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Comparison of External and Internal Training Loads in Elite Junior Male Tennis Players During Offensive vs. Defensive Strategy Conditions: A Pilot Study

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Abstract: The aim of our pilot study was to investigate the effects of offensive and defensive strategy conditions on external and internal training load factors in male tennis players. The study included 6 elite junior male tennis players (chronological age: 15.7 ± 1.0; body height: 180.7 ± 6.5 cm; body mass: 71.0 ± 10.8 kg) who had to play two simulated matches. Among the external training load variables, running activities were measured with a GPS sensor and tennis shot activities with a smart sensor. Internal training load was measured subjectively using the RPE method. The results show that players scored significantly higher on the PlayerLoad™ ($p = 0.031$; r = 0.90) and IMA CoD low right ($p = 0.031$; r = 0.90) running variables, and on the forehand spin ($p = 0.031$; r = 0.90) and backhand spin ($p = 0.031$; r = 0.90) when using a defensive strategy. There were no significant differences between the two strategy conditions in all other external and internal training load parameters. The defensive strategy has more acceleration in all three planes of motion, suggesting that conditioning training should be placed in the intermittent endurance capacities for players who predominantly use this strategy.

Keywords: tennis; strategy; GPS; RPE; inertial movement analysis

1. Introduction

The outcome of tennis matches is often extremely unpredictable. This unpredictability is also caused by the different strategies, technical-tactical decisions, state of readiness, playing surfaces, and weather conditions of the players [1]. This naturally leads to variations in match times, which can last less than an hour but can also be seen in some cases lasting more than five hours [2]. According to the International Tennis Federation (ITF) rules, high-intensity periods are separated by rest periods of predetermined duration [3], according to which most high-level matches have a work-to-rest ratio of between 1:2 and 1:5, with point durations ranging from 3 seconds to 15 seconds on average [4,5]. In addition, matches are characterized by high-intensity micromovements (accelerations, decelerations, change of directions, and jumps) as running activities. Analysing these movements, it can be seen that players execute 80% of strokes after positional movements within 2.5 m, 10% of strokes are performed between 2.5 and 4.5 m, while 5% of strokes are performed over 4.5 m and the remaining 5% do not reach the ball [6,7]. The average distance run within each rally is 6-7 metres [8] with the maximum distance run between strokes ranging from 8 to 12 metres, [9] and an average of 4 to 6 change of directions per point [3]. This type of approach to match analysis is called a reductionist method in ball games, and means that physical actions are analysed in isolation, separately from tactics-techniques [10]. Individual physical actions are modulated by tactical movements during the game, where players adopt several options defensively or offensively according to different tactical contexts [11]. In tennis, this integrated approach is based, among others, on the various playing styles that are associated with a dominant offensive or defensive strategy conception [12]. In itself, effective playing time differs between styles, with 21% for offensive players, 28.6% for all-court players and 38.5% for baseline players when tested on clay surfaces compared to total playing time [13]. In female tennis players, the evolution of technical-tactical actions, external and internal training load factors and activity profiles in closed conditions for each strategy condition has been investigated [12]. The results showed that the largest effects compared to the own (control) condition were found in technique and tactics (number of groundstrokes and errors) and activity profile (strokes per rally, rally duration, work-to-rest ratio, and effective playing time), followed by external load parameters (high and low-intensity running distance). From this it can be seen that technique-tactics will be affected first by the strategy decision, and only then will the external training load change. In addition to this, another important aspect is the study of the internal training load, which represents the athlete's internal response to the external load. In tennis, this is measured by the heart rate (HR) variables [1,14], VO_2 [3,4] blood lactate [15], and rating of perceived exertion (RPE) [16,17] data are commonly used to characterize it. The subjective RPE-based method is easy to use, integrating physiological, mechanical, and neuromuscular fatigue [18], and showing a strong correlation (r = 0.74) with HR [19]. In tennis matches, the average RPE score ranges from 10 to 16 (Borg's CR-20 scale) [3,20] and 5-8 (Borg's CR-10 scale) [21], but this may be influenced by external factors such as playing surface [22], skill level [23], gender [24] and game situation [17,20]. Among the game situations, the serve and return situation is commonly analysed, showing that serve games are more demanding than return games [17,20]. As with the external load parameters, it is also useful to consider RPE indicators in an integrated way with different strategies and tactics. Previous research in female tennis players has indicated that RPE was the highest when using the passive strategy condition [25]. To the best of our current knowledge, no research has yet been conducted that has examined the effects of different strategy conditions on external and internal training load variables in male tennis players and, therefore, we sought to address these in our current pilot study. Based on prior literature and coaching experience, we hypothesized that there would be a difference between simulated matches played in offensive and defensive strategy conditions in (i) external training load variables in running and tennis shot activities, but (ii) no significant difference in internal load factors in elite junior male tennis players.

