DETERMINANTS OF PERFORMANCE IN YOUNG TENNIS PLAYERS: A MULTIDIMENSIONAL APPROACH

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ABSTRACT

DETERMINANTS OF PERFORMANCE IN YOUNG TENNIS PLAYERS: A MULTIDIMENSIONAL APPROACH

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This study examined the associations between rankings and physical, functional, psychological, and experiential characteristics in a sample comprising top 8 junior tennis players from U12, U14, U16 age categories. Forty-six players were included in both genders, with 8 participants per group, except for U14 boys. Data were collected on training age, racquet weight, string tension, weekly training volume, and age at tournament start. Tournament participation and match statistics were gathered from national and international websites. Players underwent assessments for anthropometry (height, weight, body fat percentage), physical fitness (grip strength, flexibility, countermovement jump, medicine ball throw, sprints for 5, 10, and 20 m, shuttle run), serve speed, reaction time, mental toughness, and motor coordination. Age at peak height velocity and growth status were calculated, and national team coaches completed a questionnaire on performance parameters. Significant correlations ($p<0.05$) were found between rankings and age at tournament start (U12 boys), body fat percentage (U12 girls; U14 boys), BMI (U12 girls), grip strength (U12 girls), flexibility (U12 girls), medicine ball throw (U16 boys), motor coordination (U12 girls), string tension (U12 girls), number of international

tournaments (U12 girls), number of national and international singles and doubles matches (U14 boys; U16 boys), total tournaments and matches (U14 boys; U16 girls). Additionally, 41.4% of participants performed above the normal level in the motor coordination. Coaches emphasized motor coordination for U12 players and U14 girls, whereas mental toughness is emphasized for U14 boys and U16 players. The results may provide insight into the talent identification and development of young tennis players.

Keywords: tennis, talent identification, talent development, top-ranked junior players

ÖZ

GENÇ TENİS OYUNCULARINDA PERFORMANS BELİRLEYİCİLERİ: ÇOK BOYUTLU BİR YAKLAŞIM

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Bu çalışma, U12, U14, U16 yaş kategorilerinden en iyi 8 genç tenis oyuncusundan oluşan bir örneklemde ulusal sıralama ile fiziksel, fonksiyonel, psikolojik ve deneyimsel özellikler arasındaki ilişkileri incelemiştir. Her kategoriden erkek ve kız 8 oyuncu (U14 erkekler hariç) olmak üzere toplam 46 oyuncu çalışmaya dahil edilmiştir. Antrenman yaşı, raket ağırlığı, tel gerginliği, haftalık antrenman hacmi ve turnuvaya başlama yaşı ile ilgili veriler toplanmıştır. Turnuva katılım ve maç istatistikleri ulusal ve uluslararası resmi internet sitelerinden toplanmıştır. Oyuncular antropometri (boy uzunluğu, vücut ağırlığı, vücut yağ yüzdesi), fiziksel uygunluk (kavrama kuvveti, esneklik, dikey sıçrama, sağlık topu fırlatma, 5, 10 ve 20 m sürat, mekik koşusu), servis hızı, reaksiyon süresi, zihinsel dayanıklılık ve motor koordinasyon ölçümlerine katılmışlardır. Zirve boy hızındaki yaş ve büyüme durumu hesaplanmış ve milli takım antrenörlerinin performans parametrelerine bakış açıları hakkında bir anket uygulanmıştır. Sıralamalar ile turnuvaya başlama yaşı (U12 erkekler), vücut yağ yüzdesi (U12 kızlar; U14 erkekler), beden kitle indeksi (U12 kızlar), kavrama gücü (U12 kızlar), esneklik (U12 kızlar), sağlık topu fırlatma (U16 erkekler), motor koordinasyon (U12 kızlar), tel gerginliği (U12 kızlar), uluslararası

turnuva sayısı (U12 kızlar), ulusal ve uluslararası tekler ve çiftler maç sayısı (U14 erkekler; U16 erkekler), toplam turnuva ve maç sayısı (U14 erkekler; U16 kızlar) parametreleri arasında anlamlı ($p<0.05$) ilişkiler bulunmuştur. Ayrıca, katılımcıların %41,4'ü normal seviyenin üzerinde motor koordinasyon performans göstermiştir. Antrenörler U12 oyuncuları ve U14 kız oyuncular için motor koordinasyonun önemini vurgularken, U14 erkek ve U16 oyuncuları için zihinsel dayanıklılığın önemini belirtmişlerdir. Elde edilen sonuçlar, genç tenis oyuncularının yetenek tespiti ve gelişimine ışık tutabilir.

Anahtar Kelimeler: tenis, yetenek seçimi, yetenek gelişimi, üst seviye genç oyuncular

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TABLE OF CONTENTS

PLAGIARISM iii
ABSTRACT iv
ÖZ vi
ACKNOWLEDGMENTS viii
TABLE OF CONTENTS x
LIST OF TABLES xiii
CHAPTERS
1. INTRODUCTION 1
1.1. Purpose of the Study 5
1.2. Research Questions 5
1.3. Hypothesis 5
1.3.1. Assumptions 6
1.4. Significance of the Study 6
1.5. Definition of Terms 7
2. LITERATURE REVIEW 9
2.1. Theoretical framework of the study 9
2.2. Talent identification and development in tennis 10
2.3. Determinants of the performance in youth tennis 11
2.3.1. Physical growth and biological maturation 13
2.3.2. Physical fitness 14
2.3.3. Motor competence 16
2.3.4. Technical and tactical skills 17
2.3.5. Psychological traits 19
2.3.6. Experience, training and competition exposure 21
2.3.7. Coaches' perspectives on performance determinants in junior tennis 23
3. METHODS 26
3.1. Study Design 26
3.2. Participants 26

3.3. Data Collection Instruments 27
3.3.1. Stadiometer 27
3.3.2. Body Composition Analyzer 27
3.3.3. Hand Dynamometer 27
3.3.4. Microgate, OptoJump 27
3.3.5. Electronic Timing Gates 27
3.3.6. Radar Gun 28
3.3.7. Medicine Ball 28
3.3.8. Sit and Reach Table 28
3.3.9. KTK Battery 28
3.3.10. BlazePod System 28
3.3.11. Beep Test Application 28
3.4. Data Collection Procedures 28
3.4.1. Match and Tournament Records 30
3.4.2. Anthropometry 31
3.4.2.1. Standing Height 31
3.4.2.2. Sitting Height 31
3.4.2.3. Body Mass and Body Fat Percentage 31
3.4.3. Physical Growth 32
3.4.4. Biological Maturation 32
3.4.5. Grip Strength 33
3.4.6. Countermovement Jump 33
3.4.7. Medicine Ball Throw 33
3.4.8. T-Agility 33
3.4.9. Sprint 34
3.4.10. Sit-and-Reach 34
3.2.11. Maximum Serve Speed 34
3.2.12. Motor Skill Assessment 35
3.2.13. Reaction Time 36
3.2.14. Aerobic Endurance 37
3.2.15. Mental Toughness 37
3.2.16. Coaches' Perspective 38
3.5. Statistical analysis 39

4. RESULTS 40
4.1. Descriptive Results 40
4.2. Coaches' Perspectives 54
4.3. Correlational Analysis 57
5. DISCUSSION 69
5.1. Limitations and recommendations for future studies 80
5.2. Practical implications 80
5.3. Conclusion 82
REFERENCES 85
APPENDICES
A. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE. 105
B. PERMISSION OF THE TURKISH TENNIS FEDERATION 106
C. CONSENTS FROM PARTICIPANTS 107
D. CONSENTS FROM PARENTS 109
E. DATA COLLECTION FORMS 111
F. MENTAL TOUGHNESS SCALE 112
G. COACHES' PERSPECTIVE QUESTIONNARE 113
I. TURKISH SUMMARY / TÜRKÇE ÖZET 116
J. THESIS PERMISSION FORM / TEZ İZİN FORMU 137

LIST OF TABLES

Table 1. The number of players by age and gender 27
Table 2. Classification of motor coordination levels (adapted from Kiphard and Schilling, 2007) 35
Table 3. The descriptive statistics for the chronological age, experience, and racket specification characteristics of girls by age groups 40
Table 4. The descriptive statistics for the chronological age, experience, and racket specification characteristics of boys by age groups 41
Table 5. The anthropometrics characteristics of girls 43
Table 6. The anthropometrics characteristics of boys 43
Table 7. The descriptive statistics for physical growth and maturity of girls 44
Table 8. The descriptive statistics for physical growth and maturity of boys 44
Table 9. The descriptive statistics for physical performance parameters of girls 45
Table 10. The descriptive statistics for physical performance parameters of boys 46
Table 11. The motor coordination performance of girls 48
Table 12. The motor coordination performance of boys 48
Table 13. The motor coordination levels of players 49
Table 14. Reaction time of girls 50
Table 15. Reaction time of boys 52
Table 16. Mental toughness scores of players 53
Table 17. Coaches' perspective on the contribution of performance measures for girls 54
Table 18. Coaches' perspective on the contribution of performance measures for boys 55
Table 19. The correlation statistics between rankings and chronological age, experience, and racket specification characteristics in U12 players 58
Table 20. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U12 players. 59

Table 21. The correlation statistics between rankings and physical growth and maturity of U12 players. 59
Table 22. The correlation statistics between rankings and physical performance parameters of U12 players. 60
Table 23. The correlations between rankings and reaction times of U12 players. 60
Table 24. The correlation statistics between rankings and the chronological age, experience, and racket specification characteristics in U14 players 61
Table 25. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U14 players 62
Table 26. The correlation statistics between rankings and physical growth and maturity of U14 players 63
Table 27. The correlation statistics between rankings and physical performance parameters of U14 players 63
Table 28. The correlations between rankings and reaction times of U14 players 64
Table 29. The correlation statistics between rankings and the chronological age, experience, and racket specification characteristics in U16 players 64
Table 30. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U16 players 65
Table 31. The correlation statistics between rankings and physical growth and maturity of U16 players 66
Table 32. The correlation statistics between rankings and physical performance parameters of U16 players 66
Table 33. The correlations between rankings and reaction times of U16 players 67
Table 34. The correlations between rankings and the mental toughness of players. . 68

CHAPTER 1

INTRODUCTION

Tennis is a globally played and highly competitive sport, with over 106 million participants across 199 countries (International Tennis Federation, 2024). From the iconic grass courts of Wimbledon to the hard courts of the US Open, tennis has solidified its place on the international stage, appealing to athletes of all ages and skill levels. The sport's widespread popularity derives from its combination of physical intensity and strategic thinking, offering it accessible to both professional and recreational players. Consistent participation in tennis is associated with numerous health advantages, such as improved aerobic fitness, reduced body fat percentage, healthier lipid profiles, enhanced bone density, and a diminished risk of cardiovascular disease and mortality (Chomistek et al., 2012; Pluim et al., 2007). Tennis demands considerable agility, endurance, and muscular strength, which collectively improve athletic performance and reduce the risk of injury (Fernández-Fernández et al., 2009). The physiological advantages, along with the cognitive and emotional demands of the sport, contribute to its enduring global popularity and positive impact on overall well-being.

Historically, talent identification has focused mainly on assessing physical attributes, including strength, speed, and coordination. Johnston et al. (2018) performed a systematic review demonstrating that the majority of talent identification research has concentrated on the physical characteristics of athletes. Many other studies evaluate young athletes using quantifiable physical parameters, and overlook other critical factors (Jung, 2022). Johnston et al. (2018) noted a lack of research investigating cognitive, perceptual, and psychological factors in talent identification methodologies. There is increasing recognition of the limitations of traditional methods, resulting in a shift towards a more comprehensive, multidimensional approach.

Till and Baker (2020) underscored the importance of incorporating varied factors beyond physical attributes to enhance talent identification and development systems. This new paradigm incorporates physical attributes alongside psychological, emotional, and developmental elements, offering a more comprehensive perspective on a player's potential. A comprehensive review by Hamidi and Wazir (2022) emphasized the significance of incorporating psychological characteristics, including personality traits and emotional intelligence, in conjunction with physical fitness in talent identification systems.

Nijenhuis et al. (2024) emphasized the advantages of employing multidimensional and longitudinal approaches in talent identification in racket sports, indicating that these methods provide a more comprehensive understanding of athlete development. Highlighting multidimensional development is crucial for cultivating well-rounded athletes capable of succeeding in the intricate and challenging landscape of competitive tennis. This method promotes simultaneous progress in all aspects of an athlete's development, encompassing physical fitness, mental resilience, technical skills, and experiential learning, thus enhancing sustained performance and career longevity.

In tennis, performance is multifaceted, as demonstrated by the interplay of anthropometric, physiological, technical, tactical, and psychological attributes that collectively impact future performance (Elferink-Gemser et al., 2011; Kovacs, 2007). Tennis is a physically demanding sport that requires players to develop endurance, agility, strength, coordination, and flexibility to compete effectively (Girard & Millet, 2009). Unlike many other sports, where physical attributes may be emphasized selectively, tennis demands high performance across multiple physiological components, including speed, strength, and endurance (Kovacs, 2007). Anthropometric factors such as height and weight also influence performance (Sanchez-Muñoz, Sanz, & Zabala, 2007), but growth and maturation introduce additional complexity. Research on young tennis players highlights significant variability in biological maturity within the same chronological age groups, impacting physical and functional performance. Myburgh et al. (2016) found that elite British junior players exhibited gender-specific maturation trends, with girls

advancing in skeletal age from age 8, while boys showed delayed maturation until 12 but advanced skeletal age from 14 to 16. Similarly, Söğüt et al. (2019) and Söğüt et al. (2023) reported that girls were more advanced in maturation than boys, and in U12 and U14 players, greater maturity was associated with higher rankings, particularly in girls. Maturation influences motor performance, as demonstrated by Myburgh et al. (2020), who found that early-maturing tennis players had inferior sprint acceleration when assessed according to biological age. These findings underscore the importance of considering individual growth trajectories in talent identification, training design, and competition structures to provide fair and effective developmental pathways for young athletes (Bergeron et al., 2015).

A crucial element of tennis performance is motor proficiency. The ability of athletes to analyze complex visual information is essential for forecasting future events and is considered a core competency associated with motor performance (Lebeau et al., 2016). Newell's constraints-led approach asserts that motor performance is shaped by the interactions among the task, the environment, and the individual (Newell, 1986). This methodology is elaborated in the model for talent identification and development in sports (Elferink-Gemser, Visscher, Lemmink, & Mulder, 2007). This model demonstrates that multiple performance factors influence athletic performance.

Technical and tactical skills are more specialized for specific sports (Fernandez-Fernandez et al., 2011). In tennis, these factors encompass the ability to recognize on-court tactical situations, make appropriate decisions, and handle the ball and racket (MacCurdy, 2006). Serves and groundstrokes are the primary determinants by which technical abilities in tennis are demonstrated. Ball velocity and the percentage of correct first serves are two critical variables of a serve (Knudson, Noffal, Bahamonde, Bauer, & Blackwell, 2004). Tactical skills refer to the understanding of in-game adaptations and decision-making processes on the court (Elferink-Gemser, Kannekens, Lyons, Tromp, & Visscher, 2010). Technical proficiency is equally critical, as players must master a diverse set of skills such as serving, volleying, and groundstrokes, while also adapting these techniques to varying conditions like court surfaces and opponent styles. Reid et al. (2016) discussed the significance of

technical and tactical skills in relation to performance levels in tennis, emphasizing the need for adaptability in various match situations.

Additionally, psychological factors such as mental toughness, focus, and emotional regulation under pressure play a crucial role in determining success on the court. Athletes frequently have to perform well under highly demanding physical (e.g., fatigue) and mental (e.g., crowd pressure) conditions (Gucciardi et al., 2014). Cowden et al. (2016) examined the connections between mental toughness, resilience, and stress in competitive tennis players, highlighting the significance of psychological resilience in high-pressure situations. Psychological traits are not isolated but work in harmony with physical, technical, and experiential components, illustrating the multidimensional nature of tennis performance.

Experience is a vital determinant of player quality. The current literature on team sports has analyzed the performance disparities between expert and novice players (Didierjean & Marméche, 2005), indicating that such comparisons may enhance understanding of how training variables influence player development (Leite & Sampaio, 2010). Experienced players have exhibited enhanced performance relative to novices in detection, memory retention, and decision-making precision (Vaz et al., 2012). A study on tennis investigated the visual search strategies of professional and novice players, using player ranking as the differentiating criterion (Murray & Hunfalvay, 2016). This model demonstrates that several performance factors influence athletic performance. However, there is a paucity of knowledge concerning the influence of experience on competitive performance among young tennis players.

Moreover, coaches' perspectives on performance determinants are particularly valuable, as they stem from direct experience with athletes throughout various developmental stages. The comprehension of talent by sports coaches is likely to affect the assessment of children and adolescents participating in recreational or athletic pursuits (Gagné, 2000). Coaches can assess and quantify critical physical, technical, and psychological factors that impact athletic performance, including strength, agility, response time, and mental resilience. The techniques employed by coaches, the athletic environment, and the interpretations of athletes' behavior and

motivation are essential for establishing a safe and enjoyable atmosphere for young athletes (Mageau and Vallerand, 2003). The integration of coaches' assessments enables researchers and practitioners to formulate comprehensive and effective strategies for enhancing athletic potential and ensuring consistent performance in competitive environments.

An in-depth examination of performance determinants underscores the complexity of tennis as a sport that presents challenges to athletes across various dimensions. The current study recognizes the lack of comprehensive research that has simultaneously examined these attributes. Additional research is required to elucidate the factors influencing performance in adolescent tennis players engaged in this sport.

1.1. Purpose of the Study

The purpose of this study was to determine the associations between rankings and physical, functional, psychological, and experiential characteristics in a sample comprising the top 8 junior tennis players from U12, U14, U16 age categories. In addition to this, coaches' perspective on the contribution of performance determinants were included.

1.2. Research Questions

This study seeks to address following research questions:

(1) What are the associations between national rankings and physical, functional, psychological, and experiential characteristics among the top junior tennis players in the U12, U14, and U16 age categories?

(2) What is the coaches' perspective on the principal factors of performance in top junior tennis players?

1.3. Hypothesis

(1) This study hypothesizes that no single variable will consistently correlate with national ranking across all age groups and gender.

(2) Coaches' perspectives to young tennis performance are expected to vary by age and gender

1.3.1. Assumptions

It is assumed that all measurements used in the study are valid and reliable, that players performed to the best of their ability during the tests, that all participants—including coaches—provided accurate and honest responses, and that national rankings represent a stable indicator of performance.

1.4. Significance of the Study

Current study on tennis performance has primarily focused on individual characteristics, such as physical fitness or technical skill, frequently neglecting the complex interaction of multiple factors that contribute to success. Many studies emphasize attributes like muscular strength, agility, or technical skill, overlooking the multidimensional impact of psychological, emotional, developmental, and coaching factors on a player's success.

This study utilizes a multidimensional approach by analyzing performance factors across various dimensions, including physical, functional, psychological, and experience attributes, along with coaching perspectives. The research offers a comprehensive analysis of the factors affecting rankings across various age categories (U12, U14, U16) by incorporating variables such as training age, equipment specifications, training volume, tournament participation, and detailed match statistics, in addition to evaluations of physical fitness, reaction time, mental resilience, and motor coordination. This interconnected perspective offers deep insight into the primary factors effecting performance in young tennis players.

This study offers an original and comprehensive contribution to the field of tennis talent identification and development by systematically examining a wide range of variables—including demographic, experiential, physical, technical, and psychological factors—and their relationship with national rankings across different

age categories and gender. Moreover, this research specifically focused on a highly selective sample of players who were ranked within the top eight of their age group at the national level. Since ranking is a widely accepted and objective indicator of competitive success in tennis (Reid et al., 2007), the inclusion of this top-ranked subgroup greatly enhances the relevance and interpretability of the findings.

Furthermore, this study's originality stems from its multidimensional approach and the integration of coaches' perspectives alongside empirical performance data. By doing so, it bridges the gap between practical coaching experience and scientific assessment, providing a more multidimensional understanding of what constitutes success in youth tennis. The findings not only offer insights into age and gender-specific performance patterns but also contribute to the development of evidence-based guidelines for talent identification and individualized training strategies within youth tennis programs.

This study aims to enhance talent identification and development strategies in tennis using a multidimensional framework. It seeks to provide a more nuanced understanding of the performance determinants on national rankings among young players, while emphasizing the critical roles of physical, technical, experiential and psychological variables in their growth. The findings may offer substantial insights for coaches, tennis academies, and federations, informing evidence-based strategies for player development. Furthermore, the study may contribute to refining talent identification models in Türkiye, ultimately fostering the growth of more well-rounded and successful players within the national tennis landscape.

1.5. Definition of Terms

Age at peak height velocity: The age at which the peak growth rate transpires during the teenage growth spurt.

Biological maturity: Advancing towards the fully developed biological condition.

Maturity offset: The age gap from the peak height velocity.

Mental toughness: Encompasses a range of developed and intrinsic values, attitudes, emotions, cognitions, and behaviors that shape how an individual confronts, reacts to, and evaluates both positive and negative pressures, challenges, and adversities in order to consistently accomplish his or her aims.

Motor competence: Capability to perform goal-oriented movements, which correlates positively with physical activity and fitness levels during youth and adolescence.

Physical fitness: Capability to execute physical activities and tasks proficiently, possessing adequate strength, speed, endurance, flexibility, and coordination.

Physical growth: The measurable alterations that transpire in an organism's body over time, including changes in height, weight, and body composition.

String tension: The assessment of the tightness of the strings within the framework of a racquet.

CHAPTER 2

LITERATURE REVIEW

2.1. Theoretical framework of the study

This study utilizes the Bioecological Model of Human Development as its theoretical framework to examine the multifaceted factors of performance in top junior tennis players. The Bioecological Model of Human Development, established by Bronfenbrenner and Ceci (1994), is extensively utilized across multiple disciplines, notably in developmental psychology, education, sociology, public health, and sports science. The model offers a thorough framework for comprehending the interplay between human traits and environmental systems in shaping performance results (Bronfenbrenner & Morris, 2006). This study employed the five interconnected layers—microsystem, mesosystem, exosystem, macrosystem, and chronosystem—to analyze the assessed components. The microsystem highlights the players' immediate performance characteristics, encompassing anthropometry, physical development, biological maturity, grip strength, lower and upper body strength, agility, speed, flexibility, motor abilities, reaction time, aerobic endurance, mental toughness. The mesosystem emphasizes the interrelations between various microsystems in the athlete's life. For instance, it involves the dynamics between an athlete's family and their sports team, as well as the interplay between their educational environment and their training program. The exosystem and macrosystem highlight broader influences, including institutional support and cultural attitudes that affect talent development, such as the impact of federations' coaching education policies on coaches' perspectives on performance metrics in player development. The chronosystem includes all factors analyzes how developmental changes, encompassing physical and psychological maturation alongside extended training progression, influence a player's performance over time (Brandão et al., 2024).

The Bioecological Model provides a thorough analysis of the physical, technical, and psychological factors that improve performance by aligning the research objectives of the study with these components. Moreover, it creates a framework for adopting coaches' perspectives to improve the understanding of key elements of success. This comprehensive approach aims to establish benchmark indicators for top-ranked players and guide strategies for talent identification and development in tennis.

The study employed a quantitative cross-sectional approach to comprehensively evaluate these characteristics and their relationships with national rankings. Descriptive statistics outline mean scores by age groups and genders, whereas correlational research highlights the primary factors influencing ranking accomplishment. This design aligns with the Bioecological Model by providing a multidimensional view of the interaction between human and environmental factors, consequently facilitating the identification of performance determinants and improving effective talent identification and development strategies in tennis.

2.2. Talent identification and development in tennis

The identification and cultivation of potential in tennis have been thoroughly analyzed to determine the essential traits that contribute to enduring success in the sport. A recent study on talent identification and development in junior tennis has highlighted several crucial factors influencing player success. Tsao, Liu, and Chang (2022) developed an assessment technique to gauge tennis proficiency by measuring vertical jump, shuttle run, and shoulder flexibility. Their studies revealed that tennis players require greater flexibility than basketball players, and that shoulder mobility is crucial for effective serving and stroke performance. This study underscores the need of customized assessments in talent identification and development. A 2021 prospective study (Kolman et al., 2021) demonstrated that technical traits, such as ball speed and accuracy, are significant predictors of current and future success among male junior tennis players. The results emphasized the need of developing these skills in various gaming contexts to enhance performance outcomes. A 2022 study (Chapelle et al., 2022) examined the impact of anthropometric and physical performance factors on the progression of young tennis players in a talent

identification program. The results indicated that attributes such as speed, agility, jumping ability, motor coordination, and tennis-specific skills significantly influenced selection probabilities, especially in players aged 8 to 10. This study by Bozidar et al. (2014) examines the psychological skills of adolescent tennis players and their relationship with coaching input and leadership behavior. The results indicated substantial variations in psychological characteristics according to age, gender, and training context. A robust association was identified between particular psychological traits and coaching input, including leadership style, underscoring the influence of coaching methodologies on the psychological development of young athletes. A systematic evaluation conducted in 2015 assessed numerous instruments measuring individual talent factors in young racquet sport athletes (Faber et al., 2015). The review indicated that evaluations emphasizing cognitive and perceptual capabilities, together with coordination skills, can distinguish elite players from their non-elite counterparts. The predictive validity of these tools for future success remains ambiguous, underscoring the necessity for comprehensive, multidimensional evaluation techniques.

