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Training Tennis through Induced Variability and Specific Practice: Effects on Performance in the Forehand Approach Shot

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Featured Application: This work offers a significant contribution to the field of competitive tennis training, providing players and coaches a training program based on the application of induced variability. It establishes a solid foundation for modulating the variability loads present in the real game and guiding the training towards the pursuit of maximum sports performance.

Abstract: (1) Background: Learning and training in variable conditions favors adapting to unstable or changing environments. The aim of this study was to test the effect of variable practice on the accuracy of the forehand net approach shot in tennis. (2) Methods: Thirty (N = 30) first-class national players (12.9 ± 1.1 years old) participated, divided into three groups: (i) induced variability training (n = 10) (varying court surfaces and balls), (ii) specific training (n = 10), and (iii) usual training (control group) (n = 10). All groups trained for a month: 12 sessions of 20 min (3 per week). The accuracy of the shots was analyzed through a 2D capture and digitization process of the ball bounce on the court. (3) Results: The variability group presented better accuracy values after the period without practice than the stable training group ($p = 0.041$; $ES = 0.51$). (4) Conclusions: The application of variability in the game conditions during tennis training seems to have a favorable effect on the retention of accuracy in the forehand down-the-line approach to the net.

Keywords: variable practice; tennis; forehand; approach net shot; ball type; tennis court

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1. Introduction

Research in motor control and neuroscience proposes introducing variability during the practice of motor skills in order to optimize learning and improve motor performance [1]. Scientists have sought to confirm the beneficial effects of variability for the learning of motor skills, interpreted from different theoretical positions. Among them, the current problem in terms of research on the effects of motor variability can be addressed according to the constraints model proposed by Newell [2] and, more recently, by Davids et al. [3]. These models distinguish between (i) intrinsic motor variability, which can be naturally generated by the athlete's neuromotor system while practicing a skill; and (ii) extrinsic variability, provided by the environment where the practice is carried out and by the characteristics of the task proposed by the coach.

The way in which coaches can induce variability and the analysis of the effects it generates are issues of great importance for the improvement of sports technique. Following this framework, variability might be induced at two levels: (i) the task goal level and (ii) the execution redundancy level. The second explains how it appears in the execution of movement and contributes to development at a spatio-temporal level.

In this paradigm, skill acquisition does not simply involve developing an appropriate movement pattern, but also, in the presence of redundancy, developing a certain optimal variability of that pattern. In this way, we find an approach where deviations in movement are not interpreted as a negative interference for motor learning, but as the result of variability induced by an external agent (for example, a coach) and the presence of redundancy. This underscores the importance of designing tasks to introduce variability and adjust this load.

Thus, considering variability as a characteristic present in the kinematics of movement and inherent to any game context, it would be reasonable to think that if it is present in the development of motor actions, variable practice or induced variability could be a means to consider for the facilitation of motor learning [4] and performance. On the other hand, the variability induced in training can also provide flexibility to select or switch to new motor patterns when environmental conditions demand it, use previously learned movements, and allow access to the parameters that define these patterns [4]. In this sense, although variability is present in the execution of movement, these variations are often very small in magnitude, especially in expert athletes, and can be effective as a way to compensate for small deviations during the pursuit of performance [5].

Thereby, in recent decades, research has been developed in various sports that have sought to offer the coach a scientific alternative to the design of training tasks based on the application of induced variability. We highlight some research that forms the basis of our study, such as that of Shoenfelt et al. [6], who compared the effect of variable practice by varying the distances in basketball shooting against a constant, specific practice, concluding that this variation allowed players to improve their exploration processes of the possibilities of action in the game environment. Santos et al. [7] investigated the effects of a differential learning program based on variability, embedded in small-sided games, on the creative and tactical behavior of youth soccer players, concluding that the technical variability promoted by differential learning nurtures the regularity of positioning behavior. Ranganathan et al. [8] proposed how to approach practice strategies from the point of view of motor learning in order to improve behavioral flexibility by interacting with variable practice. Apidogo et al. [9] examined the effects of variable practice—in the form of differential learning (DL)—on the skills of handball, volleyball, and basketball, obtaining superior results from this condition of increased variability over other practice options. Mousavi et al. [10] conducted a study with the purpose of comparing the effects of contextual interference (CI) and differential learning (DL) on the performance and mental representations in a golf putting task, confirming better effects of DL in transfer situations of this gesture.

