IJSPT
INTERNATIONAL JOURNAL OF SPORTS PHYSICAL THERAPY

Casals M, Cortés J, Llenderrozos D, et al. Epidemiology and Factors Influencing Davis Cup Retirements Over the Past Twenty Years. *IJSPT*. 2024;19(11):1465-1476.
doi:10.26603/001c.123948

Original Research

Epidemiology and Factors Influencing Davis Cup Retirements Over the Past Twenty Years

Martí Casals[1a], Jordi Cortés[2], Daniel Llenderrozos[3], Miguel Crespo[4], Timothy E. Hewett[5], Lorena Martin[6], Ernest Baiget[7]

[1] Health Sciences, National Institute of Physical Education of Catalonia , [2] Department of Statistics and Operations Research, Universitat Politècnica de Catalunya, [3] National Institute of Physical Education of Catalonia, [4] International Tennis Federation, [5] Orthopaedics , Marshall University, [6] University of Southern California, [7] Performance, National Institute of Physical Education of Catalonia

Keywords: tennis, injuries, teams competition, tennis surface, sports health

https://doi.org/10.26603/001c.123948

International Journal of Sports Physical Therapy

Vol. 19, Issue 11, 2024

Background

The demands of professional tennis, including physical and psychological aspects, contribute to the frequency of retirements at elite levels of the sport.

Purpose

The aim of this study was to explore the frequency of injuries and the factors that influence the retirements of professional tennis players competing in the Davis Cup over the last two decades.

Study Design

Retrospective cohort study.

Methods

The data set includes data from 6,060 men's singles matches that included 1,814,141 games from Davis Cup ties played between 2000 to 2019. Factors that might influence the retirements were studied by means of generalized linear models using Poisson distribution. Incidence rates by 1000 games and incidence rate ratios of retirements are provided as association measures.

Results

The retirement incidence was 1.05 per 1000 games [95% CI: 0.90, 1.21]. The main risk factors associated with retirements were matches played on hard courts (IRR: 2.52 [95% CI: 1.32, 4.83]) and matches played in the final two matches of the tie and in a best-of-5-set format (IRR: 2.63 [95% CI: 1.69, 4.09] and IRR: 5.52 [95% CI: 3.50, 8.69], respectively). The most common injuries that led to retirements were those affecting the lower extremities, specifically involving muscular or tendinous tissues.

Conclusion

This study provides valuable insights for coaches, players, support teams, and epidemiologists regarding retirements and their associated risk factors in Davis Cup tournaments. These findings may guide future research and inform strategies aimed at managing player health and performance in professional tennis.

Level of evidence

Level 2b.

a Corresponding Author:
Martí Casals
Sport and Physical Activity Studies Centre (CEEAF), University of Vic – Central University of Catalonia (Uvic-UCC). Address: C. Dr. Antoni Vilà Cañellas, s/n, 08500 Vic, Spain. Tel: +34 647053785.
E-mail: marticasals@gmail.com, marti.casals1@umedicina.cat

INTRODUCTION

The Davis Cup is an annual national team competition with more than 100 years of history organized by the International Tennis Federation (ITF), in which male players represent their respective national teams in a knock-out format.[1] Until 2020, the format of the competition was structured in four groups based on the teams' results in previous years. These national teams were promoted or relegated according to the results obtained in the different phases of the competition in a home and away schedule. In each tie, five matches were played to the best of five sets in three consecutive days (Friday to Sunday); with two singles matches played on the first day, the doubles match on the second day, and the last two singles matches on the third day. The playing surface for each tie was selected by the hosting team. This format was used over a long period of time, with players competing in different countries and playing surfaces at different periods of the season. A new format of the competition, which was introduced in 2019, consists of two World Groups (I and II) which include an additional play-off round, and provides opportunities for more nations to compete.[2]

Although the competitive load in men's professional tennis is variable depending on the result or round reached in the tournament, due to the extensive competitive calendar of the Association of Tennis Professionals (ATP) and the ITF professional circuit, high-performance players are exposed to a high weekly volume of training and competition (17-19 hours per week).[3] In addition to the professional tour tournaments, many of the players also play in the Davis Cup for their respective national teams. Unlike other sports, a tennis match does not have a predefined duration, it varies according to the number of games and sets to be played to determine the winner of the match, and in particular in Davis Cup and Grand Slam matches can be well over five hours of play.[4] There is also a broad consensus that over the last two decades there has been a continuous trend in the increase in the speed of strokes and movements and consequently in the overall intensity of play in professional tennis.[5-7] Players cover about 3 m per stroke, 8-12 m per point and a total of 600-800 m per set played, with about 70% of strokes being the sum of first serves, forehand and backhand rallies.[4,8,9] This activity occurs at physiological intensities ranging from 12% to 80% of maximal oxygen consumption (VO2max) and 47% to 86% of maximum heart rate (HRmax), depending on the specific demands of each point or rally.[10,11]

Regarding health problems associated with the sport, it has been found that playing long matches on consecutive days generates neuromuscular and perceptual fatigue in the player, as well as an increase in muscle damage markers.[12] There are also factors that increase the competitive stress of the player, as matches are usually played outdoors in high temperatures or humidity conditions, which have been associated with increased medical problems and retirements in Grand Slam players.[13] A number of authors have explored the incidence of injuries in professional male tennis.[14-18] Incidence rates of 8.25, 3.34 and 6.64 per 1000 match exposures (EP) have been observed in ATP tournaments, on the United States Tennis Association (USTA) professional circuit and in Davis Cup respectively.[15,17,19] A retirement in tennis means that a player stops playing once the match has started, and the victory is automatically awarded to the opponent. Retirements in professional tennis and their causes have also been studied.[15,17,19,20] However, these studies included data from 1968 to 2013. Given the specific competition features of the Davis Cup, only one of the studies analyzed the reasons for retirements in this competition.[19] Consequently, it is relevant to determine whether the increase in the intensity of play, as described above, may have led to a change in the patterns of retirements in the Davis Cup. Therefore, the aims of this study were to describe the pattern of the epidemiology of retirements, and to determine the factors that influence match retirements over the last twenty years in Davis Cup.

