance were found to be insignificantly changed by the training program.

Human-generated Volleyball training program on Vertical Jumping Performance

The participants who underwent the human-made volleyball-generated volleyball training program experienced insignificant changes in all the variations of the horizontal jumping performance. This was the same case for the sex-specific pretest and post-test comparison. The improvement in bilateral jumping performance can be explained by the number of exercises with horizontal displacement. In the training program, there are 17 exercises with vertical displacement and 10 exercises with horizontal displacement. With this, the horizontal jump and its unilateral variation can be assumed to be not adequately focused by the training program. This was in line with the principle of specificity[43], particularly on movement analysis.

AIGVTP versus HGVTP on Horizontal Jumping Performance

A between-group comparison of AIGVTP and HGVTP in terms of its effect on horizontal jumping performance was done. The participants in both groups were found to have insignificant differences among all the variations of horizontal jumping performance. This was also the case for both male and female participants. Vertical jumping exercises might have been more emphasized in the volleyball training programs, resulting in more pronounced improvements in vertical performance since the vertical jumping performance of the participants and less noticeable differences in horizontal performance. Additionally, a lack of training specificity[43] could have contributed to the outcome. The muscles and movements involved in horizontal jumping might not have been specifically targeted by the exercises included in the programs. Specific performance improvements are crucially influenced by training specificity, and without it, the necessary adaptations for horizontal jumping may not have been adequately developed.

Conclusion

The Artificial Intelligence-generated Volleyball training program effectively improved unilateral vertical jumping performance of the right lower extremity. However, it did not significantly affect bilateral vertical jumping or left unilateral vertical jumping performance. For females, significant improvements were seen in bilateral and right unilateral vertical jumping, while for males, no significant improvements were observed in unilateral or bilateral vertical jumping performance. Similarly, participants showed significant improvement in unilateral horizontal jumping performance, while bilateral horizontal and left unilateral horizontal jumping performance remained unchanged. For female participants, bilateral horizontal jumping performance improved. However, unilateral horizontal jumping performance did not, and for male participants, no significant changes were observed in any variation of horizontal jumping performance. Participants in the human-generated Volleyball training program significantly improved bilateral and right unilateral vertical jump performance, with females showing significant improvement only in bilateral vertical jumping, while no improvements were observed in males. The program resulted in insignificant changes in all variations of horizontal jumping performance for both sexes. The human-generated volleyball training program resulted in higher bilateral vertical jumping performance than the AI-generated program, with significant improvements seen only in female participants.

In contrast, no significant differences were observed in unilateral vertical jumping performance for either group. Both groups showed no significant differences in horizontal jumping performance across all variations for male and female participants. Although AI-generated Volleyball training programs might help produce training programs, they still cannot be substituted for professional-made fitness training programs as they are still superior in some aspects. Further studies should be done on this subject to validate the study results. Also, future researchers should focus on validating the results of the present study through replication and expanding the Volleyball components, such as using the skills of the sport as a dependent variable of the study.

This study highlights the potential and limitations of using AI in sports training by comparing the AI-generated volleyball training program (AIGVTP) with the human-generated program (HGVTP). While AI-driven training offers structured periodization—an advantage in systematically planning fitness goals—the AIGVTP fell short in improving bilateral vertical jumping performance, which the HGVTP excelled at due to its focus on training specificity. This suggests that AI, although valuable for organizing long-term training cycles, may need further refinement to match the nuanced, sport-specific exercise designs typically provided by human coaches. The study advances the field by showing that while AI can efficiently create structured programs, its effectiveness in targeting specific athletic outcomes, like bilateral jumping, depends on the precise calibration of exercises. It also underscores the growing role of AI in sports, highlighting its current limitations and the need for a more tailored approach to individual and sport-specific needs.

However, AI-based programs like the AIGVTP show promise by providing scalable, data-driven training methods that can be adapted with future advancements in AI technology, particularly in enhancing sport-specific exercises. The study also emphasizes the need for further research to better integrate AI systems with the dynamic and specific demands of sports training

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