Tun J Sport Sci Med 2024; 2(1):25-32

10.61838/kman.tjssm.2.1.4

Tunisian Journal of Sports Science and Medicine

Original Research

Tennis-Specific Incremental Aerobic Test (TSIAT): Construct Validity, Inter Session Reliability and Sensitivity

Wissem Dhahbi[1, 2*], Younes Hachana[3, 4], Marouen Saouaifi[2], Sahar Souidi[3, 4], Ahmed Attia[3, 4]

[1] Research Unit "Sport Sciences, Health and Movement", High Institute of Sports and Physical Education of Kef, University of Jendouba, Kef, Tunisia

[2] Qatar Police Academy, Police College, Training Department, Doha, Qatar

[3] Research Unit, Analysis and Evaluation of Factors Affecting the Sport Performance, Higher Institute of Sports and Physical Education, Ksar Said, Tunisia

[4] Higher Institute of Sports and Physical Education, Manouba University, Tunis, Tunisia

*** Corresponding author email address**: wissem.dhahbi@gmail.com

Received: 2024-02-07 **Reviewed:** 2024-03-01 **Revised:** 2024-03-05 **Accepted:** 2024-03-11 **Published:** 2024-03-15

Abstract

Background: This study aimed to explore the discriminative capacity of the Tennis-specific Incremental Aerobic Test (TSIAT) in differentiating between international level tennis players (IP) and regional level tennis players (RP), scrutinize the absolute and relative inter-session reliabilities of TSIAT, and assess the sensitivity and the Minimal Detectable Change (MDC) of TSIAT.

Methods: A cohort-based repeated measures study design was used. Twenty-four male tennis players (age: 15.91 ± 3.09 years, body-height: 1.68 ± 0.20 m; body-mass: 67.45 ± 16.06 Kg; body-mass-index: 20.96 ± 1.97 kg·m-2) participated. TSIAT distance, peak heart rate (HRpeak), and blood lactate concentration ([La]) were measured across two sessions. Inter-session reliability, sensitivity, and MDC95 of TSIAT were assessed. Additionally, discriminant ability was evaluated by comparing TSIAT indices between IP and RP players.

Results: The TSIAT showed excellent reliability (intraclass-correlation-coefficient [3,1] = 0.95 and standard-error-of-measurement % = 1.81) and satisfactory sensitivity (smallest-worthwhile-change % = 1.22). The MDC95 for the distance index was small (<5.02%). IP achieved significantly ($p<0.05$) greater distances (d = 1.63 [large]), HRpeak (d = 1.18 [moderate]), and [La] (d = 2.51 [large]) compared to RP. The TSIAT demonstrated "very good" discriminant ability between IP and RP groups, with an area under the receiver-operating-characteristic curve of 0.89.

Conclusion: Considering the "excellent" inter-session reliability, "satisfactory" sensitivity and "very good" discriminate athletes by different performance levels, the TSIAT may serve as a trusted tennis-specific incremental aerobic test.

Keywords: *Tennis skills, high-intensity interval exercise, racquet sport, performance assessment, physical conditioning.*

How to cite this article:

Dhahbi W, Hachana Y, Saouaifi M, Souidi S, Attia A. Tennis-Specific Incremental Aerobic Test (TSIAT): Construct Validity, Inter Session Reliability and Sensitivity. *Tun J Sport Sci Med*. 2024;2(1):25-32.

1. Introduction

Tennis, the world's most widely practiced racquet sport (1), boasts a year-round schedule of tournaments and events under the governance of the International Tennis Federation (ITF) (2). These events span from professional tournaments like the Grand Slams and the Olympic Games to the ITF men's and women's circuits, encompassing competitions for juniors, seniors, and wheelchair athletes.

A tennis match, whether singles or doubles, unfolds on a rectangular court measuring 8.23 m × 23.77 m, bisected by a 0.914 m high net (3). In doubles, each side of the court extends by an additional 1.37 m. The duration of a tennis match varies with the surface type, typically ranging from 90 to 120 minutes on fast surfaces and potentially exceeding 180 minutes on clay or grass (4). The effective playing time constitutes 10-15% of the total match duration on fast courts and 20-30% on clay or grass (5). As per Cooke et al., (6), a tennis player averages 3m per shot, 8-12m per point, and 1300 to 3600m per hour of play (7). In a 3-hour match, a player strikes between 300-500 balls and changes direction four times per point scored (7). The effort in a tennis match is intermittent, with brief exertion phases (4-10 seconds) interspersed with active or passive recovery periods ranging from 10 to 120 seconds (8). Numerous studies highlight the importance of specific technical skills in racquet sports performance (9, 10). However, physical success in tennis requires a player to not only repeatedly exert intense efforts (300-500 times) but also recover effectively during submaximal effort periods and play breaks (11).