2. Materials and Methods

2.1. Experimental Approach

In this cross-sectional, applied, pilot study, we identified differences between the two strategy conditions in the most relevant external and internal load parameters in tennis. The study was a one-day study, conducted in May 2023, and took place between 2:00 pm and 4:00 pm. All players were from a Hungarian tennis club, thus we could perform the measurements under their own conditions. The experiment took place on an outdoor, windless, clay court (temperature: 21.2-24.5 °C; relative humidity: 44-56 %; Kestrel 4000 Pocket Weather Tracker, Nielsen Kellerman, Boothwyn, PA, USA).

2.2. Participants

In this pilot study, we included 6 elite junior male tennis players (chronological age: 15.7 ± 1.0; body height: 180.7 ± 6.5 cm; body mass: 71.0 ± 10.8 kg), selected by theoretical sampling. Inclusion criteria were (i) U16-U18 male age group, (ii) national age group ranking ≤10, (iii) right-hand dominant, (iv) ability to apply both offensive and defensive play. And the exclusion criteria are (i) injury/illness, (ii) has undergone some type of orthopaedic surgery in the last 12 months, (iii) has performed high-intensity activity in the last 48 hours. The players in the study participated in an average of 10.3 ± 1.5 hours of tennis trainings and 3.3 ± 0.7 hours of conditioning trainings per week in a microcycle. In addition, they averaged 23.1 ± 4.5 official national and/or international competitions per season. Of the subjects, one player was ranked in the top 200, one player in the top 500, and the other players were ranked in the top 2000 in the official junior rankings of the International Tennis Federation (ITF) at the time of the experiment, and two of these players were already ranked in the Association of Tennis Professionals (ATP) singles ranking. Prior to the start of the experiment, the players and their parents/legal guardians were informed of the research process and their written consent was obtained. The local institutional ethics committee (Hungarian University of Sports Science, Budapest, Hungary; Approval No. TE-KEB/02/2022; Approval date: 06 February 2022) approved the procedures in accordance with the latest version of the Declaration of Helsinki.

2.3. Procedures

Figure 1. shows the schematic illustration of the experimental design. The subjects were aware of the procedure, as they had attended a pre-briefing. The experiment day started with general anthropometric assessments, followed by simulated matches. Body height was measured using a fixed stadiometer (± 0.1 cm; Holtain Ltd., Crosswell, UK) and the body mass with a digital balance (± 0.1 kg; ADE Electronic Column Scales, Hamburg, Germany). After the anthropometric assessments, the players performed a general warm-up (15 mins) consisting of low-intensity circulatory exercises, muscle activation, dynamic stretching and neuromuscular activation exercises. They then proceeded to the tennis court with a tennis-specific warm-up protocol (10 mins), in which they performed groundstrokes, volleys, serves, and returns. The tennis players were then divided into pairs based on the level of play, which had been previously conducted by their own coaches. Subjects were asked to play two 10 minutes simulated matches with 5 minutes of passive rest according to a pre-described protocol [25]. The matches were played according to the ITF official rules in a tie-break format, meaning that after the first serve, the serve was exchanged in deuce. For the simulated matches brand new 53-56 g and 6.5 diameter 'Slazenger Ultra Vis' balls were used that met international standards. During the matches, tennis players had to pick up the balls and count the points themselves. Before each of the two 10 minutes blocks, the players were instructed on whether to play the match with an offensive or defensive strategy. Each instruction was given on paper and in an open format. For the offensive strategy, the players read 'try to win the point by yourself or by forcing the opponent to make a mistake', and for the defensive situation, the subjects read 'try to win the point by reducing the number of unforced errors'. The players were not allowed to talk to each other about who had received what instructions. Each player was required to play a match with both an offensive and defensive strategy, and the pairings were always set up so that two players in offensive and two players in defensive roles played against each other. Overall, we got 6 simulated matches with 6 offensive and 6 defensive strategy conditions. Halfway through the matches, the tennis players were always warned by a coach to follow the instructions given. After 10 minutes, the last point was played.