METHODS

STUDY DESIGN AND PARTICIPANTS

The Strengthening the Reporting of Observational Studies in Epidemiology statement[21] was utilized to control potential biases in the design phase (Table S1 in Supplemental material). The data set contains 6060 Davis Cup singles matches played between 2000 and 2019. Six thousand thirty-six matches were analyzed after exclusion of those matches that were walk-overs (W/O; n = 24). These matches were played by professional male tennis players from all qualifying groups and regions in which the ITF structures this competition. The matches were played throughout the year (i.e., at different times of the season), and on all four types of surfaces (i.e., clay, hard, carpet, and grass). The study focused on Davis Cup singles matches and relied solely on publicly available data. As there was no direct interaction with human subjects or animals, ethical approval was not applicable for this research.

DEFINITIONS

According to the current rules, a tennis match is officially recorded as a retirement when a player cannot continue due to illness or injury after the match has started.[22] Only retirements due to medical conditions (injuries and illnesses) were included, not taking into account a considerable number of retirements that occur due to non-medical reasons, such as match suspensions due to weather conditions, unsportsmanlike behavior of a player, and other reasons.

STUDY PROCEDURE AND VARIABLES

For this study, data of 20 years of Davis Cup singles matches played between 2000 and 2019 were included from the datasets collected by GitHub, which are available at https://github.com/JeffSackmann. The four competition groups were unified into a world group (WG I and WG II) and a non-world group (G III and G IV) for the analysis. Specifically, the following variables were evaluated: anthropometric data (players' age and height), match characteris-

tics (surface, number of sets played: best of three or five), group (World Group or not), round (final rounds: finals, semi-finals, quarterfinals, or other), number of matches, total number of games played per match, average age of the players in the match, and retirements (including reasons, and anatomy and body region of the injuries).

Furthermore, new variables were added to the original data set: type of retirements (medical conditions, non-medical conditions, unknown reasons), sources of information on retirements (location of the player: home, away, neutral) which were obtained following an exhaustive search for each retirement using the Google search engine and specialized websites such as https://www.davis-cup.com/; https://www.savannahsworld.blogspot.com; https://www.eurosport.com, and websites such as https://www.newspapers.com and https://www.the-guardian.com. For the search strategy, keywords such as "Davis Cup", "injury", "retirement" (accompanied by the identifying data of the match for which information was sought) were used, and sometimes adding the full name of the retired player.

For the complementary analysis of medical conditions (i.e., injuries and diseases), the classification determined in the tennis-specific extension of the International Olympic Committee consensus statement, developed specifically for tennis was utilized.[23] Medical conditions were classified in terms of location in four body regions: head/neck, upper extremities, trunk, and lower extremities. The type of injury was classified as: muscle/tendon, bone, joint/ligament, skin, central/peripheral nervous system or other. Illnesseswere classified according to the organ system affected as: cardiovascular, respiratory, gastrointestinal, renal, urogenital, metabolic/endocrinological, haematological, dermatological, neurological, psychiatric, ophthalmic/otorhinolaryngological, dental, rheumatological, allergic, infectious, environmental and others.[24]

STATISTICAL ANALYSES

A descriptive analysis was conducted using the data from 6036 Davis Cup matches played between 2000 and 2019. This involved the calculation of both absolute and relative frequencies for all qualitative variables. Measures of central tendency (mean and median) and dispersion statistics (standard deviation and range) were determined for the quantitative variables. Furthermore, various potential influencing factors associated with match outcomes were explored. These factors included the type of playing surface, the 'best of sets' format, group classifications, stages of the competition (round), and the sequential number of each match. These variables were examined at a bivariable level, with group comparisons examined using chi-squared tests or Fisher's exact tests, depending on data distribution and sample size. The significance level was set at 0.05.

EPIDEMIOLOGICAL MEASURES

Retirement incidence rate was calculated as the number of retirements per 1000 games. To calculate the unadjusted incidences, the *epi.2by2* function of the R package *epiR*[25] was mainly used, setting method as cohort.time. The number of retirements, exposure (no. *games*), incidence rate and the 95% confidence interval (95%CI) are provided. The raw incidence of retirements over time was studied representing their values during the range of years included in this study. In addition, adjusted relative and absolute measures of association are given as incidence rate ratio (IRR) and risk difference (with 95%CI's). At the multivariable level, a generalized linear model was fitted, assuming the frequency of the retirements followed a Poisson's distribution. The relationship of the incidence of retirements with age was studied, observing different behavior in two groups (< 27 years, ⩾ 27 years; (Figure S1 in Supplementary Material). Consequently, two different slopes for both groups were considered in the model.