A robust correlation has been established between an athlete's aerobic fitness level and their recovery capacity from high-intensity, short-duration exercise (12). Consequently, aerobic fitness emerges as a pivotal determinant of a tennis player's actual playing level (13). It facilitates rapid recovery of muscle phosphagen stores (14), enabling players to sustain higher intensity efforts for extended periods while preserving technical performance and mental concentration until the match's conclusion (4, 10, 14).

The assessment of aerobic fitness in tennis, akin to most physical and sporting activities, employs two types of tests: laboratory and field tests (10, 14). While laboratory evaluations hold paramount importance, particularly concerning result accuracy and relevance, they are costly, time-intensive, and necessitate qualified personnel (15). Conversely, field evaluations, albeit only providing an estimate of the assessed quality, offer greater specificity, accessibility, and cost-effectiveness (16).

Numerous field tests have been proposed for aerobic fitness assessment, including the Loughborough intermittent test (17), the Navten test (18), and the Leuven test (19). However, these tests have faced criticism for their limited accessibility (requiring a ball launcher, video recording of the test for performance determination, etc.) and their inability to accurately emulate a tennis match's effort pattern (20). In response to these limitations, Girard et al., (14) proposed a more tennis-specific and accessible test. This test involves executing movements (forwards, sideways, and backwards) along a predefined path marked on a tennis court, with the movement speed, effort duration, and recovery period regulated by a pre-recorded soundtrack (18). Impellizzeri and Marcora (15) assert that an effective measurement tool must be valid, reliable, and sensitive. However, the reproducibility and sensitivity of the Girard et al. test remain unexplored to our knowledge.

The theoretical backdrop underscores a knowledge gap in the evaluation of the Tennis-specific Incremental Aerobic Test (TSIAT) for distinguishing performance profiles and its inter-session reliability. Consequently, this study aims to: (1) explore the discriminative capacity of TSIAT in differentiating between international level tennis players (IP) and regional level tennis players (RP), (2) scrutinize the absolute and relative inter-session reliabilities of TSIAT, and (3) assess the sensitivity and the Minimal Detectable Change (MDC) of TSIAT.

2. Methods

2.1. Subjects

For the reliability and sensitivity analysis, twenty-four male tennis players (age (year): 15.91±3.09, body-height (m): 1.68±0.20, body-mass (kg): 67.45±16.06 and body mass index - BMI (kg·m^{-2}): 20.96±1.97) voluntarily participated. The same group was divided and employed in 12 IP and RP players to investigate the discriminant ability of TSIAT (Table 1). Eligibility for participation in this study was determined by the following criteria: a minimum of three training sessions per week or a cumulative weekly total of 180 minutes of tennis activities; at least one year of tennis training experience; and no injuries or pain that could hinder maximum effort during testing. After a comprehensive explanation of the study’s protocol, all participants’ parents provided their written consent for their children’s participation.

The protocol of this study complied with Helsinki’s declaration for human experimentation and was approved by High Institute of Sports and Physical Education of Kef, University of Jendouba ethical committee. It also complied with the ethical and procedural requirements of the journal for the conduct of Sports Med and exercise science research (21).

2.2. Study Design

A cohort-based repeated measures study design was used. The external responsiveness of the TSIAT was determined by comparing the TSIAT’ performed distance and physiological indices (i.e., Peak heart rate - HRpeak and blood lactate concentration - [La]) between two groups of tennis of different competitive levels (IP vs. RP). During the second study phase, which aimed to establish the relative and absolute inter-session reliability of TSIAT, the experimental protocol consisted of performing 2 sperate session of TSIAT in a single week.