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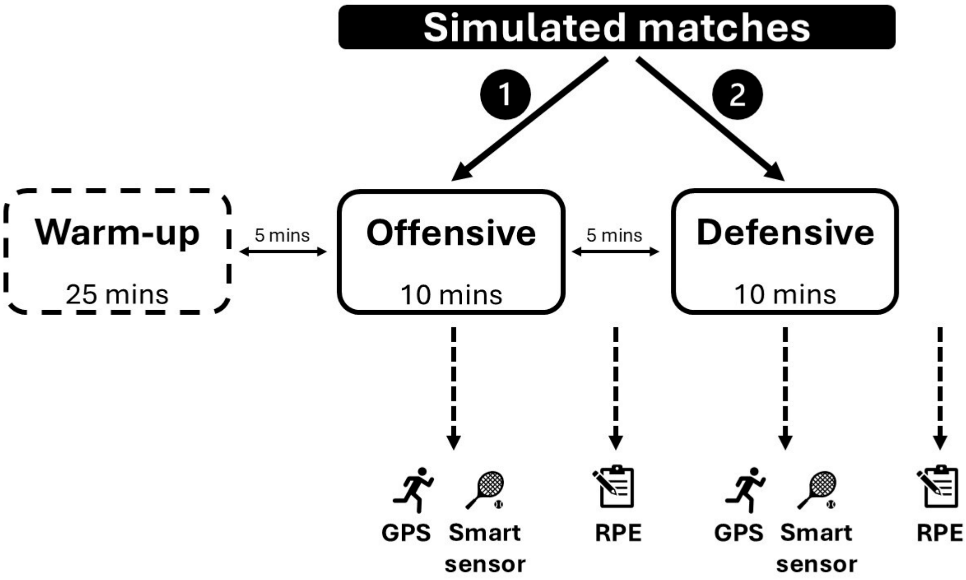

Figure 1. The schematic illustration of the experimental design. Legend: GPS = global positioning system; RPE = rating of perceived exertion.

2.4. Variables

2.4.1. External Training Load

For external training load, both running and tennis shot activities were investigated. To assess running activities, we used a GPS sensor operating at 10 Hz (OptimEye S5; Catapult Innovations, Melbourne, Australia) and a 100 Hz tri-axial piezoelectric linear accelerometer (Kionix: KXP94) integrated into it. In addition to the accelerometer data, the gyroscope and magnetometer integrated into the microsensor also help to determine the direction of each acceleration [25]. This type of GPS sensor has good reliability and accuracy in the study of movements over small areas [26,27] and also has good reliability in the study of tennis-specific movements [28]. The sensors were worn by the players between their two shoulder blades in a neoprene vest. The players were familiar with the use of the sensors, as they had previously used such a measurement device in their everyday training. The harness size was chosen by players in training sessions. The sensors were switched on 15 minutes before the measurements started but were only inserted into the vests at the start of the simulated matches. In the present study, we were directly interested only in the data collected by the inertial measurement unit (IMU) embedded in the GPS, which investigates high-intensity micromovements, since these are the most frequent running activities in tennis [29]. For the parameters under investigation, we only considered absolute values. To measure the individual micromovements, we used the PlayerLoad™ (PL) variable, which sums the acceleration in all directions of the court by a number, taking into account the instantaneous rate of change of acceleration and dividing it by the scale factor (divided by 100) [30] to obtain an arbitrary unit (AU) number. Reliability of the PL metric has previously been established at a 1.9% coefficient of variation (CV) from observations in team sport athletes [31]. In addition to this, we also investigated the number (n) of right and left change of directions (IMA CoD low and high) with low (< 2.5 m/s^2) and high (≥ 2.5 m/s^2) intensity. Rightward change of directions are defined as accelerations between 45° and 135° and leftward change of directions as accelerations between -135° and -45° [30]. These inertial movement analysis (IMA) type data have been previously used in tennis-specific research to determine the direction of accelerations [25]. All data recorded by the Catapult units were downloaded and elaborated by Catapult software (OpenField v1.22.2; Catapult Innovations, Melbourne, Australia) before being exported as a .CSV file for further analysis.