In tennis, in addition to the studies by Menayo et al. [4], other researchers such as Hernández-Davó et al. [11] or Alfonso et al. [12] have contributed new discoveries around the effects of variability in the learning and training of different strokes, concluding that there is a relationship that seems to affect performance between variable practice applied extrinsically and the intrinsic variability inherent in the execution of a skill. Similarly, these authors affirm the possibility that the effects of induced variability may be exclusive to each athlete.

Thus, considering this theoretical framework and the previous studies discussed, research around this topic offers a perspective to address and support the issue of variable practice from the scientific field.

In accordance with this problem, in a sport like tennis, the coach must know what effects the application of extrinsic variability loads produce during the training of their players in order to understand how to modulate them to achieve success in competitions. Thus, to transfer this proposal to our study, an intervention based on the induction of variability in execution (redundancy level) is established.

In the practice of a sport like tennis, one can perceive the existence of variability in spatial conditions (e.g., surfaces) and in the instruments (e.g., characteristics of the balls) [13,14]. Some studies also consider it of interest to apply variability in the form of changes in competitive rules to generate influences on performance [15].

On the other hand, in high-performance tennis, since the tournaments are contested on different types of surfaces and with variations in the characteristics of the balls, players are obliged to train according to these factors to start the competition with an optimal degree of adaptation.

Considering the aforementioned differences in surfaces and balls, we find it reasonable and necessary for a tennis player to develop adaptive mechanisms that allow them to adapt to the changing circumstances inherent in competitive tennis. However, these training conditions in variability must be close enough to the real situation to avoid negative transfers, and should also consider the specificity in the training of racket sports important for obtaining an adequate level of performance, as well as the quantification of the applied variability load [14].

Therefore, variability should be considered a very important variable in this sport, which appears both in real game conditions and for the training of the players themselves through its systematic administration in training. In this line, some research has demonstrated its effectiveness for the training of the forehand stroke from the back of the court in young tennis players, with modification of the spatial conditions [16].

In relation to other tennis strokes, such as the serve, Menayo et al. [4] confirmed that effectiveness was not negatively affected after employing large loads of variability, varying rackets and balls in training. All of these investigations confirm that the materials, mobiles, and instruments used in the game, as well as the surface of the court, should be key considerations when coaches determine specific training programs for high-level tennis players.

In relation to all of the above, this research is proposed, the main objective of which is to determine whether the application of induced variability on playing surfaces and types of balls in the training of the forehand approach shot in tennis, which is one of the most used shots in high-performance tennis [17], generates more accuracy than stable training and the usual training of tennis players. The study hypothesis is that training under conditions of induced variability will achieve better accuracy values than the other two proposed conditions.

2. Materials and Methods

2.1. Participants

This research involved 30 right-handed tennis players (age 12.9 ± 1.1 years; height 158.5 ± 8.3 cm; weight 55.12 ± 6.9 kg) of national level (N = 30), first class in their respective youngest child categories (fry, infantile, and cadet), with more than 5 years of experience in tennis practice. All participants were informed of the risks and benefits of this study and provided a document with the express consent of their parents, following the Helsinki Declaration of the World Medical Association. This research was approved by the Bioethics Commission of the University of Extremadura, Extremadura, Spain (code 134/2015). The sample was randomly divided at the beginning of this research into three groups: (i) induced variability, n = 10; (ii) specific training, n = 10; and (iii) usual training, n = 10. The three groups were evaluated using the International Tennis Number (ITN) [17], which proposes a scale from 1 (best rating) to 10 (worst rating), with no significant differences between groups (ITN = 4.91 ± 1; p = 0.033).

2.2. Measures and Instrumentation

To record the accuracy in the forehand approach shots to the net, a video camera was used, filming at a frequency of 150 Hz (Casio, model Exilim FH 100, Tokyo, Japan). Each bounce of the ball on the court was recorded using this video camera, fixed at a distance of 8 m from the baseline of the tennis court and at a height of 4 m, placed on top of the rear lighting and directed to the sending area marked as a target, with dimensions of 0.7 × 0.7 m, located 1.0 m away from the singles sideline and 1.0 m away from the baseline. This location is considered ideal by other authors [18] for accuracy tasks of these characteristics and using this type of stroke. In addition to taking the spatial coordinates X (longitudinal) and Y (transversal) of the center of the target as a point of maximum accuracy, the backcourt area of a singles game was established as a reference system, from the back line of the service boxes to the baseline, thus having a total of 5 coordinates to establish the reference system.