The model expression for i-th match is the following: $\log(\lambda_i) = \log(g_i) + \mathbf{X_i}\,\beta + ui$ where λ_i is the expected number of retirements following a Poisson distribution, g_i is the number of game exposures of matches, which in turn is the offset of this model, and $\mathbf{X_i}$ is the matrix containing all the independent variables of interest. Model selection was based on the Akaike Information Criterion (AIC). The fitted models were tested for overdispersion with the dispersion test function in the R package AER.[26] The final model considered the interaction between the variables related to the number of sets (three or five) and the number of matches (1^{st}; 2^{nd}; 3^{rd}; 4^{th}). In addition, a logistic model was adjusted by variables prior to the match with the aim of providing the probabilities of retirement under different scenarios.

All analyses were carried according to the checklist for statistical assessment of medical papers (CHAMP) statement.[27] All analyses were performed using version 4.1.3 of the R statistical software.[28] The R code of the analysis carried out in this study are available at: https://github.com/marticasals/Davis_Cup_Retirements/tree/main.

DATA AVAILABILITY STATEMENT

Data and the reproducible code used in this study are available on a publicly accessible GitHub repository (https://github.com/marticasals/Davis_Cup_Retirements/tree/main), allowing for the transparency and replicability of the statistical analysis. This ensures that other researchers can reproduce the findings of the study and build upon it for further research.

RESULTS

GENERAL CHARACTERISTICS OF DAVIS CUP MATCHES ACCORDING TO RETIREMENTS

A total of 6036 Davis Cup matches were included during the period from 2000 to 2019. The players had a median age of 24 years, with ages ranging from 15 to 46 years, and a median height of 185 cm, varying from 160 to 208 cm. Table 1 presents a descriptive overview of Davis Cup matches during this 20-year period, with a categorization based on the presence or absence of retirements. Of all matches, 5845

Table 1. Descriptive of the Davis Cup matches (2000-2019) based on the occurrence or not of retirements.

	Retirement	
	No	Yes
	N=5845	*N=191*
Surface		
Carpet	598 (98.4%)	10 (1.64%)
Clay	2200 (97.0%)	67 (2.96%)
Grass	168 (96.6%)	6 (3.45%)
Hard	2879 (96.4%)	108 (3.62%)
Best of		
3sets	1907 (98.7%)	26 (1.35%)
5sets	3938 (96.0%)	165 (4.02%)
Group		
No World Group 1	4120 (96.6%)	143 (3.35%)
World Group 1	1725 (97.3%)	48 (2.71%)
Round		
Preliminary	4877 (96.8%)	160 (3.18%)
Final	968 (96.9%)	31 (3.10%)
Matches[1]		
1st	1532 (97.6%)	38 (2.42%)
2nd	1525 (97.1%)	45 (2.87%)
3rd	1474 (96.3%)	57 (3.72%)
4th	1314 (96.3%)	51 (3.74%)
Games*	30.4 (10.7)	20.6 (11.3)
Mean of players' ages*	24.7 (3.04)	24.4 (3.36)

*Mean (SD) values were calculated for the variables "Games" and "Mean ages".

(96.8%) concluded without retirements, while 191 (3.2%) had retirements.

In terms of playing surfaces, most matches were played on clay (37.6% of matches: 97.0% without retirements, 2.96% with retirements) and hard (49.5 % of matches: 96.4% without retirements, 3.62% with retirements), with grass (2.9% of matches) and hard courts experiencing a higher frequency of retirements. The most common competition format was to best of five sets (96.0% without retirements, 4.02% with retirements). Regarding the competition stage, most of the analysed matches were seen in the preliminary rounds, although there were similar percentage of retirements in the qualifying and the final rounds (3.18% and 3.10%, respectively).

The analysis of the distribution of the retirements according to the match order in each tie showed a higher percentage of retirements occurring in the last two matches played (3.72% and 3.74%) compared to the first two matched played (2.42% and 2.87%). On the other hand, a noticeable disparity in the number of games played per match in the matches with (20.6 ± 11.3 games played) and without (30.4 ± 10.7 games played) retirements was observed. In fact, there were 34% fewer games played in matches with retirements, highlighting the potential impact of retirements on match length and intensity. The average age of the players in the matches with retirements was 24.4 years (SD: 3.36) while players in the matches without retirement 24.7 (SD: 3.04) (Table 1).

INCIDENCE OF RETIREMENTS IN THE DAVIS CUP

Through the period analyzed, there was an exposure time of 181414 games. The general retirement incidence was of 1.05 retirements per 1000 games (95% CI: 0.90, 1.21) during Davis Cup play. Three specific years (2012, 2018 and 2019) had a remarkably lower retirement incidence (Figure 1).

Both relative and absolute measures of retirement incidence in Davis Cup matches reveal a higher risk of retirements on matches played on hard courts, to best-of-five-set matches, and in the last two Davis Cup matches of the tie (Table 2). For instance, the fourth match showed the highest incidence rate in the Davis Cup, with 1.54 retirements per 1000 games. Conversely, the first match displayed the lowest retirement incidence, with 0.73 retirements per 1000 games. This indicates an IRR of retirements that is 2.10 (95% CI: 1.35, 3.28) times higher, which implies a greater risk of experiencing a retirement in the fourth match compared to the first. The risk difference between them was 0.80 (95% CI: 0.32, 1.29) retirements per 1000 games (Table 2).