2.3. Determinants of the performance in youth tennis

The literature on performance determinants in sports indicates substantial study aimed at determining the elements that affect the performance of young athletes. A multitude of studies has investigated various facets of athletic performance (Vaeyens et al., 2008), encompassing physical fitness (Kramer et al., 2016; Xiao et al., 2022; Sánchez-Pay et al., 2021; Villouta et al., 2021), technical skills (Lambrich & Muehlbauer, 2023), psychological attributes (Gould et al., 2002; MacNamara et al., 2010), and sociocultural factors (Baker & Horton, 2004). The extensive published research in this domain facilitates a thorough analysis of the determinants of success in young athletes.

Physical growth and biological maturity significantly influence strength, speed, and coordination, which are crucial for the precise execution of technical abilities (Malina et al., 2004; Baxter-Jones et al., 2005). Moreover, physical fitness—encompassing endurance, agility, and strength—directly influences a player's

capacity to maintain high-intensity rallies and recuperate between points (Roetert & Ellenbecker, 2007; Kovacs, 2007). Motor competence, which includes fundamental movement skills, serves as the basis for technical proficiency and tactical execution (Fransen et al., 2012; Vandorpe et al., 2012). Technical and tactical skills are crucial for match performance, as they determine a player's ability to control the ball, create opportunities, and adjust strategies based on opponents' strengths and weaknesses (Reid et al., 2007; Kolman et al., 2018). Psychological traits like as resilience, confidence, and concentration influence a player's ability to handle pressure and sustain consistent performance in competitive settings (Weinberg & Gould, 2018; MacNamara et al., 2010). Experience, training, and competitive exposure profoundly impact a player's development by refining skills, enhancing decision-making, and fostering flexibility in diverse match scenarios (Reid et al., 2008; Hornig et al., 2014). Furthermore, coaches' perspectives on these traits provide vital insights into the important attributes required for success in youth tennis, guiding training and development initiatives. Crespo et al. (2024) investigated the viewpoints of international high-performance tennis instructors concerning the critical mental attributes necessary for tennis and their training techniques. Coaches unanimously regarded mental skills as essential for tennis performance. This study is, to the authors' knowledge, the sole investigation that has analyzed performance factors in top junior tennis players from a comprehensive perspective.

Due to the complex and varied nature of tennis, specialists have examined multiple aspects influencing the progression of young athletes. This chapter analyzes contemporary studies on talent identification and development in tennis, highlighting the critical attributes that impact performance in young athletes. The variables encompass physical growth and biological maturation, physical fitness, motor competence, technical and tactical abilities, psychological characteristics, experience, and exposure to training and competition. An analysis of coaches' perspectives on assessing and influencing performance is conducted, as their views are essential for player development. This study synthesizes multiple disciplines to offer a thorough knowledge of the complex dynamics of tennis development, thereby enhancing evidence-based approaches in player selection and ongoing improvement.

2.3.1. Physical growth and biological maturation

In order to design effective training programs for young athletes, it is important to understand the influence of growth and maturation on their development (Balyi & Hamilton, 2004; Balyi, Way & Higgs, 2013; Ford et al., 2011). To provide young athletes with training that fosters their overall development, it is essential to fully understand these two biological processes, as they play a vital role in a child's growth and significantly impact their physical, mental, and emotional well-being (Beunen & Malina, 2008).

Young athletes must possess a comprehensive understanding of the factors and patterns that affect their development and maturation to effectively benefit from well-structured training regimens (Gabbett, Johns, and Riemann, 2008; Lloyd et al., 2014). Incorporating biological processes into training regimens can enhance athletic development, as physical growth is a crucial determinant of sports performance. Recognizing variations from standard growth and maturation patterns is crucial, as they may signify potential medical concerns or developmental delays that could impact a child's general health and well-being (Hebestreit and Bar-Or, 2008).

Myburgh, Cumming, Silva, Cooke, and Malina (2016) examined the growth and maturity status of 91 elite junior British tennis players (47 males and 44 females) aged 8 to 17, with a mean age of 12.5 years, in comparison to population norms. Skeletal maturation was evaluated using the Fels approach (Lohman et al., 1988). The study indicated that females had an advanced skeletal age relative to their chronological age beginning at 8 years, whereas males displayed average to delayed maturation from 8 to 12 years, thereafter, showing advanced skeletal age from 14 to 16 years.

Söğüt, Ödemiş, and Durmuş (2023) investigated the growth and maturity status of 70 U14 competitive tennis players and its link with national rankings. Somatic maturity was evaluated using the formula created by Mirwald et al. (2002). The study revealed that, regardless of gender, the mean height and body mass percentiles of players surpassed the 60th percentile. Increased maturity and higher BMIs were associated

with improved rankings in females. However, no significant differences were observed among the groups for boys.

Ödemiş and Söğüt (2024) examined the growth and biological maturity status of 117 young competitive table tennis players (57 males, 12.87±1.35 years; 60 females, 12.99±1.24 years) and their relationship with medal-winning performance. Physical measurements included height, sitting height, and body mass, with somatic maturity assessed using age at peak height velocity and maturity offset. Results showed that players' mean height, body mass, and BMI percentiles exceeded the 37th percentile compared to reference norms. However, no significant differences in growth or maturity status were found between medal-winning and non-medal-winning players of either gender, with the only notable difference being that medal-winning boys had more training experience. The findings suggest physical characteristics alone don't determine competitive success in youth table tennis, indicating the need for a more comprehensive approach to talent identification.

2.3.2. Physical fitness

The current tennis game is highly dynamic, and tournament schedules are demanding, making the need of physical fitness widely acknowledged (Reid & Schneiker, 2007). Xiao et al. (2022) conducted a systematic analysis analyzing the impact of several exercise training programs on the physical fitness components of young tennis players. The review analyzed nine studies focusing on components such as speed, agility, power, strength, and flexibility. Research indicated that exercise training markedly enhanced speed and agility in young athletes. However, information about gains in strength and flexibility was limited, and no conclusive results were found indicating benefits in endurance. The study underscores the imperative for further investigation, particularly regarding strength, flexibility, and endurance training in adolescent tennis players.

Kovacs (2007) performed an extensive examination of the physiological demands of tennis and the influence of physical fitness on performance improvement. The research highlighted that tennis is an intermittent sport necessitating a combination of

aerobic endurance, anaerobic power, speed, agility, and muscular strength. Kovacs highlighted that elite players exhibit superior physical conditioning, allowing them to maintain high-intensity performance throughout prolonged matches. This study analyzed different training methodologies, including high-intensity interval training (HIIT), resistance training, and flexibility exercises, with the objective of improving performance and reducing injury risk. Durmuş et al. (2023) reported that structured HIIT is an effective method for enhancing aerobic fitness and technical performance in tennis players, irrespective of age or skill level. Due to the substantial physiological demands of competitive tennis and the considerable time needed for the development of technical and tactical skills, HIIT has been suggested as an efficient method for conditioning that also facilitates technical skill acquisition.

Lambrich and Muehlbauer (2022) conducted a systematic review and meta-analysis to examine the disparities in physical fitness and stroke performance between elite and sub-elite tennis players. The results showed that elite players exhibited greater lower extremity muscle power, endurance, agility, and speed than sub-elite players. A significant effect was noted in stroke performance, consistently benefiting elite tennis players. A stronger correlation between physical fitness and stroke performance was identified in elite tennis players ($r = 0.562$) than in sub-elite players ($r = 0.372$). The research identified notable differences in lower extremity muscle power, endurance, and agility, emphasizing the critical role of these factors in tennis performance.

Reid and Schneiker (2007) performed a review of contemporary strength and conditioning practices specific to tennis. The study emphasized the intricate bioenergetic demands of tennis, characterized by intermittent phases of high-intensity exertion. The research highlighted the significance of organized resistance training programs in enhancing athletes' strength and power, which are crucial for executing explosive movements on the court. The analysis examined the challenges of periodizing training programs due to the sport's demanding schedule, suggesting the integration of tennis-specific drills with strength and conditioning regimens to improve performance.

De Queiroz Miranda et al. (2020) performed a systematic review analyzing strength training techniques and external factors in training regimens for competitive tennis athletes. The results demonstrated that integrating muscle-building workouts and plyometric exercises with tennis-specific drills was the most efficacious method for improving multiple facets of strength. This study highlights the significance of incorporating various strength training methodologies customized for tennis to enhance performance.

2.3.3. Motor competence

A variety of studies has investigated motor competence in tennis players. Söğüt (2017) examined serve velocity and motor coordination in elite and club-level junior tennis players aged 11 to 14. The study demonstrated that elite players displayed markedly higher serve speeds and improved motor coordination, highlighting the essential importance of early involvement and rigorous training in skill development.

Waldziński et al. (2024) performed a longitudinal study evaluating the development of motor coordination and tennis skills over a one-year period in players aged 10 to 12 years. Findings demonstrated that boys typically exhibited superior performance compared to girls in tennis skills and motor coordination assessments. Females had a superior improvement in balance and complex reaction evaluations, suggesting that motor development is influenced by age, gender, and task specialization.

Söğüt (2016) assessed gross motor coordination in junior tennis players aged 6 to 14 years using the Körperkoordinationstest für Kinder (KTK). The study revealed that 40.6% of players exhibited motor coordination skills surpassing the normative range, with no significant gender disparities observed. The results underscore the significance of early motor coordination development in young athletes, accessible through age-appropriate training programs.

Bisio et al. (2021) investigated motor timing abilities in young tennis players relative to non-players through a synchronization task. The research indicated that tennis players demonstrated enhanced movement strategies and spatial accuracy, especially

in tasks involving bimanual coordination. The findings indicate that tennis training improves specific motor timing skills critical for effective play.

Barbaros et al. (2023) analyze the differences in specific motor skills among tennis players in the younger age categories of U12, U14, and U16. The research evaluated explosive strength in jumping, speed, agility, and trunk strength, indicating a linear progression in these abilities with advancing age. This suggests that as individuals age, their motor skills develop, underscoring the importance of training programs tailored to specific age groups. They also investigate the issue of muscular imbalance between the anterior and posterior trunk musculature. The physical conditioning of young tennis players must be systematically structured to improve injury prevention and adaptation to competitive demands.

These studies highlight the multifaceted nature of motor competence in tennis, understanding these components can inform targeted training programs to optimize player development and performance.

2.3.4. Technical and tactical skills

Kolman et al. (2018) included results from 40 studies in a systematic review to look at how technical and tactical skills are related to tennis success. The review showed that players' technical skills (like ball speed and, to a lesser extent, ball accuracy) and tactical skills (like decision-making, anticipation, tactical knowledge, and visual search methods) were different depending on their performance levels. But these skills need to be measured together because winning a point depends a lot on the tactical choice of which stroke to make (i.e., skilled execution). The authors highlighted that more research should be done in the future to find out how technical and tactical skills affect tennis play.

Putri et al. (2024) conducted an experimental study to examine the impact of game-based and drill-based training approaches on the enhancement of fundamental tennis technical skills in male players aged 10-12 and 13-15 years. The researchers concluded that the game-based training method was more effective for the younger

demographic, whilst the drill-based approach benefited the older group. These findings underscore the significance of age-appropriate training techniques to improve essential technical skills in young tennis players.

García-González et al. (2012) performed a comparative analysis of tactical knowledge among pre-professional and intermediate tennis players. Researchers discovered that pre-professional players exhibited more complex and advanced tactical frameworks through verbal reports throughout gameplay. These players exhibited a profound comprehension of game scenarios, allowing them to make more astute strategic decisions. Studies indicate that specialized training programs aimed at improving tactical comprehension and cognitive abilities could close the divide between intermediate and advanced players.

Martínez-Gallego et al. (2019) examined professional men's tennis matches on hard courts to discern differences in movement and shot efficacy between winning and losing players. The study demonstrated that point winners utilized more aggressive techniques, dedicating more time in offensive zones and forcing their opponents to traverse bigger distances at elevated speeds. Moreover, winning players performed a greater quantity of successful strokes, made fewer unforced errors, and demonstrated superior overall efficiency. These findings highlight the significance of offensive tactics and strategic placement in attaining success at the professional level.

Sánchez Mencia et al. (2024) conducted a systematic analysis examining tactical skills in tennis, evaluating 34 articles published from 2000 to 2022. The review categorized fundamental tactical components such as anticipation, game comprehension, strategy formulation, problem representation, situational awareness, execution, player expertise, and identification. Research evaluating tactical skills has identified significant variations in player proficiency, with superior performance linked to individuals with heightened anticipatory abilities, a comprehensive understanding of game situations, extensive game knowledge, and more effectively implemented offensive strategies.

Kolman et al. (2022) developed the Tactical Skills Questionnaire in Tennis (TSQT) to evaluate self-assessed tactical competencies among competitive athletes. The

TSQT consists of four subscales: "Anticipation and Positioning," "Game Intelligence and Adaptability," "Decision-Making," and "Recognizing Game Situations." The questionnaire demonstrated strong internal consistency and reliability. National-level players considerably outperformed regional players in game intelligence, adaptability, decision-making, and situational awareness. This evaluation offers crucial insights for coaches and players aiming to identify strengths and areas for improvement in tactical skills.

Crespo et al. (2024) conducted an extensive evaluation to synthesize information on technical and tactical competencies in tennis. The analysis concluded that the development of these abilities is influenced by practice techniques (variability among/within skills), environmental factors (such as court dimensions and ball type), and cognitive features like situational awareness, anticipation, and decision-making. The authors suggested creating competency models tailored to various playing levels, including fundamental competencies, standardized descriptions, and evidence-based assessments. These models may serve as frameworks for structured training and performance evaluation.

2.3.5. Psychological traits

A study by Cowden et al. (2016) investigating the correlation between mental toughness, resilience, and stress in competitive South African tennis players revealed that elevated mental toughness is favorably associated with resilience and adversely associated with stress. This indicates that mentally resilient athletes are more adept at managing pressures and responding positively to obstacles in their sport.

A study by Cowden et al. (2014) investigated psychological correlates of mental toughness in professional tennis players, highlighting learned abilities and competitive trait anxiety. The researchers determined that acquired abilities significantly predicted mental toughness, although competitive trait anxiety was not a strong predictor. This suggests that athletes who cultivate self-discipline and problem-solving abilities may improve their mental resilience.

Cervelló et al. (2010) examined the relationship between dispositional goal orientation, assessment of the motivating environment, and factors of competitive anxiety in elite tennis players. The research indicated that an ego-involving motivating context correlated with heightened cognitive and physical anxiety, whereas task orientation served as a favorable predictor of self-confidence. These findings highlight the importance of fostering a task-oriented environment to enhance self-confidence and reduce anxiety among athletes.

In a study focusing on psychophysiological stress responses, Fernández-Fernández et al. (2015) compared young female tennis players' responses during actual competitive matches and training sessions. The findings indicated that match day resulted in elevated salivary cortisol levels for losers at all measured time points compared to winners. All players exhibited significantly reduced salivary cortisol levels during training compared to the match at all time points, except in the evening for winners. Participants who won in match and training contexts exhibited significantly elevated self-confidence alongside reduced scores in cognitive and somatic anxiety compared to those who lost. Heart rate and ratings of perceived exertion (RPE) were significantly elevated for losers solely during the match (158.9±8.3 vs. 168±6.7 bpm; 12.9±1.2 vs. 15±0.8, for losers and winners, respectively). Moderate to strong correlations were observed between cortisol levels, self-confidence, anxiety scores, and match workload (i.e., heart rate and RPE) solely on match day. The findings demonstrate that the interaction among psychophysiological responses, match workload, and outcomes was observable solely in real competitive contexts.

Sheldon and Eccles (2005) examined physical and psychological predictors of perceived ability in adult male and female tennis players. Their study revealed that variables including age, official tennis rating, perceived shot capabilities, confidence, strategy, and accomplishment motivation significantly forecasted participants' perceived tennis proficiency. This underscores the significance of incorporating perceived psychological capabilities in assessments of perceived athletic and sport-specific capacity.

In a study assessing mental toughness in talented youth tennis players, Houwer et al. (2017) compared on-court behavioral observations with self-reported measures. They developed a taxonomy of positive and negative behaviors indicative of mental toughness and found that variability in positive on-court behaviors was negatively correlated with self-reported mental toughness. The results suggest that diversity in on-court behaviors offers valuable insights about tennis players' mental toughness, particularly on the (in)stability of their psychological state during a match.

Kovacs (2010) explored the influence of personality traits on collegiate male tennis players. The personality characteristics showed low and moderate correlations with Intercollegiate Tennis Association (ITA) rankings. Higher levels of conscientiousness and emotional stability were associated with better singles rankings. This suggests that these personality factors may contribute to successful performance in competitive tennis.

A study by Cappellato (2023) examined the susceptibility of professional tennis players to obsessive-compulsive and depressive symptoms. The findings indicated that current athletes exhibited higher levels of obsessive-compulsive symptoms and superstitious behaviors compared to former athletes and control groups. Their findings support the idea that high-level agonistic sports require intensive training and adherence to strict daily routines, which may indicate a vulnerability to the onset of full-blown obsessive-compulsive disorder (as well as other disorders) in more fragile individuals.

These studies provide valuable insights into the psychological traits of tennis players, emphasizing the roles of mental toughness, resilience, motivation, personality factors, and the impact of competitive stress on athletes' psychological well-being.

2.3.6. Experience, training and competition exposure

Haksever et al. (2023) investigated the correlation between playing experience and particular performance indicators in elite tennis players. The study examined serve velocity, agility, jumping ability, and dynamic balance in individuals aged 18 to 30.

The findings indicated a substantial positive association between years of playing experience and serve velocity, implying that extended participation in the sport improves serving proficiency. No substantial link was found between experience and factors such as agility, jump performance, or dynamic balance, indicating that these attributes may require specific training beyond fundamental playing experience.

Zappalà et al. (2024) investigated the influence of early career achievements and tournament prestige on the trajectories of professional tennis players. The research employed data from the Association of Tennis Professionals (ATP) to present an innovative approach for evaluating tournament status through a co-attendance network of events. The findings indicated that those who achieved early notable successes in prestigious tournaments were more inclined to attain high rankings. This highlights the significance of early victories in prestigious events, indicating that such accomplishments may advance players toward greater career achievements.

Cui et al. (2017) examined the impact of experience and relative quality on performance in Grand Slam events. The examination of match statistics indicated that seasoned players outperformed their adversaries in serve and return metrics, with fewer double faults and greater success in second serve and return points. Moreover, they secured a higher number of rally winners and break opportunities while traversing longer miles. Players of superior relative quality exhibited enhanced serve velocity and a higher frequency of aces, displayed more aggressive returns (comprising return winners and unforced errors). Players regularly approached the net at similar intervals in all Grand Slam tournaments, demonstrating an increasing tendency in men's tennis towards tactical aggression across diverse court surfaces. The impact of experience and comparative quality offers essential insights for tailored training and enhancement of performance in both practice and setting.

Fleming et al. (2022) conducted a systematic review and analysis of literature regarding the training and match-play requirements of elite and highly trained junior tennis players, emphasizing that training sessions frequently fail to mimic the physiological and perceptual demands encountered during tournament match-play. The research demonstrated that rallies on clay courts were around 22% longer than

those on hard courts, leading to prolonged playing duration, heightened heart rates, increased blood lactate concentrations, and greater ratings of perceived exertion. Moreover, participation in numerous daily matches negatively impacted performance indicators, including jumping, sprinting, and directional changes, and was associated with increased muscle soreness, weariness, and discomfort. These findings highlight the necessity of developing training programs that precisely replicate match circumstances and controlling competition schedules to enhance player performance and recovery.

Andrade et al. (2019) investigated the relationship between the age of initiation, duration of training and competition, and ranking position in elite young tennis players. The findings revealed that tennis players who commenced training earlier have a 28% increased probability of achieving a top 20 ranking, and that each additional year of training amplifies a player's likelihood of reaching the top 20 by a factor of 1.43. Moreover, each year of competitive experience enhances the probability of tennis players attaining a top 20 ranking by a factor of 1.41, while starting competitions earlier annually elevates the potential of an athlete achieving a top 20 position by 20%. These findings underscore the importance of the age at which youth elite tennis players start practicing and their competition experience are crucial variables in determining their ranking position.

2.3.7. Coaches' perspectives on performance determinants in junior tennis

Crespo, Jiménez, et al. (2024) investigate the viewpoints of international high-performance tennis coaches regarding the mental abilities essential for tennis performance and training. The findings revealed that coaches unanimously regarded mental skills as crucial for tennis play. Senior coaches exhibit a heightened comprehension of sport psychology and emphasize the development of particular psychological skills to a greater extent than their novice counterparts. Coaches, irrespective of their education or experience, regarded mental skills as crucial for tennis performance and indicated that the primary methods for acquiring knowledge about them were training courses and practical experience.

Robertson et al. (2018) examined the views of 177 licensed coaches in table tennis, tennis, and badminton concerning the significance of anthropometric metrics, physical performance, and motor coordination abilities. Coaches evaluated the importance of numerous talent attributes on a scale from 1 to 10, highlighting both clear distinctions and significant similarities across the racquet sports. In addition to the similarities and differences among the racquet sports discussed, it is important to highlight that all criteria received elevated ratings (minimum: 5.5; maximum: 9.4 on a scale of 1-10). The anthropometric features and the assessment of 30m sprint speed exhibited the lowest values, whereas the best values were observed in eye-hand coordination, agility, and various ball abilities. These insights are vital for talent discovery and development in tennis, aiding coaches in spotting and cultivating essential qualities in prospective players.

Weinberg and Jackson (1990) examined the tactics utilized by high school and age-group tennis coaches to bolster self-efficacy in their players. The research revealed 13 separate ways, with coaches commonly use approaches such as promoting positive self-talk, exemplifying confidence, delivering instruction and practice, offering generous prizes, and deploying verbal persuasion. These strategies were considered moderately to very efficient in enhancing players' self-efficacy, which is essential for optimal performance. The study highlights the significance of psychological therapies and the contribution of coaches in cultivating mental resilience and confidence among tennis players.

A study conducted by Busuttil et al. (2024) sought to investigate tennis instructors' perceptions and techniques concerning the development of grip holdings, a crucial skill in tennis. Professionally accredited coaches of differing experience levels (n = 140 with less experience and n = 86 with more experience) engaged in an online questionnaire to articulate their views on the significance of developing grip holdings and utilizing physically restrictive equipment in coaching. Regardless of the coach's experience, the improvement of technique and the instruction of grip position were identified as the two most critical components in the development of fundamental tennis skills. The Semi-western grip for forehand (less: 68%; more: 65%), a combination of Continental and Eastern grips for double-handed backhand

(less: 59%; more: 48.8%), and the Continental grip for serves (both: 94%) were recognized as the most often taught stances for various shots. The recognized barriers to cultivating grip holdings comprised habit (less: 62%; more: 56%), discomfort (less: 58%; more: 50%), and lack of confidence (less: 44%; more: 21%). Notably, 65% of trainers indicated a willingness to utilize physically restrictive methods to improve grip-specific skill acquisition. This study serves as a crucial resource, assisting coaches in enhancing their approaches for foundational tennis development and promoting additional research in this field.

CHAPTER 3

METHODS

3.1. Study Design

This cross-sectional cohort study employed a multidimensional approach to evaluating the determinants of competitive performance among top-ranked youth tennis players. The study incorporated assessments of anthropometric characteristics, physical growth and maturation, strength (upper and lower body), speed, agility, flexibility, aerobic endurance, motor coordination, reaction time, technical skill (serve speed), and psychological factors (mental toughness), along with tournament and match records and coaches' evaluations.

3.2. Participants

A total of 46 competitive tennis players aged under 12 (U12), under 14 (U14), and under 16 (U16) were recruited for this study. The sample comprised of top-ranked 8 boys and 8 girls in each age category based on the results from the national team selection tournaments. Due to their injuries two players of U14 boys were not able to join the camp. The inclusion criteria consisted of: (i) being registered with the Turkish Tennis Federation and (ii) being able to qualify for the last 8 in the national team selection tournament for Tennis Europe Summer Cups. Birth dates, training age, racquet weight, string tension, weekly training volume, age to start tournament, number of national and international tournaments, number of official single and double matches information were collected. The number of players by age groups and gender are presented in Table 1. Ethical approval was secured from the Human Subjects Ethics Committee of Middle East Technical University (0402-ODTUİAEK-2024). Written informed consents were acquired from the children (refer to

Appendix C) and their parents or legal guardians (refer to Appendix D) following a detailed explanation of the measurements and the study's purpose.

Table 1. The number of players by age and gender

Age groups	Girls	Boys	Total
U12	8	8	16
U14	8	6	14
U16	8	8	16

3.3. Data Collection Instruments

3.3.1. Stadiometer

Standing and sitting heights were assessed utilizing a portable stadiometer (Seca 213, Hamburg, Germany).

3.3.2. Body Composition Analyzer

The players' body mass and body fat % were assessed using a body composition analyzer (TANITA MC-780MA, Japan).

3.3.3. Hand Dynamometer

A hand dynamometer (Baseline, Smedley, Germany) was employed to assess hand grip strength.

3.3.4. Microgate, OptoJump

The lower limb power of the subjects was measured by Countermovement Jump (CMJ) Test (Microgate, OptoJump, Italy).

3.3.5. Electronic Timing Gates

Electronic timing gates (Witty Photocell gates, Microgate, Italy) were used to measure the speed and agility of the players.