The recordings were played back using Kinovea, version 0.9.5. [19]. This software is a video annotation tool, which is open source, free, and designed for sports analysis. It allows users to capture, slow down, compare, annotate, and measure motion in videos. Each X and Y coordinate of the reference system and the target was digitized and transformed into real coordinates, with an error of less than 1.0 cm. The radial error (RE) was calculated as a measure of accuracy in the strokes using the formulae proposed by other authors [20]. Formula (1) was applied to the digitized coordinates of each bounce of the ball on the court. Finally, the obtained data were processed for subsequent statistical treatment.

$$RE = \sqrt{\left(X - X'\right)^2 + (Y - Y')^2} \quad (1)$$

X and Y = longitudinal and transversal coordinate of the ball bounce on the court.

X′ and Y′ = real coordinates of maximum accuracy according to the location of the target.

Formula (1). Formula for obtaining accuracy in strokes through the calculation of radial error (RE).

The data collection was carried out on outdoor tennis courts, taking into account the wind speed, which can interfere with the speed and effectiveness of certain tennis strokes [5]. To control for this potential interference, an anemometer (Technoline, EA 3000, NeXtime, Haarlem, The Netherlands) was used, and it was observed that during the measurement, the wind speed remained below 3.33 m/s. In this context, a study artificially inducing wind during tennis serve execution demonstrated that intensities below 4.3 m/s did not negatively impact the achieved accuracy [5].

In the context of maintaining consistency in ball delivery, a ball-throwing machine (Playmate Volley, Morrisville, North Carolina, United States) was employed to launch balls to the players. Prior to data collection, a reliability test was conducted, yielding the following results (Table 1).

Table 1. Reliability Test of the Ball-throwing Machine.

N	Launch Speed ($Km \cdot h^{-1}$)	Launch Frequency (sec.)	CV Launch Speed	CV Launch Frequency
50	45.7 ± 0.6	4.6 ± 0.9	1.2%	4.2%

N: number of balls thrown; CV: coefficient of variation.

The ball-throwing machine was calibrated before each trial, and the reliability of the device was assessed to observe the launch frequency and velocity based on the calculation of the coefficient of variation (CV). For launch velocity measurements, a mobile radar system (Stalker ATS 4.02; Radar Sales, Plymouth, MN, USA) was employed. The results of the reliability tests obtained in the frequency (CV = 4.2%) and in the throwing speed (CV = 1.2%) indicate a high degree of consistency, in line with other studies in which the same methodology was used [21].

To analyze the effect of the training sessions, a pre-test was applied before starting the intervention phase, as well as a post-test after the training sessions and a re-test one week after the post-test. Each of them consisted of 60 repetitions, 4 sets of 15 repetitions with 60 s of rest between sets and 4.6 s between strokes. All three groups performed all the tests under the same conditions, using standard intermediate bounce balls (type 2) and clay courts.

Prior to the tests, the players performed a general activation based on their daily routine: a brief warm-up of the main muscles with specific tennis movements, dynamic and ballistic exercises, and twenty minutes of exchanging strokes in different directions.

2.3. Procedure

The two experimental training groups, through induced variability and specificity, performed 60 parallel forehand net approach shots in each of the 12 proposed training sessions. The conditions of variable and specific practice were programmed according to the three categories of balls and courts used by the International Tennis Federation (ITF) [20]: (i) Category 1 (slow bounce), (ii) Category 2 (medium/medium-fast bounce), and (iii) Category 3 (fast bounce). These categories aim to allow some flexibility in the selection of the ball among three possibilities: (i) type 1 (fast), which is recommended for use on slow bounce surfaces; (ii) type 3 (slow), which is 6–8% larger than the standard ball, causing greater deceleration, and is suitable for fast bounce surfaces; and (iii) the standard ball, type 2 (intermediate), which is between the fast and slow ball in terms of bounce characteristics and is used on medium-fast courts.

Four sets of fifteen repetitions each were performed, with 60 s breaks between sets and 4.6 s between strokes, corresponding to a hitting frequency of thirteen strokes per minute (Table 2). This throwing frequency has been observed as optimal to achieve the best percentage of hits through an appropriate technique in competition players [21]. The players had to perform a parallel approach shot aiming to hit the ball in the center of the target.