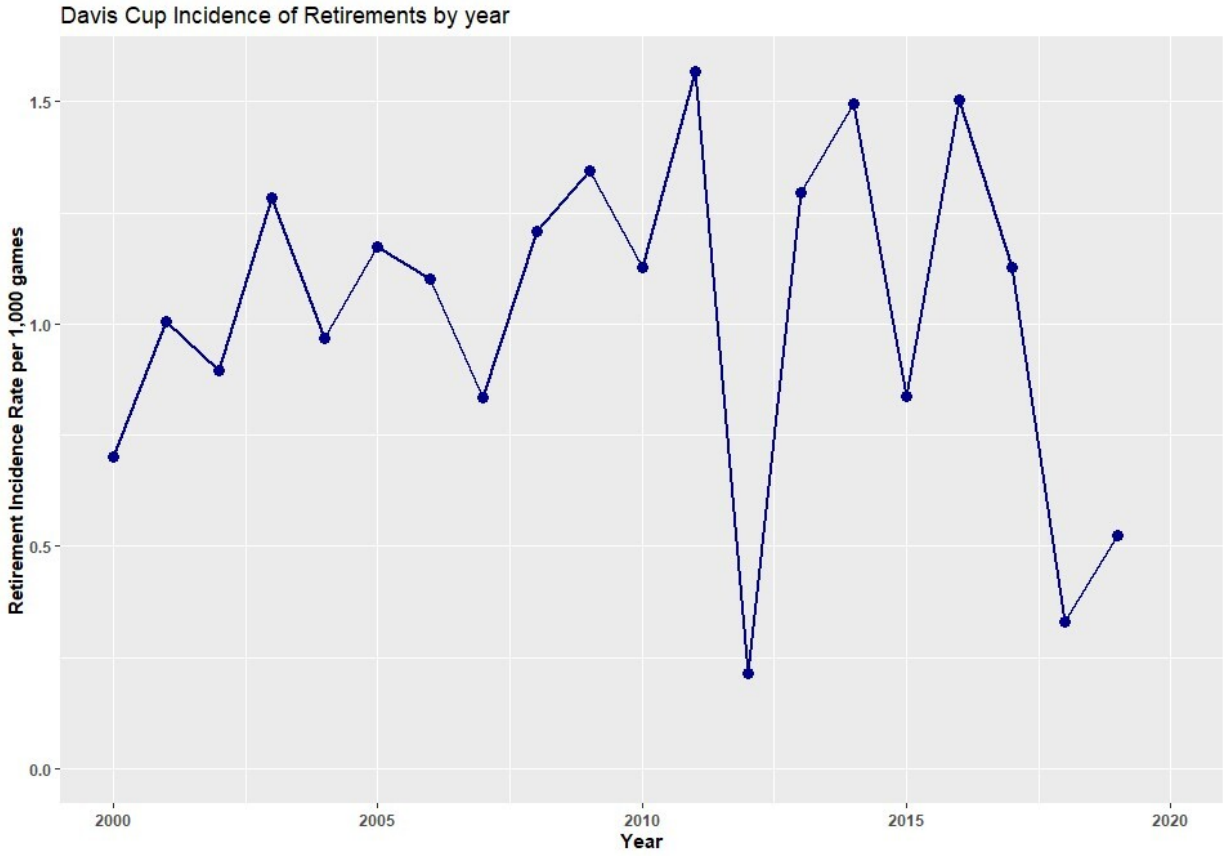

Figure 1. Evolution of the incidence rate over the year-period 2000-2019 in Davis Cup. The incidence rate is expressed as the number of retirements per 1000 games played.

MULTIVARIABLE ANALYSIS OF DAVIS CUP RETIREMENTS

The IRR for the different factors of the final model chosen in matches of Davis Cup during 2000-2019 is shown in Figure 2.

Regarding play surfaces, the incidence of retirements on clay, hard, or grass court was more than double than on the carpet surface, which was statistically significantly different. The incidence of retirements is also different depending on the age of the players. If they are younger (mean age below 27), the incidence rate decreases by half over five-year period. Meanwhile, if the mean age of the players is at least 27 years, the incidence rate doubles over a five-year period, but without reaching a statistically significant difference.

Finally, the number of the singles matches also plays a role in the number of retirements, depending on the number of sets for the tie: If the matches are at best of three sets, retirements are less usual in the third and fourth matches. On the contrary, if the matches are at best of five sets, retirements are more likely to happen in the last matches of the tie.

A table showing the retirement probabilities per match based on the variables available prior to the start of the match was generated to assess the likelihood of retirements in tennis matches (Table 3). For instance, on hard courts, approximately one out of every 50 matches results in a retirement, whereas on carpet, retirements occur in approximately one out of every 125 matches. In terms of age, the highest probability of retirement is observed at the extremes of the age spectrum, such as 18 and 36 years old, with a probability of approximately one retirement in every 18 matches. Conversely, for ages between 26 and 28, the probability of retirement decreases to one in every 56 matches. Regarding the number of matches, the highest retirement probability is found in a five-game tie during the last match, where there is one retirement in every 15 matches.

REASONS FOR RETIREMENTS IN DAVIS CUP MATCHES: INJURIES, ILLNESSES, AND NON-MEDICAL CAUSES

Information on the reason for retirements was obtained for 74 (38.7%) of the 191 retirements in the period analyzed, while 61.3% of the retirements (n=117) were due to unknown causes. Of these 74 retirements, 73.0% (n=54/74) were due to injury, 14.9% (n=11/74) were for non-medical reasons, and 12.2% (n=9/74) were due to illness. Of the injuries, 53.7% (n=29/54) occurred when the injured player was playing away, and 46.3% (n=25/54) when playing at home. The most frequent injuries were to the lower extremities (n=34/54; 63%), were to the muscle/tendon (n=29/54; 54%) and were located in the thigh (n=15/54; 28%), as shown in Table 4. In terms of retirements due to illness (n=9), the most recurrent type of illness was metabolic causes with 55% (n=5/9) of the total number of illnesses,

Table 2. Retirement incidence rates, incidence rate ratio, risk difference, and the 95% confidence intervals, expressed per 1000 games played.

