Educational Applications According to the Time-Length Index for Developing Certain Physical Abilities and Biomechanical Variables of the Serve Stroke in Wheelchair Tennis (for Individuals with Disabilities)

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Received: 18/08/2025
Accepted: 23/09/2025

Abstract

The significance of this research lies in the development of training treatments for disabled tennis players within their training programs. The utilization of specific characteristics and indicators, including temporal indicators examined in this study, has enabled the post-assessment correlation of performance changes. This linkage enables the identification of suitable training solutions to enhance and elevate performance levels by concentrating on physical training within these modules. This approach is particularly effective when incorporated into a program that emphasizes the serve skill and methods to enhance its performance. The research problem under consideration is focused on the development of the capability of wheelchair tennis players to execute fundamental skills with the required proficiency and the mechanical conditions that accompany correct motor performance. The investigation of the underlying causes is also a component of this study, with a focus on the relationship between time and movement. The objective is to establish a connection and activate the mechanical aspect through the analysis of the characteristics and indicators associated with performance.

Keywords: Tennis players, Wheelchair, Time-Length Index.

DOI: https://doi.org/10.64401/x09me539

1. Introduction

In the contemporary world, scientific and technological progress has been witnessed across various domains of life. Scientific development is widely regarded as a critical benchmark for evaluating the progress and advancement of nations. It is evident that nations that possess both knowledge and technology in the domain of sports are the most successful in achieving sports excellence. This underscores the substantial emphasis placed on scientific research and its practical applications.

The contemporary global landscape is characterized by a heightened level of competition among nations as they strive to demonstrate superiority in scientific and technical domains, with the ultimate objective of achieving dominance in the domain of sports. Concurrently, disability sports, comprising a diverse array of sports disciplines, represent a sports sector that has undergone substantial development and a comprehensive scientific renaissance grounded in scientific research. Moreover, these advancements are contingent upon the utilization of standardized tests and appropriate measurement tools, which are regarded as the optimal methods to attain the highest targeted sports levels. The integration of individuals into society, enhancement of interpersonal interactions, and provision of comprehensive care in the physical, psychological, and mental domains are all facilitated by disability sports. Disability sports represent the optimal and most effective means for the rapid reintegration of persons with disabilities into their communities, fostering harmony and connection once again, especially as productive members actively engaged and interacting within society. Furthermore, the development and advancement of nations is contingent upon the cultivation and refinement of human, economic, educational, scientific, and cultural resources, and others to the greatest extent possible, with increasing attention paid to them on a daily basis without discrimination. The development and enhancement of human potential serve as the foundational element upon which other resources depend for their growth and advancement. This objective is realized through the provision of care and support within the context of this particular sport.From this perspective, developed countries have focused on providing equal opportunities for individuals with limited mobility (people of determination) to engage in physical exercise. Furthermore, they promote engagement in competitive events alongside their able-bodied counterparts, thereby enhancing their overall quality of life. The appropriate care provided has aimed to nurture and educate them, thereby increasing their social interaction and integration into everyday life, as well as enhancing their contributions to work and productivity according to their abilities and capacities. The following text is intended to provide a comprehensive overview of the subject matter. Wheelchair tennis is a sport that demands a combination of skills, fitness, and strategic thinking. It first appeared in the Paralympic Games program in 2015. The significance of this research lies in its identification of educational interventions for disabled tennis players within their training programs. The utilization of specific characteristics and indicators, including the temporal indicators examined in this study, has enabled the establishment of a correlation between performance changes and measurement outcomes. Furthermore, the objective is to ascertain educational solutions that will enhance and elevate their performance level. This objective is realized through a concentrated approach within these modules, emphasizing physical training, particularly when integrated into the program with an emphasis on the serve skill and methods to enhance its execution.