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To measure tennis shot activities, we used a tennis racket-mounted smart sensor (Zepp Tennis 2.2.1, Zepp Labs, USA) with a dual accelerometer and a dual 3-axis gyroscope. The validation procedure of this sensor showed good results for the number of strokes and ball speed, and moderate results for the other types of strokes [32]. Currently, it is the only smart sensor that is compatible with all rackets [33]. The smart sensors are mounted on the end of players' rackets using a manufacturer-provided ‘flex-mount’ adapter that can be easily moved from one type of racket to another, and thus reduce interference caused by different grips [34]. Players were also aware of the use of smart sensors and player profiles with sociodemographic data were created beforehand, through which the sensors and the associated phone app (Zepp Tennis, Zepp Inc., USA) were linked. Each player used the same sensor for each of the two simulated matches in order to avoid data dissociation, and each sensor was connected to a separate smartphone on a Bluetooth basis to avoid interference. Among the tennis shot variables, we examined (i) forehand velocity ($km \cdot h^{-1}$), (ii) backhand velocity ($km \cdot h^{-1}$), (iii) forehand spin (revolutions per minute, rpm), and (iv) backhand spin (revolutions per minute, rpm). All data were detected in the phone application and then exported to .CSV file format for further analysis.

2.4.2. Internal Training Load

To examine the internal load, we measured the players' rating of perceived exertion (RPE) (Borg's CR-10 scale). The validity of this RPE scale shows a strong correlation with heart rate (r = 0.74; $p < 0.001$) and blood lactate (r = 0.83; $p < 0.001$) during aerobic exercise [35]. Even in small field sports such as tennis, RPE measurements are often used to assess the internal exertion of athletes [14,16]. Immediately after each simulated match, RPE data were recorded following a preliminary protocol [36] (Figure 1). Players were asked ‘How demanding was the match?’ and were asked to score this on a 0-10 Likert scale. The obtained RPE results were manually recorded on paper, which were then entered into a spreadsheet software (Microsoft Excel, 16.49, Microsoft Inc., Washington, USA) on a computer and finally used in CSV. file format for further analysis.

2.5. Statistical Analyses

Statistical analyses were performed using SPSS Statistics Package (version 20.0, SPSS Inc., Chicago, IL, USA). First of all, all data’s distribution were checked by Shapiro-Wilk's test, kurtosis and skewness values, and visual inspection of their histograms and QQ plots. Descriptive statistics are reported as mean ± standard deviation (SD). Since none of the dependent variables followed a normal distribution, a Wilcoxon signed-rank test was used to determine the differences between the two strategy conditions (offensive and defensive). Effect sizes (ES) were interpreted using r principle as follows very small < 0.1, small 0.1-0.3, medium 0.3-0.5, large > 0.5 [37]. The significance level was set at $p < 0.05$.

3. Results

Table 1 shows the descriptive statistics of the external and internal load variables data. In terms of running activities, there is a significant difference with a large effect size between the offensive and defensive strategy conditions for the PL (T = 0.0; Z = 2.201; $p = 0.031$; r = 0.90) (Figure 2A) and IMA CoD low right (T = 0.0; Z = 2.201; $p = 0.031$; r = 0.90) (Figure 2B) parameters. No significant difference was observed between the two strategy conditions for the IMA CoD low left (T = 2.0; Z = 1.782; $p = 0.090$; r = 0.73), IMA CoD high right (T = 3.0; Z = 1.572; $p = 0.140$; r = 0.64), IMA CoD high left (T = 12.0; Z = 1.214; $p = 0.279$; r = 0.50) parameters. For the tennis shot activities, a significant difference was observed with high effect size between the offensive and defensive strategy condition in the forehand spin (T = 0.0; Z = 2.201; $p = 0.031$; r = 0.90) (Figure 3A) and in the backhand spin strokes (T = 0.0; Z = 2.201; $p = 0.031$; r = 0.90) (Figure 3B). No significant differences were observed in the forehand velocity (T = 6.0; Z = 0.365; $p = 0.855$; r = 0.15) and in the backhand velocity (T = 16.0; Z = 1.153; $p = 0.313$; r = 0.47). No significant difference was observed between the two conditions in the RPE parameter when testing the internal load (T = 1.5; Z = 1.633; $p = 0.102$; r = 0.67).