2.3. Procedures

To minimize extraneous variables, participants adhered to their regular diet, consumed a light meal at least 3 hours pre-test, maintained their usual sleep schedule, and abstained from strenuous activity for 24 hours before testing. A familiarization session was conducted seven days prior to baseline testing to acclimate participants to the measurement protocol. Testing commenced following a standardized 15-minute warm-up with a subsequent 5-minute rest period. Data collection occurred at consistent times (between 9:00 and 11:00 a.m.) to mitigate the impact of circadian rhythm on performance (22). The outdoor testing environment (monitored every 30 minutes using a VaisalaOyj digital environmental station) maintained a temperature range of 19°C-23°C, humidity of 52%-56%, and light wind velocity (under 10 km/h). The protocol consisted of two TSIAT sessions separated by 3-5 days. The best attempt from each session was used for discriminant ability analysis of TSIAT. Strong verbal encouragement was provided by the experimenter throughout testing to maximize participant effort. The HRpeak and [La] were recorded.

2.4. The Tennis-specific incremental aerobic test (TSIAT)

This TSIAT was proposed by Girard et al., (14). Six cones are placed at varying distances according to the diagram on a half tennis field (Figure 1). The participant begins the course from the central mark of the court (starting position), racket in hand. At the signal, he must randomly move towards the 7 cones one by one (the 7th cone will be chosen from the two placed at the back). At each cone, he makes a shot, forehand for those placed on their right, or backhand for those placed on their left. The participant was asked to complete the maximum possible number of circuits. The first circuit must be completed in 40.5 seconds. With each new circuit, the duration of the effort is reduced by 0.8 seconds. The recovery period between efforts has been set at 15 seconds. The test is stopped when the participant can no longer reach the last target in time or can no longer make the shots correctly. A tolerance zone of 1 meter has been set.

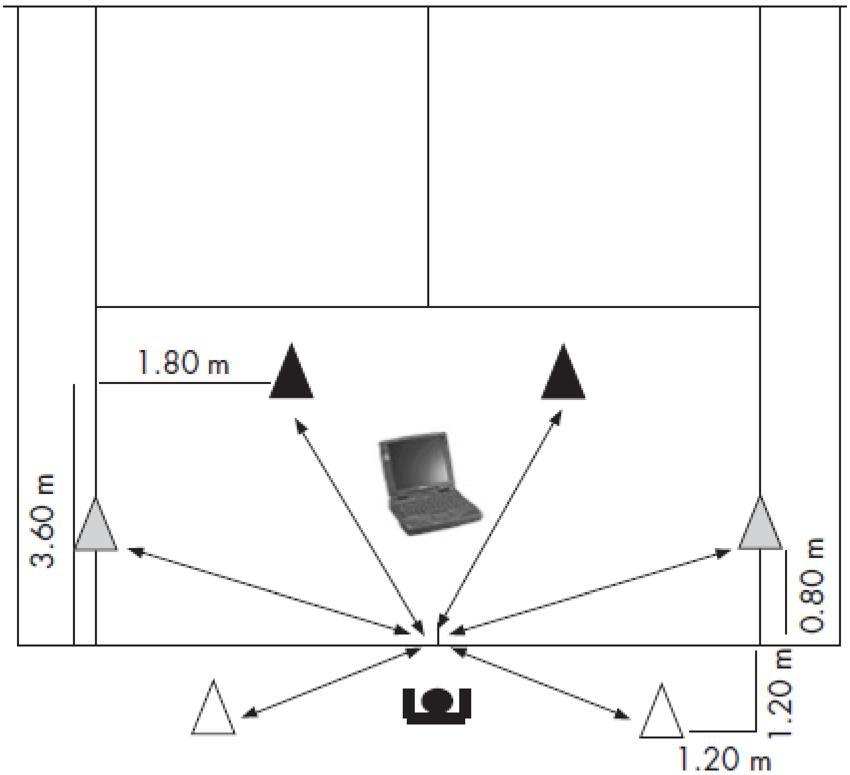

Figure 1. The Tennis-specific incremental aerobic test (TSIAT) diagram (14). The positions of forward (black cones), lateral (grey cones), and backward (white cones) targets are indicated. See Methods section for further details.

2.5. Physiological measurements

The 5 s heart rate (HR) values were recorded by HR monitor with the athletes wearing a chest belt (S810, Polar, Kempele, Finland). 25 ml capillary blood samples were taken from the fingertip and analyzed for [La] by using the Lactate Pro (LT-1710, Arkray, Japan) portable analyzer 3 minutes directly after stopping test.

