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THE EFFECTIVENESS OF HIIT TRAINING IN ENHANCING NEUROMUSCULAR EFFICIENCY AND DEVELOPING THE BLOCKING SKILL IN VOLLEYBALL PLAYERS

Dr. Ahmed Wahan Hamid
University of Diyala
College of Physical Education and Sports Sciences
ahmed.walhan@uodiyala.edu.iq

Abstract:
Research Objectives:
• To apply the efficacy of High-Intensity Interval Training (HIIT) for improving neuromuscular efficiency and skill development of blocking in volleyball players
•To determine the effects of HIIT on neuromuscular adaptation and consequently, blocking ability in volleyball players.
Since the research problem is best addressed by the experimental method, the researcher took this approach. The sample of the study was intentionally chosen against the backdrop of senior volleyball players in the province of Diyala and distributed among 4 sports clubs. The main sample, which consisted of players from Khanqin Sports Club and Al-Wajihiya Sports Club, was randomly selected with the lottery method. The sample was split into two: experimental and control. 18 players from Khanqin Club and 14 players from Al-Wajihiya Club.
The results of the study showed statistically significant differences in neuromuscular efficiency between groups, with the experimental group undergoing HIIT training performing better than controls. This result is a proof of the effectiveness of this type of training in provoking neuromuscular adaptations of volleyball players. In addition, HIIT training had a clear influence on motor skills associated with rapid and explosive movement, as well as precise neuromuscular coordination.
Due to the beneficial role of HIIT in the present study on the aforementioned qualities, the researcher suggests including HIIT in training programs applicable to youth age categories in volleyball, as the data observed indicate an improved neuromuscular efficiency and skills performance, especially for key defensive skills like blocking. Ultimately, it is suggested that volleyball coaches in Diyala and other areas should implement evidence based high-intensity interval training protocols (e.g., intensity, reps, and recovery) according to players/ athlete levels and physical.

Keywords:
HIIT Training Effectiveness, Neuromuscular Efficiency, Volleyball

Introduction

HIIT is one of the most contemporary training strategies that has been effective in improving physical performances and health (16). This approach involves alternating between high-intensity exercise and short recovery periods. Numerous studies have shown that the benefits of HIIT are not limited to cardiovascular

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fitness, they include improvements of the neuromuscular function. This shows the muscles are able to fire in a quicker more effective fashion and developing nerve/muscle coordination.

Neuromuscular efficiency is well-known as a key factor of sporting success, especially in sports requiring fast responses and explosive power. Optimising our communication pathways that happen between the central nervous system and our peripheral muscular system; we can optimize the effects of physical training as well as enhance performance at both training and competitive levels.

As a team sport, Volleyball demands a high degree of integration of physical and functional capacities under conditions of quick response, specific timing and repetition of movement against sustained physical and neural stress [1]. To fulfil these demands, we must rethink conventional training programmes, privileging modalities capable of combining anaerobic stimulation and high neuromuscular loading, namely, High-Intensity Interval Training (HIIT).

It is critical to make neuromuscular efficiency appropriate to each skill, especially skills like blocking because they require a rapid and accurate reflex. HIIT improves your reaction time and responsiveness because it builds neuromuscular adaptations and coordination between your muscles and nervous system. This helps athletes perform complex, high-power movements with more precision and efficiency.

Neuromuscular efficiency, is an advance physiologically relevant measures of the functional capacity of the CNS to activate muscle fibres. The execution reflects in the precision and quality of the motor performance, notably, anaerobic reaction time, explosive strength and timing of response. This indicator becomes especially relevant in competitor sports with powerful vertical jumps, rises, anticipation, and reaction times which is essential in volleyball and its primary complex of movements that directly relies on neuromuscular effectiveness.

We are aware of the importance of the scientific integration of the practical implementation of a specific technology in evaluating the effect of the most recent approaches of training: High-Intensity Interval Training (HIIT) on selected neuromuscular physiological variables of volleyball players. HIIT involves short bouts of HIE interspersed with periods of active recovery and is thought to elicit multi-level adaptive responses in the neuromuscular system. These responses should provide a large real-world improvement in athlete functional and motor performance.