3.3.6. Radar Gun

A sports radar gun (SR3600; Sports-radar, Homosassa, FL, USA) was utilized to measure the serve speed of the players.

3.3.7. Medicine Ball

1 kg medicine ball were used to measure the upper body power of the players.

3.3.8. Sit and Reach Table

Sit and reach table were used to measure the lower back and hamstrings flexibility of the players.

3.3.9. KTK Battery

The Körperkoordinationstest für Kinder (Kiphard & Schilling, 2007) battery were used to measure the gross motor coordination of the players.

3.3.10. BlazePod System

BlazePod (Play Coyotta Ltd., Tel Aviv, Israel) system was used to measure the reaction times of the players.

3.3.11. Beep Test Application

Beep test mobile application was used to measure the aerobic endurance of the players.

3.4. Data Collection Procedures

All tests were administered by experienced graduate sport sciences students who had previously used these instruments in earlier projects. Players were tested on five

sessions. In the first testing session, they were initially administered a brief questionnaire regarding their demographic, experiential, and training related characteristics. Psychological skills and anthropometric measurements were also collected in the first session. In the second session which were held after some reasonable rest in the same day; physical fitness performance tests such as grip strength, flexibility, countermovement jump, medicine ball throw, t-agility, sprint, maximum serve speed was completed on an outdoor hard surface tennis court. Third session were held the next day in order to give time players to recover. In this session, motor coordination test was performed. Fourth session were held after some reasonable rest in the same day and reaction time test was measured. Lastly, fifth session were held the next day to give time players to recover. In this session, shuttle run test were performed. All procedures were completed in three days.

Session 1 (Day 1) began with a brief questionnaire to gather demographic information, training history (e.g., weekly training volume, age of first tournament participation), and equipment details (racquet weight, string tension). Anthropometric measurements, including standing and sitting height, body mass, body fat percentage, and leg length, were collected using standardized protocols. Psychological assessments, specifically the Mental Toughness in Sport Scale, were also administered during this session.

Session 2 (Day 1, post-rest) focused on physical fitness and tennis-specific performance tests conducted on an outdoor hardcourt. After a rest period, participants completed grip strength assessments, countermovement jumps, overhead medicine ball throws, 20 m sprints (with 5 m and 10 m splits), T-agility tests, sit-and-reach flexibility measurements, and maximal serve speed evaluations using a radar gun. Rest intervals between trials (30 seconds to 5 minutes) were enforced to mitigate fatigue.

Session 3 (Day 2) began with motor coordination. Participants performed the Körperkoordinationstest für Kinder (KTK) to evaluate balance, hopping, and lateral movement skills.

Session (4) (Day 2, post-rest) after some reasonable rest in the same day reaction time was assessed using the BlazePod system, which measured hand and foot responses to visual cues.

Session (5) (Day 3) addressed aerobic endurance. As the last measurement of the protocol the shuttle run (beep test) was administered to estimate aerobic capacity, with predicted VO2max values derived from performance data.

Due to their injuries two players of U14 boys were not able to join the camp. U14 girls could not participate in aerobic fitness measurements because they had tournament matches on the same day. One girl in U14 did not attend to KTK and reaction time tests because of her stomachache. Three players did not attend to aerobic endurance tests in U16 category: one boy due to his leg injury, one girl due to her leg injury and one girl due to her menstrual cycle.

Measurements were conducted at four national team tennis camps held at the Turkish Tennis Federation Center, with official permission from the Federation (see Appendix B). Data collection began with the U14 camp (26–28 June), followed by the U16 boys' camp (14–17 July), the U12 camp (21–24 July), and the U16 girls' camp (26–28 July).

Following each camp, coaches (n = 7) completed a structured questionnaire to evaluate their perspectives on the contribution of 27 performance parameters to player success. Responses were analysed to align empirical findings with coaching expertise. The process was structured to balance testing demands with athlete recovery, ensuring minimal interference with training and tournament schedules.

3.4.1. Match and Tournament Records

Information of the players on the age to start official tournaments, the number of national and international tournaments, the number of official single and double matches were obtained from the official webpages of the Turkish Tennis Federation, Tennis Europe and International Tennis Federation.

3.4.2. Anthropometry

Portable stadiometer was used to assess standing and sitting heights (Seca 213, Hamburg, Germany). The players' body mass and body fat % were assessed using a body composition analyzer (TANITA MC-780MA, Japan). The leg length was determined by deducting the sitting height from the standing height. Body mass index (BMI) was determined by dividing body mass (kg) by the square of the height (m). All anthropometric measurements were performed according to the reference handbook (Lohman, Roche, & Martorell, 1988).

3.4.2.1. Standing Height

The participants were positioned with their backs against the stadiometer, heels together, and heads aligned in the Frankfort plane, which is defined as a horizontal line extending from the lower margin of the orbit to the upper margin of the external auditory meatus. The vertex, the summit of the head, was established by locating the line of the head's highest point with the Frankfort plane. The participants' heads were carefully lowered to ensure accuracy, and the sliding headpiece of the stadiometer was thereafter lowered to the vertex. Measurements were documented to the nearest 0.1 cm.

3.4.2.2. Sitting Height

The participants were directed to sit on a bench with their spines erect. The measurer examined the subjects' buttocks and backs for contact with the stadiometer. The measurer assessed the distance from the stadiometer to the participant's head, ensuring the measurement was perpendicular to the bench. Measurements were conducted with precision to the nearest 0.1 cm.

3.4.2.3. Body Mass and Body Fat Percentage

The participants were instructed to place themselves at the center of the body composition scale, barefoot and in minimal attire. The individual was positioned

stationary with their body mass uniformly distributed. The measurements were recorded to the closest 0.1 kilogram.

3.4.3. Physical Growth

Anthropometric measurements, such as height-for-age, weight-for-age, and BMI-for-age, were evaluated against Frisancho's reference data (Frisancho, 2008). Percentile and z-score values were computed for height, body mass, and BMI.

3.4.4. Biological Maturation

Multiple approaches exist to evaluate biological maturation in children, encompassing assessments of skeletal, sexual, dental, and somatic maturity. This study utilized the age at peak height velocity (APHV) to assess the somatic maturity of the players. This method was chosen for its recognition as one of the most practical and commonly employed frameworks in sports science. The APHV was calculated utilizing the predictive model established by Mirwald, Baxter-Jones, Bailey, and Beunen (2002). The maturity offset was determined by removing the difference between the APHV and chronological age. The athletes' ages were calculated by deducting their birth dates from the measuring date. The equations proposed by Mirwald et al. (2002) provide a non-invasive method for estimating the APHV using growth patterns of leg and trunk length. These equations calculate APHV by utilizing factors including leg length, sitting height, chronological age, standing height, and weight, providing a non-invasive assessment of somatic maturity. This study employed the equations developed by Mirwald et al. (2002) to compute the APHV values of athletes.

Boys:
Maturity Offset=−9.236+(0.0002708×(Leg Length×Sitting Height))−(0.001663×(Age×Leg Length))+(0.007216×(Age×Sitting Height))+(0.02292× Height ÷ Weight)

Girls:
Maturity Offset=−9.376+(0.0001882×(Leg Length×Sitting Height))+(0.0022×(Age×Leg Length))+(0.005841×(Age×Sitting Height))−(0.002658×(Age×Weight))+(0.07693× Height ÷ Weight)

3.4.5. Grip Strength

Hand grip strength was assessed using a hand dynamometer (Baseline, Smedley, Germany). During the assessment, participants were instructed to sit on a platform, maintain their arms at their sides, and generate maximum power on the dynamometer with their dominant hand for five seconds. The best score of three was used for analysis.

3.4.6. Countermovement Jump

Countermovement Jump (CMJ) Test (Microgate, OptoJump, Italy) was used to assess the lower limb power of the subjects. Subjects were asked to place in the middle of two CMJ plates and then perform a jump while their hands were on their hips. Besides hand position, subjects were instructed to jump after a downward motion. The resting period was 30 seconds between three trials. The best attempt was taken into consideration.

3.4.7. Medicine Ball Throw

An overhead medicine ball throw specific to tennis was employed to evaluate upper body power, as previously outlined by several tennis federations, including the Lawn Tennis Association (LTA – British Tennis), the German Tennis Federation, and the United States Tennis Association (USTA) (Myburgh et al., 2016; Roetert et al., 1996; Ulbricht et al., 2016). The overhead throw was executed with a 1 kg medical ball. They were instructed to toss it with their both hands employing. Participants were allowed two attempts, with passive rest intervals between attempts; throws were recorded to the closest 1 cm, utilizing the maximum distance for analysis.

3.4.8. T-Agility

Agility performance was measured using the T-agility test. Before the test, cone markers were placed in a T-shaped pattern. Players were asked to run forward, touch the front cone, touch the cones on the left and right sides in sequence, and finally

touch the front cone again before running backward to the starting line. Electronic timing gates (Witty Photocell gates, Microgate, Italy) were used in the test. The test was performed twice, and the fastest time was recorded.

3.4.9. Sprint

A 20 m sprint with splits at 5 m and 10 m was used to assess speed with electronic timing gates (Witty Photocell gates, Microgate, Italy). Participants commenced 50 cm behind the initial timing gate, as defined by Ulbricht, Fernandez-Fernandez, and Ferrauti (2013). The quickest trial of two attempts was documented and measured to the closest 0.01 seconds.

3.4.10. Sit-and-Reach

The purpose of the sit-and-reach test is to evaluate the flexibility of the participant's lower back and hamstrings. Participants were instructed to sit on the floor with their shoes removed, feet flat against the table, and legs extended straight. Every participant will be urged to extend their fingers along the table to the maximum extent. The distance from the fingertips to the table's edge will be recorded. The examination was conducted twice, and the maximum score was documented.

3.2.11. Maximum Serve Speed

The serve performance test demonstrates significant external validity concerning its correlation with tennis functional performance, as it involves a multi-segment movement necessitating coordination, power generation throughout the kinetic chain, and precise timing of muscle activations (Fernandez-Fernandez et al., 2014). It has been previously emphasized as the most dependable metric of on-court performance and has demonstrated a strong link with junior individual rankings (Fernandez-Fernandez et al., 2014). Serve speed assessments were performed on an outdoor tennis court. Participants conducted the assessments using their personal rackets. Tests utilized tennis balls sanctioned by the International Tennis Federation. The serve speed of the players was assessed with a sports radar gun (SR3600; Sports-

radar, Homosassa, FL, USA). Each player delivered their maximum serve from the service line at 30-second intervals. Five successful serves were documented, and their average was utilized for analysis.

3.2.12. Motor Skill Assessment

Gross motor coordination of the participants was assessed using the Körperkoordinationstest für Kinder (KTK), developed by Kiphard and Schilling (2007) for children ranging from 5 to 14 years of age. A Turkish version of the KTK, were adapted (Özkara & Kalkavan, 2018). The KTK has four subtests: backwards walking on three balance beams (KTKBeam), jumping over foam barriers (KTKHop), lateral movement on wooden planks (KTKBoard), and bilateral lateral jumping over a wooden rod (KTKJump).

Table 2. Classification of motor coordination levels (adapted from Kiphard and Schilling, 2007)

MQ Scores	Classification
131 – 145	High
116 – 130	Good
86 – 115	Normal
71 – 85	Moderate
56 – 70	Impairment

The KTK was administered and evaluated in accordance with the handbook (Kiphard & Schilling, 2007). Participants were assessed individually following their familiarization with the exercises. The KTKBeam test has three balancing beams, each measuring 3 meters in length, with varying widths of 3 cm, 4.5 cm, and 6 cm. Participants were instructed to walk backwards three times on each balancing beam, with a maximum of eight steps permitted per beam. The highest possible score for this examination is 72. In the KTKHop test, participants are expected to hop on one leg over foam obstacles with heights varying from 0 to 60 cm. The highest possible score is 78. During the KTKBoard assessment, participants shifted their bodies laterally between two boards for a duration of 20 seconds. The test score is the

aggregate of the two trials. In the KTKJump assessment, participants were instructed to leap laterally over a wooden rod measuring 2 cm in height over a duration of 15 seconds. The score is the aggregate of the two trials. Each subset of results was translated to a motor quotient based on age and gender. The Total KTK motor quotient (TotalKTKMQ) scores facilitate the categorization of gross motor coordination skills into five distinct levels (Table 2).

3.2.13. Reaction Time

Reaction times were measured with the BlazePod system (Play Coyotta Ltd., Tel Aviv, Israel). BlazePod is a wireless lighting system with eight LEDs and a central PDA controller. Light signals may be activated or deactivated by a participant or tester based on the task requirements. The reliability and validity of the BlazePod system were assessed in several studies (De Oliveira et al., 2021; Hoffman, 2020).

Both hand and foot reactions were assessed using the Simple Reaction, Selective Reaction, and Discriminative Reaction Tests, in accordance with the Çağın Hand and Foot Reaction Tests Protocol. The reliability and validity of this protocol were assessed (Çağın, M., et al. 2024). Simple reaction time involves a singular stimulus and a corresponding singular response. This serves as an illustration of a blue light on the pod and the subject's response by pressing the pod whenever the blue light is illuminated. Selective reaction time involves multiple stimuli, each eliciting a distinct response. This scenario is illustrated by the subject's behaviors of pushing the pod with a blue cup when the blue light activates, using red cups when the red light activates, and using green cups when the green light is activated. In discriminative reaction time scenario, multiple warnings precede a singular conduct. This scenario occurs when the blue, red, and green colors illuminate on the pod; however, the participant simply presses the pod when the blue color is enabled.

A countdown created by the application would signify the beginning of the drill. Subsequent to the countdown, the participant responded to a lighted pod by tapping it with their hand, first to the left and then to the right. The trial lasted 20 seconds, and the pods lighted in a random order. The identical approach was employed for the

foot. The mean response time for the trial was documented. Once familiarized with the test, players underwent the assessment twice, and the highest score was recorded for analysis.

3.2.14. Aerobic Endurance

The shuttle run test was utilized to evaluate the aerobic endurance of the participants. In this assessment, participants were instructed to sprint back and forth along a 20 m track, ensuring they touched the 20 m line simultaneously with the emission of a sound signal from a beep test application. The frequency of the sound waves escalates, resulting in an increment of running speed by 0.5 km/h per minute, commencing with an initial pace of 8.5 km/h. The test concluded when the participant could no longer maintain the prescribed tempo. The tests are confirmed using VO2 measurements, and the estimated VO2max can be predicted using equations that account for gender and age (Léger et al., 1988; Léger & Lambert, 1982). VO_2max (maximal oxygen uptake) was estimated using the following formula developed by Léger et al. (1988): $VO_2max = 31.025 + 3.238 (speed) – 3.248 (years) + 0.1536 (speed) (years)$

The formula provides an estimate of the participant's aerobic capacity, expressed in milliliters of oxygen per kilogram of body weight per minute (ml/kg/min). This method is widely used in youth sport science due to its practicality, non-invasiveness, and reliability in estimating cardiovascular endurance. Tests that encompass accelerations, decelerations, and directional changes can be classified as semi-specific (Fernandez-Fernandez J, Ulbricht A, Ferrauti A. 2014). The shuttle run test has established itself as a standard field assessment, incorporated into the routine testing protocols of various national tennis federations, including USTA and Tennis Australia (Roeterr & Ellenbecker 2007; Reid et al. 2013).

3.2.15. Mental Toughness

The Mental Toughness in Sport Scale was used to measure the mental toughness of players. The scale was developed by Gucciardi et al. (2014) and consists of one

subscale. There are a total of eight items in the seven-point Likert-type scale (1= Completely False - 7= Completely True). The validity and reliability of the scale for Turkish sample were conducted on 400 adolescent athletes by Özgör and Aşçı (2018), and the Cronbach alpha internal consistency coefficient was calculated as 0.78. Participants were asked to complete the questionnaire in the first session of the measurements. Before starting participants declared to answer the questions with full honesty.

3.2.16. Coaches' Perspective

A questionnaire was administered to assess coaches' perspectives on the contribution of performance measures. The questionnaire comprised three sections. The questionnaire's purpose and intended use were outlined in the initial section, along by the necessary material and terminology for its completion. The second section comprised descriptive questions concerning the experts. The final section contained 27 inquiries regarding the determinants to be assessed. These 27 questions were created to ascertain coaches' perspectives on these criteria. The questionnaire was developed by tennis instructors collaborating with a board of education within the Turkish Tennis Federation and a sports scientist who holds the position of Associate Professor in the Department of Physical Education and Sports at Middle East Technical University. The questionnaire was constructed in accordance with the five design processes proposed by Brace (2004) in his book "How to Plan, Structure and Write Survey Material for Effective Market Research." The procedures undertaken during the questionnaire design phase were as follows.

1. Identification of Research Question and Objectives: The questionnaire sought to ascertain the coaches' perspectives through determinants to be evaluated in the study.
2. Participation Profile and Sampling Approach: The poll included ten national team tennis coaches as participants.
3. Question Design: Under the guidance of a TTF board of education licensed coach and sports scientist, subject area specialists formulated the questions in the clearest manner possible. The questionnaire questions were analyzed to

confirm its clarity and alignment with the tennis language utilized in Turkey, the location of the study.

4. Scale Design: The questionnaire employed a 10-point Likert scale. The definitions for 1 point and 10 points, representing the extremities of the scale, were provided in the initial section of the questionnaire.
5. Questionnaire Structuring: Following its original development, the questionnaire was administered to two level 4 certified tennis coaches at two-week intervals, and feedback on its clarity, design, and completion duration was gathered. The questionnaire was completed following the acquisition of feedback through two iterations, taking the feedback into account. The complete form of the questionnaire is included in the Appendix.

3.5. Statistical analysis

This study employed a census sampling approach, including all top-ranked young tennis players who participated in the national training camps across their respective age categories. Specifically, the top 8 players were selected per age group and invited to attend the camps. As this represented the entire accessible population of top junior players for each category, no sample size calculation was required (Creswell, 2012).

Data collected from the various sources were subjected to a multidimensional analysis to identify the factors that correlate with national rankings. A descriptive analysis of the data was conducted according to gender and age categories. All values were reported as means and standard deviations. Pearson correlation coefficients were utilized to assess the relationships between ranking and performance determinants. According to the classification established by Hopkins, Marshall, Batterham, and Hanin (2009), correlation strengths were categorized as follows: trivial ($r < .1$), small ($.1 < r \leq .3$), moderate ($.3 < r \leq .5$), large ($.5 < r \leq .7$), very large ($.7 < r \leq .9$), nearly perfect ($.9 < r < 1.0$), and perfect ($r = 1.0$). The significance level was established at $p < 0.05$. All statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 28.0 (SPSS Inc., Chicago IL).

CHAPTER 4

RESULTS

4.1. Descriptive Results

The descriptive statistics for chronological age, training age, weekly training volume, age to start tournament, number of national and international tournaments, number of official single and double matches, racquet weight, string tension for girls are represented in Table 3.

Table 3. The descriptive statistics for the chronological age, experience, and racket specification characteristics of girls by age groups

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Chronological age (years)	12.21	0.30	13.68	0.70	15.66	0.68
Training age (years)	5.75	0.65	5.51	1.07	6.75	1.67
Weekly tennis training (hours)	15.81	5.29	22.25	8.38	19.88	4.29
Weekly fitness training (hours)	5.81	1.36	7.63	4.78	7.75	3.28
Total weekly training (hours)	21.63	5.82	29.88	7.72	27.63	7.05
Age to start tournament (years)	8.14	1.17	7.58	0.71	8.00	0.59
Number of national tournaments (#)	34.50	6.85	58.13	9.86	61.50	16.67
Number of international tournaments (#)	3.50	2.67	20.75	8.03	31.25	17.20
Number of total tournaments (#)	38.00	7.87	78.88	16.17	92.75	18.54
Number of national single matches (#)	128.00	22.08	218.88	41.33	201.63	51.63
Number of national double matches (#)	23.38	6.14	43.88	10.06	37.13	11.90
Number of international single matches (#)	10.00	10.30	60.00	34.81	67.00	34.55
Number of international double matches (#)	6.00	6.57	41.13	25.09	43.25	24.15
Number of total national matches (#)	151.38	25.80	262.75	40.63	238.75	60.79
Number of total international matches (#)	16.00	16.84	363.88	84.42	110.25	56.50
Number of total matches (#)	167.38	33.47	626.63	118.45	349.00	73.93
Racquet weight (g)	286.25	7.91	290.00	7.56	297.50	5.98
String tension (kg)	23.00	0.60	22.94	0.50	24.13	0.83

The descriptive statistics for chronological age, training age, weekly training volume, age to start tournament, number of national and international tournaments, number of official single and double matches racquet weight, string tension for boys are given in Table 4.

Table 4. The descriptive statistics for the chronological age, experience, and racket specification characteristics of boys by age groups

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Chronological age (years)	12.23	0.44	13.87	0.47	15.70	0.46
Training age (years)	6.56	1.68	5.67	0.82	6.38	1.41
Weekly tennis training (hours)	18.75	3.72	17.17	6.52	21.25	2.76
Weekly fitness training (hours)	5.31	2.79	6.50	4.46	8.56	4.66
Total weekly training (hours)	24.06	4.87	23.67	6.59	29.81	4.66
Age to start tournament (years)	7.92	0.85	7.45	0.50	7.48	0.93
Number of national tournaments (#)	39.88	10.47	56.83	12.51	68.75	13.78
Number of international tournaments (#)	6.25	2.87	16.00	11.47	38.13	15.05
Number of total tournaments (#)	46.13	10.29	72.83	21.31	106.88	17.26
Number of national single matches (#)	146.88	37.84	210.17	55.20	236.63	38.99
Number of national double matches (#)	30.63	12.65	41.67	17.91	45.50	11.87
Number of international single matches (#)	18.63	7.09	41.33	29.68	105.88	56.95
Number of international double matches (#)	8.38	4.81	32.17	23.85	71.50	40.42
Number of total national matches (#)	177.50	49.59	251.83	70.66	282.13	44.84
Number of total international matches (#)	27.00	11.51	73.50	53.35	177.38	96.70
Number of total matches (#)	204.50	52.44	325.33	117.36	459.50	89.09
Racquet weight (g)	280.50	5.78	287.50	4.18	300.63	1.77
String tension (kg)	23.50	0.88	22.92	0.80	23.75	0.71

The dataset encompasses various parameters related to the players' demographic information and competitive experience. These ranges offer a comprehensive picture of the players' training intensity and competitive involvement. For female athletes, the chronological age ranges from 11.68 to 16.56 years, while for male athletes, it spans from 11.55 to 16.40 years. The age at which athletes began participating in tournaments varies from 6.20 to 9.57 years for girls and from 5.75 to 9.44 years for boys. Weekly tennis training hours differ across age groups, with girls U12 training between 7 and 24 hours, girls under 14 (U14) training between 15 and 40 hours, and girls under 16 (U16) training between 15 and 28 hours. Boys' training hours range

from 12 to 22 for U12, 9 to 29 for U14, and 16 to 24 for U16. Similarly, weekly fitness training hours range from 3 to 8 hours for girls U12, 3 to 15 hours for U14, and 4 to 14 hours for U16. Boys' weekly fitness training hours vary between 3 to 12 hours for U12, 3 to 15 hours for U14, and 4 to 18 hours for U16. The total weekly training commitments span from 10.5 to 47 hours for girls and 14 to 30 hours for boys.

In terms of competitive participation, the total number of tournaments varies by age group. U12 girls participate in 26 to 48 tournaments, while U14 girls compete in 59 to 107 tournaments, and U16 girls in 68 to 120 tournaments. Boys in the U12 category participate in 25 to 58 tournaments, U14 boys in 33 to 90 tournaments, and U16 boys in 84 to 128 tournaments. National tournament participation for U12 girls ranges from 26 to 43, while for U12 boys, it ranges from 17 to 52. International tournament participation for this age group spans from 0 to 7 for girls and 2 to 11 for boys. U14 girls compete in 48 to 74 national tournaments, while boys participate in 33 to 68, with international participation ranging from 8 to 33 for girls and 0 to 31 for boys. In the U16 category, girls compete in 36 to 82 national tournaments and boys in 44 to 82, with international tournament participation ranging from 7 to 58 for girls and 5 to 53 for boys.

The total number of national singles matches also varies across age groups. U12 girls compete in 99 to 162 matches, while U12 boys play in 80 to 212 matches. U14 girls participate in 160 to 287 matches, while boys play between 118 and 269 matches. U16 girls compete in 115 to 280 matches, while boys participate in 158 to 286 matches. The number of doubles matches played by U12 girls ranges from 16 to 35, while for boys it ranges from 7 to 48. U14 girls play between 28 to 58 doubles matches, and boys between 14 to 64. For U16 girls, the number of doubles matches played ranges from 18 to 53, while for boys, it ranges from 32 to 70. Regarding international singles matches, U12 girls play between 0 and 33 matches, U14 girls between 21 and 118 matches, and U16 girls between 16 and 110 matches. In doubles, U12 girls play between 0 and 21 matches, U14 girls between 9 and 88 matches, and U16 girls between 11 and 75 matches. For boys, the number of international singles matches is between 6 and 26 in U12, 0 to 68 in U14, and 16 to 207 in U16. Boys'

international doubles match range from 1 to 13 in U12, 0 to 58 in U14, and 5 to 139 in U16.