The research problem was formulated on the basis that consistent performance results from training processes built on sound foundations and keeping pace with developmental advancements by employing all principles that can serve the skill. Consequently, this approach

DOI: https://doi.org/10.64401/x09me539

is conducive to achieving the desired objective. The utilization of effective measurement methods and the analysis of technical errors occurring to players during performance, such as video analysis, is a consideration that merits attention. Furthermore, computer analysis is of paramount importance in establishing possible mechanisms, means, and methods. Subsequent to the identification of the mechanical variables and indicators necessary to formulate the components for advancing the skill to a higher level, attention is directed toward the issue of developing the capability of wheelchair tennis players to execute basic skills with the required ability and the mechanical conditions accompanying correct motor performance, as well as exploring the reasons behind these. One of the rationales pertains to the interplay between time and movement, thereby establishing a nexus between the mechanical dimension and its activation through the examination of performance-related characteristics and indicators. The indicators must be defined, measured, and the educational applications related to developing the abilities associated with each indicator must be conducted (Al-Kadhimi, Dhafer Hashim, 2000, p. 175). Given its impact on skill performance, and considering the physical abilities of the players and their correlation to the mechanical laws that govern movement, there will be an emphasis on effort economy and the execution of the skill with high precision. The crux of the issue lies in the frequent oversight by coaching professionals of a pivotal factor contributing to substandard performance and its subsequent decline. This failure stems from a lack of rigorous examination of the biomechanical conditions and variables associated with the technical characteristics of the skill, compounded by the dearth of updated content in educational curricula grounded in principles derived from the timing and outcomes of movement tests and analyses.

2- Procedures

2.1. Research Methodology

The researcher employed an experimental method with a group design that was suitable to the nature of the research problem. This approach necessitates the study of a phenomenon or issue that requires the availability of data or information about that phenomenon. In order to ensure the validity of the study's findings, it is imperative that the researcher seek a sample that accurately represents the original population under study. The following text is intended to provide a comprehensive overview of the subject matter.

Table (1): The mean, standard error, median, standard deviation, and skewness for the research variables.

Variables	Arithmetic Mean	Standard Error	Median	Standard Deviation	Skewness
Age	20.667	4.177	17.000	7.234	1.695
Training Age	4.667	2.186	3.000	3.786	1.597
Weight	70.000	5.000	75.000	8.660	-1.732
Forearm Length	27.667	1.202	27.000	2.082	1.293
Upper Arm Length	28.333	1.202	29.000	2.082	-1.293
Shoulder Width	43.333	1.764	44.000	3.055	-0.935

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2-2 Research Population and Sample

Consequently, the researcher opted to select a group of wheelchair tennis players (wheelchair tennis for people with disabilities) from the Central Sub-Federation in Babil. The participants were selected through the utilization of purposive sampling. The research population comprised eight players, of whom 31% constituted the sample under investigation. It should be noted that three of these players participated in both the exploratory experiment and the main experiment, due to the relatively small number of disabled players in Babil. The training curriculum components were applied to them. In order to circumvent factors with the potential to compromise the experiment's outcomes, homogeneity procedures were implemented on the sample utilizing the skewness coefficient, as illustrated in Table 1.

The results indicated sample homogeneity, as evidenced by the low skewness coefficient, thus providing a novel indicator. The closer this value is to zero, the more moderate or near-moderate the distribution is, thus confirming that the research sample is homogeneous.

2.3 Identification of the Most Important Physical Abilities

After reviewing the experts' opinions to gather their ideas regarding the most prominent physical abilities suitable for the study sample individuals, three abilities were selected that received the highest percentages: speed strength (100%), maximal strength (94%), and strength endurance (86%), as shown in Table 2.

Table (2): The percentages approved by the experts and specialists for testing physical abilities.

Tests	Relative Importance
Maximum Arm Strength	24%
Explosive Arm Strength	4%
Arm Movement Speed	22%
Arm Strength Endurance	2%
Arm Speed Endurance	20%
Arm Speed-Strength	1%

Subsequently, the researcher prepared a questionnaire for the same experts to select the appropriate test for each skill. The tests that received the highest ratings were chosen, with one test selected for each skill, as follows:

2.4 Biomechanical Variables

After careful review of sources and consulting specialists, the biomechanical variables were identified, including the most important angles related to executing the strike:

(Shoulder angle of the striking arm, elbow angle, forearm strike angle, racket tilt angle).

Additionally, the times and trajectories related to the temporal indicator of the movement pattern of the strike were determined:

(Length of the racket head path, duration of the racket head movement path, racket head speed, angular velocity of the striking arm, peripheral speed of the striking arm). (Carolykisner & Lynn Colby, 2007, p. 56).

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2.5 Exploratory Experiment

The researcher conducted an exploratory experiment for the scale on Monday, May 13, 2024, with a sample consisting primarily of wheelchair athletes with disabilities who were present at the Rehabilitation Center's court in Babylon. The present exploratory experiment focused on the filming process and involved the same sample due to the small size of the research population, with the aim of assessing the feasibility of filming. Cameras were strategically positioned to delineate the player's movement trajectory, thereby enabling the extraction of biomechanical research variables.