Davis Cup	Retirements	Games	Incidence rate (95%IC)	IRR (95%CI)	Risk difference (95%CI)
Surface					
Carpet	10	19685	0.51 (0.24, 0.93)	1 (Ref.)	0 (Ref.)
Clay	67	67669	0.99 (0.77, 1.26)	1.95 (1.00, 4.25)	0.48 (0.09, 0.88)
Grass	6	5494	1.09 (0.40, 2.38)	2.15 (0.64, 6.53)	0.58 (-0.34, 1.51)
Hard	108	88566	1.22 (1.00, 1.47)	2.40 (1.26, 5.15)	0.71 (0.32, 1.10)
Best of					
3 sets	26	41386	0.63 (0.41, 0.92)	1 (Ref.)	0 (Ref.)
5 sets	165	140028	1.18 (1.01, 1.37)	1.88 (1.24, 2.96)	0.55 (0.25, 0.85)
Group					
World	143	124970	1.14 (0.96, 1.35)	1 (Ref.)	0 (Ref.)
No World	48	56444	0.85 (0.63, 1.13)	1.35 (0.96, 1.91)	0.29 (-0.01, 0.60)
Round					
Final	160	149780	1.07 (0.91, 1.25)	1 (Ref.)	0 (Ref.)
Preliminary	31	31634	0.98 (0.67, 1.39)	1.09 (0.74, 1.66)	0.09 (-0.29, 0.47)
Matches					
1st	38	51755	0.73 (0.52, 1.01)	1 (Ref.)	0 (Ref.)
2nd	45	52472	0.86 (0.63, 1.15)	1.17 (0.74, 1.85)	0.12 (-0.22, 0.47)
3rd	57	44041	1.29 (0.98, 1,68)	1.76 (1.15, 2.73)	0.56 (0.15, 0.97)
4th	51	33146	1.54 (1.15, 2.02)	2.10 (1.35, 3.28)	0.80 (0.32, 1.29)

IRR: injury risk rate.

followed by infectious diseases (n=2/9; 22%), gastrointestinal diseases (n=1/9; 11%), and respiratory diseases (n=1/9; 11%).

DISCUSSION

This study aimed to describe the frequency of injuries and the main match factors that influence player retirements in Davis Cup matches. The analysis of 6036 Davis Cup matches spanning two decades (2000-2019) revealed a player retirement incidence of 3.2% or 1.05 retirements per 1000 games which was reasonably constant during the analyzed period. The hard-court surfaces, the matches played in best-of-five-sets, and the last two matches played in the tie were the variables that showed the highest incidence rate. Moreover, the youngest and the oldest players had higher probability of retirement. The most common reason for the retirement was injury, especially in the lower-extremities due to muscular and tendon injuries.

Previous authors have reported that the playing surface significantly affects the external and the internal match load,[11,29] and the different court characteristics and game styles of tennis players might affect their retirement rate.[30] The present study highlights hard court surfaces as a key factor contributing to the high incidence of retirements, as has been previously observed.[31] Playing on hard courts leads to high-intensity changes of direction, resulting in high rates of acceleration and deceleration, which consequently increases the load on muscles and tendons.[32] These surfaces, coupled with the endurance challenge of the best-of-five set matches, seem to increase the physical strain on players. These factors have a clear impact on retirements, as the hitting and movement workload in best-of-five matches is significantly greater than in best-of-three-set matches.[9] Furthermore, the knockout format played througout the year seems to also play a critical role, underlining the multifaceted nature of challenges faced by athletes in this elite competition.

The injury pattern found, which predominantly affected the lower extremities (62.96%), and was often related to muscular or tendinous (53.7%) and joint or ligament (42.6%) issues, aligns with the existing literature on injury trends in professional tennis.[19,33] However, it is important to note that while acute injuries are more prevalent in the lower body, chronic injuries tend to affect the upper extremity.[34] Most tennis injuries occur in the lower extremity (31%–67%), followed by the upper extremity (20%–49%), and lastly, the trunk (3%–21%),[14] highlighting the importance of understanding the specific regions of the body that are more vulnerable to injuries in tennis. While the current study focused on retirements in Davis Cup matches, the broader context of tennis injuries highlights the need for adopting comprehensive injury prevention measures that consider the unique demands tennis places on different body regions.

A novel finding is that the incidence of retirements occurred during the preliminary rounds (3.18%) and the final phase (3.10%) of the Davis Cup are similar. This finding might show that the pressures faced by players in different