Table 2. Structure of the experimental groups' training.

Groups	Court Surfaces	Balls	Sets	Rep.	BTF (sht·min^{-1})	Breaks (sec.)	Sessions
Variability	Slow (clay)/fast (concrete)	Fast, slow, intermediate	4	15	13	60	12
Specificity	Slow	Intermediate	4	15	13	60	12

Rep. = repetitions performed in each training session; BTF = ideal ball throwing frequency; sht·min^{-1} = shots per minute; sec. = seconds.

According to the categories, the induced variability group trained on two types of surfaces, fast (concrete, hard court) and slow (clay), balanced every 3 training sessions, until completing the four weeks it lasted (12 sessions) and using in each of the sessions the three types of balls based on the speed after the bounce (slow, intermediate, and fast), randomized in a series of nine trials. The specific training group trained only on a slow surface until completing the four weeks, using the same type of ball (intermediate) in each of the sessions (Figure 1).

The control group carried out their usual training with a similar number of days and training hours per week to the two experimental groups. Thus, they trained on a clay surface (slow court) three days a week for a month (12 sessions), with sessions of 1 h and 30 min. This group trained with intermediate balls (type 2), which are the conditions in which all groups (control, specificity, and variability) normally train in their daily practice.

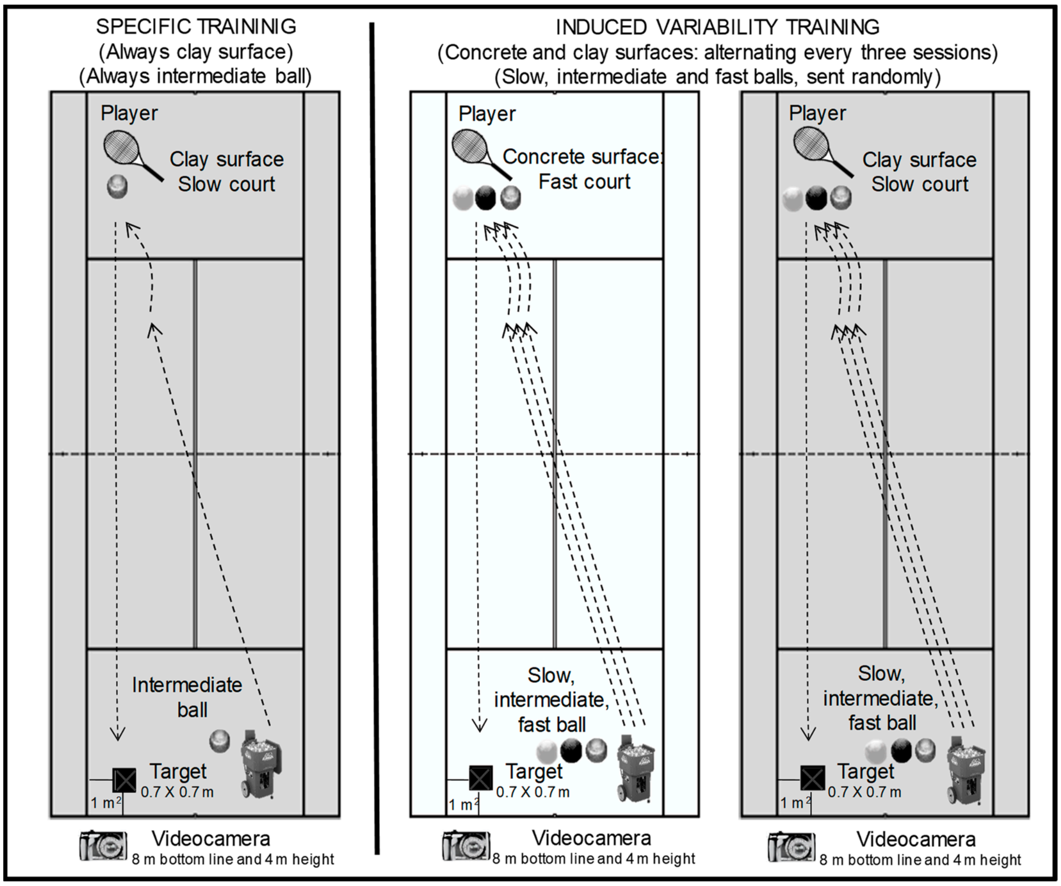

Figure 1. Experimental setup.