2.6. Statistical Analyses

Data analyses were performed using SPSS version 28.0 for Windows. Means and standard deviations (SD) were calculated after verifying the normality of distributions using Kolmogorov-Smirnov statistics. Dependent *t*-tests were used to evaluate the equality of means for test and retest TSIAT indices scores. Estimates of effect size (Cohen's *d*), mean differences protected against type 2 errors. The relative inter-session reliability was determined by calculating the ICC model 3,1 ($ICC_{[3,1]}$). The absolute intra-session reliability was examined using the standard error of measurement (SEM). The sensitivity of the test was assessed by comparing the smallest worthwhile change (SWC) and SEM, using the thresholds proposed by Smith & Hopkins (23). Minimal detectable change at 95% confidence interval (MDC_{95}) was also calculated for TSIAT' distance index. Heteroscedasticity was also examined.

Independent t-tests were used to evaluate the equality of means for male and female students' TSIAT scores. The external responsiveness of the TSIAT was analyzed using the receiver operator characteristics (ROC) curve (24). The latter analysis determines the sensitivity and specificity of a tool to classify individuals according to a fixed criterion (15). Significance for all the statistical tests was accepted at $p<0.05$ a priori.

3. Results

Residual data for participants anthropometric characteristics and all TSIAT' indices scores were normally distributed (p=0.072–0.126).

3.1. Inter-session reliability, sensitivity and MDC of the TSIAT

Dependent t-tests evaluating the equality of means showed no significant test-retest bias for TSIAT indices (i.e., Distance, HRpeak and [La]) (p:0.285-0.407, d:0.09-0.19 [*trivial*]). Absolute and relative inter-session reliability TSIAT' distance was expressed in Table 2. TSIAT' performed distance showed an excellent reliability ($ICCs_{[3,1]}$ = 0.95 and SEM%: 1.81). On the other hand, TSIAT showed a satisfactory sensitivity, hence SEM value was approximately equal to SWC values (SWC% = 1.22). In addition, the MDC_{95} for distance index was small (<5.02%). Moreover, heteroscedasticity coefficients were all small and non-significant ($r < 0.30$, $p > 0.05$).

Table 1. Comparison of TSIAT' mean scores between the test and retest measurements (n=24)*

Variables		Test	Retest	*p*	Cohen's *d*
Distance	(m)	1973.78±115.16	1985.07±124.63	0.285	0.09 [*trivial*]
HRpeak	(bpm)	194.71± 9.95	195.66±9.41	0.395	0.10 [*trivial*]
[La]	(mmol·L^{-1})	9.36±2.53	9.81±2.32	0.407	0.19 [*trivial*]

HRpeak = Peak heart rate; TSIAT = Tennis-specific incremental aerobic test; [La] = blood lactate concentration.
*The values are presented as mean ± SD.

Table 2. Inter-session relative and absolute reliability indices and MDC95 of the Tennis-specific aerobic test

Variable		$ICC_{3,1}$	SEM (%)	SWC (%)	MDC_{95}(%)
Distance	(m)	0.95	35.84 (1.81%)	23.77(1.22%)	99.35 (5.02%)

ICC3,1= Intra-class Correlation Coefficient model 3,1; CV= coefficient of variation; SEM= standard error of measurement; SWC= smallest worthwhile change; MDC95= minimal detectable change at 95% confidence interval.

3.2. The discriminant ability of TSIAT

Separate group (IP and RP) anthropometric characteristics and TSIAT indices (Distance, HRpeak and [La]) are displayed in Table 3. Independent sample t-test revealed no difference between groups for body-mass (kg) (p=0.601, d=0.21[*small*]); body-height (cm) (p=0.966, d=0.52 [*small*]); body mass index (BMI: kg·m^{-2}) (p=0.363, d=0.37 [*small*]). However, Distance (d=1.63[*large*]), HRpeak (*d*=1.18[*moderate*]) and [La] (d=2.51[*large*]) were significantly higher for IP compared to RP group (p<0.05). A ROC analysis was performed between IP and RP groups: "*very good*" discriminant ability was found for TSIAT. The areas under the ROC curve was 0.89 (Table 3 and Figure 2).

Table 3. Descriptive data and comparison of the characteristics TSIAT indices of international and regional level tennis players groups.