This facilitated the research team's analysis. The determination of distances and heights was conducted in accordance with the configuration of the filming camera and the utilization of scale measurement. It was agreed that the placement of cards would be in accordance with a frequency of 120 frames per second, with the cards to be aligned vertically with the player's movement path during the stroke.

In order to ensure proper filming of the movement from both sides, cameras were positioned parallel to the court's sidelines and perpendicular to the baseline, specifically near the corner where the two lines meet, on both sides of the court (right and left), to guarantee capturing the player's movement during the serve. With the assistance of the support team, appropriate images were taken to best display the previously mentioned indicators.

2.5 Preliminary Tests

Following the completion of the preceding experiments and the verification of the accuracy of the tests and the equipment used, and subsequent preparation of the research sample, the researcher conducted the initial imaging of the research sample, which constitutes the first part of the tests.

The imaging procedure was conducted on Monday, 13 May 2024, at 9:00 am, with a focus on the skill of serving to ascertain the biomechanical variables under investigation. On the subsequent day, the researcher conducted a series of physical tests. The initial trial was designed to assess strength endurance, whereas the subsequent trial focused on power, which was characterized by velocity.

Following the administration of an appropriate rest period, the researcher, with the assistance of the designated team, conducted these physical tests on the subjects of the research sample. The researcher then recorded the extracted information using a data recording form for the purpose of subsequent statistical analysis.

2.6 Main experiment

Following a thorough review of video recordings documenting the performance of the serving skill, and drawing upon the insights of experts and specialists in sports training, biomechanics, and tennis, the researcher developed educational applications pertaining to the temporal length index as derived from filming and analysis. As demonstrated in Appendix 1, these were presented to the experts, and some modifications were made as follows:

The educational applications were initiated immediately following the administration of the preliminary assessments. These were part of the specific preparation period and continued until close to the competition dates. The educational units incorporated a segment of the primary section.

DOI: https://doi.org/10.64401/x09me539

The duration of the educational applications was two months, with three units per week, thus totaling 23 units over the two-month period? Training days were Sunday, Tuesday, and Thursday, contingent upon the availability of the players and their respective coaches.

The temporal length index-based training programmer entailed the performance of maximum strength, speed-strength, and strength endurance exercises by the sample. These exercises were conducted using resistance bands and medicine balls with the objective of developing various types of strength. The researcher utilized standardized exercises for tennis players, with the intensity being specified through the number of repetitions within a designated time frame or by manipulating the time within a set number of repetitions. The exercises were adapted according to the type of training and suited the physical capabilities of athletes with disabilities. The temporal length index was utilized to facilitate a precise analysis of the time intervals between specific movements during the motor performance of disabled tennis players. This approach aimed to enhance the continuity of their high-level performance, in addition to developing the physical abilities related to the speed of performance required in wheelchair tennis.

The Time-Length Index is a metric that has been developed for the purpose of evaluating the quality of motor performance, and of detecting weaknesses and deficiencies in strength and movement speed. The researcher utilised the Time-Length Index to enhance physical capabilities, including speed, strength, and endurance. These devices are indispensable for wheelchair tennis players, as they facilitate the regulation of the time required to perform tennis movements on the court while moving the wheelchair with great speed.

In this section, the close relationship of the Time-Length Index with temporal characteristics in biomechanics is observed. The index is instrumental in describing and evaluating sports movements in terms of time and analyzing the frequency and speed of movement performance. This is precisely what is required in order to successfully perform wheelchair tennis skills (Salama, Ibrahim, 1999, p. 160).

The researcher's utilisation of the Time-Length Index is poised to enhance the efficacy of training by quantifying and analysing the execution times of movements or training exercises. This will assist in reconsidering the volume, intensity, and duration of training to suit the capabilities of disabled athletes. For a more detailed discussion of this topic, please refer to Appendix 1.

2.7 Post-Test

The post-tests were conducted on July 15, 2024. The researcher ensured that all tests were administered under the same conditions as the pre-test as much as possible and within the time frame specified for the experiment.

2.8 Statistical Tools:

The researcher used the statistical software package (SPSS) to analyze the research results.