2.4. Statistical Analysis

The SPSS statistical package for Windows (Statistical Package for the Social Sciences Inc, version 29.0, Chicago, IL, USA, EEUU) was used for the data statistical analysis. The significance level for statistical tests was $p \leq 0.05$. The Shapiro–Wilk test detected a lack of normality in the data distribution. Attending to these results and the sample size, a non-parametric H of Kruskal–Wallis was applied to confirm the effects of practice schedules between groups. Effect sizes (ES) were estimated by calculating the epsilon-square $\left(E_R^2\right)$ [22], since, according to King and Minium [23], it is a good method. This coefficient assumes these values: 0.00 < 0.01—negligible; 0.01 < 0.04—weak; 0.04 < 0.16—moderate; 0.16 < 0.36—relatively strong; 0.36 < 0.64—strong; and 0.64 < 1.00—very strong. The Friedman ANOVA was applied to find the effects of the practice schedules between tests on each group. Effect sizes (ES) were estimated by Kendall's W test (W). This coefficient assumes the same values as the epsilon-square $\left(E_R^2\right)$.

3. Results

The accuracy results—mean radial error—of each of the training groups—usual, specific, and induced variability—are shown in Table 3 and Figure 2. The values recorded in the pre-test, post-test, and re-test are included.

The accuracy data presented through the median, as well as the dispersion data, represented by the standard error and the difference between the maximum and minimum accuracy, reflected by the range, are included in Table 3. It can be observed that the usual training group obtained values of 206.63 cm in the pre-test, 95.58 cm in the post-test, and 180.09 cm in the re-test. In this same group, the dispersion data regarding the achieved accuracy, represented through the standard error, reflect values of 11.45 cm in the pre-test, 7.00 cm in the post-test, and 13.98 cm in the re-test. Regarding the differences between the maximum and minimum values achieved in accuracy, the ranges show values of 116.44 cm in the pre-test, 72.69 cm in the post-test, and 125.30 cm in the re-test.

Table 3. Descriptive values (cm) by groups and practice schedules.

		Usual	**Specific**	**Variability**
Radial Error Pre-test	Mean	206.97	230.77	232.94
	Standard deviation	36.21	48.45	30.69
	Median	203.63	231.54	235.76
	Variance	1311.03	2347.14	942.13
	Standard error	11.45	16.15	9.71
	Range	116.44	161.50	95.15
	N	10	9	10
Radial Error Post-test	Mean	100.42	98.18	165.75
	Standard deviation	22.14	22.34	111.42
	Median	95.58	97.92	110.22
	Variance	490.20	498.93	12,414.71
	Standard error	7.00	7.06	35.23
	Range	72.69	68.02	316.12
	N	10	10	10
Radial Error Re-test	Mean	201.85	241.69	192.60
	Standard deviation	44.22	43.50	46.23
	Median	180.09	236.44	180.46
	Variance	1955.62	1892.41	2137.61
	Standard error	13.98	13.76	14.62
	Range	125.30	120.63	133.15
	N	10	10	10