Table 1. External and internal load variables data of the offensive and defensive strategy conditions.

Variables	Offensive	Defensive				
	Mean ± SD	**Mean ± SD**	***T***	***Z***	***p***	***r***
PlayerLoad™ (AU)	70.0 ± 14.0	103.8 ± 7.9	0.0	2.201	0.031*	0.90
IMA CoD low right (n)	27.7 ± 3.8	45.7 ± 4.1	0.0	2.201	0.031*	0.90
IMA CoD low left (n)	43.7 ± 8.5	58.9 ± 9.0	2.0	1.782	0.090	0.73
IMA CoD high right (n)	1.3 ± 0.8	4.1 ± 4.9	3.0	1.572	0.140	0.64
IMA CoD high left (n)	6.7 ± 2.0	5.3 ± 1.0	12.0	1.214	0.279	0.50
Forehand velocity ($km \cdot h^{-1}$)	100.2 ± 2.2	99.8 ± 3.0	6.0	0.365	0.855	0.15
Backhand velocity ($km \cdot h^{-1}$)	98.0 ± 4.9	93.5 ± 3.9	16.0	1.153	0.313	0.47
Forehand spin (rpm)	1383.0 ± 138.7	1665.5 ± 105.5	0.0	2.201	0.031*	0.90
Backhand spin (rpm)	1256.5 ± 112.7	1550.0 ± 140.1	0.0	2.201	0.031*	0.90
RPE (AU)	5.3 ± 0.8	6.7 ± 1.4	1.5	1.633	0.102	0.67

Legend: IMA = inertial movement analysis; CoD = change of direction; RPE = rating of perceived exertion; * indicates significant difference between strategy conditions ($p < 0.05$).

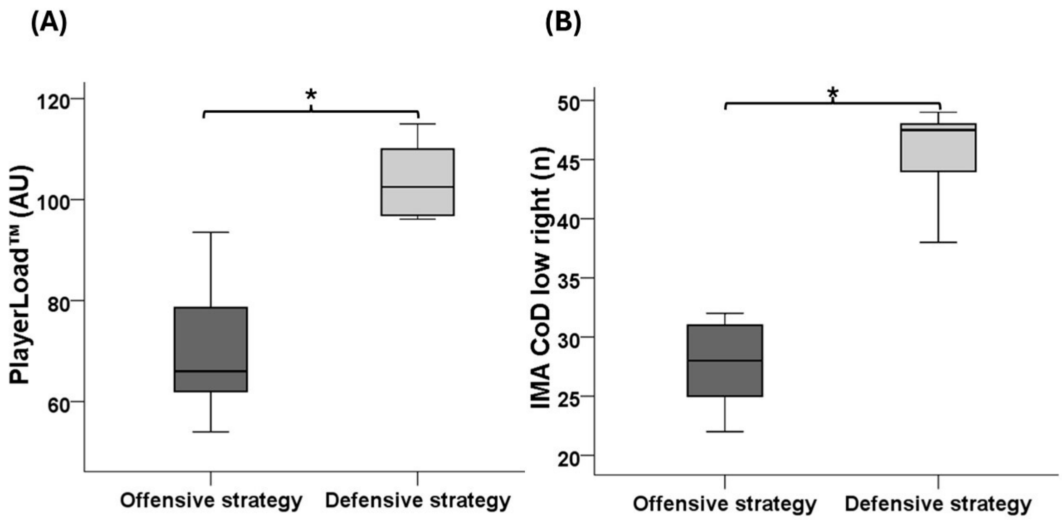

Figure 2. The significantly different running activity variables of the offensive and defensive strategy conditions. The boxplots show the median, the upper, and lower quartiles, and the min and max values of the strategy conditions in the PlayerLoad™ **(A)**, and in the IMA CoD low right **(B)** parameters. Legend: * indicates a significant difference between strategy conditions ($p < 0.05$).