Although HIIT protocols are being used with greater frequency throughout physical preparation programmes for team sports, the structural and temporal characteristics of this type of training have not yet been established for some modern physiological variables—like neuromuscular efficiency—especially in volleyball players. These63 crowd is in a major stage63 physiologic63 development64, skill65 development63. As such there is an immediate requirement to conduct methodically controlled research into the effects of HIIT on these important physiological markers, determining both the nature of the adaptations it drives and the degree to which these changes are able to translate to better performance in the competitive domain. This is especially true for higher skills such as blocking where, at the higher end of the performance spectrum physical effort and technical execution must be married together.

Research Aim:

• To utilise the effectiveness of High-Intensity Interval Training (HIIT) in enhancing neuromuscular efficiency and developing the blocking skill among volleyball players.
• To identify the effectiveness of HIIT in improving neuromuscular efficiency and the performance of the

2. Research Methodology and Field Procedures

2.1 Research Method

The researcher employed the experimental method, as it is deemed the most appropriate approach for addressing the research problem.

2.2 Research Population and Sample

The research population was purposefully selected from among advanced volleyball players in Diyala Province, who were distributed across four sports clubs. The primary sample for the study was selected randomly using the lottery method and comprised players from Khanqin Sports Club and Al-Wajihiya Sports Club. The sample was divided into two groups: an experimental group and a control group. The experimental group consisted of 18 players from Khanqin Sports Club, while the control group included 14 players from Al-Wajihiya Sports Club.

To conduct the exploratory (pilot) experiment, four players from Khanqin Club were selected; their results were excluded from the main experiment. Consequently, the final number of participants included in the study was 28 players. These participants were utilised to implement the training programme and to measure

2.3 Tools, Instruments, and Data Collection Methods

2.3.1 Methods of Data Collection

- Arabic and international scientific sources
- The World Wide Web (Internet)
- Direct observation
- Testing and measurement

2.3.2 Instruments and Equipment Used in the Study

- Official volleyball court
- Official volleyballs
- Whistle
- Training poles (markers)
- Cones
- Measuring tape
- Plyometric boxes
- Weights
- Medicine balls of various weights
- Resistance bands
- Digital camera (Nikon D5100)
- Video camera (Sony)
- Laptop computer (Dell)
- EMG device

2.4 Field Procedures

2.4.1 Tests Employed in the Research

Measurement of Neuromuscular Efficiency:

To assess neuromuscular efficiency, the researcher used an electromyography (EMG) device.

EMG Device Utilised in the Study:

The researcher employed a modern electromyography system (Myotrace 400), which operates on two channels and includes the following components:

- A Bluetooth-enabled signal receiver/transmitter, weighing approximately 370 grams
- Surface electrodes (sensors)
- Connection cables linking the sensors to the EMG unit

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The system was operated using the **Noraxon Myotrace 400** software, which was installed on a laptop computer. This application allows for the visualisation and storage of EMG signals (each muscle's signal recorded separately). Moreover, the software includes a detailed interface displaying the precise anatomical locations for placing surface electrodes for both anterior and posterior muscle groups of the body.

Figure (2): Surface Electrodes

Figure (1): EMG Device

The electromyography (EMG) signal is inherently random in nature, due to the continuous variation in the recruitment of motor units. To ensure accurate recording, the raw signal is passed through a high-pass filter to eliminate electrical noise originating from power lines and surrounding electronic devices. Additionally, it is processed through a low-pass filter to remove motion artefacts caused by cable movement and mechanical vibrations from the EMG device itself.

Given that the EMG signal is of low amplitude, it must be amplified prior to being displayed on a monitor or stored for analysis. Importantly, amplification must preserve the waveform's integrity, meaning that neither the shape nor the spectral content of the signal should be altered. Once properly amplified, the signal undergoes a series of processing steps using a laptop, which facilitates detailed analysis.

Several pre-processing techniques are typically applied to the raw EMG signal before extracting the final data. From the processed signal, various quantitative indicators are derived—such as peak values, mean values, and the area under the curve (AUC). These indicators form the basis for evaluating neuromuscular performance and were employed in the current study.