Variables		International level tennis players (n=12)	Regional level tennis players (n=12)	*p*-values	Cohen's *d*
Groups' characteristics					
Body Mass	(kg)	65.56 ± 11.56	63.42 ± 8.81	0.601	0.21 [*small*]
Body Height	(m)	1.76 ± 0.09	1.72 ± 0.06	0. 966	0.52 [*small*]
BMI	($kg \cdot m^{-2}$)	20.6 ± 1.91	21.32 ± 1.97	0. 363	0.37 [*small*]
TSIAT' indices					
Distance	(m)	2064.11 ± 74.74	1906.03 ± 115.17*	0.012	1.63 [*large*]
HRpeak	(bpm)	187.91 ± 8.27	197.91 ± 8.66*	0.029	1.18 [*moderate*]
[La]	($mmol \cdot L^{-1}$)	7.33 ± 1.45	11.56 ± 1.89*	0.020	2.51 [*large*]

BMI = Body Mass Index; HRpeak = Peak heart rate; TSIAT = Tennis-specific incremental aerobic test; [La] = blood lactate concentration.
*Significant difference between groups (p < 0.05); Values are given as mean ± SD.

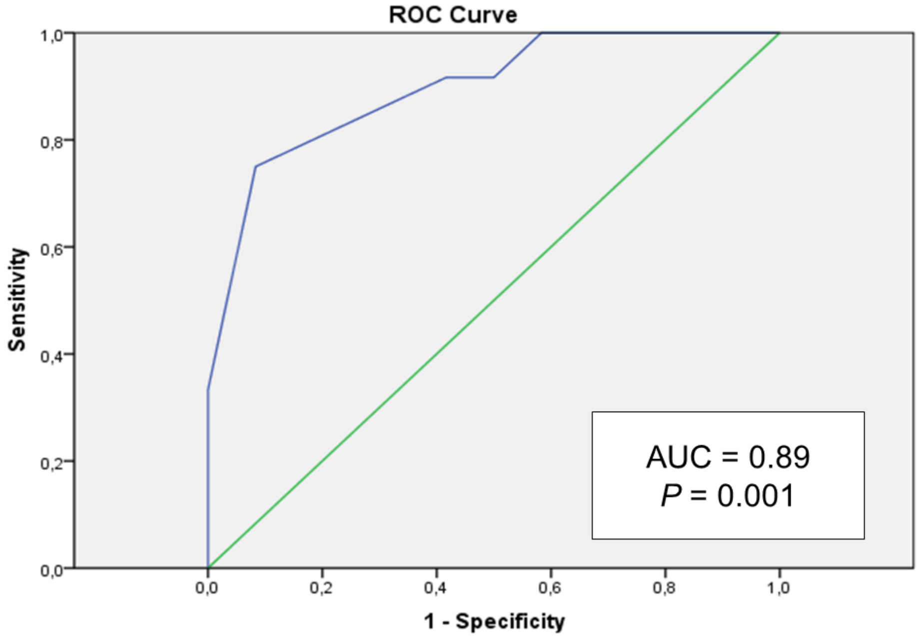

Figure 2. ROC curve of TSIAT performance for tennis players by competitive level. AUC = area under the curve; TSIAT = Tennis-specific incremental aerobic test ; ROC = receiver operator characteristics.

4. Discussion

This study investigated the construct validity, inter-session reliability, sensitivity, and minimal detectable change of the Tennis-Specific Incremental Aerobic Test (TSIAT). Our findings indicate that the TSIAT demonstrates high inter-session reliability and acceptable sensitivity for detecting minimal performance changes. Additionally, the TSIAT effectively discriminates between endurance levels in tennis players, as evidenced by its ability to distinguish between international-level (IP) and regional-level (RP) players.

Reliable and valid assessments are fundamental for tennis coaches to optimize training programs and minimize injury risk. However, ensuring data consistency across testing sessions is crucial (25). Extrinsic errors, especially procedural inconsistencies, can compromise reliability (26). Inconsistent equipment placement is a well-established culprit (27). However, anthropometric variations, running speed fluctuations, data processing errors, and equipment malfunctions can also contribute. In Sports Med, where repeated assessments by the same or different personnel are routine for tracking progress, both inter-session and inter-rater reliability are essential (28).