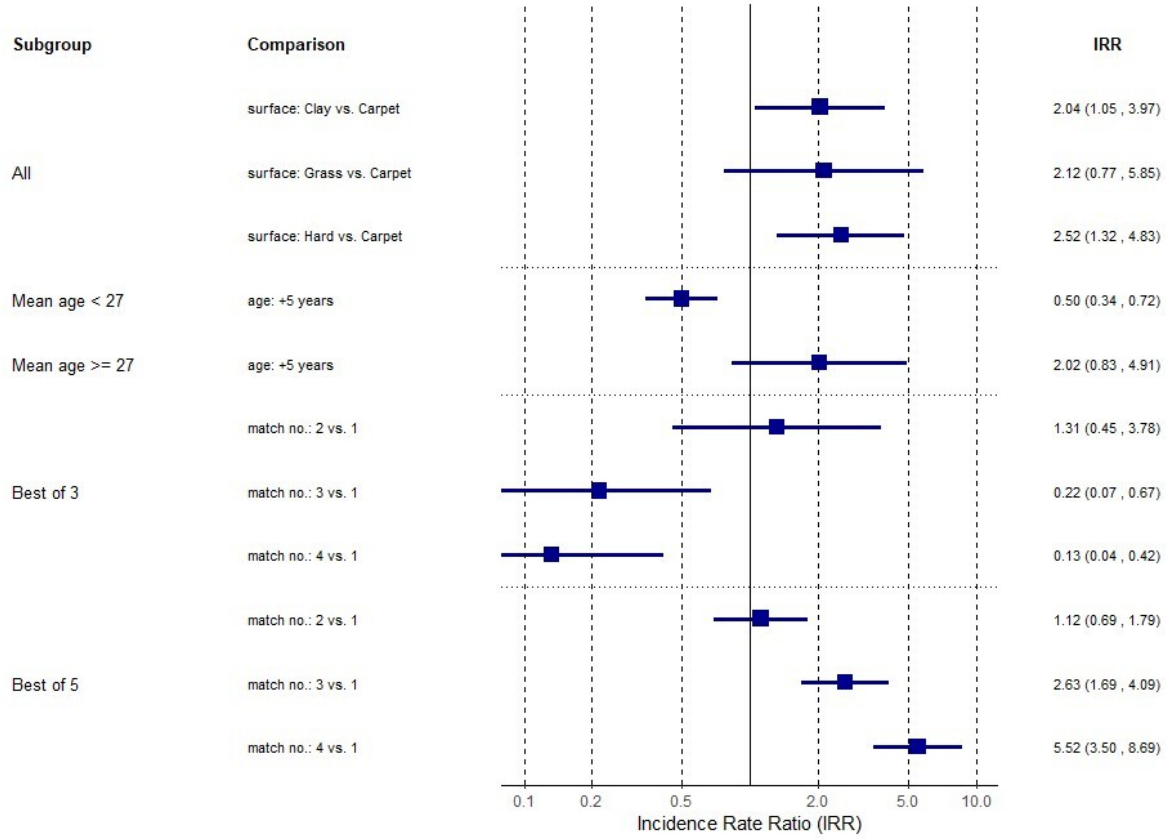

Figure 2. Incidence rate ratio for different factors of Davis Cup matches.

competitive stages (preliminary vs. final stages) in which retirements occur are similar. On one hand, preliminary rounds often serve as a gateway for players striving to secure a spot in the main draw of the Davis Cup, and the pressure to perform at their best can be immense. Furthermore, players in the preliminary rounds may have already navigated through multiple matches to reach this stage, potentially leading to physical and mental fatigue.[35] On the other hand, retirements during the final phase of the Davis Cup may reflect the culmination of a long and gruelling journey over the course of a whole season. The fact that the final phase is played late in the season, when players may already be experiencing cumulative physical and mental fatigue, could be considered a contributing factor. Players who have advanced to this stage have already demonstrated their skill and endurance, but they now face the added pressure of representing their country on a prestigious international stage. The desire to perform exceptionally for their nation, coupled with the accumulated physical and psychological toll of earlier matches, could be contributing factors to retirements during this phase. Future research in this area should delve deeper into understanding the specific factors that influence retirements during these critical phases of the Davis Cup. This could include examining the psychological aspects of player performance, assessing the impact of match scheduling and recovery strategies, and exploring the role of team dynamics and national pride in influencing players' decisions to retire.

LIMITATIONS

Limitations of this study include lack of comprehensive data regarding the reasons for retirement in 110 cases. One specific aspect that warrants attention is the documentation of injuries. The authors acknowledge that this study lacks detailed information on how injuries were documented during the matches. Understanding the precise nature and severity of injuries is essential for a comprehensive analysis of retirements in professional tennis. While efforts were made to gather data on retirements, the absence of detailed injury documentation is a limitation that future research should aim to address. This data gap suggests an opportunity for more granular data collection in future research to enable a more detailed exploration of retirement causes in professional tennis. Ensuring consistency in injury surveillance in tennis would greatly improve the understanding and management of injuries in the sport.

Additionally, it is important to note that while the current findings suggest an association between certain match conditions (such as hard courts and best-of-five-set formats) and a higher incidence of retirements, the study design does not allow the determination of specific factors underlying these associations. For example, hard courts might increase the risk due to their surface properties, but other factors such as match duration, player fatigue, or tournament schedule could also contribute to the higher retirement rates observed. Future research should aim to

Table 3. Retirement probabilities per match with variables available before the start of the match.

Variable	Subgroup	Value	Probability (95%CI)
Surface	All	Carpet	0.008 (0.004 – 0.019)
		Clay	0.016 (0.010 – 0.028)
		Grass	0.018 (0.007 – 0.047)
		Hard	0.020 (0.012 – 0.033)
Age	All	18	0.055 (0.034 – 0.088)
		20	0.042 (0.029 – 0.062)
		22	0.032 (0.023 – 0.045)
		24	0.025 (0.018 – 0.034)
		26	0.019 (0.013 – 0.028)
		28	0.017 (0.010 – 0.027)
		30	0.023 (0.015 – 0.035)
		32	0.031 (0.016 – 0.057)
		34	0.042 (0.016 – 0.102)
		36	0.056 (0.016 – 0.181)
Match number of the tie	3 sets	1	0.022 (0.008 – 0.057)
		2	0.030 (0.012 – 0.070)
		3	0.004 (0.002 – 0.011)
		4	0.003 (0.001- 0.007)
Match number of the tie	5 sets	1	0.012 (0.006 – 0.022)
		2	0.013 (0.007 – 0.024)
		3	0.033 (0.019 – 0.056)
		4	0.068 (0.038 – 0.117)

explore these specific factors to better understand the underlying causes of retirements.