In terms of equipment, the string tension of girls' rackets ranges from 22.5 to 24 in U12, while for boys, it ranges from 21 to 23. In U14, the string tension is between 22.5 and 23.5 for girls and 21.5 to 23.5 for boys. For U16 girls, the range is between 23 and 25, while for boys, it ranges from 22.5 to 25. The racket weight also varies between categories; in U12, it ranges from 280g to 305g for girls and from 270g to 285g for boys. In U14, the range is between 280g and 300g for girls and 285g to 295g for boys. For U16 players, the racket weight is between 285g and 305g for girls and between 300g and 305g for boys.

The descriptive statistics for body height, body mass, BMI, and body fat percentage of girls are presented in Table 5.

Table 5. The anthropometrics characteristics of girls

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Body height (cm)	159.91	5.76	164.89	5.67	167.19	3.91
Body mass (kg)	49.23	4.76	56.54	3.56	57.94	3.31
Body mass index (kg/m^2)	19.28	1.84	20.79	0.65	20.69	0.90
Body fat percentage (%)	21.46	2.02	22.49	1.82	19.74	3.61

The descriptive statistics for body height, body mass, BMI, and body fat percentage of boys are given in Table 6.

Table 6. The anthropometrics characteristics of boys

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Body height (cm)	155.76	10.09	168.62	13.31	176.16	6.36
Body mass (kg)	43.30	8.21	59.23	18.85	61.44	9.16
Body mass index (kg/m^2)	17.74	2.08	20.40	3.72	19.73	1.88
Body fat percentage (%)	16.73	3.56	17.05	4.58	9.40	3.05

The descriptive statistics for height for age, weight for age, and BMI for age, APHV, and maturity offset of girls are given in Table 7.

Table 7. The descriptive statistics for physical growth and maturity of girls

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Height (z-scores)	0.96	0.96	0.87	0.63	0.76	0.53
Height (percentiles)	76.13	24.76	77.10	15.47	74.92	15.65
Body mass (z-scores)	0.55	0.42	0.70	0.15	0.39	0.21
Body mass (percentiles)	69.42	12.63	75.60	4.67	64.93	7.87
BMI (z-scores)	0.16	0.46	0.31	0.16	0.03	0.20
BMI (percentiles)	55.32	16.88	62.14	6.07	50.93	7.95
APHV (years)	11.61	0.40	11.92	0.27	12.64	0.35
Maturity offset (years)	0.59	0.21	1.74	0.65	3.04	0.47

The heights of U12 girls ranged from the 24th to 98th percentiles, while U14 girls' heights fell between the 55th and 97th percentiles, and U16 girls were in the 51st to 93rd percentiles. For body mass, U12 girls were between the 52nd and 92nd percentiles, U14 girls between the 69th and 81st, and U16 girls ranged from the 52nd to 77th percentiles. When it comes to BMI, U12 girls were in the 41st to 80th percentiles, U14 girls fell within the 53rd to 70th, and U16 girls ranged from the 41st to 64th percentiles.

The descriptive statistics for height for age, weight for age, and BMI for age, APHV, and maturity offset of boys are given in Table 8.

Table 8. The descriptive statistics for physical growth and maturity of boys

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Height (z-scores)	0.47	1.06	0.77	1.31	0.68	0.73
Height (percentiles)	60.50	28.69	70.45	36.18	70.89	19.29
Body mass (z-scores)	- 0.14	0.73	0.51	1.08	0.35	0.55
Body mass (percentiles)	46.15	24.65	63.03	29.34	61.92	18.81
BMI (z-scores)	-0.25	0.78	0.19	0.91	-0.25	0.52

Table 8. (continued)

BMI (percentiles)	43.13	23.17	54.31	27.54	40.68	18.78
APHV (years)	13.59	0.58	13.52	0.79	13.77	0.53
Maturity offset (years)	-1.19	0.69	0.34	1.22	1.93	0.70

Similarly, U12 boys' heights ranged from the 22nd to 98th percentiles, U14 boys ranged between the 8th and 99th, and U16 boys were in the 39th to 98th percentiles. U12 boys' body mass fell between the 7th and 75th percentiles, U14 boys were in the 17th to 99th, and U16 boys ranged from the 38th to 87th percentiles. For BMI, U12 boys ranged from the 3rd to 79th percentiles, U14 boys from the 21st to 96th, and U16 boys from the 21st to 77th percentiles.

The descriptive statistics for grip strength, countermovement jump, medicine ball throw, agility, linear sprinting, flexibility, maximum serve speed and aerobic endurance performances of girls are given in table 9.

Table 9. The descriptive statistics for physical performance parameters of girls

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Grip strength (kg)	31.14	2.65	31.71	3.48	33.25	4.61
Countermovement jump (cm)	26.34	2.95	26.74	2.92	26.20	4.26
Medicine ball throw (cm)	612.38	73.81	663.00	51.26	686.88	78.89
T-agility (s)	10.82	0.35	10.83	0.41	10.78	0.65
5 m sprint (s)	1.13	0.06	1.14	0.05	1.16	0.05
10 m sprint (s)	1.95	0.09	1.96	0.05	1.98	0.07
20 m sprint (s)	3.47	0.15	3.47	0.08	3.50	0.14
Sit and reach (cm)	29.49	4.37	31.50	5.72	29.94	6.85
Serve speed (km/h)	126.28	5.67	142.35	6.30	126.65	7.13
Shuttle distance covered (m)	1368.00	218.45	-	-	1980.00	150.99
VO2Max (ml/ (kg min)	35.62	4.78	-	-	40.30	3.76

The descriptive statistics for grip strength, countermovement jump, medicine ball throw, agility, linear sprinting, flexibility, maximum serve speed and aerobic endurance performances of boys are given in table 10.

Table 10. The descriptive statistics for physical performance parameters of boys

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Grip strength (kg)	24.90	4.79	36.52	9.17	48.09	7.44
Countermovement jump (cm)	23.31	2.74	31.40	6.66	34.01	3.35
Medicine ball throw (cm)	521.50	172.34	818.50	167.40	845.63	110.99
T-agility (s)	10.99	0.45	9.87	0.40	9.44	0.35
5 m sprint (s)	1.16	0.07	1.05	0.06	1.02	0.03
10 m sprint (s)	2.01	0.09	1.85	0.05	1.76	0.03
20 m sprint (s)	3.58	0.21	3.28	0.15	3.06	0.03
Sit and reach (cm)	24.78	3.98	23.33	5.43	28.31	10.87
Serve speed (km/h)	118.80	13.80	145.83	16.70	174.20	11.78
Shuttle distance covered (m)	1382.86	167.50	1486.67	162.89	1831.43	236.32
VO2Max (ml/ (kg min)	36.33	3.67	36.23	3.74	41.10	6.62

The physical performance data across different age groups (U12, U14, and U16) reflect clear, progressive changes in various metrics for both boys and girls. These findings demonstrate age-related progression in most physical performance metrics, with boys generally showing larger improvements in strength and speed compared to girls as they age.

In grip strength, U12 girls demonstrate a range of 27.70 to 34.80 kg, while U14 girls range from 26.90 to 38.70 kg, and U16 girls range from 25.90 to 41.10 kg. For boys, U12 players exhibit lower grip strength values, with a range of 19.20 to 31.90 kg. However, it increases in U14 boys, with a range from 27.00 to 48.60 kg, and U16 boys display the highest values, ranging from 40.90 to 60.00 kg.

In the countermovement jump test, U12 girls show a jump range of 22.50 to 30.30 cm, U14 girls jump between 23.00 and 31.40 cm, and U16 girls jump between 22.00 and 33.30 cm. Boys show a more noticeable improvement, with U12 boys jumping between 18.30 and 26.50 cm, U14 boys ranging from 24.70 to 44.10 cm, and U16 boys jumping between 30.40 and 40.70 cm.

In the medicine ball throw, U12 girls show distances between 528.00 and 746.00 cm, which increase for U14 girls (595.00 to 765.00 cm) and peak for U16 girls (610.00 to

828.00 cm). For boys, U12 players show a wide range of 373.00 to 880.00 cm, U14 players progress to 627.00 to 1069.00 cm, and U16 boys show a range of 704.00 to 1060.00 cm.

T-agility times decrease with age for both genders. U12 girls range from 10.23 to 11.33 seconds, U14 girls range from 10.09 to 11.38 seconds, and U16 girls range from 10.08 to 12.23 seconds. For boys, the U12 group has times between 10.40 and 11.68 seconds, U14 boys range from 10.09 to 11.38 seconds, and U16 boys seems to display an improvement, with times ranging from 8.79 to 9.83 seconds.

In the 5-meter sprint, U12 girls show times between 1.03 and 1.20 seconds, U14 girls range from 1.10 to 1.22 seconds, and U16 girls show times between 1.07 and 1.26 seconds. Boys show similar trends, with U12 boys ranging from 1.08 to 1.26 seconds, U14 boys from 0.97 to 1.14 seconds, and U16 boys from 0.97 to 1.05 seconds.

In the 10-meter sprint, U12 girls have times ranging from 1.84 to 2.06 seconds, U14 girls range from 1.91 to 2.05 seconds, and U16 girls from 1.91 to 2.08 seconds. Boys improve more rapidly, with U12 boys ranging from 1.93 to 2.16 seconds, U14 boys from 1.80 to 1.95 seconds, and U16 boys achieving faster times between 1.70 and 1.79 seconds.

For the 20-meter sprint, U12 girls range from 3.26 to 3.69 seconds, U14 girls from 3.40 to 3.65 seconds, and U16 girls from 3.34 to 3.81 seconds. Boys also show faster times as they age, with U12 boys ranging from 3.34 to 3.94 seconds, U14 boys ranging from 3.11 to 3.53 seconds, and U16 boys between 3.02 and 3.10 seconds.

Flexibility, as measured by the sit-and-reach test, also demonstrates variation between boys and girls. U12 girls range from 22.00 to 35.40 cm, U14 girls from 24.00 to 39.00 cm, and U16 girls from 19.00 to 39.50 cm. Boys display slightly lower flexibility with the scores 19.50 to 29.80 cm in U12, and 18.50 to 31.00 cm in U14 but their range broadens in U16 (13.50 to 46.00 cm).

When observing serve speed, girls do not show a steady progression. U12 girls serve between 119.00 and 138.40 km/h, U14 girls between 136.00 and 154.00 km/h, and U16 girls show a range from 119.40 to 138.00 km/h. In contrast, boys exhibit a clear progressive increase. U12 boys range from 101.20 to 140.60 km/h, U14 boys from 114.60 to 164.60 km/h, and U16 boys serve between 155.20 and 188.20 km/h.

Lastly, VO2Max, a measure of aerobic capacity, varies across age groups. Girls in U12 show values between 31.24 and 42.46 ml/kg/min and U16 girls show a broader range from 36.40 to 43.89 ml/kg/min. Boys exhibit a more consistent improvement in VO2Max, with U12 boys ranging from 30.60 to 39.97 ml/kg/min, U14 boys from 32.19 to 39.58 ml/kg/min, and U16 boys ranging from 35.96 to 52.56 ml/kg/min.

Table 11 presents the KTKBeam, KTKHop, KTKBoard, KTKJump, and Total KTK motor quotient scores of girls.

Table 11. The motor coordination performance of girls

Age Groups	U12		U14	
	Mean	SD	Mean	SD
KTKBeam	50.25	9.87	55.29	9.79
KTKHop	76.38	2.77	76.00	2.52
KTKJump	93.38	6.12	93.00	9.09
KTKBoard	49.88	3.87	55.43	5.86
TotalKTKMQ	112.13	5.54	113.14	12.02

Table 12 presents the KTKBeam, KTKHop, KTKBoard, KTKJump, and Total KTK motor quotient scores of boys.

Table 12. The motor coordination performance of boys

Age Groups	U12		U14	
	Mean	SD	Mean	SD
KTKBeam	51.25	10.03	58.83	16.23
KTKHop	72.13	7.66	76.17	2.64

Table 12. (continued)

KTKJump	94.13	7.75	97.67	11.00
KTKBoard	50.25	5.37	56.00	4.90
TotalKTKMQ	113.25	9.69	117.33	10.75

The analysis of KTK beam test reveals that U12 girls exhibit a range from 34 to 61, while U14 girls demonstrate a slightly wider range from 38 to 71. Similarly, U12 boys' scores vary between 39 and 72, with U14 boys showing a range of 30 to 72. In KTK jump test, U12 girls achieve scores between 71 and 78, closely followed by U14 girls whose scores range from 72 to 78. For boys, U12 participants present scores from 58 to 78, while U14 boys exhibit a slightly narrower range from 71 to 78. KTK hop test performance is often indicative of more complex motor coordination. It displays broader ranges: U12 girls score between 84 and 102, U14 girls between 81 and 104, U12 boys from 81 to 103, and U14 boys from 84 to 111.
In KTK board test ability, U12 girls score between 45 and 55, while U14 girls show a wider range of 50 to 66. U12 boys achieve scores from 44 to 62, and U14 boys from 48 to 62, reflecting similar variability across age groups. Total KTK scores highlight distinct differences in motor competence across the cohorts. U12 girls' scores range from 106 to 124, and U14 girls' from 96 to 135, while U12 boys fall between 102 and 128, with U14 boys scoring between 105 and 131. In relation to age and gender, each group of scores was transformed into a motor quotient. The total KTK motor quotient (TotalKTKMQ) scores facilitate the categorization of gross motor coordination performances into five distinct levels. Values for U12 girls, range from 106 to 124, and from 96 to 135 for U14 girls. U12 boys demonstrate values between 102 and 128, and U14 boys between 105 and 131.

The motor coordination levels of girls and boys are presented in Table 13.

Table 13. The motor coordination levels of players

KTK Categories	Girls	Boys	Total	Percentile
High	1	1	2	6.90
Good	3	7	10	34.48

Table 13. (continued)

Normal	11	6	17	58.62
Moderate	-	-	-	-
Impairment	-	-	-	-

The category classifications place for U12 boys and girls between categories 3 and 4 which means normal to good as a level explanation, while U14 boys and girls fall into categories between 3 to 5 which is normal to high level. These data reflect that motor competence scores are higher in the older age group.

The reaction times of girls are presented in Table 14.

Table 14. Reaction time of girls

Age Groups		U12		U14		U16	
		Mean	SD	Mean	SD	Mean	SD
Simple Reaction Time (s)							
	Hand	0.77	0.07	0.71	0.06	0.52	0.05
	Accuracy	94.50	6.77	96.73	4.52	98.00	2.39
	Foot	0.88	0.15	0.85	0.15	0.66	0.15
	Accuracy	92.56	8.74	97.07	3.80	98.97	1.93
Selective Reaction Time (s)							
	Hand	1.20	0.16	1.14	0.10	0.98	0.09
	Accuracy	87.73	10.45	91.26	5.99	96.38	4.50
	Foot	1.46	0.32	1.48	0.14	1.20	0.23
	Accuracy	92.88	7.35	90.33	9.80	96.20	5.84
Discriminative Reaction Time (s)							
	Hand	0.73	0.09	0.70	0.05	0.56	0.07
	Accuracy	98.12	4.22	98.81	3.15	99.07	1.73
	Foot	0.88	0.18	0.86	0.18	0.64	0.11
	Accuracy	97.80	2.45	98.79	2.09	97.37	4.25

In U12 girls, simple reaction time using the hand ranges from 0.710 to 0.922 seconds, with accuracy levels between 80% and 100%. U14 girls demonstrate times between 0.643 and 0.807 seconds, with accuracy levels between 89.7% and 100%. U16 girls exhibit times ranging from 0.450 to 0.607 seconds, with accuracy levels between 93.5% and 100%.

In selective reaction time using the hand, U12 girls exhibit times between 1.028 and 1.506 seconds, with accuracy between 64.7% and 100%. U14 girls demonstrate times ranging from 0.966 to 1.252 seconds, with accuracy levels between 81.2% and 100%. U16 girls show times between 0.857 and 1.100 seconds, with accuracy ranging from 87.5% to 100%.

For discriminative reaction time using the hand, U12 girls exhibit times between 0.581 and 0.894 seconds, with accuracy between 88% and 100%. U14 girls demonstrate times ranging from 0.620 to 0.767 seconds, with accuracy between 91.7% and 100%. U16 girls show times between 0.465 and 0.686 seconds, with accuracy levels between 96% and 100%.

For U12 girls, simple reaction time using the foot ranges from 0.649 to 1.109 seconds, with accuracy between 77.78% and 100%. U14 girls demonstrate times ranging from 0.640 to 1.103 seconds, with accuracy levels between 91.7% and 100%. U16 girls exhibit times between 0.502 and 0.923 seconds, with accuracy between 95.2% and 100%.

In selective reaction time using the foot, U12 girls demonstrate times between 0.982 and 1.833 seconds, with accuracy levels between 80% and 100%. U14 girls show response times ranging from 1.345 to 1.759 seconds, with accuracy levels between 71.4% and 100%. U16 girls exhibit times ranging from 0.822 to 1.555 seconds, with accuracy levels between 84.6% and 100%.

Finally, for discriminative reaction time using the foot, U12 girls show response times between 0.636 and 1.064 seconds, with accuracy levels between 94.44% and 100%. U14 girls exhibit times ranging from 0.670 to 1.218 seconds, with accuracy

levels between 95.24% and 100%. U16 girls demonstrate times between 0.476 and 0.823 seconds, with accuracy levels between 88.2% and 100%.

The reaction times of boys are presented in Table 15.

Table 15. Reaction time of boys

Age Groups		U12		U14		U16	
		Mean	SD	Mean	SD	Mean	SD
Simple Reaction Time (s)							
	Hand	0.72	0.11	0.70	0.11	0.73	0.08
	Accuracy	95.51	4.06	96.41	3.30	95.59	4.58
	Foot	0.89	0.10	0.89	0.15	0.71	0.22
	Accuracy	96.92	3.61	99.24	1.86	97.92	2.53
Selective Reaction Time (s)							
	Hand	1.38	0.16	1.23	0.12	1.10	0.11
	Accuracy	87.73	10.45	91.73	10.96	93.26	5.09
	Foot	1.67	0.18	1.51	0.18	1.20	0.21
	Accuracy	93.45	8.73	94.79	10.01	94.97	4.98
Discriminative Reaction Time (s)							
	Hand	0.73	0.05	0.61	0.06	0.71	0.08
	Accuracy	97.00	5.55	98.42	2.55	98.18	3.94
	Foot	0.92	0.13	0.86	0.12	0.70	0.13
	Accuracy	95.63	5.50	94.27	5.33	94.96	4.27

For U12 boys, simple reaction time using the hand ranges from 0.566 to 0.931 seconds, with accuracy levels between 90.5% and 100%. U14 boys demonstrate response times spanning from 0.583 to 0.845 seconds, with accuracy between 91.7% and 100%. U16 boys exhibit times ranging from 0.635 to 0.874 seconds, with accuracy between 88% and 100%.

For selective reaction time using the hand, U12 boys demonstrate times between 1.213 and 1.594 seconds, with accuracy ranging from 66.7% to 100%. U14 boys

demonstrate times ranging from 1.127 to 1.460 seconds, with accuracy between 75% and 100%. U16 boys show times ranging from 0.977 to 1.303 seconds, with accuracy between 86.7% and 100%.

In discriminative reaction time using the hand, U12 boys exhibit times between 0.676 and 0.813 seconds, with accuracy between 88% and 100%. U14 boys demonstrate times ranging from 0.513 to 0.680 seconds, with accuracy levels between 94.1% and 100%. U16 boys show times between 0.607 and 0.827 seconds, with accuracy between 88.9% and 100%.

In U12 boys, simple reaction time using the foot ranges from 0.769 to 1.062 seconds, with accuracy spanning from 90.5% to 100%. U14 boys exhibit times ranging from 0.654 to 1.093 seconds, with accuracy levels between 95.5% and 100%. U16 boys show times ranging from 0.566 to 1.225 seconds, with accuracy levels between 93.1% and 100%.

For selective reaction time using the foot, U12 boys demonstrate times between 1.395 and 1.959 seconds, with accuracy between 75% and 100%. U14 boys exhibit times ranging from 1.204 to 1.685 seconds, with accuracy between 75% and 100%. U16 boys show response times ranging from 0.858 to 1.503 seconds, with accuracy levels between 85.7% and 100%.

For discriminative reaction time using the foot, U12 boys exhibit times between 0.756 and 1.096 seconds, with accuracy spanning from 85% to 100%. U14 boys demonstrate times ranging from 0.734 to 1.042 seconds, with accuracy levels between 86.7% and 100%. U16 boys show response times ranging from 0.530 to 0.978 seconds, with accuracy levels between 86.7% and 100%.

The mental toughness scores of players are given in Table 16.

Table 16. Mental toughness scores of players

Gender	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD

Table 16. (continued)

Girls	5.94	0.63	5.88	0.58	5.85	0.69
Boys	6.23	0.53	5.71	0.30	6.14	0.30

Table 16 presents the mental toughness scores of players across U12, U14, and U16 age groups. Among girls, the mean scores show a slight decline with age, from 5.94 (SD = 0.63) in U12 to 5.88 (SD = 0.58) in U14 and 5.85 (SD = 0.69) in U16. In boys, the highest mean score is observed in U12 (6.23, SD = 0.53), followed by a decrease in U14 (5.71, SD = 0.30) before rising again in U16 (6.14, SD = 0.30). The standard deviation values suggest greater variability among girls, whereas boys, particularly in U14 and U16, exhibit more consistency in their scores. Overall, boys tend to have higher mental toughness scores than girls across all age groups, with the most pronounced differences seen in U12 and U16.

4.2. Coaches' Perspectives

Scores of Coaches' perspectives on performance determinants in tennis are given in Table 17 and Table 18

Table 17. Coaches' perspective on the contribution of performance measures for girls

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Age to start tennis	7.57	2.07	8.00	1.73	8.29	1.89
Weekly training hours (tennis)	7.29	1.70	8.71	0.95	9.57	0.53
Weekly training hours (fitness)	7.00	2.24	8.14	1.57	9.29	1.11
Age to start tournament	6.14	2.12	6.71	1.89	7.71	1.89
Number of national tournaments	6.57	2.15	7.86	1.57	8.14	1.68
Number of international tournaments	6.29	2.50	8.29	0.95	9.29	0.76
Number of single matches	7.00	2.31	8.43	0.53	9.43	0.53
Number of double matches	6.71	1.98	7.43	1.13	8.00	1.41

Table 17. (continued)

Height	6.86	1.46	7.43	0.79	8.14	1.21
Body mass	6.86	1.68	7.57	0.98	8.57	0.79
Body mass index	6.86	1.68	7.43	1.13	8.29	1.11
Body fat percentage	7.00	1.41	7.43	1.13	8.29	1.11
Growth and biological maturity level	8.29	1.25	8.71	0.95	9.29	0.76
Grip strength	5.43	2.37	6.86	2.19	7.57	1.62
Lower body strength (vertical jump)	6.43	1.72	7.71	1.38	8.43	1.51
Upper body strength (overhead medicine ball throw)	5.86	1.95	7.57	1.40	8.43	1.27
Agility	8.43	1.62	8.43	1.13	9.14	1.07
5 m sprint	7.00	2.45	8.14	0.38	9.43	0.79
10 m sprint	7.00	1.91	7.71	1.38	8.57	1.72
20 m sprint	7.14	1.86	7.86	1.57	8.57	1.81
Flexibility	8.00	1.00	7.86	0.38	8.86	0.90
Balance	8.43	1.13	7.57	1.13	9.14	1.07
Serve speed	5.43	1.72	7.57	1.62	9.14	0.90
Motor coordination	8.57	1.62	9.14	0.90	9.43	0.79
Reaction time	7.86	1.57	8.71	0.76	9.14	0.90
Aerobic endurance	6.57	1.81	8.00	1.53	9.14	0.90
Mental toughness	8.14	2.04	8.57	1.13	9.71	0.49

Table 18. Coaches' perspective on the contribution of performance measures for boys

Age Groups	U12		U14		U16	
	Mean	SD	Mean	SD	Mean	SD
Age to start tennis	8.57	1.13	7.86	1.95	8.29	1.89
Weekly training hours (tennis)	7.14	1.68	8.43	0.98	9.57	0.53
Weekly training hours (fitness)	6.86	2.04	8.14	1.57	9.14	1.46
Age to start tournament	5.86	1.21	7.57	1.27	7.71	1.50
Number of national tournaments	6.43	1.40	8.00	1.53	8.43	1.81

Table 18. (continued)

Number of international tournaments	6.00	1.91	8.14	0.69	9.43	0.53
Number of single matches	6.57	1.27	8.43	0.53	9.57	0.53
Number of double matches	6.29	0.95	7.57	1.27	8.43	1.40
Height	7.14	0.90	8.43	0.53	8.57	0.79
Body mass	6.86	1.86	8.00	1.15	8.57	0.79
Body mass index	6.57	1.40	7.57	1.27	8.57	0.98
Body fat percentage	6.43	1.40	7.57	1.27	8.43	1.13
Growth and biological maturity level	7.57	1.27	8.43	0.79	9.29	0.49
Grip strength	5.43	1.90	7.14	1.95	7.71	1.70
Lower body strength (vertical jump)	6.43	1.90	7.86	1.21	8.57	1.62
Upper body strength (overhead medicine ball throw)	6.14	1.77	7.57	0.98	8.71	1.11
Agility	8.57	1.27	8.86	1.21	9.29	0.76
5 m sprint	7.71	2.29	8.43	0.79	9.00	0.82
10 m sprint	7.29	1.38	8.00	1.15	8.71	1.11
20 m sprint	7.14	1.68	7.86	1.57	8.57	1.81
Flexibility	8.29	0.95	7.86	0.38	8.86	0.90
Balance	8.43	1.13	8.71	0.95	9.29	0.95
Serve speed	5.86	1.95	8.43	1.62	9.43	0.79
Motor coordination	9.00	1.00	8.86	0.69	9.14	0.90
Reaction time	8.14	1.57	8.57	0.79	9.29	0.76
Aerobic endurance	6.86	1.86	8.43	1.13	9.14	0.90
Mental toughness	7.86	2.19	9.14	0.90	9.71	0.49

National team coaches provided scores based on their perspectives from 1 less important to 10 very important, to the performance determinants in every age group and the findings are summarized below, highlighting key trends in each category. In general, they emphasized motor coordination for U12 players and U14 girls, whereas mental toughness is emphasized for U14 boys and U16 players.