The Intraclass Correlation Coefficient (ICC) assesses inter-session relative reliability, indicating whether group rankings (not absolute values) are maintained across test administrations (27). Our study found excellent inter-session relative reliability for the TSIAT (e.g., Distance) with an ICC of 0.95. However, ICC can be influenced by sample heterogeneity (29). Therefore, to corroborate the ICC findings, we examined the Standard Error of Measurement (SEM), an absolute reliability measure unaffected by inter-subject variability (29). Notably, when data exhibits homoscedasticity, as observed in our distance data ($r < 0.30$, $p > 0.05$) (30), SEM analysis can be particularly valuable for establishing absolute reliability (30). Following established criteria, an SEM% below 5% indicates good absolute reliability (31). Our investigation yielded an inter-session SEM% of 1.81% for TSIAT distance performance, supporting this notion. Furthermore, we evaluated the likelihood of meaningful differences in TSIAT outcomes using the SWC (smallest worthwhile change). As shown in Table 2, the distance SEM (1.81%) was comparable to the SWC (1.22%), suggesting the test's "satisfactory" potential to detect genuine performance changes. The Minimal Detectable Change (MDC_{95}) provides a threshold for interpreting score changes relative to measurement error (32). The distance MDC_{95} in our study was 99.35 meters. Consequently, a distance change exceeding 5.02% of the original score can be confidently attributed to a true improvement in performance (beyond measurement error) with 95% certainty (30).

This study assessed the construct validity of the TSIAT by comparing performance between distinct athlete groups with known ability differences (international-level vs. regional-level) (33). A strong test should readily discriminate between these groups, and the TSIAT demonstrated this capability. Notably, the TSIAT exhibited excellent discriminant ability, as evidenced by a significant difference in performance between IP and RP players.

The significant differences ($p<0.05$) in TSIAT distance, peak heart rate (HRpeak), and blood lactate concentration ([La]) between IP and RP players highlight TSIAT's effectiveness in differentiating performance profiles. The large effect sizes (d = 1.63, 1.18, and 2.51 for distance, HRpeak, and [La], respectively) further reflect the superior aerobic fitness of IP, which allows them to sustain high-intensity efforts for longer periods and recover more quickly (14, 18). The Area Under the Curve (AUC) of the Receiver Operating Characteristic (ROC) curve served as a measure of this discriminatory power. An AUC of 0.5 indicates no discrimination, while 1.0 signifies perfect discrimination (24). Values exceeding 0.7 are considered indicative of good ability to distinguish groups (34, 35). In this study, the AUC was an impressive 0.89 (34). Furthermore, a TSIAT score exceeding 158.08 meters effectively differentiated between male and female athletes. The ROC curve itself is a visual representation of sensitivity (true positive rate) versus false positive rate (1-specificity) across various score thresholds (34). Therefore, the TSIAT demonstrates "very good" ability to discriminate between athletes of different performance levels.

4.1. Practical Applications

The TSIAT's established reliability and sensitivity for measuring incremental aerobic performance in tennis players make it a valuable tool for coaches. Integrating this test into training regimens allows for effective monitoring of athlete progress.

5. Conclusions

This study established the Tennis-Specific Incremental Aerobic Test's (TSIAT) strong construct validity, excellent inter-session reliability, and acceptable sensitivity. Notably, the TSIAT demonstrates consistent performance replication, detects performance changes, and effectively discriminates between competitive levels in tennis players. Future research could explore the test's generalizability by examining its validity and reliability across different sexes or similar racquet sports (e.g., badminton and paddle tennis).

Acknowledgments

The authors are grateful to all the participants for their enthusiasm and commitment to the completion of this study.

Ethical Approval and Consent to Participate

The studies involving humans were approved by The Special Committee of Scientific Research Ethic of High Institute of Sports and Physical Education of Kef. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Consent for Publication

Not applicable.

Availability of Data and Materials

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Competing Interests

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Funding

The authors declare that no financial support was received for the research, authorship, and/or publication of this article.

Authors' Contributions

WD: Formal Analysis, Investigation, Methodology, Software, Writing – original draft. YH: Data curation, Funding acquisition, Methodology, Project administration, Validation, Writing – review & editing. MS: Data curation, Investigation, Writing – review & editing. SS: Funding acquisition, Writing – review & editing. AA: Data curation, Investigation, Writing – review & editing.

Declaration

Microsoft Copilot was used to improve some passage of the manuscript (36).