PRACTICAL APPLICATIONS

This study presents a comprehensive analysis of retirements in Davis Cup tennis matches over a 20-year period (2000-2019), filling a notable research gap. By examining this extensive timeframe, it unveils potential shifts in retirement patterns and sheds light on the evolving landscape of player injuries and match retirements, contributing significantly to the understanding of athlete health in professional tennis tournaments. The findings from this study can help coaches better understand the risk factors associated with high-level team competitions and lays the groundwork for more targeted and effective policies aimed at safeguarding athlete health in the competitive realm of Davis Cup tennis.

CONCLUSIONS

This results of this study indicate a retirement incidence of 3.2% or 1.05 retirements per 1000 games, with a consistent trend throughout the analyzed period. Higher retirement rates were observed on hard courts, during best-of-five-set matches, and in the last two matches of elimination rounds, highlighting specific conditions that increase the risk of retirements. Younger and older players were found to have a higher probability of retirement, indicating that the extremes of the age spectrum are more vulnerable. The most common cause of retirement was injury, particularly affecting the lower extremities, muscles, and tendons, underlining the need for targeted injury prevention.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

FUNDING STATEMENT/ACKNOWLEDGMENTS

This research was funded by the Ministerio de Ciencia e Innovación (Spain) (PID2019-104830RB-I00) and the Departament de Recerca i Universitats de la Generalitat de Catalunya (Spain) [2021 SGR 01421 (GRBIO)]. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Submitted: April 28, 2024 CST, Accepted: September 05, 2024 CST

Table 4. Characteristics of the 54 Davis Cup injuries between 2000-2019* according to anatomy and body region.

Variable	Type	n (%)
Injury anatomy	Thigh injury	15 (27.77%)
	Upper back injury	5 (9.25 %)
	Ankle injury	6 (11.11%)
	Hamstring injury	4 (7.40%)
	Wrist injury	4 (7.40%)
	Knee injury	5 (9.25%)
	Shoulder injury	4 (7.40%)
	Abdominal injury	7 (12.96%)
	Foot injury	1 (1.85%)
	Thumb injury	1 (1.85%)
	Achilles tendon injury	1 (1.85%)
	Pectoral injury	1 (1.85%)
Injury classification	Muscular/tendinous	29 (53.70%)
	Joint/ligament	23 (42.60%)
	Bone	2 (3.70%)
	Other	0 (0.00%)
Body region	Lower extremities	34 (62.96%)
	Upper extremities	11 (20.38%)
	Trunk	9 (16.66%)
	Head and neck	0 (0.00%)

*11 retirements were for non-medical reasons, 9 for illness and 117 were to unknown causes.

REFERENCES

1. Gayton WF, Steinroeder W, Bonnica C, Loignon AC. An investigation of home disadvantage in Davis Cup tennis. *Percept Mot Skills*. 2009;109(2):382-386. doi:10.2466/pms.109.2.382-386

2. Davis Cup – The World Cup of Tennis. Accessed April 25, 2024. https://www.daviscup.com/en/home.aspx

3. Vescovi JD. Acute:chronic training loads in tennis: which metrics should we monitor? *Br J Sports Med*. 2017;51(18):1321-1322. doi:10.1136/bjsports-2017-097596

4. Reid M, Duffield R. The development of fatigue during match-play tennis. *Br J Sports Med*. 2014;48(Suppl 1):i7-i11. doi:10.1136/bjsports-2013-093196

5. Colomar J, Corbi F, Brich Q, Baiget E. Determinant physical factors of tennis serve velocity: A brief review. *Int J Sports Physiol Perform*. 2022;17(8):1159-1169. doi:10.1123/ijspp.2022-0091

6. Fernandez-Fernandez J, Kinner V, Ferrauti A. The physiological demands of hitting and running in tennis on different surfaces. *J Strength Cond Res*. 2010;24(12):3255. doi:10.1519/JSC.0b013e3181e8745f

7. Gale-Watts AS, Nevill AM. From endurance to power athletes: The changing shape of successful male professional tennis players. *Eur J Sport Sci*. 2016;16(8):948-954. doi:10.1080/17461391.2016.1192690

8. Reid M, Morgan S, Whiteside D. Matchplay characteristics of Grand Slam tennis: implications for training and conditioning. *J Sports Sci*. 2016;34(19):1791-1798. doi:10.1080/02640414.2016.1139161

9. Whiteside D, Reid M. External match workloads during the first week of Australian Open tennis competition. *Int J Sports Physiol Perform*. 2017;12(6):756-763. doi:10.1123/ijspp.2016-0259

10. Baiget E, Fernández-Fernández J, Iglesias X, Rodríguez FA. Tennis play intensity distribution and relation with aerobic fitness in competitive players. *PLOS ONE*. 2015;10(6):e0131304. doi:10.1371/journal.pone.0131304

11. Fernandez-Fernandez J, Sanz-Rivas D, Mendez-Villanueva A. A review of the activity profile and physiological demands of tennis match play. *Strength Cond J*. 2009;31(4):15. doi:10.1519/SSC.0b013e3181ada1cb