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3. Presentation and Discussion of Results

3.1. Presentation, Analysis, and Discussion of Physical Test Results

Table (3): The mean values and standard deviations for the physical variables that were examined in the two tests.

Variables	Arithmetic Mean	N	Standard Deviation
Pre-Test (Maximum Strength)	333.333	3	57.735
Post-Test (Maximum Strength)	365.000	3	49.244
Pre-Test (Speed-Strength)	9.000	3	1.000
Post-Test (Speed-Strength)	12.333	3	1.528
Pre-Test (Strength Endurance)	23.000	3	3.000
Post-Test (Strength Endurance)	28.333	3	2.082

3.2. Discussion of the Results of Physical Strength Tests for the Research Sample

The results presented in Table 3 indicate statistically significant differences between the pre-test and post-test in the maximal strength test. The researcher ascribes this phenomenon to the incorporation of high-intensity resistance exercises, which have been demonstrated to contribute to the development of muscular strength. The following essay will provide a comprehensive overview of the relevant literature on the subject.

Maximal strength is defined as the greatest amount of force an athlete is capable of exerting as a result of a complete muscle contraction against a large resistance applied once. This training, categorised as either near-maximal or maximal intensity, underscores the capacity of muscles to adapt to resistance training. This adaptation has been shown to result in increased force production and improved muscular capacity. As stated by Ahmed, Osama, Riyad and Ahmed Abdel Meguid Amin (1988, p. 34). The following essay will provide a comprehensive overview of the relevant literature on the subject.

An analysis of the results related to the speed-strength test reveals that the observed differences can be attributed to physical training utilising ropes of varying weights, which were adapted to the abilities of athletes with special needs. The development of speed-strength is considered a complex attribute that combines both strength and speed.

Abdel Khaleq (1999, p. 123) defined it as "the ability of an individual to overcome resistance in the shortest possible time". In 1999, Bastawisi (p. 187) proposed an interpretation of the concept, defining it as the capacity of the nervous and muscular systems to overcome resistance at the highest possible velocity of muscular contraction. As Risan Khrebt and Ali Turki (2002, p. 156) have indicated, there is a correlation between speed-strength and skillful performance. The higher the skill proficiency, the greater the muscular coordination and the better the temporal and motor balance, which in turn elevates the level of speed-strength.

Meanwhile, Abdel Khaleq, Essam (1999, p. 122) considered speed-strength to be the result of composite abilities, represented by strength multiplied by speed, and it constitutes a fundamental component of physical fitness in many sports.

Furthermore, many researchers emphasise the importance of the interrelation between strength and speed. However, achieving a high level of this strength requires coordination and

DOI: https://doi.org/10.64401/x09me539

integration between these two elements (Al-Hajiyah, Sami Kazem & Abdul Qader Sami, 1990, p. 165).

Training speed-strength relies on two methods: either training explosive strength or developing it through overload of maximal strength. In cases where strength development is insufficient through traditional training, researchers suggest resorting to endurance strength training using specialized exercises (Jaber, Abbas Fadel, 2011, p.128). The researcher applied this approach by focusing on endurance strength training, noting the limited capacity for prolonged endurance, which may lead to random differences between pre-test and post-test results.

Endurance strength is defined as an individual's ability to sustain muscular effort against resistance for the longest possible duration. This performance represents a composite attribute combining endurance and strength. This ability affects both the nervous and muscular systems, in addition to internal physiological effects. Multiple definitions have emerged for this ability; for example, Mufti Ibrahim Hamada (1998, p.190) defined it as the capacity to maintain a consistent force output over an extended period.

Considering the limited capabilities of athletes with disabilities and the fact that their performance occurs in wheelchairs, which are difficult to stabilize, relying solely on the upper body to sustain effort, this negatively impacts their ability to maintain prolonged exertion. Therefore, results often show slight and statistically insignificant differences due to these challenges.

3.3. Presentation and Analysis of the Kinematic Variable Results for the Angle Related to the Performance of the Serve Stroke and Its Discussion

Table (4): Means and standard deviations of the performance angle during the preparation phase for the research sample.