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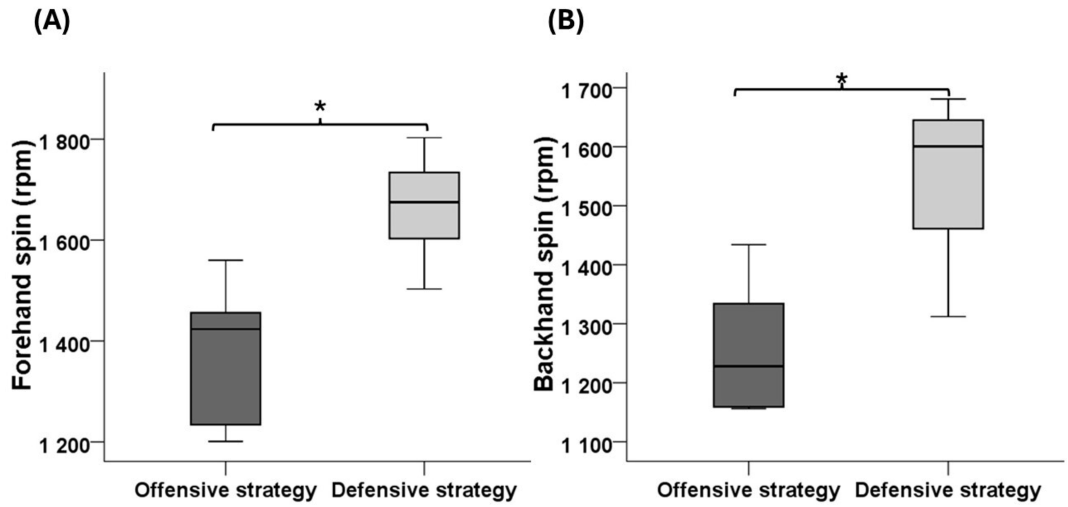

Figure 3. The significantly different tennis shot activity variables of the offensive and defensive strategy conditions. The boxplots show the median, the upper, and lower quartiles, and the min and max values of the strategy conditions in the forehand spin **(A)**, and in the backhand spin **(B)** parameters. Legend: * indicates a significant difference between strategy conditions ($p < 0.05$).

4. Discussion

The aim of this pilot study was to investigate the difference between the offensive and defensive strategy conditions in external load factors such as running and hitting activities and internal load factors such as the rating of perceived exertion (RPE). We hypothesized that there would be a significant difference between the two conditions in (i) running and tennis shot activities, but (ii) no difference in RPE.

In today's sports science, the analysis of the different load parameters (external and internal) in the analysis of individual ball games is no longer based on a reductionist analysis, but on an integrated approach with technique and tactics [10]. In football, for example, this approach can be understood in terms of comparing each position, the most intensive period of the match, and general and specific tactical roles [38]. For example, the distance covered in the high-intensity running zone in a match is the greatest for the wide midfielder position (~800-1500 m) compared to other positions [39,40]. All of this can be further decomposed by including specific tactical roles in the analysis, as this provides the actual physical workload of the athletes [41]. For instance, when a player playing in the central midfielder position is in an attacking role, he is covering a greater distance in the high-intensity running zone than when he is defending [42,43]. This integrated approach is most commonly used in tennis to assess the impact of, for example, matches in different playing surfaces on external and internal load factors [22,44] or various playing situations [17,20] or the profile of different playing styles and strategies [12,13,25].