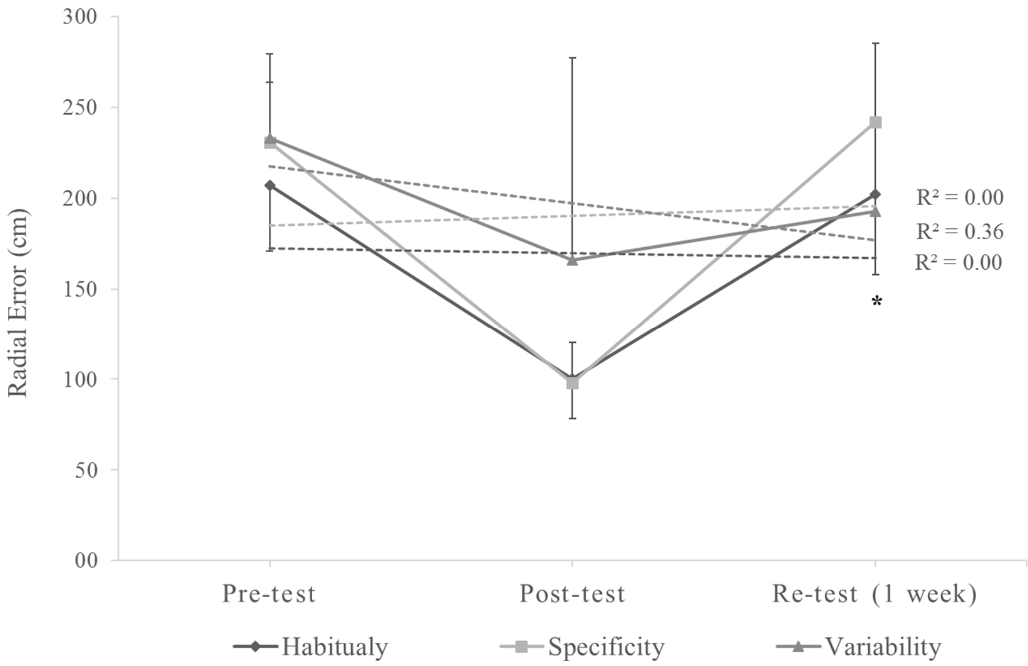

Figure 2. Evolution of the accuracy achieved by the players in each practice condition from the pre-test to the retention test. The bars show the standard deviation. * $p = 0.041$; $ES = 0.51$; significant differences between the specificity and variability groups in the retention test can be seen.

The specific training group obtained median values of 231.54 cm in the pre-test, 97.92 cm in the post-test, and 2236.44 cm in the re-test. In this same group, the standard error data reflect dispersion values of 16.15 cm in the pre-test, 7.06 cm in the post-test, and 13.76 cm in the re-test. The differences between the maximum and minimum accuracy values show ranges of 161.50 cm in the pre-test, 68.02 cm in the post-test, and 120.63 cm in the re-test.

The training group, through induced variability, obtained median values of 235.76 cm in the pre-test, 110.22 cm in the post-test, and 180.46 cm in the re-test. In this same group, standard error values reflect dispersion values of 9.71 cm in the pre-test, 35.23 cm in the post-test, and 14.62 cm in the re-test. Regarding the differences between the maximum and minimum accuracy values achieved, the ranges show values of 95.15 cm in the pre-test, 316.12 cm in the post-test, and 133.15 cm in the re-test.

As reflected, participation was maintained in the three groups in the tests developed (N = 10). Only the experimental 'dropout' of one of the tennis players from the specific practice group was noted, who could not perform the pre-test (N = 9). However, this player continued participating in subsequent training and tests (Table 3).

3.1. Intra-group Analisys

Table 3 shows the mean and standard deviations of the intra-group analysis. In the usual training group, there were significant increases in accuracy in the post-test (206.97 ± 36.21 vs. 100.42 ± 22.14; p = 0.001; ES = 0.32). However, a significant loss of accuracy can be observed between the post-test and the re-test (100.42 ± 22.14 vs. 201.85 ± 44.22; p = 0.005; ES = 0.28). In the specific training group, there were significant increases in accuracy in the post-test (230.77 ± 48.45 vs. 98.18 ± 22.34; p = 0.003; ES = 0.31). By contrast, a significant loss of accuracy can be observed between the post-test and the re-test (98.18 ± 22.34 vs. 241.69 ± 43.50; p = 0.007; ES = 0.29). In the variability training group, no significant changes in accuracy were produced from this practice condition. In all of these results, an effect size that is relatively strong can be seen, according to the reference values [23].

3.2. Between-group Analisys

Figure 2 presents the results of the accuracy (mean radial error) of the inter-group analysis. Significant differences can be observed in the retention test between the practice groups in induced variability and in specificity. The variability group presents better accuracy values than the specificity group after the period without practice (192.60 ± 46.23 vs. 241.69 ± 43.50 cm; p = 0.041; ES = 0.51). In this case, a strong effect size is obtained [23].

Regarding the evolution of performance reflected in Figure 2, the trend lines indicate that the group trained through induced variability shows a clear trend towards improved accuracy throughout the intervention (R^2 = 0.36). However, the usual and specific training groups do not seem to show such a marked trend towards improvement.

4. Discussion

In this research, the effect of training through induced variability, specific and habitual, on the accuracy of the right net approach shot in tennis was analyzed.

Regarding the intra-group comparison, it is noteworthy that the variability group presents better accuracy values than the specific training group after the period without practice, that is, in the retention test, compared to the post-test. These results are in line with other studies, which have reported greater accuracy after practicing tennis under variability conditions than when doing so in specificity with young tennis players who practiced the tennis service [11,12].