References

1. Tsai C-Y, Tsai I-L, Lai C-J, Chow D, Wei L, Cheng L-P, et al. Airracket: Perceptual design of ungrounded, directional force feedback to improve virtual racket sports experiences. Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems. 2022:1-15. [DOI]
2. Fernandez J, Mendez-Villanueva A, Pluim B. Intensity of tennis match play. British journal of sports medicine. 2006;40(5):387-91. [PMID: 16632566] [PMCID: PMC2653872] [DOI]
3. Lames M, McGarry T. On the search for reliable performance indicators in game sports. International Journal of Performance Analysis in Sport. 2007;7(1):62-79. [DOI]
4. Pluim BM, Jansen MG, Williamson S, Berry C, Camporesi S, Fagher K, et al. Physical demands of tennis across the different court surfaces, performance levels and sexes: a systematic review with meta-analysis. Sports medicine. 2023;53(4):807-36. [PMID: 36752978] [DOI]
5. Martin C, Thevenet D, Zouhal H, Mornet Y, Delès R, Crestel T, et al. Effects of playing surface (hard and clay courts) on heart rate and blood lactate during tennis matches played by high-level players. The Journal of Strength Conditioning Research. 2011;25(1):163-70. [PMID: 21157392] [DOI]
6. Cooke K, Davey PR. Tennis ball diameter: the effect on performance and the concurrent physiological responses. Journal of sports sciences. 2005;23(1):31-9. [PMID: 15841593] [DOI]
7. Pereira LA, Freitas V, Moura FA, Aoki MS, Loturco I, Nakamura FY. The activity profile of young tennis athletes playing on clay and hard courts: preliminary data. Journal of human kinetics. 2016;50(1):211-8. [PMID: 28149359] [PMCID: PMC5260656] [DOI]
8. Fleming J. Fuelling the elite and highly trained young tennis player: University of Huddersfield; 2022.
9. Robertson K, Pion J, Mostaert M, Norjali Wazir MRW, Kramer T, Faber IR, et al. A coaches' perspective on the contribution of anthropometry, physical performance, and motor coordination in racquet sports. Journal of sports sciences. 2018;36(23):2706-15. [PMID: 29465332] [DOI]
10. Lees A. Science and the major racket sports: a review. Journal of sports sciences. 2003;21(9):707-32. [PMID: 14579868] [DOI]
11. Baiget i Vidal E. Biomechanical, force-time curve and neuromuscular training impact on serve performance in high level tennis player 2022.
12. Chang S-C, Adami A, Lin H-C, Lin Y-C, Chen CP, Fu T-C, et al. Relationship between maximal incremental and high-intensity interval exercise performance in elite athletes. PloS one. 2020;15(5):e0226313. [PMID: 32396576] [PMCID: PMC7217474] [DOI]
13. Faber IR, Bustin PM, Oosterveld FG, Elferink-Gemser MT, Nijhuis-Van der Sanden MW. Assessing personal talent determinants in young racquet sport players: a systematic review. Journal of sports sciences. 2016;34(5):395-410. [PMID: 26109450] [DOI]
14. Girard O, Chevalier R, Leveque F, Micallef J-P, Millet G. Specific incremental field test for aerobic fitness in tennis. British journal of sports medicine. 2006;40(9):791-6. [PMID: 16855066] [PMCID: PMC2564396] [DOI]
15. Impellizzeri FM, Marcora SM. Test validation in sport physiology: lessons learned from clinimetrics. International journal of sports physiology performance. 2009;4(2):269-77. [PMID: 19567929] [DOI]
16. Weatherly H, Drummond M, Claxton K, Cookson R, Ferguson B, Godfrey C, et al. Methods for assessing the cost-effectiveness of public health interventions: key challenges and recommendations. Health policy 2009;93(2-3):85-92. [PMID: 19709773] [DOI]
17. Davey PR, Thorpe RD, Williams C. Fatigue decreases skilled tennis performance. Journal of sports sciences. 2002;20(4):311-8. [PMID: 12003276] [DOI]
18. Fargeas-Gluck M-A, Léger LA. Comparison of two aerobic field tests in young tennis players. The Journal of Strength Conditioning Research. 2012;26(11):3036-42. [PMID: 22207255] [DOI]
19. Vergauwen L, Spaepen AJ, Lefevre J, Hespel P. Evaluation of stroke performance in tennis. Medicine science in sports exercise. 1998;30(8):1281-8. [DOI]