12. Gescheit DT, Cormack SJ, Reid M, Duffield R. Consecutive days of prolonged tennis match play: performance, physical, and perceptual responses in rrained players. *Int J Sports Physiol Perform*. 2015;10(7):913-920. doi:10.1123/ijspp.2014-0329

13. Smith MT, Reid M, Kovalchik S, Woods TO, Duffield R. Heat stress incident prevalence and tennis matchplay performance at the Australian Open. *J Sci Med Sport*. 2018;21(5):467-472. doi:10.1016/j.jsams.2017.08.019

14. Abrams GD, Renstrom PA, Safran MR. Epidemiology of musculoskeletal injury in the tennis player. *Br J Sports Med*. 2012;46(7):492-498. doi:10.1136/bjsports-2012-091164

15. Hartwell MJ, Fong SM, Colvin AC. Withdrawals and retirements in professional tennis players. *Sports Health*. 2016;9(2):154-161. doi:10.1177/1941738116680335

16. McCurdie I, Smith S, Bell PH, Batt ME. Tennis injury data from The Championships, Wimbledon, from 2003 to 2012. *Br J Sports Med*. 2017;51(7):607-611. doi:10.1136/bjsports-2015-095552

17. Okholm Kryger K, Dor F, Guillaume M, et al. Medical reasons behind player departures from male and female professional tennis competitions. *Am J Sports Med*. 2015;43(1):34-40. doi:10.1177/0363546514552996

18. Pluim BM, Staal JB, Windler GE, Jayanthi N. Tennis injuries: occurrence, aetiology, and prevention. *Br J Sports Med*. 2006;40(5):415-423. doi:10.1136/bjsm.2005.023184

19. Maquirriain J, Baglione R. Epidemiology of tennis injuries: An eight-year review of Davis Cup retirements. *Eur J Sport Sci*. 2016;16(2):266-270. doi:10.1080/17461391.2015.1009493

20. Breznik K, Batagelj V. Retired matches among male professional tennis players. *J Sports Sci Med*. 2012;11(2):270-278.

21. Elm E von, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. 2008;61(4):344-349. doi:10.1016/j.jclinepi.2007.11.008

22. International Tennis Federation | ITF. January 2, 2024. Accessed April 25, 2024. https://www.itftennis.com/en/

23. Verhagen E, Clarsen B, Capel-Davies J, et al. Tennis-specific extension of the International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020. *Br J Sports Med*. 2021;55(1):9-13. doi:10.1136/bjsports-2020-102360

24. Pluim BM, Fuller CW, Batt ME, et al. Consensus statement on epidemiological studies of medical conditions in tennis, April 2009. *Clin J Sport Med*. 2009;19(6):445. doi:10.1097/JSM.0b013e3181be35e5

25. Stevenson M, Sergeant E, Heuer C, et al. epiR: Tools for the analysis of epidemiological data. March 11, 2024. Accessed April 7, 2024. https://cran.r-project.org/web/packages/epiR/index.html

26. Kleiber C, Zeileis A. *Applied Econometrics with R*. Springer Science & Business Media; 2008. doi:10.1007/978-0-387-77318-6

27. Mansournia MA, Collins GS, Nielsen RO, et al. A CHecklist for statistical Assessment of Medical Papers (the CHAMP statement): explanation and elaboration. *Br J Sports Med*. 2021;55(18):1009-1017. doi:10.1136/bjsports-2020-103652

28. R: The R project for statistical computing. Accessed April 25, 2024. https://www.r-project.org/

29. Pluim BM, Jansen MGT, Williamson S, et al. Physical demands of tennis across the different court surfaces, performance levels and sexes: a systematic review with meta-analysis. *Sports Med*. 2023;53(4):807-836. doi:10.1007/s40279-022-01807-8

30. Alexander S, Naaz N, Fernandes S. The incidence of injuries across various tennis surfaces: a systematic review. *ITF Coach Sport Sci Rev*. 2022;30(88):39-44. doi:10.52383/itfcoaching.v30i88.353

31. Pluim BM, Clarsen B, Verhagen E. Injury rates in recreational tennis players do not differ between different playing surfaces. *Br J Sports Med*. 2018;52(9):611-615. doi:10.1136/bjsports-2016-097050

32. Damm L, Starbuck C, Stocker N, Clarke J, Carré M, Dixon S. Shoe-surface friction in tennis: influence on plantar pressure and implications for injury. *Footwear Sci*. 2014;6(3):155-164. doi:10.1080/19424280.2014.891659

33. Perkins RH, Davis D. Musculoskeletal injuries in tennis. *Phys Med Rehabil Clin*. 2006;17(3):609-631. doi:10.1016/j.pmr.2006.05.005

34. Fu MC, Ellenbecker TS, Renstrom PA, Windler GS, Dines DM. Epidemiology of injuries in tennis players. *Curr Rev Musculoskelet Med*. 2018;11(1):1-5. doi:10.1007/s12178-018-9452-9

35. Girard O, Racinais S, Micallef JP, Millet GP. Spinal modulations accompany peripheral fatigue during prolonged tennis playing. *Scand J Med Sci Sports*. 2011;21(3):455-464. doi:10.1111/j.1600-0838.2009.01032.x

SUPPLEMENTARY MATERIALS

Supplemental File 1

Download: https://ijspt.scholasticahq.com/article/123948-epidemiology-and-factors-influencing-davis-cup-retirements-over-the-past-twenty-years/attachment/247025.docx