Explosive Power of the Legs:

Vertical Jump from Static Position (Sargent Jump Test)

(Hammoudat, 1987, p. 177)

Test Objective:

To measure the explosive strength of the leg muscles.

Equipment and Tools Used:

- A wall with a height of 3.50 metres
- A measuring tape
- A vertically mounted board on the wall, measuring 0.5 metres in width and 1.5 metres in length, marked with white horizontal lines at 2 cm intervals
- Chalk pieces
- Cloth for cleaning the board after each attempt

Test Procedure:

The participant holds a piece of chalk and stands facing the wall-mounted board. While fully extending the arm holding the chalk upward, the participant makes a mark on the board—this represents the standing reach height. Then, from a static position, the participant performs a vertical jump using both feet

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simultaneously while powerfully swinging the arms forward and upward to reach the maximum possible height. The jump height is calculated as the difference between the initial and second chalk marks.

Test Conditions:

1. The jump must be executed using both feet simultaneously from a standing position—no preliminary step is allowed.
2. Measurements must be taken to the nearest centimetre.
3. Each participant is allowed three attempts, with the best score recorded.

Scoring:

The vertical distance between the first and second chalk marks indicates the explosive power of the leg muscles.

Explosive Strength Test for the Arms

(Allawi, 1982, p. 106)

Test Objective:

To assess the explosive strength of the arm muscles.

Equipment and Tools:

- A medicine ball weighing 3 kg
- A measuring tape
- A chair with a strap to firmly secure the trunk to the chair

Test Procedure:

The participant sits upright on the chair while holding the medicine ball with both hands above the head. The torso must remain in contact with the backrest of the chair. A strap is secured around the participant's trunk and fastened to the rear edge of the chair to prevent any forward movement during the throw. The ball is then thrown forward using both hands, without any assistance from the trunk.

Each participant is allowed three attempts, with the best result recorded.

Scoring:

The distance is measured from the front edge of the chair to the nearest point where the ball first lands.

- Official volleyball court
- 10 official volleyballs
- Net set at the official height (2.43 metres)

Performance Specifications:

The participant stands at the centre of one half of the volleyball court. On the opposite side, a skilled spiker and a coach are positioned. The coach tosses the ball to the spiker, who performs five spike attacks from position (2), followed by five from position (3), and five from position (4). The participant is required to execute a legal block against each spike.

Conditions:

1. Any attempt in which the spike is deemed invalid will be cancelled.
2. The spike sequence (positions 2, 3, 4) must follow the specified order.
3. The participant must perform the block in accordance with official rules.
4. A rest period of 30 seconds is allowed after every five attempts.
5. Any block that violates the above conditions is considered void.

Scoring:

Each of the 15 attempts is scored as follows:

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1. If the ball lands within the opponent's court (coach and spiker's side) in a way that prevents the receiving team from recovering the ball, the participant is awarded **3 points**, provided the block was legally performed.
2. If the ball lands within the participant's own court (blocker's side) but in a way that allows teammates to continue play, **2 points** are awarded.
3. If the ball lands in the opponent's court but in a recoverable manner, **1 point** is awarded.
4. If none of the above conditions are met, the score for that attempt is **zero**.

Based on the above criteria, the participant is awarded a cumulative score out of a maximum of **45 points** for

2.4.2 Pilot Experiments

The first pilot experiment, which focused on the physiological equipment, was conducted on **3 February 2025 at 10:30 a.m.** in the Physiology Laboratory at the College of Physical Education and Sport Sciences, University of Diyala. The objectives of this preliminary trial were as follows:

- To verify the functionality and accuracy of the physiological equipment under controlled laboratory conditions.
- To assess the suitability of the laboratory environment for conducting the required measurements in accordance with the study's methodological standards.
- To ensure that the researcher and the supporting team were proficient in operating the analytical software linked to the equipment and capable of configuring each device appropriately.
- To determine the optimal duration for each physiological test, ensuring a smooth workflow during the primary field measurements with minimal disruption or human error.
- To identify and address any potential technical or procedural obstacles in advance of the actual experiment, thereby guaranteeing the collection of accurate and reliable data during both the pre-test and post-test phases.