20. Edriss S, Romagnoli C, Caprioli L, Zanela A, Panichi E, Campoli F, et al. The Role of Emergent Technologies in the Dynamic and Kinematic Assessment of Human Movement in Sport and Clinical Applications. Applied Sciences. 2024;14(3):1012. [DOI]
21. Guelmami N, Ben Ezzeddine L, Hatem G, Trabelsi O, Ben Saad H, Glenn JM, et al. The Ethical Compass: establishing ethical guidelines for research practices in sports medicine and exercise science. International Journal of Sport Studies for Health. 2024;7(2):31-46. [DOI]
22. Drust B, Waterhouse J, Atkinson G, Edwards B, Reilly T. Circadian rhythms in sports performance--an update. Chronobiology international. 2005;22(1):21-44. [PMID: 15865319] [DOI]
23. Smith TB, Hopkins WG. Variability and predictability of finals times of elite rowers. Medicine science in sports exercise. 2011;43(11):2155-60. [PMID: 21502896] [DOI]
24. De Vet HC, Bouter LM, Bezemer PD, Beurskens AJ. Reproducibility and responsiveness of evaluative outcome measures: theoretical considerations illustrated by an empirical example. International journal of technology assessment in health care. 2001;17(4):479-87. [PMID: 11758292] [DOI]
25. Dhahbi W, Chaouachi A, Padulo J, Behm DG, Chamari K. Five Meters Rope-climbing Test: Commando-specific Power Test of the Upper-Limbs. International journal of sports physiology and performance. 2015;10(4):509-15. [PMID: 25392939] [DOI] [DOI]
26. Zaffagnini S, Grassi A, Serra M, Marcacci M. Return to sport after ACL reconstruction: how, when and why? A narrative review of current evidence. Joints. 2015;3(1):25. [DOI]
27. Currell K, Jeukendrup AE. Validity, reliability and sensitivity of measures of sporting performance. Sports Med. 2008;38(4):297-316. [PMID: 18348590] [DOI]
28. Baskaran K, Macedo AF, He Y, Hernandez-Moreno L, Queirós T, Mansfield JS, et al. Scoring reading parameters: an inter-rater reliability study using the MNREAD chart. PloS one. 2019;14(6):e0216775. [PMID: 31173587] [PMCID: PMC6555504] [DOI]
29. Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. J Strength Cond Res. 2005 19(1):231-40. [PMID: 15705040] [DOI]
30. Atkinson G, Nevill AM. Statistical methods for assessing measurement error (reliability) in variables relevant to sports medicine. Sports Med. 1998;26(4):217-38. [PMID: 9820922] [DOI]
31. Nevill AM, Atkinson G. Assessing agreement between measurements recorded on a ratio scale in sports medicine and sports science. Br J Sports Med. 1997;31(4):314-8. [PMID: 9429009] [PMCID: PMC1332566] [DOI]
32. Hachana Y, Attia A, Nassib S, Shephard RJ, Chelly MS. Test-retest reliability, criterion-related validity, and minimal detectable change of score on an abbreviated Wingate test for field sport participants. Journal of strength and conditioning research / National Strength & Conditioning Association. 2012;26(5):1324-30. [PMID: 22516906] [DOI] [DOI]
33. Currell K, Jeukendrup AE. Validity, reliability and sensitivity of measures of sporting performance. Sports medicine. 2008;38:297-316.
34. Deyo RA, Centor RM. Assessing the responsiveness of functional scales to clinical change: an analogy to diagnostic test performance. Journal of chronic diseases. 1986;39(11):897-906. [PMID: 2947907] [DOI]
35. Mannion AF, Elfering A, Staerkle R, Junge A, Grob D, Semmer NK, et al. Outcome assessment in low back pain: how low can you go? European Spine Journal. 2005;14:1014-26. [PMID: 15937673] [DOI]
36. Dergaa I, Fekih-Romdhane F, Glenn JM, Fessi MS, Chamari K, Dhahbi W, et al. Moving Beyond the Stigma: Understanding and Overcoming the Resistance to the Acceptance and Adoption of Artificial Intelligence Chatbots. New Asian Journal of Medicine. 2023;1(2):29-36. [DOI]