Regarding to age groups; when U12 boys were observed (table 18) it is seen that age to start tennis, agility and motor coordination variables are more emphasized, while the motor coordination variable has the highest scores. For U12 girls (table 17) it is seen that agility, balance and motor coordination parameters are more prioritized while the motor coordination has the highest score. When U14 girls' parameters were observed, motor coordination, reaction time, growth and maturity level and weekly tennis training hours are more emphasized with motor coordination having the highest score.

For U14 boys' agility, motor coordination and mental toughness parameters were mostly emphasized with mental toughness having the highest score. Lastly, it is seen that mental toughness is the most emphasized parameter for U16 players, while weekly tennis training hours, number of matches and 5 m sprint are next emphasized for girls, weekly tennis training hours, number of matches and serve speed are next emphasized for boys.

4.3. Correlational Analysis

In this section, correlational analyses are presented to examine the associations between various performance determinants and national tennis rankings, where it is important to note that a lower ranking number corresponds to a higher competitive performance. The correlations between rankings and chronological age, experiential characteristics, racquet weight, and string tension in U12 players are given in Table 19. The analysis revealed key factors contributing to national rankings in U12 tennis players, with notable differences between girls and boys. In U12 girls, there were very large and negative correlations between international tournament participation ($r = -0.829$, $p = 0.011$) and string tension ($r = -0.732$, $p = 0.039$) with rankings, which means that more participation in international tournaments and higher string tension was associated with better rankings. In U12 boys, nearly perfect and positive correlation was found between ranking and age to start tournament ($r = 0.917$, $p = 0.001$), indicating that players who started competing earlier tended to have better rankings. The findings revealed no significant correlations between rankings and the other variables in U12 players.

Table 19. The correlation statistics between rankings and chronological age, experience, and racket specification characteristics in U12 players

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Chronological age (years)	0.168	0.691	-0.212	0.614
Training age (years)	0.178	0.673	0.061	0.886
Weekly tennis training (hours)	- 0.085	0.841	-0.376	0.359
Weekly fitness training (hours)	- 0.482	0.226	-0.402	0.323
Total weekly training (hours)	- 0.190	0.652	-0.518	0.189
Age to start tournament (years)	0.058	0.892	0.917	0.001**
Number of national tournaments (#)	0.051	0.904	-0.554	0.154
Number of international tournaments (#)	- 0.829	0.011*	-0.142	0.737
Number of national single matches (#)	- 0.243	0.562	-0.560	0.149
Number of national double matches (#)	0.128	0.762	-0.473	0.237
Number of international single matches (#)	- 0.629	0.095	-0.358	0.384
Number of international double matches (#)	- 0.595	0.120	-0.188	0.656
Number of total national matches (#)	- 0.177	0.674	-0.548	0.160
Number of total international matches (#)	- 0.617	0.103	-0.299	0.472
Number of total tournaments (#)	- 0.237	0.572	0.604	0.113
Number of total matches (#)	- 0.447	0.267	-0.584	0.129
String tension (kg)	- 0.732	0.039*	0.247	0.555
Racquet weight (g)	0.221	0.598	-0.252	0.547

*p<0.05, **p<0.01

The correlations between rankings and body height, body mass, BMI, and body fat percentage in U12 players are given in Table 20. In U12 girls, body fat percentage (r = 0.866, p = 0.005) and BMI (r = 0.850, p = 0.008) were very largely and positively correlated with rankings, suggesting that higher body fat percentage and BMI were associated with worse rankings. The findings revealed no significant correlations between rankings and the other variables in U12 girls and no significant correlations between rankings and any variable for U12 boys.

Table 20. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U12 players.

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Body height (cm)	- 0.347	0.400	-0.30	0.943
Body mass (kg)	0.556	0.152	0.247	0.555
Body fat percentage (%)	0.866	0.005*	0.560	0.149
Body mass index (kg/m^2)	0.850	0.008*	0.478	0.231

*p<0.05, **p<0.01

The correlations between rankings and physical growth and maturity characteristics in U12 players are given in Table 21. In U12 girls, BMI z-score (r = 0.856, p = 0.007) and BMI percentile (r = 0.862, p = 0.006) were very largely and positively correlated with rankings, suggesting that higher BMI was associated with worse rankings. The findings revealed no significant correlations between rankings and the other variables in U12 girls and no significant correlations between rankings and any variable for U12 boys.

Table 21. The correlation statistics between rankings and physical growth and maturity of U12 players.

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Height (z-scores)	- 0.354	0.390	0.045	0.915
Height (percentiles)	- 0.423	0.296	0.087	0.838
Body mass (z-scores)	- 0.435	0.282	0.339	0.412
Body mass (percentiles)	0.476	0.233	0.312	0.452
BMI (z-scores)	0.856	0.007*	0.508	0.198
BMI (percentiles)	0.862	0.006*	0.495	0.213
APHV (years)	0.084	0.843	0.024	0.955
Maturity offset (years)	- 0.014	0.974	-0.207	0.622

*p<0.05, **p<0.01

The correlations between rankings and physical performance parameters in U12 players are given in Table 22. In U12 girls, grip strength (r = 0.730, p = 0.040), flexibility (sit-and-reach, r = 0.884, p = 0.004), and motor coordination (KTKMQ, r = 0.711, p = 0.048) were very largely and positively correlated with rankings, which

indicates that lower grip strength, lower flexibility and lower motor coordination were linked to better rankings. The findings revealed no significant correlations between rankings and the other variables in U12 girls and no significant correlations between rankings and any variable for U12 boys.

Table 22. The correlation statistics between rankings and physical performance parameters of U12 players.

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Grip strength (kg)	0.730	0.040*	0.086	0.839
Sit and reach (cm)	0.884	0.004*	0.265	0.525
Countermovement jump (cm)	0.513	0.194	-0.152	0.719
Medicine ball throw (cm)	0.259	0.536	0.333	0.421
T-agility (s)	- 0.697	0.055	0.417	0.304
5 m sprint (s)	0.087	0.838	0.528	0.179
10 m sprint (s)	- 0.113	0.791	0.312	0.451
20 m sprint (s)	- 0.380	0.353	0.271	0.516
Shuttle distance covered (m)	- 0.637	0.248	-0.368	0.416
VO2Max (ml/ (kg min)	- 0.632	0.252	-0.351	0.440
Serve speed (km/h)	0.519	0.187	0.028	0.948
TotalKTKMQ	0.711	0.048*	0.626	0.097

*p<0.05, **p<0.01

The correlations between rankings and reaction times in U12 players are given in Table 23. The findings revealed no significant correlations between rankings and any variable in U12 players.

Table 23. The correlations between rankings and reaction times of U12 players.

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Hand simple reaction time	- 0.422	0.297	0.161	0.704
Hand selective reaction time	- 0.355	0.389	0.120	0.777
Hand discrimination reaction time	- 0.176	0.678	0.488	0.220
Foot simple reaction time	- 0.088	0.835	-0.099	0.815

Table 23. (continued)

Foot selective reaction time	- 0.430	0.287	-0.086	0.839
Foot discrimination reaction time	- 0.136	0.748	0.250	0.550

*p<0.05, **p<0.01

The correlations between rankings and chronological age, experiential characteristics, racquet weight, and string tension in U14 players are given in Table 24. In U14 girls, there were no statistically significant correlations ($p<0.05$) between rankings and chronological age, training age, weekly training volume, age to start tournament, number of national and international tournaments, number of official single and double matches, racquet weight, and string tension. However, some moderate and negative correlations were observed, particularly with chronological age ($r=-0.601$), number of international double matches ($r=-0.582$), and number of international single matches ($r=-0.518$), implying that players with more experience in international matches tended to have better rankings, despite non-significance. For U14 boys, several performance-related parameters showed very large to nearly perfect correlations with ranking. The number of national single matches ($r=-0.892$, $p=0.017$), international single matches ($r=-0.922$, $p=0.009$), international double matches ($r=-0.970$, $p=0.001$), total national matches ($r=-0.865$, $p=0.026$), total international matches ($r=-0.947$, $p=0.004$), total tournaments ($r=-0.830$, $p=0.041$), and total matches ($r=-0.951$, $p=0.004$) were all negatively correlated with ranking, indicating that greater competition experience, especially at the international level, is strongly associated with better rankings. The findings revealed no significant correlations between rankings and the other variables in U14 boys.

Table 24. The correlation statistics between rankings and the chronological age, experience, and racket specification characteristics in U14 players

Variables	U14 Girls		U14 Boys	
	r	*p*	*r*	*p*
Chronological age (years)	-0.601	0.115	-0.069	0.897
Training age (years)	-0.055	0.898	-0.262	0.616
Weekly tennis training (hours)	-0.452	0.260	-0.516	0.295
Weekly fitness training (hours)	-0.018	0.966	0.204	0.699

Table 24. (continued)

Total weekly training (hours)	-0.503	0.204	-0.373	0.467
Age to start tournament (years)	-0.427	0.292	0.228	0.664
Number of national tournaments (#)	-0.151	0.722	-0.765	0.077
Number of international tournaments (#)	-0.545	0.163	-0.708	0.115
Number of national single matches (#)	-0.049	0.909	-0.892	0.017*
Number of national double matches (#)	-0.206	0.625	-0.663	0.152
Number of international single matches (#)	-0.518	0.189	-0.922	0.009*
Number of international double matches (#)	-0.582	0.130	-0.970	0.001*
Number of total national matches (#)	-0.100	0.813	-0.865	0.026*
Number of total international matches (#)	-0.435	0.282	-0.947	0.004*
Number of total tournaments (#)	-0.362	0.378	-0.830	0.041*
Number of total matches (#)	-0.344	0.403	-0.951	0.004*
String tension (kg)	0.383	0.350	0.033	0.950
Racquet weight (g)	0.039	0.928	0.064	0.904

*p<0.05, **p<0.01

The correlations between rankings and anthropometric characteristics in U14 players are given in Table 25. In U14 girls, there were no statistically significant correlations ($p<0.05$) between ranking and other study variables. In U14 boys, the only notable finding was a very large and negative correlation between body fat percentage and ranking ($r=-0.848$, $p=0.033$), suggesting that higher body fat percentages may be linked to better performance in U14 boys.

Table 25. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U14 players

Variables	U14 Girls		U14 Boys	
	r	*p*	*r*	*p*
Body height (cm)	-0.234	0.577	-0.010	0.985
Body mass (kg)	-0.509	0.197	-0.374	0.465
Body fat percentage (%)	-0.481	0.227	-0.848	0.033*
Body mass index (kg/m^2)	-0.533	0.174	-0.497	0.316

*p<0.05, **p<0.01

The correlations between rankings and physical growth and maturity characteristics in U14 players are given in Table 26. There were no statistically significant correlations ($p<0.05$) between ranking and study variables in U14 players.

Table 26. The correlation statistics between rankings and physical growth and maturity of U14 players

Variables	U12 Girls		U12 Boys	
	r	*p*	*r*	*p*
Height (z-scores)	-0.024	0.955	0.045	0.933
Height (percentiles)	-0.033	0.939	0.202	0.701
Body mass (z-scores)	-0.221	0.598	-0.260	0.618
Body mass (percentiles)	-0.226	0.590	-0.055	0.918
BMI (z-scores)	-0.110	0.795	-0.466	0.351
BMI (percentiles)	-0.108	0.798	-0.375	0.463
APHV (years)	-0.484	0.224	0.016	0.976
Maturity offset (years)	-0.426	0.293	-0.042	0.937

*p<0.05, **p<0.01

The correlations between rankings and physical performance parameters in U14 players are given in Table 27. There were no statistically significant correlations (p<0.05) between ranking and any physical performance parameter in U14 players.

Table 27. The correlation statistics between rankings and physical performance parameters of U14 players

Variables	U14 Girls		U14 Boys	
	r	*p*	*r*	*p*
Grip strength (kg)	0.046	0.914	-0.115	0.828
Sit and reach (cm)	-0.076	0.857	-0.807	0.052
Countermovement jump (cm)	-0.131	0.758	0.792	0.060
Medicine ball throw (cm)	-0.107	0.801	0.061	0.909
T-agility (s)	0.305	0.463	-0.038	0.943
5 m sprint (s)	0.252	0.547	-0.094	0.860
10 m sprint (s)	0.262	0.530	0.130	0.806
20 m sprint (s)	0.399	0.327	-0.132	0.804
Shuttle distance covered (m)	0.186	0.724	0.921	0.255
VO2Max (ml/ (kg min)	-0.035	0.948	0.988	0.099
Serve speed (km/h)	- 0.320	0.440	-0.323	0.532
TotalKTKMQ	0.212	0.648	-0.030	0.955

*p<0.05, **p<0.01

The correlations between rankings and reaction times in U14 players are given in Table 28. There were no statistically significant correlations ($p<0.05$) between ranking and reaction times in U14 players.

Table 28. The correlations between rankings and reaction times of U14 players

Variables	U14 Girls		U14 Boys	
	r	*p*	*r*	*p*
Hand simple reaction time	-0.124	0.792	0.555	0.253
Hand selective reaction time	-0.366	0.420	0.594	0.213
Hand discrimination reaction time	0.664	0.104	0.172	0.745
Foot simple reaction time	0.090	0.849	0.755	0.083
Foot selective reaction time	0.597	0.157	0.482	0.333
Foot discrimination reaction time	-0.018	0.969	-0.256	0.625

*p<0.05, **p<0.01

The correlations between rankings and chronological age, experiential characteristics, racquet weight, and string tension in U16 players are given in Table 29. In U16 girls, the total number of matches played (r=-0.730, p=0.040) was very largely and negatively correlated with rankings. It emphasizes that increased match experience was positively associated with better ranking within this group. For U16 boys, the number of international double matches (r=-0.759, p=0.029) and total international matches (r=-0.722, p=0.043) were very largely and negatively correlated with ranking, emphasizing the role of international competition experience in performance. More participation in international tournaments is related to better rankings. There were no statistically significant correlations ($p<0.05$) between ranking and the other variables in U16 players.

Table 29. The correlation statistics between rankings and the chronological age, experience, and racket specification characteristics in U16 players

Variables	U16 Girls		U16 Boys	
	r	*p*	*r*	*p*
Chronological age (years)	0.159	0.707	0.038	0.929
Training age (years)	0.210	0.618	0.476	0.233

Table 29. (continued)

Weekly tennis training (hours)	0.102	0.810	0.316	0.445
Weekly fitness training (hours)	0.408	0.315	- 0.041	0.924
Total weekly training (hours)	0.252	0.547	0.147	0.728
Age to start tournament (years)	0.082	0.847	0.233	0.579
Number of national tournaments (#)	- 0.420	0.301	0.516	0.190
Number of international tournaments (#)	- 0.014	0.975	- 0.331	0.423
Number of national single matches (#)	- 0.548	0.159	0.427	0.291
Number of national double matches (#)	- 0.512	0.194	0.192	0.649
Number of international single matches (#)	- 0.451	0.262	- 0.688	0.059
Number of international double matches (#)	- 0.164	0.698	- 0.759	0.029*
Number of total national matches (#)	- 0.566	0.144	0.422	0.298
Number of total international matches (#)	- 0.346	0.401	- 0.722	0.043*
Number of total tournaments (#)	- 0.390	0.339	0.123	0.771
Number of total matches (#)	- 0.730	0.040*	- 0.571	0.139
String tension (kg)	- 0.070	0.869	0.165	0.696
Racquet weight (g)	0.098	0.818	- 0.247	0.555

*p<0.05, **p<0.01

The correlations between rankings and anthropometric characteristics in U16 players are given in Table 30. Although not significant, for U16 girls, body height showed a moderate positive correlation (r=-0.661, p=0.074), supporting the trend where shorter players may achieve better rankings. In U16 boys, despite non-significance, BMI (r=-0.570, p=0.140) exhibited moderate and negative correlations with ranking, suggesting that players with higher BMI may have an advantage, although these findings were not statistically significant. There were no statistically significant correlations (p<0.05) between ranking and the other variables in U16 players.

Table 30. The correlation statistics between rankings and the body height, body mass, BMI, and body fat percentage in U16 players

Variables	U16 Girls		U16 Boys	
	r	*p*	*r*	*p*
Body height (cm)	0.661	0.074	- 0.111	0.794
Body mass (kg)	0.263	0.528	- 0.423	0.297
Body fat percentage (%)	- 0.521	0.186	- 0.273	0.513
Body mass index (kg/m^2)	- 0.414	0.308	- 0.570	0.140

*p<0.05, **p<0.01

The correlations between rankings and physical growth and maturity characteristics in U16 players are given in Table 31. For U16 girls, the only notable finding was a very large and positive correlation between rankings and height percentiles (r=-0.710, p=0.048), which means that shorter stature is linked with better rankings. There were no statistically significant correlations (p<0.05) between ranking and the other variables in U16 players.

Table 31. The correlation statistics between rankings and physical growth and maturity of U16 players

Variables	U16 Girls		U16 Boys	
	r	*p*	*r*	*p*
Height (z-scores)	- 0.672	0.068	- 0.113	0.791
Height (percentiles)	0.710	0.048*	- 0.113	0.791
Body mass (z-scores)	-0.204	0.628	- 0.440	0.276
Body mass (percentiles)	0.216	0.607	- 0.445	0.270
BMI (z-scores)	- 0.502	0.205	- 0.602	0.114
BMI (percentiles)	- 0.498	0.209	- 0.601	0.115
APHV (years)	- 0.360	0.381	0.592	0.122
Maturity offset (years)	0.475	0.234	- 0.083	0.845

*p<0.05, **p<0.01

The correlations between rankings and physical performance parameters in U16 players are given in Table 32. The only notable finding for U16 boys was a very large and negative correlation between rankings and medicine ball throw (r=-0.759, p=0.029). It emphasizes the role of upper-body power in performance. There were no statistically significant correlations (p<0.05) between ranking and the other physical performance parameters in U16 players.

Table 32. The correlation statistics between rankings and physical performance parameters of U16 players

Variables	U16 Girls		U16 Boys	
	r	*p*	*r*	*p*
Grip strength (kg)	- 0.249	0.552	- 0.114	0.788
Sit and reach (cm)	0.517	0.189	- 0.560	0.149
Countermovement jump (cm)	0.454	0.259	- 0.084	0.842

Table 32. (continued)

Medicine ball throw (cm)	- 0.654	0.079	- 0.759	0.029*
T-agility (s)	- 0.232	0.580	0.564	0.145
5 m sprint (s)	- 0.412	0.310	0.357	0.385
10 m sprint (s)	- 0.188	0.656	0.309	0.456
20 m sprint (s)	- 0.047	0.911	0.021	0.960
Shuttle distance covered (m)	0.596	0.593	- 0.392	0.385
VO2Max (ml/ (kg min)	0.559	0.623	- 0.331	0.468
Serve speed (km/h)	0.483	0.226	- 0.265	0.525

*p<0.05, **p<0.01

The correlations between rankings and reaction times in U16 players are given in Table 33. There were no statistically significant correlations (p<0.05) between ranking and reaction times in U16 players.

Table 33. The correlations between rankings and reaction times of U16 players

Variables	U16 Girls		U16 Boys	
	r	*p*	*r*	*p*
Hand simple reaction time	0.630	0.094	- 0.160	0.705
Hand selective reaction time	0.162	0.701	0.473	0.236
Hand discrimination reaction time	0.385	0.347	- 0.132	0.755
Foot simple reaction time	- 0.360	0.382	0.110	0.795
Foot selective reaction time	- 0.118	0.782	0.065	0.878
Foot discrimination reaction time	0.336	0.415	0.257	0.540

*p<0.05, **p<0.01

The correlations between rankings and mental toughness scores in U16 players are given in Table 34. Although not significant, for U16 girls, mental toughness (r=-0.636, p=0.090) exhibited a moderate and negative correlation with ranking, suggesting that players with higher mental toughness may have an advantage, although these findings were not statistically significant.

Table 34. The correlations between rankings and the mental toughness of players.

Age Groups		Mental toughness	
		r	*p*
U12	Boys	-0.061	0.886
	Girls	0.448	0.266
U14	Boys	-0.346	0.502
	Girls	0.288	0.489
U16	Boys	-0.636	0.090
	Girls	-0.180	0.670

*p<0.05, **p<0.01

To sum up, this study aimed to assess the associations between national rankings and the physical, functional, psychological and experiential characteristics of top junior tennis players in the U12, U14, and U16 age categories. The findings partially support the study's hypotheses. Among experiential variables, significant correlations with ranking were found in all groups except U12 boys and U14 girls. However, no single variable consistently correlated with national ranking across all age categories and both genders. The study also explored coaches' perspectives on the key factors of performance in top-ranked junior tennis players. These results support the hypothesis, as coaches' priorities regarding performance variables differed by both age and gender.

CHAPTER 5

DISCUSSION

Identifying and nurturing talented young tennis players is a critical aspect of long-term success in the sport, as early performance indicators can shape future competitive achievements. Understanding the key determinants of ranking success provides valuable insights for optimizing training programs and talent development strategies. This study aims to conduct a comprehensive examination of the numerous aspects that influence a player's ranking, including demographic, experience, training-related, physical, technical, and psychological qualities. In addition, coaches' perspectives on performance determinants were considered. The results highlight significant correlations between performance determinants and national rankings, demonstrating the complex dynamics of talent identification in young tennis players. Initial tournament experience (U12 boys), body composition (body fat percentage in U12 girls and U14 boys; BMI in U12 girls), and physical qualities such as grip strength and flexibility (U12 girls) were correlated with ranking. Power and coordination were essential components, as demonstrated by the medicine ball throw in U16 males and motor coordination in U12 females. Competitive experience factors (U14 and U16 players) were linked to higher rankings. Additionally, 41.4% of participants performed above the normal level in motor coordination (KTK), underscoring its role in early development. Coaches highlighted motor coordination as a key factor for U12 and U14 girls, while mental toughness was emphasized for U14 boys and U16 players, suggesting an evolving emphasis on psychological resilience as players progress.

The findings indicated no significant correlation between rankings and the growth and maturity status of U12, U14, and U16 players, align with some studies while contrasting with others. Research by López-Plaza et al. (2023) found that maturity

status did not significantly influence motor performance in young tennis players, except for jump height in males, suggesting that biological maturation alone may not be a key determinant of success in junior tennis. Similarly, Söğüt et al. (2023) examined growth and maturity in young elite and sub-elite tennis players, finding no significant differences among national, main draw, and qualifying male players in terms of growth and maturity variables. However, in female players, those at higher competitive levels were significantly more advanced in maturation and had higher BMI than lower-ranked players, indicating that the role of maturity may vary based on gender. Baxter-Jones et al. (1995) asserts that early-maturing athletes may have benefits in strength, speed, and power, leading to enhanced performance levels. Malina et al. (2004) assert that physical growth and skeletal maturity substantially influence motor performance, indicating that early maturation may provide a competitive edge in physically demanding sports. The variability in these results may stem from sport-specific demands, measurement inconsistencies, or the diminishing influence of maturation on performance as athletes approach full maturity. In tennis, where technical skill, tactical intelligence, and mental toughness are essential in addition to physical talents, growth and maturity may not correlate as strongly with competitive success as in other sports. This indicates that although physical growth is significant, other multifaceted aspects, including training quality, experience, and psychological preparedness, probably exert a more substantial influence on the rankings of young tennis players.

Research suggests that reduced grip strength and flexibility are associated with higher rankings in U12 females, indicating that lower upper-body strength and mobility did not hinder performance at this level and may even improve movement efficiency or technical execution. Conversely, elevated upper-body power (medicine ball throw) correlated with superior rankings in U16 boys, underscoring the growing significance of strength and explosiveness as players develop. No substantial relationships were identified between rankings and other physical fitness characteristics, such as countermovement jump, sprint times (5, 10, and 20 meters), shuttle run performance, and reaction time, across all age groups. This suggests that while physical fitness remains a key component of overall athletic development, it may not be the primary determinant of ranking success in junior tennis. This

underscores the need for an age-specific approach to physical development, ensuring that training priorities align with the changing demands of competitive tennis.

These findings challenge traditional perspectives that emphasize grip strength, flexibility, and general physical conditioning as key contributors to performance. Studies such as Kovacs (2006) and Roetert et al. (2007) emphasize the importance of grip strength for racket control and shot stability and flexibility for movement efficiency and injury prevention, yet this research indicate that these factors may not be crucial for success in younger age groups. However, the positive correlation between upper-body power and rankings in U16 boys supports research by Sánchez-Pay et al. (2021), which found a significant positive correlation between the medicine ball throw (shot put) and serve velocity in professional players highlights the increasing relevance of explosive strength in older junior players, particularly in serve power and shot effectiveness.