The second pilot experiment, which targeted explosive power in the legs and arms, was conducted the following day, **4 February 2025 at 10:30 a.m.**, at the College of Physical Education and Sport Sciences, University of Diyala.

2.4.3 Pre-Testing

The pre-tests for the study variables were conducted on **Sunday and Monday, 11–12 February 2025**, starting at 10:30 a.m. They took place in the Physiology Laboratory and the Physical Training Hall at the College of Physical Education and Sport Sciences, University of Diyala. The tests were carried out under the direct supervision of the researcher and the specialised research team. This stage aimed to obtain baseline measurements for the study variables, adhering to standardised and precise testing procedures.

2.4.4 Main Experiment

The training programme was designed according to the High-Intensity Interval Training (HIIT) methodology, which is based on alternating short bouts of high-intensity physical effort—ranging between 85–95% of the maximum heart rate—with periods of active rest that allow for partial recovery while maintaining metabolic stimulation. The programme aimed to elicit physiological adaptations in the cardiovascular and autonomic nervous systems (through activation of Heart Rate Variability – HRV), enhance neuromuscular transmission efficiency, activate high-threshold motor units, increase the explosive strength of both upper and lower limbs, and improve intermittent effort tolerance.

The implementation of the experimental protocol commenced on **15 February 2025** and continued until **10 April 2025**, lasting for a total of **8 weeks**. Training was conducted **three times per week**—on Sundays, Tuesdays, and Thursdays. Each session lasted **60 minutes** in total. High-intensity intervals ranged

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between **30–45 seconds**, while active recovery periods lasted between **60–90 seconds**. The number of repetitions per session varied between **6 and 10**, depending on the training week.

1. Warm-up (10–12 minutes):
   - General preparation exercises (light jogging – dynamic stretching – joint mobility movements)
   - Specific preparation (light jumps – short agility drills)
2. Main Part (30–40 minutes):

The core segment of each training session was carried out according to the HIIT protocol, integrating targeted drills to stimulate neuromuscular and physiological adaptation. Each high-intensity bout was followed by a period of active recovery, and the exercises varied in focus to elicit comprehensive athletic

High-Intensity Activity	Exercise Type	Duration
Repetitive vertical bounds (explosive jump sequences)	Lower-body explosive power development	30 seconds
Rapid overhead medicine ball presses	Upper-body muscle activation	30 seconds
Lateral movement drills with ball reception	Neuromuscular skill stimulation	45 seconds
Vertical jump with simulated net blocking	Full neuromuscular system activation	30 seconds
	Cardiovascular and sympathetic system stimulation	45 seconds

3. Cool-down Phase (5–10 minutes):
   - Static stretching and muscle relaxation exercises
   - Monitoring heart rate to ensure return to baseline levels

2.5 Statistical Tools

The Statistical Package for the Social Sciences (**SPSS**) was used to process the data and extract the results.

3. Presentation, Analysis, and Discussion of Results

3.1 Presentation of Means and Standard Deviations for Pre- and Post-Tests of the Experimental and Control Groups

3.1.1 Presentation and Analysis of Means and Standard Deviations for Pre- and Post-Tests of the Experimental Group Variables

Table (1) presents the values of the **means**, **standard deviations**, and the **calculated t-values** for the pre- and

Variable	Pre-test1		Pre-test2		t-value	Error Margin	Sig. Level
	Mean	SD.	Mean	SD.			
Right Deltoid Muscle	**1491.98**	**2.318**	**1531.61**	**4.024**	**4.597**	**0.000**	**Significant**
Left Deltoid Muscle	**1022.46**	**4.515**	**1128.38**	**4.225**	**72.669**	**0.001**	**Significant**
riceps Brachii Muscle	**1263.01**	**14.302**	**1468.13**	**16.454**	**34.615**	**0.000**	**Significant**
Lower Limb Explosive Power	**38.304**	**1.745**	**43.291**	**2.154**	**4.984**	**0.001**	**Significant**
Upper Limb Explosive Power	**5.122**	**0.282**	**6.219**	**0.241**	**7.742**	**0.000**	**Significant**
Block Skill	**30.926**	**2.092**	**39.002**	**2.038**	**8.805**	**0.000**	**Significant**