Variables	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)
Shoulder Angle	94.766 ± 13.55	95.666 ± 13.576
Elbow Angle	74.900 ± 10.050	74.300 ± 10.194
Forearm Swing Angle	106.466 ± 20.128	122.633 ± 77.463
Bat Inclination Angle	70.700 ± 89.460	126.733 ± 93.353

3.3.1. Discussion of Performance Angle Results

A substantial discrepancy was identified in the shoulder angle of the arm utilised for the stroke, following a comprehensive analysis and presentation of results from both the preparatory and main phases. The researcher ascribes this discrepancy to the utilisation of the swing, which contributes to the rotation of the shoulders and necessitates a reduction in the shoulder joint angle of the striking arm, concomitant with a closer proximity of the arm to the body during the preparatory phase of the movement. The objective of this is to increase the distance the arm moves, which leads to increased acceleration in the main phase of the movement. Moreover, the considerable distance traversed by the racket prior to impact has been documented (Elliott, Bruce, and others, 2003, p. 79).

DOI: https://doi.org/10.64401/x09me539

In addition to weighting, it contributes to increasing the angular velocity due to the distance traveled, despite the absence of a significant difference between the pre-test and post-test for the other angles. This indicates the presence of random differences favoring the post-test. The researcher attributes these random differences to the amount of change that occurred in angular displacement over short time intervals, where the angle increases during the preparatory phase and decreases during the main phase. This is considered preparation that helps bring the arm closer and accelerate the racket movement from flexion to extension to achieve angular velocity, thereby increasing the racket's momentum due to the high speed during ball striking.

3.4 Presentation and Analysis of Results for Kinematic Variables of Times and Trajectories

Table (5): Means and standard deviations of the investigated kinematic variables.

Variables	Pre-Test (Mean ± SD)	Post-Test (Mean ± SD)
Bat Path Length	2.770 ± 0.4668	2.940 ± 0.5076
Motion Time of Bat Path	0.2767 ± 0.14012	0.2700 ± 0.1249
Bat Head Speed	17.0567 ± 0.80600	17.480 ± 0.2116
Angular Velocity	3981.288 ± 5000.033	4073.44 ± 4977.230
Peripheral Velocity	20.168 ± 1.5119	24.946 ± 6.316

3.4.1. Discussion of Kinematic Path Results Related to the Time-Length Index

The researcher ascribes the existence of significant differences in the results of analysing the movement path length of the racket head between the pre-test and post-test to the intervention. The findings indicated that the post-test phase exhibited superior outcomes, suggesting that the movement of the racket head during the stroke, particularly in the preparatory phase, is measured in a consistent manner with that of the final phase. This observation was further augmented by the incorporation of additional factors that contributed to augmenting the momentum of the racket's movement. This phenomenon occurs as a result of the high velocity attained during the initial contact of the ball, which consequently leads to the continuation of the racket's movement along the stroke path up to its initial point. Consequently, the total movement path length increases. This increase in the movement path length has a positive effect on the racket's performance, as the path length contributes to achieving high acceleration and momentum, thereby significantly reducing the performance time. Consequently, the movement path length of the racket head is regarded as a pivotal factor in enhancing the performance time (Mardan Hussein, Iyad Abdul Rahman, 2011, p.103).

Furthermore, it has been demonstrated that the greater the speed of the racket's movement resulting from the improved movement path length, the greater the opportunity to develop the player's various physical abilities. These motor changes are considered evidence of the importance of utilising temporal length indicators as a fundamental biomechanical variable when designing and implementing speed-strength training exercises. These exercises have been shown to assist players in enhancing their capabilities and achieving an optimal balance during stroke preparation, thereby leading to an overall enhancement in performance. The

DOI: https://doi.org/10.64401/x09me539

temporal length indicator facilitated the clarification that the development occurring in peripheral speed values is related to biomechanical movement variables of the striking arm. This arm operates sequentially, involving angular velocity, radius, and shoulder angle, all of which contribute to the coordinated transfer of movement to the upper limb (Alawi, Mohammed Hassan, and Mohammed Nasr Eldin Radwan, 2000, p.184).

Conversely, the development in angular velocity contributed to enhancing the efficiency of the muscles responsible for extending the arm joints. This is of crucial importance for increasing the range of movement of the shoulder joint during the stroke in the shortest possible time, as well as for adopting appropriate angles at the elbow and wrist joints. The researcher emphasised the importance of utilising resistance band exercises to achieve strength within the correct movement path, thereby facilitating a high final velocity during the stroke. This should be commensurate with the distance traversed by the arm and the time taken to cover this distance, thereby positively impacting stroke speed, provided that the stroke rate remains constant.