Success in tennis has its own complexity, which depends on factors such as the athlete's anthropometric characteristics, physical capacity, technical-tactical skills, psychological characteristics, and medical characteristics [1]. Based on this complexity, many factors influence match data. Research by Murias and colleagues [45] showed that heart rate and lactate levels were higher on clay surfaces than on hard court surfaces, and Reid and colleagues [43] confirmed these, and even RPE was higher on clay surfaces. Another integrated approach to look at the differences between serve and return games [14] have a higher internal load than return games[17,20], but there can of course be differences depending on the level of knowledge [14]. A third integrated approach in tennis is to look at differences between different playing styles and playing strategies in terms of external and/or internal load factors. In the present pilot study, this was also investigated in a closed setting, as there is little research on this topic and even less among male tennis players. A previous study has investigated the impact of the use of offensive and defensive strategies on match activities and physiological characteristics [4]. The results of this study showed that the defensive strategy resulted in a longer duration of each rally and effective playing time, as well as higher heart rate and blood lactate values (all $p < 0.01$). In the present study, we did not examine the aforementioned load variables, but our results showed that for the defensive strategy condition, significantly higher values were obtained for the PlayerLoad™ variable, which implies that players in this strategy perform more accelerations in all three planes of motion than in the offensive strategy. In our case, no significant difference was observed between the two strategies for an internal load variable such as RPE, which is also supported by previous research [25]. It is always the technique-tactics that will be affected first by the application of different strategies, and only then the tennis shot and running activities, and then, at the very end, what all these will result in, the internal load [46,47]. Our results also show that the tennis shot activities such as the spin of the shots is also strongly influenced by strategy, as balls were hit with higher spin in both the forehand and backhand sides in the defensive condition ($p = 0.031$; r = 0.90). The defensive strategy as a whole is characterised by tactics such as playing mostly from the baseline to the middle of the court without coming up to the net and avoiding hitting sharp angles in order to minimise wide shots [25]. In contrast, when using the offensive strategy, we can see from our results that there was significantly less running activity in terms of quantity (PlayerLoad™, IMA CoD low right), which was also realized because, as we have seen from previous research, this strategy has a higher work:rest ratio, so there is less effective time to perform micromovements [12,25]. The tactical characteristics of the offensive strategy are completely opposite to the defensive strategy. First of all, offensive-style players like to run up to the net more and finish points there, and they use high-angle shots and vary them frequently. According to experts [25,48] attacking players also use higher velocity groundstrokes to finish points faster, but this is not supported by our results, as there was no significant difference in average speed for any of the groundstrokes between the test conditions we assessed (all $p > 0.05$). This can be strongly influenced by age, gender and skill level.

From a practical point of view, the results of the present pilot study and the results of previous studies on similar topics suggest that the characteristics of each strategy should be taken into account from both a physical and a technical-tactical point of view when planning training sessions. In fact, for those types of players who prefer a predominantly defensive strategy, intermittent endurance capacities are the most important factor in conditioning training [1,12] because this strategy requires higher aerobic and anaerobic-lactic capacities due to longer ball movements and more acceleration in all three planes of motion (PlayerLoad™). In contrast, the offensive strategy is dominated by anaerobic-alactic energy production and explosive power capacity. In technical-tactical training, the defensive strategy should focus on higher spin groundstrokes, baseline play and minimizing unforced errors, while the offensive strategy should focus on higher angle and speed shots and more net play. It should be noted, however, that since success in tennis is complex in all aspects (physical and technical-tactical), it is necessary to develop all the other skills in addition to those listed above for each strategy, especially for junior athletes, for whom long-term and complete development is the goal based on the LTAD (Long Term Athlete Development) model [49]. Also, the periodisation of training should take into account the different strategies of the players. For example, in the preparation period, in the periods between competitions or after an injury, the focus should be more on complex training, but in the competitive period, in order to provide more specific training, it is advisable to plan tennis players' training sessions both on and off the court in a strategy and playing style specific way. In addition, in today's modern tennis, monitoring of match data such as external and internal training load variables is now essential for the development of player profiles.

A primary limitation of our research is the relatively small number of participants included in the study. Nevertheless, the experimental protocol of the present pilot study will be extended to a larger sample in the future. In addition, we only focused on youth players in this study, but it is definitely worthwhile to look at elite adult tennis players in the future, as their data can be used to

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help coach junior players in the future. For running activities, it is also worth investigating variables that focus on both high-intensity accelerations and decelerations, and monitoring of internal workload not only on a subjective RPE basis, but also by measuring objective physiological responses. However, the strength of our study is that we studied elite, ITF junior ranked tennis players, two of whom had already had ATP ranking. Last but not least, this type of measurement has, to the best of our knowledge, only been used for women's tennis players and is appearing here for the first time in men's tennis.

5. Conclusions

In conclusion, we can say that the use of different playing strategies influences the spread of external load factors such as accelerations in three planes of motion, low-intensity change of directions in different directions, and also the spin of the groundstrokes. All of this allows for even more specific coaching for tennis players in terms of strategy and style of play both on and off the court. Last but not least, when analysing matches, monitoring can be done by strategy following the integrated methodology.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

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Conflicts of Interest: The authors declare no conflicts of interest regarding the publication of this manuscript.

Abbreviations

The following abbreviations are used in this manuscript:

ATP	Association of Tennis Professionals
CoD	Change of direction
GPS	Global positioning system
HR	Heart rate
IMA	Inertial movement analysis
IMU	Inertial measurement unit
ITF	International Tennis Federation
RPE	Rating of perceived exertion

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