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3.1.2 Presentation and Analysis of the Arithmetic Means and Standard Deviations for the Pre- and Post-Tests of the Control Group Across the Research Variables

Table (2) presents the arithmetic means, standard deviations, and the calculated t-value for the pre- and

Variable	Pre-test1		Pre-test2		t-value	Error Margin	Sig. Level
	Mean	SD.	Mean	SD.			
Right Deltoid Muscle	1475.023	37.811	1512.05	45.114	2.490	0.032	Significant
Left Deltoid Muscle	1020.04	2.356	1062.07	59.659	2.374	0.039	Significant
riceps Brachii Muscle	1257.398	12.645	1298.61	53.991	2.738	0.021	Significant
Lower Limb Explosive Power	37.945	1.660	39.136	1.714	1.749	0.111	Not Significant
Upper Limb Explosive Power	5.041	0.297	5.455	0.655	2.214	0.051	Not Significant
Block Skill	30.428	1.949	34.285	1.772	6.211	0.000	Significant

3.2 Presentation and Analysis of the Arithmetic Means and Standard Deviations for the Experimental and Control Groups in the Post-Tests of the Research Variables

Table (3) presents the arithmetic means, standard deviations, and the calculated t-values for the post-test

Variable	Experimental Group		Control Group	
	Mean	SD.	Mean	SD.
Right Deltoid Muscle	1531.61	4.024	1512.05	45.114
Left Deltoid Muscle	1128.38	4.225	1062.07	59.659
riceps Brachii Muscle	1468.13	16.454	1298.61	53.991
Lower Limb Explosive Power	43.291	2.154	39.136	1.714
Upper Limb Explosive Power	6.219	0.241	5.455	0.655
Block Skill	39.002	2.038	34.285	1.772

Table (4) presents the values of the differences in arithmetic means and standard deviations, along with the calculated *t*-values, error margins, and levels of significance between the experimental and control groups in

Variable	Mean Difference	SD. Mean Difference	Standard Error of the Differences	t-value	Error Margin	Sig. Level
Right Deltoid Muscle	19.552	45.360	13.676	1.699	0.005	Significant
Left Deltoid Muscle	66.305	60.408	18.213	3.641	0.005	Significant
riceps Brachii Muscle	169.525	61.209	18.455	9.186	0.000	Significant
Lower Limb Explosive Power	4.154	2.652	0.7999	5.194	0.006	Significant
Upper Limb Explosive Power	0.763	0.765	0.230	3.310	0.000	Significant
Block Skill	4.714	2.091	0.558	8.434	0.000	Significant

3.3 Discussion of Results

Discussion of the Neuromuscular Efficiency Variable – Right Deltoid EMG

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The findings of the study revealed a clear improvement in the neuromuscular efficiency of the **right deltoid muscle** among participants in the experimental group following the implementation of the HIIT training protocol. Although the numerical difference may appear modest, the statistical significance indicates a genuine effect attributable to the intensive training stimulus, which specifically targeted this muscle region.

Neuromuscular efficiency is commonly assessed using electromyography (EMG), which reflects the nervous system's ability to efficiently recruit and activate motor units during muscular performance—particularly in skills that demand both precision and instantaneous power, such as **blocking** in volleyball. This skill requires players to execute explosive jumps with high timing accuracy (Enoka & Duchateau, 2015). The observed improvement in EMG signals from the right deltoid indicates enhanced neural activation, likely a result of the repeated and focused arm-based drills embedded within the HIIT training units.