The absence of significant correlations between countermovement jump, speed, endurance, and reaction time and rankings in this study aligns with research suggesting that technical skills, tactical intelligence, and match experience often outweigh pure physical attributes in competitive junior tennis (Kramer et al., 2017). A study by Vuong et al. (2021) investigating physical determinants in elite junior tennis players indicated that while "Change of Direction (COD) Speed" linked with ranking positions, the overall relationship between physical attributes and rankings was less substantial than anticipated. This suggests that technical and tactical skills may be more crucial in determining success at the junior level (Vuong et al., 2021). Volk et al. (2023) found that change of direction performance metrics, such as tennis modified 505 time and tennis modified 505 time_change of direction, demonstrated significant correlations with ranking positions among girls. Additionally, maximal power demonstrated a significant correlation with ranking positions in female players. These findings suggest that specific physical attributes, notably change of direction performance and power output, are relevant to competitive success in elite junior female tennis players. While explosive power, speed, and endurance contribute to general athleticism, their direct impact on rankings may be limited, especially in younger age groups where players rely more on court positioning, shot

consistency, and strategic play. The lack of correlation with reaction time supports the idea that anticipatory skills and decision-making may be more important than reflex alone. For instance, Shim et al. (2005) found that skilled players were significantly more accurate than novices in anticipating stroke type and direction, utilizing movement-pattern information to reduce response delays. Similarly, Triolet et al. (2013) observed that anticipation behaviors occurred predominantly in situations where players faced tactical disadvantages, suggesting reliance on contextual cues and early information to predict opponents' shots.

Motor competence, as assessed by the KTK test appears to be positively correlated with ranking in U12 girls, while the correlation in other groups (U12 boys and U14 players) is not significant. This suggests that in younger female players, lower motor competence may be associated with better ranking. However, this relationship is not as evident in boys or older players. When considering the motor coordination levels of the players based on KTK percentiles, the majority fall into the "Normal" category (58.62%), followed by the "Good" category (34.48%), with only a small portion classified as "High" (6.90%). Notably, no players were categorized as having "Moderate" or "Impairment" levels of motor coordination. This distribution indicates that most young tennis players in the study possess at least an average level of motor coordination, which is expected given their engagement in an intensive sport requiring well-developed movement skills.

Motor coordination is a fundamental component of athletic performance, particularly in skill-based sports like tennis. Study findings contrast with much of the existing literature, which generally associates higher motor competence with better performance in sports requiring complex movement patterns, such as tennis (Söğüt, 2017). However, several possible explanations could clarify why this relationship appears reversed in U12 girls and absent in other groups Coordination development is indeed influenced by maturation and growth spurts, which vary widely in U12 players. Corso (2018) indicates that during the adolescent growth spurt, movement coordination tends to deteriorate, likely due to rapid changes in body dimensions and muscle-tendon stiffness.

At younger ages, particularly in tennis, technical skill development and training hours may play a more critical role than general motor coordination. Players with lower KTK scores might compensate for reduced general coordination with superior tennis-specific skills (e.g., stroke technique, anticipation, and tactical awareness). Prior research has shown that early sport specialization may lead to enhanced performance in technical aspects of the game, despite lower general motor competence (Myer et al., 2015).

A comprehensive review titled "Performance Parameters in Children and Adolescent Athletes" highlights that success in sports is dependent on numerous mental and physical components, including somatotype, motor skills, age, nutritional status, physiology, psychology, training level, genetic endowment, and injury risk (Birrer & Levine, 1987). The review emphasizes that while motor skills are crucial, other factors such as psychological attributes and training levels gain prominence as athletes mature. This aligns with the observation that the lack of significant correlation between motor competence and performance in U12 boys and U14 players suggests that motor competence alone may not be a strong predictor of performance at later stages. As players develop, technical skills, tactical awareness, and psychological attributes become increasingly important in determining competitive success.

Study results are aligned with Söğüt (2016), as none of the participants performed below the normal level in motor coordination, with 40.6% performing above normal. The gross motor coordination levels of junior tennis players aged 6-14 were assessed using the KTK. No significant gender differences were found, and while older players had better raw scores, age did not significantly affect motor quotient scores.

On the other hand, some studies have found stronger relationships between motor competence and sports performance across all age groups, especially in sports requiring dynamic movements and coordination under pressure, is supported by existing literature. For instance, a meta-analysis by Utesch et al. (2019) found a moderate to large positive relationship between motor competence and physical fitness, which strengthens with increasing age. The discrepancy in findings across

studies could indeed be attributed to factors such as sample size variations, differences in training backgrounds, or the level of competition among players.

For U12 boys and older players (U14 and U16), motor coordination does not appear to have a direct relationship with ranking. This suggests that as players progress, other performance factors (e.g., strength, agility, endurance, technical and tactical skills, and mental resilience) may become more critical than general coordination. A study on young soccer players indicated that while motor coordination levels improve with age, the differences among age groups are not significant when adjusted for age, suggesting that factors beyond motor coordination play a more substantial role in performance as players mature (Dirik & Söğüt, 2021). Additionally, a study examining elite youth soccer players found that maturity status influenced performance in speed and agility tests, highlighting the importance of physical development stages over motor coordination alone (Rommers et al., 2018).

Although motor proficiency is typically considered essential for success in sports, its significance in tennis seems to be more complex. Research indicates that among U12 girls, decreased KTK scores may correlate with elevated rankings, due to sport-specific adaptations, training focus, and other performance variables compensating for general coordination deficiencies. As players progress, motor coordination diminishes in importance, underscoring that tennis success is influenced by a complex interplay of technical, physical, and psychological factors.

This study analyzed serve speed (km/h) as a technical indicator to investigate its correlation with player rankings. The correlation analysis among all age categories (U12, U14, and U16) revealed no statistically significant relationship between serve speed and ranking, suggesting that increased serve velocity does not inherently lead to higher competitive performance in young tennis players.

These findings correspond with prior research highlighting the complex nature of service efficacy. A study of junior tennis players aged 11-14 revealed that elite players not only achieved greater serve speeds but also displayed enhanced motor coordination, indicating that elements beyond serve speed, such as coordination and

technical skill, are vital for performance at the junior level (Söğüt, 2017). From a technical standpoint, serve speed is a crucial but isolated metric in evaluating a player's overall serving competence. In tennis, an effective serve is characterized by speed, precision, spin, tactical variation, and consistency (Kovacs & Ellenbecker, 2011). Multiple studies have demonstrated that although serve speed enhances a player's attacking capability, the placement and tactical application of various serve types (such as slice, kick, and flat serves) are often more vital in competitive contexts. This is particularly noticeable in junior programs, when players improve their technical capabilities. Research reveals that junior players exhibit a lower frequency of serves landing near the lines compared to professionals, underscoring a developmental component of serve precision and strategy (Kovalchik & Reid, 2017). Moreover, serve biomechanics and kinetic chain efficiency are essential to serve performance. Research indicates that serving technique, body synchronization, and the timing of force application substantially affect serve efficacy, surpassing the significance of speed alone (Girard et al., 2007). This could explain why some players with moderate serve speed may achieve higher rankings by compensating with better placement, spin, or tactical serve selection.

In contrast to study findings, serve speed has been identified as a critical factor influencing match outcomes in professional tennis. Players with exceptionally fast serves, who averages first serves at 136 mph and has recorded speeds up to 144 mph, often dominate their service games, making it challenging for opponents to break serve (Carayol, 2025). However, in youth tennis, where players are still developing physically and technically, serve speed alone may not be the best predictor of success. A comprehensive evaluation of technical skills—including serve accuracy, consistency, and tactical adaptability—is essential. A prospective study involving male youth tennis players (average age 13.4 years) found that both ball speed and accuracy were significant predictors of current and future performance. Notably, future elite players demonstrated greater accuracy, especially in variable game situations that required adaptive responses, highlighting the importance of tactical adaptability in addition to serve speed (Kolman et al., 2021). In conclusion, while serve speed is a valuable technical indicator, its limited correlation with rankings in young players suggests that technical proficiency in serving should be evaluated

multidimensionally, incorporating accuracy, spin, and strategic serve patterns to better understand its role in competitive success.

The correlation results suggest that mental toughness did not show a significant relationship with rankings in U12, U14 and U16 players. Jean Piaget's theory of cognitive development posits that children generally enter the formal operational stage between the ages of 11 and 14, during which they cultivate abstract reasoning abilities. Before this period, during the concrete operational period (about 7 to 11 years), children's cognition is predominantly centered on tangible things and experiences. They begin to understand logical processes but have difficulties with abstract concepts. This developmental trajectory suggests that younger children rely more on physical attributes and concrete reasoning, while the capacity for abstract thinking and the influence of psychological factors grow more pronounced during puberty (Piaget, 2005). The shift from concrete to abstract thinking aligns with the observation that younger players tend to depend more on physical characteristics, such as agility and reaction time, whereas psychological attributes, including abstract reasoning and strategic thinking, become more significant in later developmental phases. Additionally, self-reported measures of mental toughness may not fully capture its impact on competitive performance.

Although it is not significant, dataset reveals a moderate negative correlation in U16 boys ($r = -0.636$, $p = 0.090$), indicating that higher mental toughness is associated with better rankings in this group. The emerging significance of mental toughness in U16 boys suggests that it may play a growing role in distinguishing top-ranked players, supporting findings from Jones et al. (2002) that mental toughness becomes more influential at higher competitive levels. This aligns with previous research (Cowden, 2016), which highlights mental toughness as a key determinant of success in tennis, particularly in high-pressure situations. However, the lack of significant correlations in younger age groups may indicate that its impact develops over time. Future studies with longitudinal tracking and alternative psychological assessments could further clarify the role of mental toughness in junior tennis performance.

The correlation analysis of experience, training, and competition exposure variables provides several important insights into junior top-ranked tennis players'

performance. Training age and weekly training hours showed weak and non-significant relationships with rankings, suggesting that increasing training volume alone does not necessarily lead to higher rankings. This supports findings that highlight the significance of well-organized and focused training programs, which tend to be more effective than merely extending training hours (Reid et al., 2009). In U12 boys, early participation in tournaments was significantly associated with higher rankings, underscoring the importance of early competitive exposure for long-term success. A study investigating the career trajectories of tennis players identified a correlation between the competitive level at which players secure their initial victory and their probability of attaining elite status. Early successes in prestigious competitions may positively influence subsequent performance (Zappalà et al., 2024). Conversely, numerous studies suggest that delayed specialization, in which young athletes engage in multiple sports before committing to tennis, may provide benefits such as reduced injury risks and lower burnout rates (DiFiori et al., 2014). While early rivalry may promote ranking improvement, the long-term effects of intense competition in youth require thorough examination.

A notable correlation was identified between the number of international tournaments and rankings in U12 females, indicating that increased participation in international tournaments is associated with higher rankings. A greater frequency of national and international matches in the U14 and U16 boys' categories correlated with improved rankings. A significant correlation is observed between the total number of matches and rankings among U16 girls. Highlighting the necessity of competition exposure for skill development and consistent performance. This aligns with research demonstrating that match experience is crucial for skill development and cognitive performance (García-González et al., 2015). The notable correlations related to international match numbers indicate that exposure to high-level competition enhances performance, corroborating research that elite-level rivalry promotes adaptation and development (Schinke et al., 2012). The findings underscore the significance of tournament participation and competitive exposure in attaining elevated rankings, suggesting that organized competitive experience is crucial for the advancement of tennis players.

Nevertheless, opposing research cautions against excessive involvement in tournaments. Studies indicate that persistent competition among youth athletes, lacking adequate recovery, can result in physical and mental fatigue, negatively impacting long-term performance and heightening injury risk (Brenner et al., 2024). A study of elite youth tennis players indicated that although match experience is crucial, an overly demanding tournament schedule may restrict opportunities for technical development and organized training (Carter, 2021).

The results indicate that exposure to international competition significantly influences ranking enhancement, whereas training age and weekly training hours show no definitive association with performance. This corresponds with studies emphasizing the significance of match experience in skill enhancement and decision-making (Del Villar et al., 2007). Contradictory evidence (Bompa & Buzzichelli, 2019; Meeusen et al., 2013) indicates that overtraining and heightened competitiveness, in the absence of sufficient rest, may result in a stagnation or deterioration of performance. The results underscore the significance of match play in enhancing ranks; yet it is essential to equilibrate competition and training to maximize long-term progress.

Coaches' insights indicate a developmental hierarchy in performance attributes, highlighting the importance of motor coordination and technical skills in younger athletes (U12 males, U12 females, and U14 females), while stressing the essential role of mental resilience in older groups (U14 males, U16 males, and U16 females). This is consistent with the findings of Robertson et al. (2018), who identified agility, ball skills, and hand-eye coordination as critical attributes for younger players, emphasizing their significance in core skill development and adaptability. Furthermore, research conducted by Vandorpe et al. (2011) and Lidor et al. (2009) emphasizes the significance of motor coordination in the initial stages of athletic development for skill acquisition and sustained sports performance. Busuttil et al. (2024) also emphasized coaches' overarching emphasis on technical proficiency, including grip postures, to establish biomechanical efficiency in the early stages of growth. As athletes develop, the growing demands of competition prioritize psychological resilience, a trend corroborated by Crespo et al. (2024), who reported

that experienced coaches incorporate mental skills (e.g., concentration, emotional regulation) into training to navigate high-pressure performance scenarios. This transition reflects tactics identified by Weinberg and Jackson (1990), including confidence modeling and verbal persuasion, which are essential for enhancing self-efficacy in older athletes. Collectively, these findings reflect a structured developmental framework in tennis coaching, where early motor and technical foundations enable later psychological readiness, aligning training priorities with athletes' evolving competitive needs.

When evaluating the connection between the study variables and coaches' perspectives, a strong alignment is observed in several key areas. Coaches emphasized the importance of early tournament exposure, consistent match play, and international competition experience as critical factors for player development and success — which aligns with the study's findings. In both U12 boys and U16 groups, early tournament participation and greater match volume, particularly at the international level, were significantly associated with better national rankings. Similarly, coaches highlighted physical fitness elements such as upper body power and mental toughness, which corresponds to the observed correlations between medicine ball throw performance, mental toughness, and improved rankings in U16 boys. In U14 boys, coaches' views on the value of extensive competition exposure were supported by strong negative correlations between total match numbers and ranking. Conversely, in some cases, such as the positive correlation between lower grip strength, flexibility, and motor coordination with better rankings in U12 girls, the findings appear to contrast with traditional coaching assumptions that prioritize higher scores in these domains.

These discrepancies suggest that coaches' perspectives may need to be reevaluated or that other contextual factors (e.g., playing style, tactical intelligence, early specialization) not directly captured in the current dataset might influence these relationships. Overall, most of the statistically significant findings are largely consistent with the coaches' performance evaluations, reinforcing the value of their experiential insights while also highlighting areas where objective data can refine or challenge conventional beliefs.

5.1. Limitations and recommendations for future studies

Injuries present a limitation, as players who are unable to perform at their full capacity or who miss testing sessions due to injury may not be accurately represented in the dataset. This could impact the overall findings, as performance assessments may not always reflect a player's true potential when health-related constraints are involved. Additionally, the study's primary limitations lie in the tactical dimension. The absence of a dedicated tactical parameter means that key strategic aspects of match play, such as shot selection, adaptability, and positioning, are not directly assessed. In the psychological domain, the study focuses on mental toughness, but additional dimensions like concentration and motivation could provide a more comprehensive understanding of psychological resilience in young tennis players. Similarly, in the technical aspect, the current study evaluates maximum serve speed, incorporating accuracy parameter and assessments of other shots, such as groundstrokes and volleys, could enhance the technical analysis. Expanding these areas in future research could contribute to a more multidimensional approach to determinants of performance in top-ranked young tennis players and development in tennis.

5.2. Practical implications

The results of this study provide clear, evidence-based guidance for coaches, sports scientists, and tennis federations aiming to optimize player development and ranking progression. A key takeaway is that competition experience, particularly at the international level, has a nearly perfect association with higher rankings across all age groups. Coaches and federations should prioritize structured competition pathways that expose young players to higher levels of play early in their careers.

For U12 players, the findings emphasize the importance of international tournament participation, particularly for girls, where more experience at this level was strongly linked to better rankings. Equipment choices also play a role, as lower string tension was associated with higher rankings, possibly due to improved power. Interestingly, lower grip strength, flexibility, and motor coordination scores correlated with better

rankings in U12 girls, suggesting that excessive focus on these attributes may not be beneficial at this stage. Training should concentrate on improving sport-specific movement efficiency and offering match-play experience. In U12 boys, commencing tournament involvement at a younger age was significantly associated with enhanced rankings, highlighting the significance of early engagement in competitive settings.

The volume of international and national matches significantly impacted U14 players, particularly males. U14 boys who engaged more frequently in singles and doubles matches, particularly at the international level, achieved significantly higher rankings, underscoring the necessity for organized match scheduling and competitive strategy. Significantly, an elevated body fat percentage was associated with enhanced performance in this cohort, indicating that extreme leanness may not universally confer an advantage and that personalized physical development should be considered. No statistically significant associations were seen in U14 females; nevertheless, trends indicated that increased experience in international singles and doubles matches may enhance ranks. Coaches ought to promote tournament participation while also emphasizing progressive development tactics customized to each player's growth trajectory.

The significance of competitive experience for U16 players persisted robustly. In U16 females, an increased total match volume correlated with superior ranks, underscoring the necessity for regular match participation at this level. Notably, reduced height exhibited a significant link with superior rankings, indicating that achievement in this domain may be affected by playstyle modifications that prioritize agility and movement efficiency. In U16 boys, upper body power, as assessed by the medicine ball throw, and participation in international doubles matches were significantly correlated with elevated ranks. Coaches must incorporate power-based training while guaranteeing that players have significant international match experience. Despite lacking statistical significance, mental toughness had moderate relationships with ranking, indicating that psychological resilience may contribute to performance.

The findings have obvious consequences for stakeholders in junior tennis development: coaches should prioritize international match experience, tailor training

to age-specific requirements, and emphasize sport-specific adaptations over general physical traits. Parents must be apprised of the significance of organized competition timelines and pragmatic expectations about physical growth, ensuring that players are not coerced into achieving superfluous physical standards that may not enhance performance. Federations, academies, and clubs may establish organized competition routes that offer early international exposure, especially for U12 and U14 players, while also facilitating physical and mental development programs aligned with performance trends. Strength and conditioning experts may customize training regimens according to age-specific ranking factors, prioritizing power enhancement in older demographics while deemphasizing flexibility and grip strength in younger athletes. By aligning training, competition schedules, and development programs with these findings, stakeholders can better support young tennis players in maximizing their performance and achieving higher rankings.

5.3. Conclusion

The current study demonstrates that selected tests (standing height, sitting height, body mass and body fat percentage, grip strength, countermovement jump, medicine ball throw, t-agility, sprint, sit-and-reach, maximum serve speed, KTK motor skill assessment, hand and foot reaction tests protocol, shuttle run, mental toughness scale in sport, coaches' perspective) within a multidimensional approach can explain a portion of the performance determinants in top-ranked young tennis players. The findings of this study underscore the multifaceted determinants of national rankings among young tennis players, with distinct patterns emerging across age groups and genders. In U12 girls, higher rankings were associated with increased international tournament participation and lower string tension, while greater grip strength, flexibility, motor coordination, body fat percentage, and BMI were linked to lower rankings. In U12 boys, an earlier start in tournament competition was nearly perfectly correlated with higher rankings, with no other significant associations observed. For U14 girls, no statistically significant relationships emerged, though trends suggested that greater international match experience may contribute to improved rankings. In contrast, U14 boys exhibited strong negative correlations between ranking and various competition volume metrics, particularly at the

international level, with an unexpected association between higher body fat percentage and better performance. Among U16 girls, total match experience was positively associated with higher rankings, reinforcing the potential advantage of increased competition exposure. Similarly, in U16 boys, international competition experience and upper body power were strongly linked to improved rankings, with additional trends suggesting potential benefits of greater mental toughness and BMI, though these were not statistically significant. Moreover, 41.4% of participants demonstrated above-normal motor coordination levels in the KTK assessment. Coaches emphasized motor coordination as a critical factor for U12 players and U14 girls, while mental toughness was highlighted as a key determinant for U14 boys and U16 players. These findings highlight the interplay between experiential, physical, and psychological attributes in shaping competitive success, emphasizing the importance of competition exposure, motor coordination, and mental toughness in player development. This research underscores the importance of fostering competition experience, prioritizing motor coordination in younger players, and nurturing mental toughness as players progress, ensuring a well-rounded approach to long-term tennis development.

The results of this study demonstrated that, although several individual parameters encompassing demographics, training history, equipment characteristics, growth and maturation status, physical performance capacities, technical skill, motor coordination, psychomotor abilities, psychological traits, and coaches' perspectives—were correlated with national rankings, these associations were not consistent across age groups. Tournament experience was the only parameter that exhibited a statistically significant relationship with ranking across all examined age categories (U12, U14, and U16). This consistent association likely reflects the cumulative advantage conferred by competitive exposure, as greater participation increases opportunities for point accumulation. These findings suggest that tennis performance cannot be adequately explained by isolated variables or assessments confined to a single domain. Rather, they underscore the importance of adopting a multidimensional and integrative approach that simultaneously accounts for developmental, physical, technical, cognitive, psychological, and experiential factors. By framing performance through this holistic lens applicable across all stages of

youth development—this study provides a novel contribution to the literature on talent identification and player development in tennis.

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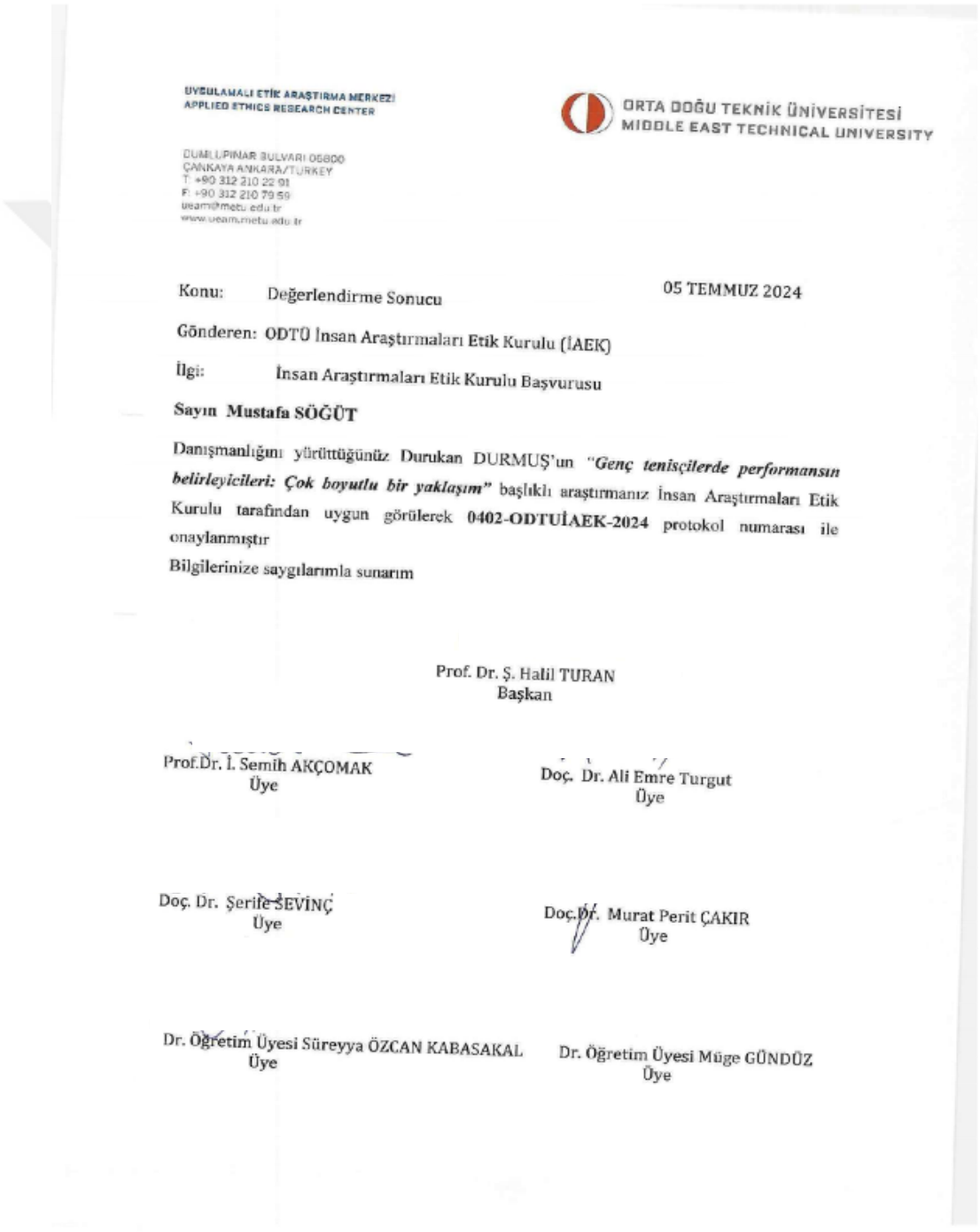
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APPENDICES

A. APPROVAL OF THE METU HUMAN SUBJECTS ETHICS COMMITTEE



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Konu: Değerlendirme Sonucu

05 TEMMUZ 2024

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Mustafa SÖĞÜT

Danışmanlığını yürüttüğünüz Durukan DURMUŞ'un ***"Genç tenisçilerde performansın belirleyicileri: Çok boyutlu bir yaklaşım"*** başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek **0402-ODTÜİAEK-2024** protokol numarası ile onaylanmıştır

Bilgilerinize saygılarımla sunarım

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Başkan

Prof.Dr. İ. Semih AKÇOMAK
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Üye

Dr. Öğretim Üyesi Müge GÜNDÜZ
Üye

B. PERMISSION OF THE TURKISH TENNIS FEDERATION

TÜRKİYE
TENİS FEDERASYONU BAŞKANLIĞI

Sayı : E-73784777-125.99-6456285 18.12.2023

Konu : Tez Çalışması Hk.