The researcher's programme was designed to enhance the players' ability to perform such sequential movements by means of strength training. This comprised exercises to improve speed, utilising elastic bands and various pulling exercises. These were selected to facilitate the players' mastery of a skill analogous to the sequential movement of serve strokes. With regard to the other variables in the movement trajectory that demonstrated non-significant results, the researcher ascribes this to the differences in time and speed, which are minor variables accompanied by slight increases despite the superiority in the post-test values. The observed increase in velocity can be attributed to a reduction in the time required for the movement path of the racket head. This performance is related to the joints that connect the moving parts of the body in a coordinated manner, as the final speed is achieved when the moving body part attains a sequential coordination among all body parts.

4- Conclusions and Recommendations

4.1 Conclusions

1- The prepared training program demonstrated a clear effect, as evidenced by the differences between the pre-test and post-test results in favor of the post-test concerning the research variables.

2- The training applications had a positive impact on developing strength components, including speed-strength and maximal strength.

3- The results showed the post-test superiority in enhancing strength endurance; however, the differences related to shoulder angle between the main and preparatory phases were not statistically significant.

4- The post-test superiority was evident in some variables due to the statistically significant differences recorded in the results.

4.2. Recommendations

1- Direct efforts towards developing training curricula for individuals with disabilities, with a focus on variables and abilities related to tennis in general, and serving specifically, as it is the key to the game.

2- Emphasize the importance of kinematic variables associated with performance time and angles used during serve skill training, and generalize these principles to other skills in a manner compatible with the nature of the performance.

DOI: https://doi.org/10.64401/x09me539

3- Work on enhancing physical aspects and developing specific abilities for each skill using exercises with appropriate volume and intensity tailored to the special conditions and physical capabilities of individuals with disabilities, which differ from regular warm-up exercises.
4- Focus on improving training units for individuals with disabilities by integrating the mechanical aspect of performance with kinematic variables, even when relying solely on the upper body, and apply these concepts in sports other than tennis.
5- Pay attention to the importance of angles such as the elbow angle, the angle between the racket and the forearm, and the racket tilt angle, as these are fundamental variables in the preparatory phase. These angles' values, which often favor the post-test, should be reduced, although the differences were not statistically significant.
6- It was found that the length of the movement path and angular velocity have a clear advantage in the post-test, which reflected on the performance of the racket-related paths and head speed associated with time length compared to path time and peripheral velocity.
7- Paths, times, and peripheral velocity constitute key factors in achieving the final speed of the striking arm. Although there were no significant differences, the results showed a tendency in favor of the post-test.

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DOI: https://doi.org/10.64401/x09me539

Appendix

Appendix (1)
Training Models for the Time-Length Indicator in Wheelchair Tennis

These models typically rely on focused exercises to improve the time required for fundamental movements such as rapid and efficient wheelchair mobility, ball response, and reaction time enhancement. A summarized training model is as follows:

- General warm-up exercises with stretching of the primary muscles used in wheelchair tennis.
- Slow and fast wheelchair movement drills to enhance control and bodily coordination.
- Exercises to improve wheelchair mobility time.
- Shuttle drills moving back and forth between designated points on the court with time recording.
- Training for rapid starts and quick stops of the wheelchair.
- Drills for rapid direction changes within specified time frames.
- Reaction time and shooting exercises.
- Quick reaction drills using a rebound ball or coach throwing successive balls, gradually reducing the interval between balls.
- Drills for accurate and fast ball striking immediately after reaching the ball.
- Speed and temporal power endurance.
- Repetition of intensive play phases with defined rest intervals (e.g., 30 seconds of intense play followed by 30 seconds of rest) to improve the ability to maintain performance speed during match times.
- Gradually increasing intensity training.
- Dividing the training session into different time stations to develop the ability to perform at maximum speed during varied time periods while monitoring and improving the time indicator.
- Use of precise timing devices.
- Timing devices or specialized applications to record time intervals between movements and accurately assess player performance.
- Analysis of timing results to enhance future exercises and identify weaknesses for gradual improvement.
- The typical duration of the training program is usually 8 weeks, with an average of 3 sessions per week. Each session lasts between 35-40 minutes and includes a gradual increase in intensity, focusing on reducing the time intervals between key movements in the game.

DOI: https://doi.org/10.64401/x09me539