Del Vecchio et al. (2019) also emphasised that high-intensity training protocols stimulate central nervous system activity and increase the efficiency of neural transmission to the targeted musculature. This process accelerates the activation of fast-twitch muscle fibres and improves skill-specific responsiveness, aligning

The researcher believes that the improvement in **neuromuscular efficiency of the right deltoid muscle** in the experimental group reflects a direct functional adaptation of the neuromuscular system as a result of consistent high-intensity loading. This enhancement appears logical given the critical role of the deltoid muscle in executing fundamental volleyball skills—particularly **serving** and **directional control**. In contrast, the control group exhibited no notable improvement, which reinforces the hypothesis that the observed neuromuscular gains are attributable to the specific nature of the HIIT programme, rather than random or external factors.

Discussion of the Neuromuscular Efficiency Variable – Left Deltoid EMG

The results showed that the neuromuscular efficiency of left deltoid muscle significantly improved in participants of the experimental group after the HIIT protocol was implemented. The increased EMG from this muscle reflects a more efficient neuromuscular conduction, probably due to the specific training sessions developed through increased mucle activation to the repeated and high loads.

As being a validated, accurate measurement for neuromuscular adaptations, EMG (electromyography) The method itself is reported to be especially suitable for motor unit (MU) activation patters assessment to characterize skill execution and development as well as physical exertion (Rainoldi et al., 2004), particularly with regards to the upper-limb that exhibits bilateral symmetry (e.g., volleyball). The presence of development in left deltoid is consistent with a balanced design of the HIIT programme, where both arms were simultaneously loaded at a high effort, which may have further accelerated central and peripheral neural adaptations.

Farina et al. As reported by Reid et al.(2014), the performance of intermittent bouts of high-intensity muscular effort provides a potent stimulus to the neural pathways innervating the involved muscle, resulting in greater motor unit recruitment and improved effectiveness of the motor nerve-muscle fiber connection.

The researcher believes that the observed improvement is an indication that the training programme was not just aimed at improving skill performance, but was purposely designed to provoke corresponding neuromuscular physiological responses. This adaptation is especially apparent in muscles that are not primary movers for any given motor task (e.g. left deltoid). This even more substantiates the impact of the training design in facilitating the symmetry of neuromuscular structures across the bilateral symmetry of human body—one of the fundamental preconditions for functional development in volleyball players.

This is likely due to the way the exercise was designed, with a combination of pushing and jumping with the arms, which could be seen as an ideal method for providing conditions necessary to drive deeper recruitment

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of muscle fibers," said the researcher. In the control group, however, there was no significant improvement, confirming that the neuromuscular adaptations had actually functioned as a direct effect of the training programme used..

Discussion of the Explosive Power Variable – Lower Limbs

The results of the study showed a statistically significant improvement in **lower-limb explosive power** among participants in the experimental group following the application of the HIIT training protocol. This finding reflects enhanced player capacity to generate high levels of force in a short duration—an essential physical requirement in volleyball, particularly for performing the **blocking skill**.

This improvement can be attributed to the nature of the HIIT exercises, which included high-intensity repetitions of short, multidirectional jumps. These movements effectively stimulated **fast-twitch muscle fibres** and improved **neuromuscular transmission efficiency** (Markovic & Mikulic, 2010). The repeated alternation between effort and relative recovery further contributed to the development of anaerobic endurance and neural adaptations associated with explosive strength.

The researcher believes that incorporating **specialised high-intensity exercises** provided athletes with an effective stimulus to improve their neuromechanical response during vertical jumping—particularly when combined with skill execution at high repetition levels. This integration led to increased efficacy in both **neurological and mechanical responsiveness**. The control group, on the other hand, demonstrated no notable improvement, reinforcing the conclusion that the training modality was the decisive factor in enhancing this variable. These improvements ultimately translated into greater jump height and efficiency

Discussion of the Explosive Power Variable – Upper Limbs

The results for the experimental group revealed a statistically significant fact that there was greater posttraining upper-limb explosive power after the HIIT training protocol. This finding provides evidence for the specificity of the neurophysiological adaptations induced by the training, by improving the generation of high peak force in a short time period—an important feature of the arms during blocking, since upper-limb power is necessary for maximum height and reach over the net in volleyball blocking.[7]

Firing rapid-action motor units is a function of the nervous system, but explosive arm strength also requires the coordination (intermuscular coordination) of agonist and stabilising muscles during a dynamic movement (23). It is known that HIIT activates this system specifically with repeated bouts of pressing, throwing, and high-velocity pushing (Cormie et al., 2011). In those subjects, high-intensity stimulation of the upper body with short-rest intervals improved neuromuscular facilitation and motor control [43].