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(İnsan Araştırmaları Etik Kurulu)

Orta Doğu Teknik Üniversitesi Beden Eğitimi ve Spor Doktora öğrenciniz Durukan DURMUŞ'un "Genç tenisçilerde performansın belirleyicileri: Çok boyutlu bir yaklaşım" başlıklı doktora tez çalışması için gerekli ölçümleri yapması Federasyon Başkanlığımızca uygun görülmüştür.

Gereği hususunda bilgilerinize arz ederim.

Serhat ALTINEL
Genel Sekreter

Bu belge, güvenli elektronik imza ile imzalanmıştır.
Doğrulama Kodu: 815ED82C-B246-449B-AF3B-C65783FDB170 Doğrulama Adresi: https://www.turkiye.gov.tr/gsb-ebys

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Bilgi için:Göksu GÜLPINAR
Genel Sekreter Yardımcısı

29867696 - 729867696 - 729867696 - 729867696

C. CONSENTS FROM PARTICIPANTS

Bu çalışma ODTÜ Beden Eğitimi ve Spor Bölümü doktora öğrencisi Durukan Durmuş tarafından yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın amacı, teniste yetenek tespiti ve gelişimine yönelik çok boyutlu bir yaklaşım geliştirmektir. Bu amaçla, genç tenisçilerin ulusal sıralamalarının olası korelasyonları araştırılacaktır. Çalışmaya U12, U14 ve U16 yaş kategorilerindeki elit müsabık erkek ve kadın tenis oyuncuları dahil edilecektir. Oyuncuların ulusal sıralamaları ve turnuva kayıtları Türkiye Tenis Federasyonu (TTF) resmi internet sayfasından toplanacaktır. Demografik, deneyimsel ve antrenmanla ilgili özellikler antrenörlerden ve ebeveynlerden elde edilecektir. Antropometrik, fiziksel uygunluk ve motor koordinasyon ölçümleri yapılacaktır. Oyuncuların zirve boy hızı yaşı ve büyüme durumları hesaplanacaktır. Servis hızı, reaksiyon süresi ve psikolojik beceriler ölçülecektir. Performans parametrelerinin katkısına ilişkin antrenörlerin bakış açısına yönelik bir soru formu uygulanacaktır.

Araştırma verileri TTF Ankara Tenis Merkezinde düzenlenecek olan gelişim kampları sırasında toplanacaktır. Kampa U12, U14 ve U16 yaş gruplarındaki sporcular katılımcı olarak davet edilecektir. Veri toplama süreci toplam 3 gün sürecektir. Çalışmada sizden testlerde elinizden gelenin en iyisini yapmanız ve sorulara doğru cevap vermeniz istenecektir.

Bu çalışmaya katılmak tamamen gönüllülük esasına dayalıdır. Herhangi bir yaptırıma veya cezaya maruz kalmadan çalışmaya katılmayı reddedebilir veya çalışmayı bırakabilirsiniz. Araştırma esnasında cevap vermek istemediğiniz sorular olursa boş bırakabilirsiniz. Bu araştırmanın sonuçları bilimsel yayınlarda veya eğitim amaçlı kullanılabilir, fakat katılımcıların kimliği gizli tutulacaktır.

Çalışma esnasında, testleri yaparken fiziksel olarak yorgunluk hissedebilirsiniz. İstediğiniz zaman prosedürü durdurabilir ve çalışmayı herhangi bir kaybınız olmaksızın bırakabilirsiniz. Yapılacak olan testler fiziksel özellikleri belirlemek için araştırmalarda sık kullanılan yöntemler olup önemli bir risk taşımamaktadır fakat aşağıdaki semptomları daha önce göstermiş insanlarda stres tepkilerine (kalp atışlarının hızlanması, çok nadir ve aşırı durumlarda bayılma gibi) yol açabilir. Bu yüzden aşağıdaki semptomlardan herhangi birini daha önce geçirdiyseniz araştırmaya katılmanız uygun değildir.

- Kardiyovasküler bozukluklar
- Bayılma nöbetleri veya nörolojik nöbetler

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için doktora öğrencisi Durukan Durmuş'a ulaşabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Ad Soyad Tarih İmza

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D. CONSENTS FROM PARENTS

Sevgili Veli,

Bu çalışma ODTÜ Beden Eğitimi ve Spor Bölümü doktora öğrencisi Durukan Durmuş tarafından yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

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Çocuğunuzdan alacağımız veriler tamamen gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir. Elde edilecek bilgiler sadece bilimsel amaçla kullanılacak, çocuğunuzun ismi ve kimlik bilgileri veya sizin isminiz ve kimlik bilgileriniz, hiçbir şekilde kimseyle paylaşılmayacaktır. Çalışma esnasında, çocuğunuz testleri yaparken fiziksel olarak yorgunluk hissedebilir. Yapılacak olan testler fiziksel özellikleri belirlemek için araştırmalarda sık kullanılan yöntemler olup önemli bir risk taşımamaktadır fakat aşağıdaki semptomları daha önce göstermiş insanlarda stres tepkilerine (kalp atışlarının hızlanması, çok nadir ve aşırı durumlarda bayılma gibi) yol açabilir. Bu yüzden çocuğunuz aşağıdaki semptomlardan herhangi birini daha önce geçirdiyse araştırmaya katılması uygun değildir.

- Kardiyovasküler bozukluklar
- Bayılma nöbetleri veya nörolojik nöbetler

Katılım sırasında ölçümlerden ya da herhangi bir uygulama ile ilgili başka bir nedenden ötürü çocuğunuz kendisini rahatsız hissettiğini belirtirse, ya da kendi belirtmese de araştırmacı çocuğun rahatsız olduğunu öngörürse, çalışmaya ölçümler tamamlanmadan ve derhal son verilecektir. Şayet siz çocuğunuzun rahatsız olduğunu hissederseniz, böyle bir durumda çalışmadan sorumlu kişiye çocuğunuzun çalışmadan ayrılmasını istediğinizi söylemeniz yeterli olacaktır.

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için doktora öğrencisi Durukan Durmuş'a ulaşabilirsiniz.

Yukarıdaki bilgileri okudum ve çocuğumun bu çalışmada yer almasını onaylıyorum
(Lütfen alttaki iki seçenekten birini işaretleyiniz)

Evet onaylıyorum ___ ***Hayır, onaylamıyorum ___***

Veli adı-soyadı: _____ Bugünün Tarihi: _____

Çocuğun adı soyadı ve doğum tarihi: _____

(Formu doldurup imzaladıktan sonra araştırmacıya ulaştırınız)

E. DATA COLLECTION FORMS

ÖLÇÜM KAYIT FORMU

Genel Bilgiler				
Adı Soyadı	Yaş Grubu	Cinsiyeti	Doğum Tarihi	Test Tarihi
Antrenman Yaşı	HAS (Özel)		HAS (Fitness)	

Antropometrik Ölçümler			
Boy Uzunluğu	Oturma Yüksekliği	Vücut Ağırlığı	Yağ %

Fiziksel Uygunluk									
El Kavrama		Uzan Eriş		Dikey Sıçrama		Sağlık Topu		T-Çeviklik	
5 m		10 m		20 m		Mekik Koşusu		Response Time	

Servis Hızı				
1	2	3	4	5

KTK Denge	Tekrar	1	2	3	Toplam
	6 cm				
	4,5 cm				
	3 cm				
				Genel Toplam	

KTK Atlama	Yükseklik	0	5	10	15	20	25	30	35	40	45	50	55	60	Toplam
	Sağ														
	Sol														
														Genel Toplam	

KTK Sıçrama	1	2	Toplam	**KTK Taşıma**	1	2	Toplam

Reaksiyon Süresi Ölçümleri

NO	AD/SOYAD	1. BASİT R (EL)	2. SEÇİCİ R (EL)	3. AYRIŞIMLI R (EL)	1. BASİT R (AYAK)	2. SEÇİCİ R (AYAK)	3. AYRIŞIMLI R (AYAK)
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							

F. MENTAL TOUGHNESS SCALE

	Tamamen Yanlış	Çoğunlukla Yanlış	Biraz Yanlış	Ne Doğru Ne Yanlış	Biraz Doğru	Çoğunlukla Doğru	Tamamen Doğru
1.Hedeflerime ulaşma konusunda yeteneğime inanıyorum.							
2.Görevleri yaparken odaklanmamı düzenleyebilirim. /ayarlayabilirim.							
3.İstediğim şekilde performans sergilemek için duygularımı kullanabilirim.							
4.Başarıyı devam ettirebilmek için uğraşıyorum/çaba gösteriyorum.							
5.Hedeflerime ulaşmada gerekli olan bilgimi uygulamada kullanırım.							
6.Genellikle olumsuzlukların (zorlukların) üstesinden gelirim.							
7.Mücadele ederken (meydan okurken) uygun becerileri veya bilgileri uygulayabilirim/kullanabilirim							
8.Çoğu durumda olumlu bir şey bulabilirim.							

G. COACHES' PERSPECTIVE QUESTIONNARE

Çalışmanın Amacı

Bu araştırma, ODTÜ Beden Eğitimi ve Spor Bölümü öğretim üyesi Doç. Dr. Mustafa SÖĞÜT danışmanlığında doktora çalışmasını gerçekleştiren Durukan Durmuş tarafından yürütülmektedir. Araştırmanın amacı, teniste yeteneğin belirlenmesi ve geliştirilmesine yönelik çok boyutlu bir yaklaşım geliştirmektir. Bu amaçla genç tenis oyuncularının ulusal sıralamaları ile ilişkili olabilecek değişkenler incelenecektir.

Aşağıdaki parametrelerin genç tenis oyuncularının sıralamaları üzerindeki etkilerini değerlendiriniz. 1 puan önemli değil, 10 çok önemli anlamına gelmektedir.

Adı ve Soyadı:
Cinsiyet:
Doğum Tarihi:
Antrenörlük Kademesi:
Deneyim (yıl):

Parametre	1	2	3	4	5	6	7	8	9	10
Tenise başlama yaşı										
Haftalık tenis antrenman saati										
Haftalık kondisyon antrenman saati										
İlk turnuva oynadığı yaş										
Katıldığı resmi ulusal turnuva sayısı										
Katıldığı resmi uluslararası turnuva sayısı										
Maç sayısı (tekler)										
Maç sayısı (çiftler)										
Boy uzunluğu										
Vücut Ağırlığı										
Vücut Kitle İndeksi										
Vücut Yağ Yüzdesi										
Büyüme ve biyolojik olgunluk düzeyi										
El kavrama kuvveti										
Alt vücut kuvveti										

Üst vücut kuvveti										
Çeviklik										
Sürat (5 metre)										
Sürat (10 metre)										
Sürat (20 metre)										
Esneklik										
Denge										
Servis hızı										
Motor koordinasyon										
Reaksiyon zamanı										
Aerobik dayanıklılık										
Zihinsel dayanıklılık										

H. CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: DURMUŞ Durukan

Email:

ORCID:

Adress:

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	Ankara University, Department of Physical Education and Sports	2020
BS	Gazi University, Department of Physical Education and Sports	2017

WORKING REFERENCE

2021- Present	Gazi University, Faculty of Sports Sciences	Research Assistant

I. TURKISH SUMMARY / TÜRKÇE ÖZET

GİRİŞ

Tenis, 199 ülkede 106 milyondan fazla katılımcının yer aldığı, küresel düzeyde yaygın ve dikkat çekici bir spordur (ITF Küresel Tenis Raporu, 2024). Wimbledon'ın prestijli çim kortlarından mahalle sahalarına kadar, tenis hem rekreasyonel hem gelişimsel hem de elit düzeyde oynanmakta ve büyük ilgi görmektedir. Bu geniş katılım, bireysel mücadele, teknik çeşitlilik ve her yaş grubuna hitap etmesi gibi unsurların birleşiminden kaynaklanmaktadır.

Popülerliğinin ötesinde tenis, yaşam boyu fiziksel ve zihinsel sağlık açısından önemli katkılar sağlar. Araştırmalar, düzenli tenis oynamanın aerobik kapasiteyi artırdığını, vücut yağ oranını düşürdüğünü, lipid profillerini iyileştirdiğini, kemik yoğunluğunu artırdığını ve kalp-damar hastalıkları ile erken ölüm riskini azalttığını göstermektedir (Chomistek vd., 2012; Pluim vd., 2007). Ayrıca, oyunun karar verme, baskı altında duygusal kontrol ve duruma hızlı uyum sağlama gibi zihinsel talepleri, bütüncül gelişime katkı sunmaktadır (Fernandez-Fernandez vd., 2009).

Tenis performansı, tek bir alandaki yeterlilikle açıklanamayacak çok boyutlu faktörlerin etkileşimiyle şekillenir. Tenis; antropometrik özellikler, fiziksel kapasite, teknik yeterlilik, taktik beceri ve psikolojik özelliklerin bir arada gelişmesini gerektirir (Elferink-Gemser vd., 2011; Kovacs, 2006). Özellikle genç sporcularda biyolojik gelişim, kronolojik yaşı aynı olan bireyler arasında bile güç, hız ve koordinasyon gibi özelliklerde önemli farklılıklar yaratabilir (Myburgh vd., 2016; Söğüt vd., 2019). Motor koordinasyon, temel hareket becerilerinin gelişimi ve bu becerilerin teknik yeterliliğe dönüşmesi için temel bir altyapıdır (Söğüt, 2016; Bisio vd., 2021). Teknik ve taktik yeterlilik ise karar verme, örüntü tanıma ve doğru uygulamalarla doğrudan müsabaka sonuçlarını etkiler (Kolman vd., 2018). Psikolojik özellikler, özellikle zihinsel dayanıklılık ve duygusal kontrol, sporcuların baskı

altında istikrarlı kalmasını sağlar (Cowden vd., 2016; Fernandez-Fernandez vd., 2015). Antrenman geçmişi ve müsabaka deneyimi de oyuncunun gelişim süreci ve performans düzeyini belirleyen önemli faktörlerdendir (Murray & Hunfalvay, 2016).

Son yıllarda tenis branşında yetenek belirleme yaklaşımları önemli ölçüde gelişmiştir. Önceden daha çok fiziksel ölçümlere dayanan geleneksel yaklaşımlar, günümüzde yerini çok boyutlu ve uzun vadeli gelişimi esas alan modellere bırakmıştır (Johnston vd., 2018; Till & Baker, 2020). Bu yeni modeller, yalnızca fiziksel yeterlilikleri değil; aynı zamanda psikolojik, teknik ve çevresel değişkenleri de dikkate almaktadır (Nijenhuis vd., 2024). Antrenör görüşleri, oyuncularla uzun süreli birebir çalışmaları sayesinde, bu alanların gelişim dönemleri içerisindeki önemini değerlendirme açısından çok kıymetlidir (Reid vd., 2009; Crespo vd., 2024).

Ancak, mevcut literatürde farklı performans alanlarının etkisini bir arada değerlendiren çalışmaların sayısı yetersizdir. Gençlik tenisinde sıklıkla yalnızca fiziksel ya da teknik bir özelliğe odaklanılmış; oysa müsabık başarıyı şekillendiren psikolojik, gelişimsel ve çevresel faktörler göz ardı edilmiştir. Bu çalışmada, U12, U14 ve U16 yaş kategorilerindeki elit düzeydeki sporcuların ulusal sıralamaları ile ilişkili unsurlar, bütüncül bir yaklaşımla incelenmiştir. Değerlendirmede; antropometri, fiziksel yeterlilik, motor koordinasyon, psikolojik dayanıklılık, antrenman geçmişi, ekipman özellikleri, maç deneyimi ve antrenör görüşleri dikkate alınmıştır. Bu değişkenlerin birlikte incelenmesi sayesinde, gençlik tenisinde müsabık başarıya katkı sağlayan temel faktörlerin daha iyi anlaşılması ve yetenek seçimi ile gelişiminin bilimsel temellere dayalı olarak yönlendirilmesi hedeflenmiştir.

Teniste Yetenek Belirleme ve Geliştirme

Teniste potansiyel tespiti ve gelişimi, bu branşta kalıcı başarıya katkı sağlayan temel unsurları belirlemek amacıyla çok yönlü şekilde analiz edilmiştir. Genç sporcularda yetenek belirleme ve gelişim süreçlerine yönelik güncel çalışmalar, başarıyı etkileyen çeşitli belirleyici faktörleri ortaya koymuştur.

Tsao, Liu ve Chang (2022), dikey sıçrama, mekik koşusu ve omuz esnekliği gibi testleri kullanarak tenis becerilerini değerlendiren özel bir tarama yöntemi geliştirmiştir. Araştırma, tenis oyuncularının basketbolculara kıyasla daha fazla esnekliğe ihtiyaç duyduğunu ve omuz mobilitesinin etkili servis ve vuruşlar açısından kritik olduğunu göstermiştir. Bu bulgular, tenis özelinde yapılandırılmış değerlendirme protokollerinin gerekliliğini ortaya koymaktadır.

Kolman ve ark. (2021) tarafından yapılan prospektif bir çalışma, top hızı ve isabet oranı gibi teknik parametrelerin, genç erkek tenisçilerde hem mevcut hem de gelecekteki başarı için önemli göstergeler olduğunu ortaya koymuştur. Araştırma, bu becerilerin farklı oyun durumlarında geliştirilmesinin performansı artırmak açısından zorunlu olduğunu vurgulamaktadır.

Chapelle ve ark. (2022) ise yetenek seçimi sürecindeki genç tenisçilerin gelişiminde antropometrik ve fiziksel performans değişkenlerinin etkisini incelemiştir. Elde edilen veriler; hız, çeviklik, sıçrama yeteneği, motor koordinasyon ve tenise özgü becerilerin özellikle 8–10 yaş grubundaki sporcular için seçim şansını anlamlı düzeyde etkilediğini göstermiştir.

Bozidar ve ark. (2014), ergen tenisçilerin psikolojik becerilerini ve bu beceriler ile antrenör katkısı ve liderlik davranışları arasındaki ilişkileri incelemiştir. Bulgular, yaş, cinsiyet ve antrenman bağlamına göre psikolojik profillerde anlamlı farklılıklar olduğunu göstermiştir. Ayrıca, liderlik tarzı gibi belirli psikolojik özelliklerle antrenör katkısı arasında güçlü ilişkiler saptanmış; bu da antrenman metodolojilerinin genç sporcuların psikolojik gelişiminde belirleyici olabileceğini ortaya koymuştur.

Faber ve ark. (2015) tarafından gerçekleştirilen sistematik bir derleme, genç raket sporcularında bireysel yetenek unsurlarını ölçen çok sayıda değerlendirme aracını incelemiştir. Derleme, koordinasyon becerileriyle birlikte bilişsel ve algısal yeteneklere odaklanan ölçümlerin, elit oyuncuları ayırt etmekte etkili olduğunu belirtmiştir. Ancak bu araçların gelecekteki performansı öngörme gücü belirsizliğini korumaktadır. Bu durum, yetenek belirleme süreçlerinde çok boyutlu ve kapsamlı değerlendirme sistemlerine ihtiyaç olduğunu göstermektedir.

Gençlik Tenisinde Performansın Belirleyicileri

Genç sporcularda performans düzeyini etkileyen faktörleri ortaya koymak amacıyla yürütülen literatür çalışmaları, performansın birçok boyutla ilişkili olduğunu göstermektedir. Fiziksel uygunluk (Kramer vd., 2016; Xiao vd., 2022; Sánchez-Pay vd., 2021; Villouta vd., 2021), teknik beceriler (Lambrich & Muehlbauer, 2023), psikolojik özellikler (Gould vd., 2002; MacNamara vd., 2010) ve sosyokültürel etkiler (Baker & Horton, 2004), genç sporcuların başarısında etkili temel alanlardır (Vaeyens vd., 2008).

Fiziksel büyüme ve biyolojik olgunluk, güç, hız ve koordinasyon gibi teknik uygulamaların hassasiyetini doğrudan etkileyen parametrelerdir (Malina vd., 2004; Baxter-Jones vd., 2005). Dayanıklılık, çeviklik ve patlayıcı güç gibi fiziksel yeterlilik özellikleri ise müsabaka temposunu sürdürme ve puanlar arası toparlanma kapasitesiyle ilişkilidir (Roetert & Ellenbecker, 2007; Kovacs, 2007).

Motor yeterlilik, temel hareket becerilerini kapsar ve hem teknik gelişimin hem de taktik uygulamaların temelini oluşturur (Fransen vd., 2012; Vandorpe vd., 2012). Teknik ve taktik beceriler, oyuncunun topu kontrol etme, fırsat yaratma ve rakibin güçlü/zayıf yönlerine göre strateji belirleme kabiliyetini belirler (Reid vd., 2007; Kolman vd., 2018). Bu yönüyle doğrudan maç performansına etki eder.

Psikolojik özellikler —özgüven, dayanıklılık ve odaklanma gibi— bir sporcunun baskı altında karar verme ve tutarlılığı sürdürme becerisini destekler (Weinberg & Gould, 2018; MacNamara vd., 2010). Deneyim, antrenman yaşı ve rekabet ortamı, hem teknik-taktik gelişimi hem de çeşitli maç senaryolarına uyum sağlama becerisini besler (Reid vd., 2008; Hornig vd., 2014).

Antrenörlerin farklı performans alanlarına yönelik görüşleri, gençlik tenisinde başarıya katkı sunan faktörlerin anlaşılmasında kritik önemdedir. Crespo vd. (2024), uluslararası düzeyde yüksek performanslı antrenörlerin tenis performansında önemli gördüğü zihinsel özellikleri ve bu özelliklerin nasıl geliştirildiğine dair yaklaşımlarını incelemiştir. Tüm antrenörler, zihinsel becerilerin tenis başarısı için vazgeçilmez olduğunu vurgulamıştır.

Tenisin çok boyutlu ve karmaşık yapısı, genç oyuncuların gelişiminde fiziksel, teknik, taktik, psikolojik ve deneyimsel birçok değişkenin birlikte değerlendirilmesini zorunlu kılmaktadır. Bu bölümde ele alınan araştırmalar, genç sporcularda başarıya etki eden özellikleri belirlemeyi amaçlamış ve değişkenler arasında fiziksel büyüme, biyolojik olgunluk, motor beceriler, fiziksel yeterlilik, teknik ve taktik yeterlilik, psikolojik dayanıklılık, antrenman ve müsabaka maruziyeti ile antrenör bakış açılarının belirleyici rol oynadığını ortaya koymuştur. Bu çalışma, farklı değişkenleri sentezleyerek tenis gelişiminde etkili olan temel faktörleri açıklamakta; oyuncu seçimi ve gelişiminde kanıta dayalı uygulamaları destekleyecek kapsamlı bir bakış açısı sunmaktadır.

Genç Tenisçilerde Performans Parametrelerine Yönelik Antrenörlerin Bakış Açıları

Crespo, Jiménez ve arkadaşları (2024), uluslararası düzeyde yüksek performanslı tenis antrenörlerinin tenis performansında gerekli olan zihinsel becerilere ilişkin görüşlerini incelemiştir. Bulgular, tüm antrenörlerin zihinsel becerilerin tenis performansı açısından kritik öneme sahip olduğu konusunda fikir birliğine vardığını göstermektedir. Kıdemli antrenörlerin spor psikolojisini daha iyi kavradığı ve daha az deneyimli antrenörlere kıyasla belirli psikolojik becerilerin gelişimine daha fazla önem verdiği görülmüştür. Eğitim düzeyi ve deneyim süresinden bağımsız olarak, tüm antrenörler zihinsel becerileri önemli bulmakta; bu becerilere ilişkin bilgilerin en çok eğitim programları ve saha deneyimi yoluyla edinildiğini belirtmektedir.

Robertson ve ark. (2018), tenis, masa tenisi ve badminton branşlarında görev yapan 177 lisanslı antrenörün; antropometrik özellikler, fiziksel performans ve motor koordinasyon becerilerinin önemi konusundaki görüşlerini incelemiştir. Antrenörler, raket sporları arasında hem belirgin farklılıkları hem de önemli benzerlikleri vurgulamış; performans belirleyicilerini 1 ile 10 arasında derecelendirerek değerlendirmiştir. Sonuçlara göre tüm kriterler genel olarak yüksek puan almış (en düşük: 5,5; en yüksek: 9,4); el-göz koordinasyonu, çeviklik ve çeşitli top kontrol becerileri en yüksek öneme sahip özellikler olarak öne çıkmıştır. Antropometrik ölçümler ve 30 m sprint testi ise görece daha düşük puanlanmıştır. Bu bulgular, tenis

sporunda yetenek tanımlama ve gelişim süreçlerinde hangi niteliklerin öncelikli değerlendirildiğini göstermesi açısından önem taşımaktadır.