Focusing specifically on the stroke treated in the present study, the results found agree with other researchers [16,24] on the influence of variable practice in learning the forehand, although their study did not specifically analyze, as we did, the situation of approaching the net. In that study, both a group of children aged between 9 and 10 years and another group of young students aged between 18 and 19 years obtained a higher performance practicing the forehand in a variable way than doing it in a specific way. Similarly, previous studies confirmed positive effects on the right approach to the net in tennis after applying variability loads through the use of weighted wrists by amateur players [25].

The results observed in the different training conditions on the forehand net approach shot must be understood from the perspective of the reality of the game. It must be considered that the situations that occur in a tennis match present unpredictability, uncertainty, and a reduced reaction time to make decisions. In this sense, the results in which the accuracy of the stroke was only improved in the retention test by the group that trained in variability could be related to the adaptations produced by this type of training.

Thus, they could especially be in line with a greater adaptive capacity or positive transfer to tennis performance when, for example, a player has to go from competing on a slow court to a fast court in a short period of time.

On the other hand, the fact that no significant differences were found between the three groups in the post-test leads us to think about issues related to the quantity and intensity of the load, especially the one induced in variability, which has not allowed us to fully accept the study hypothesis. In this sense, we agree with other authors who affirm the importance of carrying out an individualized application of variability loads to achieve the best possible effects on tennis performance [12]. This issue reflected in the results of our research suggests the need to develop new studies that clear up these unresolved questions.

This issue about the induced variability load would also explain the results observed in the intra-group comparison. In the specific and habitual training groups, there were significant increases in the accuracy of the forehand approach shot in the post-test compared to the pre-test. By contrast, in these groups, there was a significant loss in the re-test compared to the post-test, which is why we cannot talk about the maintenance of performance over a week. For its part, the practice group, through induced variability, did not significantly improve accuracy after the training period or even after the period without practice. This result does not coincide with those previously obtained, which confirmed positive effects on the forehand approach to the net in tennis by amateur players after applying variability loads through the use of weighted wrists [25]. However, we understand that the variability induced in that study was carried out with amateur players who present a wide range of improvement, and differs greatly from the variability applied in our research with competition tennis players who do not present so much margin. Therefore, this lack of coincidence should be assessed with caution.

These results reinforce the need to apply individualized variability loads, adjusted according to a detailed analysis of their effects on game performance that impact in the short, medium, and long term. In fact, other authors who investigated the effects of different variability loads in the format of contextual interference applied to tennis service training concluded that their results are not so evident in complex motor skills, as is the case with the right approach shot analyzed in our study [26].

Additionally, another factor that could explain this result would be the possible onset of fatigue, as some authors have concluded that it could affect motor memory during the practice of sports skills [27,28]. However, this explanation requires scientific verification in order to modulate the training load in this action of the game in tennis so that it does not negatively affect performance.

Future research directions emanating from this study should address the individualized quantification of induced variability loads in the learning and training of tennis strokes. It is considered a priority to abandon group studies and carry out intra-subject research designs, as there are too many uncontrollable factors during the practice of this sport, as well as those specific to each player, among which, there may be aspects such as fatigue or others, which can condition the effects of these types of programs based on the generation of variability on the accuracy achieved in strokes.

5. Conclusions

As the main conclusion of our research, we highlight the idea that the use of variability in the conditions of tennis training seems to have a favorable impact on the retention of performance in the accuracy of the forehand parallel approach shot to the net. It is necessary to know the characteristics of the variability inherent to the sport in question, in our case tennis, in order to be able to design workloads and training systems aimed at improving certain variables associated with sports performance. These variability loads must be sufficiently adjusted to stimulate an increase in performance without exceeding the levels of variability to limits that could generate negative transfers and, consequently, negatively impact performance.

On the other hand, it is necessary to comment on a possible limitation of this study in relation to the sample size. While we have emphasized that the effects of induced variability should be interpreted individually and that these loads will affect each athlete exclusively, we should not forget that it would be interesting to complement the results of an intra-subject study with investigations in which the groups were made up of a larger number of participants.

Finally, we want to highlight that in this research we have tried to maintain a high ecological value by manipulating the practice conditions according to the reality of the tennis game. The induced variability loads have been based on the manipulation of variables that are usually present in competitive-level tennis players; however, it seems necessary to continue investigating the intensity and quantity of these loads and their impact on performance in terms of the accuracy in strokes.

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Conflicts of Interest: The authors declare no conflicts of interest.

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