According to rashid and al-rubaie 2020) there are structured training programmes that include a graded intensity and load variability training programmes can greatly improved the volleyball players technical performance physiological capacity. Targeted, high-intensity interventions are considered one of the most effective approaches for building neuromuscular efficiency—particularly for skills that require rapid, exact motor responses and timing. Thus, the application of high-intensity, skill-specific training protocols like HIIT has been shown to produce large-functional and -technical adaptations, thus re-iterating its application in volleyball conditioning programmes—especially for actions requiring explosive force and rapid visual information processing.

The authors stated that the effects on this variable seem to be a consequence of carrying out exercises involving forward pushing, medicine ball throws, and bilateral arm-driven jumps, with the aim of transverse augmentation to improve neuromuscular integration (Cameron et al. In comparison, the control group did not appear to change in any statistically meaningful way; which lends support to the interpretation that the improvements were due to the training stimulus and not random scatter.

4. Conclusion

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Numerical values were calculated for both the experimental and control groups to quantify the differences obtained from the neuromuscular efficiency, and when subjected to the study it showed significant differences statistically between the two groups, favouring the experimental group that underwent the HIIT training protocols. This result corroborates the efficacy of this training mode in inducing neuromuscular adaptations in volleyball players. In fact, a clear finding was the specific effect of HIIT on motor skills—namely, those requiring rapid or explosive strength or fine neuromuscular coordination.

In conclusion, a systematic and periodised approach to HIIT plays a significant role in developing meso- and micro-adaptations that lead to compensatory macro-adaptations in a simultaneous manner that translates to improvements in the functional traits of athletic performance, particularly in youth athletes at the advanced stages of development.

Given the role of block (main defender skill) in the current study findings, the researcher prescribes inclusion of HUTP_HIIT into volleyball training programmes in youth categories, as the short-term enhancement of neuromuscular output (and therefore skill performance) can be beneficial. Based upon published scientific principles regarding the balance between effort, frequency, and rest, HIIT training should be encouraged in Diyala and other regions but must be adjusted to fit the physical capabilities and level of development of the athlete to achieve the desired results.

Finally, player development centres should be encouraged to implement HIIT-based training programmes, as part of comprehensive training practices, in light of the statistically significant findings of this study in favour of HIIT compared to traditional training types.

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Appendix (1): Sample Training Unit Model

Exercise	Objective of the Exercise	Intensity Applied	Repetitions per Set	Work Duration per Set	Rest Duration
Vertical Squat Jumps	Develop explosive strength of the legs	90% of maximal effort	10 repetitions	30 seconds	20 seconds
Speed Ladder – Fast Foot Movement	Improve neuromuscular reaction speed	85% of maximal effort	30 seconds of execution	30 seconds	20 seconds
Lateral Jumps Over Low Hurdles	Enhance balance and neuromuscular coordination	80% of maximal effort	15 repetitions (right + left)	30 seconds	20 seconds
Sprint in Place	Stimulate central nervous system	95% of maximal effort	30 seconds	30 seconds	20 seconds
Explosive Push-Ups (Clap Push-Ups)	Strengthen upper body and explosive power	90% of maximal effort	10 repetitions	30 seconds	20 seconds
Squat to Overhead Dumbbell Press	Enhance upper-lower limb integration	85% of maximal effort	12 repetitions	30 seconds	20 seconds
Solo Block Repetitions Against Wall	Improve timing and jumping accuracy	70% of maximal effort	8 repetiti	10 minutes (total)	30 seconds

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			ons × 2 sets		between trials
Block Against Active Spiker	Develop blocking skill under realistic conditions	75% of maximal effort	6 attempts × 2 sets	10 minutes (total)	1 minute between repetitions
Blocking to Auditory Cue	Enhance neuromuscular response to stimuli	80% of maximal effort	10 repetitions	5 minutes (total)	30 seconds