Weinberg ve Jackson (1990), lise ve yaş grubu düzeyinde görev yapan tenis antrenörlerinin oyuncularının öz yeterliliklerini artırmak için kullandıkları stratejileri analiz etmiştir. Çalışmada, antrenörlerin 13 farklı yöntem kullandığı saptanmıştır. Bunlar arasında pozitif iç konuşma teşviki, örnek olma, açık talimat verme, uygulamalı tekrar yaptırma, sözel ikna, ödüllendirme ve özgüven kazandırıcı iletişim öne çıkmaktadır. Bu stratejilerin, oyuncuların özgüvenini ve zihinsel dayanıklılığını geliştirmede orta ila yüksek düzeyde etkili olduğu belirtilmiştir. Araştırma, psikolojik destek tekniklerinin ve antrenör katkısının, sporcuların zihinsel hazırlık süreçlerindeki rolünü vurgulamaktadır.

Busuttil ve arkadaşları (2024), tenis antrenörlerinin raket tutuşu gelişimine dair görüşlerini ve kullandıkları yöntemleri araştırmıştır. Çalışmaya, farklı deneyim düzeylerinden toplam 226 akredite antrenör (140 az deneyimli, 86 daha deneyimli) katılmıştır. Antrenörler, tutuş becerilerinin geliştirilmesinin temel teknik gelişimde en kritik unsurlardan biri olduğu görüşünde birleşmiştir. En sık öğretilen tutuşlar şunlardır: forehand için semi-western (%68 az deneyimli, %65 deneyimli), çift el backhand için continental ve eastern kombinasyonu (%59 az deneyimli, %48,8 deneyimli) ve servis için continental tutuş (her iki grup için %94).

Tutuş gelişimini engelleyen başlıca faktörler; alışkanlık (%62 az, %56 deneyimli), rahatsızlık (%58 az, %50 deneyimli) ve özgüven eksikliği (%44 az, %21 deneyimli) olarak tanımlanmıştır. Antrenörlerin %65'i, bu becerileri desteklemek amacıyla fiziksel olarak sınırlayıcı ekipman ve teknikler kullanmaya istekli olduklarını belirtmiştir. Bu çalışma, temel tenis tekniklerinin öğretilmesinde antrenörlerin yaklaşım tarzlarına ışık tutmakta ve antrenman sürecine yönelik kanıta dayalı katkılar sunmaktadır.

Bu bölüm, genç tenisçilere yönelik antrenör perspektiflerini çok boyutlu şekilde ortaya koyarak hem zihinsel gelişim hem de fiziksel-teknik becerilerin öğretimi açısından uygulamalı veriler sağlamaktadır. Antrenörlerin gözünden değerlendirilen bu bakış açıları, yetenek gelişiminde önemli bir rehber niteliğindedir.

Çalışmanın Amacı

Bu çalışmanın amacı, U12, U14 ve U16 yaş kategorilerinde yer alan üst düzey sekiz genç tenisçinin ulusal sıralamaları ile fiziksel, fonksiyonel, psikolojik ve deneyimsel özellikleri arasındaki ilişkileri incelemektir. Ayrıca, performans parametrelerine ilişkin antrenör görüşleri de araştırmaya dâhil edilmiştir.

Araştırma Soruları

Bu çalışma aşağıdaki sorulara yanıt aramaktadır:

(1) U12, U14 ve U16 yaş kategorilerindeki başarılı genç tenisçilerde ulusal sıralamalar ile fiziksel, fonksiyonel, psikolojik ve deneyimsel özellikler arasında nasıl ilişkiler bulunmaktadır?

(2) Antrenörlerin, genç tenisçilerin performansını etkileyecek parametrelere yönelik bakış açıları nelerdir?

Hipotezler

(1) Tüm yaş ve cinsiyet gruplarında, ulusal sıralamalar ile tek bir değişken arasında güçlü ve tutarlı bir ilişki bulunmayacağı öngörülmektedir.

(2) Antrenör görüşlerinin, yaş ve cinsiyete göre farklılık göstereceği beklenmektedir.

Varsayımlar

Kullanılan tüm ölçüm araçlarının geçerli ve güvenilir olduğu; oyuncuların testlerde elinden gelenin en iyisini yaptığı, antrenörler ve diğer katılımcıların doğru ve dürüst yanıtlar verdiği; ulusal sıralamaların ise performansın güvenilir bir göstergesi olduğu varsayılmıştır.

Çalışmanın Önemi

Mevcut tenis performans araştırmaları genellikle fiziksel uygunluk veya teknik becerilere odaklanmakta, ancak başarının çok sayıda faktörün karmaşık etkileşimiyle

şekillendiği göz ardı edilmektedir. Bu çalışma, fiziksel, fonksiyonel, psikolojik ve deneyimsel özelliklerin yanı sıra antrenör görüşlerini de içeren çok boyutlu bir değerlendirme sunmaktadır. Fiziksel uygunluk, reaksiyon süresi, mental dayanıklılık ve motor koordinasyon gibi faktörler ile antrenman süresi, ekipman özellikleri, antrenman hacmi, turnuva katılımı ve maç oynama sayıları gibi değişkenler kapsamlı şekilde analiz edilmiştir. Bu bütüncül yaklaşım, farklı yaş kategorilerindeki tenisçilerin sıralamaları ile ilişkili faktörleri derinlemesine anlamaya olanak tanımaktadır.

Araştırma, demografik, deneyimsel, fiziksel, teknik ve psikolojik değişkenlerin yaş ve cinsiyet gruplarına göre ulusal sıralamalarla ilişkisini inceleyerek tenis yeteneklerinin belirlenmesi ve geliştirilmesine özgün katkılar sağlamaktadır. Çalışmanın hedefi, ulusal düzeyde kendi yaş gruplarında ilk sekizde yer alan seçkin bir oyuncu grubunu incelemek olup, bu sayede bulguların geçerliliği ve yorumlanabilirliği artmaktadır.

Araştırmanın özgünlüğü, çok boyutlu yaklaşımı ve antrenörlerin deneyimlerini ampirik performans verileriyle bütünleştirmesinden kaynaklanmaktadır. Böylece pratik deneyim ile bilimsel değerlendirme arasında bir köprü kurulmuş, genç tenisinde başarı ile ilişkili faktörlerin daha kapsamlı şekilde anlaşılması sağlanmıştır. Elde edilen bulgular, yaş ve cinsiyete özgü performans modelleri hakkında değerli bilgiler sunmakta ve genç tenis programlarında yetenek tanımlama ve bireyselleştirilmiş antrenman stratejilerinin geliştirilmesine katkı sağlamaktadır.

Çalışma çok boyutlu bir yaklaşım kullanarak teniste yetenek belirleme ve geliştirme stratejilerinin iyileştirilmesini hedeflemektedir. Genç tenisçilerin ulusal sıralamalarındaki performans belirleyicilerine dair kapsamlı bir anlayış sunarken, fiziksel, teknik, deneyimsel ve psikolojik değişkenlerin gelişim sürecindeki önemini vurgulamaktadır. Elde edilen bulgular, antrenörler, tenis akademileri ve federasyonlar için rehberlik sağlayarak, oyuncu gelişimi için kanıta dayalı stratejilerin oluşturulmasına katkıda bulunabilir. Ayrıca, çalışma Türkiye'deki yetenek belirleme modellerinin geliştirilmesine destek olarak, ulusal tenis sahnesinde daha donanımlı ve başarılı oyuncuların yetişmesini destekleyebilir.

YÖNTEM

Çalışma Dizaynı

Bu kesitsel kohort çalışması, üst sıralarda yer alan genç tenisçilerin rekabetçi performansını etkileyen faktörleri çok yönlü olarak incelemiştir. Araştırmada, oyuncuların antropometrik özellikleri, fiziksel büyüme ve olgunlaşma durumu, üst ve alt vücut kuvveti, hız, çeviklik, esneklik, aerobik dayanıklılık, motor koordinasyon, reaksiyon zamanı, teknik becerileri (servis hızı) ile psikolojik özellikleri (mental dayanıklılık) detaylı şekilde değerlendirilmiş; ayrıca turnuva ve maç kayıtları ile antrenörlerin performans değerlendirmeleri de çalışmaya dâhil edilmiştir.

Çalışma, bu özelliklerin ulusal sıralamalarla ilişkisini incelemek amacıyla nicel ve kesitsel bir yöntem kullanmıştır. Betimsel istatistikler ile yaş grupları ve cinsiyetlere göre ortalama değerler sunulurken, korelasyon analizleri sıralamadaki başarıyı etkileyen önemli faktörleri ortaya koymuştur. Bu yaklaşım, birey ile çevresi arasındaki etkileşimi çok boyutlu olarak ele alan Biyoekolojik Model ile uyumludur. Böylece, tenis sporunda performansı etkileyen faktörlerin belirlenmesi ve yetenek tanımlama ile geliştirme çalışmalarının daha etkili yapılması mümkün olmuştur.

Katılımcılar

Bu araştırmaya, Türkiye'deki milli takım seçme kamplarına katılan toplam 46 elit düzeyde genç tenisçi dâhil edilmiştir. Katılımcılar U12, U14 ve U16 yaş kategorilerinde, yaş gruplarının her birinde sıralamada ilk sekizde yer alan müsabık sporculardan oluşmaktadır. Seçim kriterleri, Türkiye Tenis Federasyonu'na resmi kayıtlı olmak ve ilgili yaş kategorisinde yapılan milli takım seçmelerinde ilk sekize girmiş olmak şeklinde belirlenmiştir.

Sporcuların doğum tarihleri, antrenman yaşı, haftalık antrenman süresi, ilk turnuva yaşları, oynadıkları ulusal ve uluslararası turnuva sayıları, resmi maç sayıları, raket ağırlığı ve tel gerginliği gibi detaylı antrenman ve ekipman bilgileri toplanmıştır.

Araştırma için etik onay ilgili üniversitenin Etik Kurulu'ndan alınmış, katılımcılara ve velilerine araştırmanın amacı anlatılmış, yazılı onam alınmıştır.

Ölçümler

Araştırmada, oyuncuların fiziksel, teknik, motor, psikolojik ve deneyimsel özelliklerini değerlendirmek amacıyla çok yönlü test bataryaları uygulanmıştır:

Antropometrik ölçümler arasında boy (ayakta ve oturarak), kilo, bacak uzunluğu ve vücut yağ oranı yer almıştır. Boy ve kilo ölçümleri taşınabilir ölçüm cihazlarıyla, vücut kompozisyonu analizleri ise çok frekanslı segmental cihazlarla yapılmıştır. Biyolojik olgunluk durumu, Mirwald ve arkadaşlarının (2002) geliştirdiği APHV (en yüksek boylanma hızı yaşı) yöntemiyle tahmin edilmiştir.

Fiziksel yeterlilik, kavrama kuvveti (el dinamometresiyle), alt vücut kuvveti (CMJ testi), üst vücut kuvveti (1 kg'lık sağlık topu atışı), sprint (5 m ve 10 m), çeviklik (T-testi), esneklik (otur-uzan testi), servis hızı (radar tabancası) ve aerobik dayanıklılık (20 m mekik testi) gibi ölçümlerle değerlendirilmiştir.

Motor koordinasyon için KTK (Körperkoordinationstest für Kinder) testi uygulanmıştır. Bu test; geriye denge, zıplama, yanal sıçrama ve platformda yanal geçiş alt testlerinden oluşmaktadır (Kiphard & Schilling, 2007).

Reaksiyon süresi değerlendirmelerinde BlazePod cihazı ve Çağın protokolü kullanılmış; sporcuların görsel uyarılara el ve ayakla verdikleri yanıt süreleri ölçülmüştür.

Zihinsel dayanıklılık, Gucciardi ve arkadaşlarının geliştirdiği ölçeğin Türkçe uyarlaması olan "Sporda Zihinsel Dayanıklılık Ölçeği" ile değerlendirilmiştir (Özgör & Aşçı, 2018).

Antrenör görüşleri, ulusal antrenörler ve spor bilimcilerle hazırlanan 27 maddelik yapılandırılmış anket aracılığıyla toplanmıştır. Antrenörlerden, bu belirleyicileri önem sırasına göre 1 (en az) ila 10 (en çok) arasında derecelendirmeleri istenmiştir.

Maç deneyimine dair bilgiler, oyuncuların ilk turnuva yaşları, toplam ulusal ve uluslararası maç sayıları, çiftler ve tekler maç sayıları gibi değişkenleri kapsamakta olup, resmi federasyon kayıtları kullanılarak elde edilmiştir.

Veri Toplama Süreci

Veriler, 2024 Haziran–Temmuz aylarında Türkiye Tenis Federasyonu merkezinde düzenlenen milli takım kamplarında, üç günlük beş oturum boyunca toplanmıştır. U14, U16 erkek, U12 ve U16 kız kamplarının ardından, her yaş grubundaki antrenörler (n=7), 27 performans belirleyicisine yönelik görüş anketini doldurmuştur.

1. Oturum (1. Gün sabah): Demografik bilgiler, antropometrik ölçümler, zihinsel dayanıklılık ölçeği.
2. Oturum (1. Gün öğleden sonra): Fiziksel uygunluk testleri ve servis hızı.
3. Oturum (2. Gün sabah): Motor koordinasyon (KTK).
4. Oturum (2. Gün öğleden sonra): Reaksiyon zamanı testleri.
5. Oturum (3. Gün): Aerobik dayanıklılık (bip testi).

Testler arasında yeterli dinlenme süreleri verilmiş, antrenman ve turnuva yükleriyle çakışmaması için dikkatli bir planlama yapılmıştır. Kamplar sırasıyla U14, U16 erkek, U12 ve U16 kız grupları için düzenlenmiştir. Kamplar sonrasında antrenörlerden anket yoluyla değerlendirmeler alınmıştır.

Belirli testlere katılamayan sporcular (sakatlık, hastalık, vb.) belgelenmiş ve ilgili analizlerden çıkarılmıştır.

İstatistiksel Analiz

Tüm değişkenler yaş ve cinsiyete göre ayrı ayrı analiz edilmiş, tanımlayıcı istatistikler (ortalama ± SD) raporlanmıştır. Pearson korelasyon katsayıları kullanılarak ulusal sıralama ile performans değişkenleri arasındaki ilişkiler değerlendirilmiştir. Etki büyüklükleri Hopkins vd. (2009) kriterlerine göre yorumlanmış, anlamlılık düzeyi $p < 0.05$ olarak kabul edilmiştir. Veriler SPSS 28.0 programıyla analiz edilmiştir.

BULGULAR

Bu bölümde, ulusal sıralamalar ile fiziksel, teknik, motor koordinasyon, psikolojik ve deneyimsel değişkenler arasındaki ilişkiler Pearson korelasyon analizi ile değerlendirilmiştir. Ayrıca, antrenörlerin yaş gruplarına göre farklı performans parametrelerine verdikleri önem düzeyleri raporlanmıştır. Bunun yanı sıra, tenis branşında daha düşük sıralama rakamlarının daha yüksek rekabet performansını ifade ettiği hususu da özellikle vurgulanmıştır.

U12 kız grubunda, uluslararası turnuvalara katılım ($r = -0.829$, $p = 0.011$) ve tel gerginliği ($r = -0.732$, $p = 0.039$) ile sıralama arasında güçlü negatif ilişkiler tespit edilmiştir. Bu, daha fazla uluslararası tecrübenin ve yüksek tel gerginliğinin daha iyi sıralama ile ilişkili olduğunu göstermektedir. Öte yandan, kavrama kuvveti ($r = 0.730$, $p = 0.040$), esneklik (otur-uzan testi; $r = 0.884$, $p = 0.004$) ve motor koordinasyon (KTK toplam puanı; $r = 0.711$, $p = 0.048$) ile sıralama arasında anlamlı pozitif ilişkiler bulunmuştur. Ayrıca vücut yağ yüzdesi ($r = 0.866$, $p = 0.005$) ve vücut kitle indeksi (VKİ; $r = 0.850$, $p = 0.008$) de daha kötü sıralamalarla ilişkili bulunmuştur.

U12 erkeklerde, turnuvaya başlama yaşı ile sıralama arasında neredeyse mükemmel düzeyde pozitif bir ilişki görülmüştür ($r = 0.917$, $p = 0.001$). Bu bulgu, spora erken yaşta başlayan sporcuların sıralamada daha üst sıralarda yer alma eğiliminde olduğunu göstermektedir.

U14 kızlarda, sıralama ile herhangi bir değişken arasında istatistiksel olarak anlamlı bir korelasyon bulunmamıştır. Ancak U14 erkeklerde; ulusal ve uluslararası tekler ve çiftler maç sayısı ile toplam müsabaka sayılarının sıralama ile güçlü negatif ilişkili olduğu gözlemlenmiştir (örneğin, uluslararası çift maç sayısı $r = -0.970$, $p = 0.001$). Bu durum, yoğun müsabaka deneyiminin sıralama başarısına katkısını ortaya koymaktadır. Ayrıca, vücut yağ yüzdesi de sıralama ile negatif yönde ilişkili bulunmuştur ($r = -0.848$, $p = 0.033$).

U16 kız sporcularda toplam maç sayısı ile sıralama arasında negatif ve anlamlı ilişki görülmüştür ($r = -0.730$, $p = 0.040$). Bu, maç deneyiminin bu yaş grubunda da

başarıyı desteklediğini göstermektedir. Ayrıca boy persentil değerleri ile sıralama arasında da anlamlı bir ilişki mevcuttur ($r = -0.720$, $p = 0.048$).

U16 erkeklerde ise uluslararası çift maç sayısı ($r = -0.759$, $p = 0.029$), toplam uluslararası maç sayısı ($r = -0.722$, $p = 0.043$) ve sağlık topu atışı performansı ($r = -0.759$, $p = 0.029$) ile sıralama arasında güçlü negatif ilişkiler bulunmuştur. Bu da uluslararası müsabaka deneyimi ile üst vücut kuvvetinin, bu yaş grubundaki sporcuların sıralama başarısı üzerinde etkili olduğunu göstermektedir.

Antrenörlerin yaş gruplarına göre performans parametrelerine yönelik bakış açıları incelenmiştir. Milli takım antrenörleri, her yaş grubu için performans belirleyicilerini 1 (en az önemli) ile 10 (en önemli) arasında puanlamıştır. U12 erkek grubunda motor koordinasyon, çeviklik ve spora başlama yaşı ön plana çıkarken; motor koordinasyon en yüksek puanla değerlendirilmiştir. U12 kızlarda da benzer şekilde motor koordinasyon öne çıkarken; çeviklik ve denge unsurları da önemsenmiştir.

U14 kız grubunda motor koordinasyon yine en yüksek puanı almış; reaksiyon süresi, biyolojik olgunluk seviyesi ve haftalık antrenman süresi de dikkat çeken diğer unsurlar olmuştur. U14 erkeklerde ise zihinsel dayanıklılık, motor koordinasyon ve çeviklik en çok vurgulanan parametreler arasında yer almıştır.

U16 sporcularda ise hem kız hem erkek gruplarda zihinsel dayanıklılık en çok önem verilen özellik olarak öne çıkmıştır. Kızlarda bunun yanında 5 metre sprint süresi, haftalık antrenman hacmi ve maç sayısı; erkeklerde ise servis hızı gibi parametreler de dikkate alınmıştır.

Bu bulgular, antrenörlerin yaş gruplarına özgü performans önceliklerine sahip olduğunu göstermekte ve motor becerilerden psikolojik faktörlere geçişin gelişimsel olarak nasıl şekillendiğine dair ipuçları sunmaktadır.

TARTIŞMA

Genç müsabık tenisçilerin başarıya ulaşmasında etkili olan faktörlerin anlaşılması, yetenek tanımlama ve sporcu gelişimi açısından kritik öneme sahiptir. Bu çalışmada

elde edilen bulgular, ulusal sıralamalar ile demografik veriler, antrenman ve müsabaka geçmişi, fiziksel özellikler, teknik yeterlilik ve psikolojik beceriler gibi çok boyutlu değişkenler arasında anlamlı ilişkiler olduğunu ortaya koymuştur. Yaş ve cinsiyete göre farklılık gösteren bu ilişkiler, genç tenisçilerin gelişimini etkileyen faktörlerin karmaşık doğasını vurgulamaktadır.

U12 erkek sporcularda, turnuvaya başlama yaşının sıralama ile güçlü ilişkisi, erken rekabet ortamına girmenin gelişim sürecini hızlandırabileceğini göstermektedir. Bu bulgu, Zappalà ve arkadaşlarının (2024) erken başarı ile uzun vadeli performans arasında kurduğu ilişkiyle örtüşmektedir. Ancak literatürde, erken branşlaşmanın uzun vadeli bazı riskleri (örneğin sakatlık, tükenmişlik) beraberinde getirebileceği ve çoklu spor geçmişinin olumlu etkileri olabileceği de belirtilmiştir (DiFiori vd., 2014). U12 kız sporcularda, uluslararası turnuva tecrübesinin sıralama ile güçlü ilişkisi; U14 ve U16 erkeklerde ise hem ulusal hem de uluslararası maç sayısının sıralama başarısını olumlu etkilediği görülmüştür. U16 kızlarda da benzer şekilde maç sayısı başarıyla ilişkili bulunmuştur. Bu bulgular, müsabaka deneyiminin oyun bilgisi, zihinsel dayanıklılık ve teknik yeterliliği geliştirmedeki rolünü desteklemektedir (García-González vd., 2015; Schinke vd., 2012). Ancak fazla müsabakaya bağlı yorgunluk ve sakatlık riski gibi potansiyel olumsuzluklara da dikkat edilmelidir (Brenner vd., 2024; Carter, 2021).

Biyolojik olgunluk göstergeleri ile sıralama arasındaki ilişki, genel olarak anlamlı bulunmamıştır. Bu sonuç, Lopez-Plaza vd. (2022) ve Söğüt vd. (2023) gibi çalışmalarla uyumludur. Özellikle kız sporcularda, fiziksel olgunluğun sıralamaya etkisi erkeklere göre daha belirgin olabilmektedir. Bununla birlikte, tenisin yalnızca fiziksel avantajlara değil; teknik, taktik ve zihinsel becerilere de dayalı bir spor olduğu göz önüne alındığında, erken olgunlaşma avantajı bu branşta daha sınırlı etkiye sahip olabilir.

Fiziksel uygunluk açısından elde edilen bulgular da dikkat çekicidir. Örneğin U12 kızlarda düşük kavrama kuvveti ve esnekliğin daha iyi sıralamalarla ilişkili olması, bu yaşta üst vücut kuvvetinden ziyade teknik etkinliğin ve hareket verimliliğinin daha belirleyici olabileceğini düşündürmektedir. U16 erkeklerde ise sağlık topu

atışıyla ölçülen üst vücut kuvveti ile sıralama arasındaki pozitif ilişki, yaşla birlikte kuvvetin önem kazandığını göstermektedir. Buna karşılık, sıçrama, sprint, dayanıklılık ve reaksiyon süresi gibi diğer ölçütlerle sıralama arasında belirgin bir ilişki bulunmamıştır. Bu da genç yaş gruplarında teknik becerilerin ve oyun bilgisi gibi unsurların fiziksel kapasiteden daha belirleyici olabileceğine işaret etmektedir.

Motor koordinasyonla ilgili bulgular bazı yaş gruplarında dikkat çekici ters ilişkilere işaret etmiştir. U12 kızlarda daha düşük KTK puanına sahip oyuncuların daha yüksek sıralamada yer alması, koordinasyon becerilerinin gelişimsel dönemlerde dalgalanabileceğini göstermektedir. Özellikle hızlı büyüme dönemlerinde koordinasyonda geçici düşüşler yaşanabilir (Corso, 2018). Bunun yanı sıra, bazı sporcular genel motor becerileri sınırlı olsa da spora özgü teknik becerilerle başarı sağlayabilir. Bu durum, erken yaşta sadece tenise odaklanan sporcuların genel motor yeterlilikte geride kalmasına rağmen teknik açıdan avantajlı olabileceğini göstermektedir (Myer vd., 2015). Daha ileri yaş gruplarında ise sıralama ile motor koordinasyon arasında anlamlı ilişki bulunmaması, oyuncular olgunlaştıkça motor koordinasyonunun ötesindeki faktörlerin performansta daha önemli bir rol oynadığını öne sürmektedir (Dirik & Söğüt, 2021).

Servis hızı ile sıralama arasında tüm yaş gruplarında anlamlı bir ilişki bulunmamıştır. Bu, genç yaş gruplarında sadece servis hızının değil; isabetlilik, spin, yerleşim ve taktik çeşitliliğin daha belirleyici olduğunu göstermektedir (Kovacs & Ellenbecker, 2011; Kovalchik & Reid, 2017). Ayrıca etkili servis tekniklerinin temelinde doğru biyomekanik ve vuruş zinciri koordinasyonu yer aldığından, ham hızdan çok teknik kalite öne çıkmaktadır (Girard vd., 2007).

Zihinsel dayanıklılık ile sıralama arasında istatistiksel olarak anlamlı bir ilişki bulunmamakla birlikte, U16 erkeklerde orta düzeyde negatif bir korelasyon gözlenmiştir. Bu durum, bilişsel gelişimle birlikte zihinsel becerilerin ileri yaşlarda daha belirleyici hâle geldiğini göstermektedir (Cowden, 2016). Ayrıca öz bildirimle toplanan psikolojik verilerin sınırlı güvenilirliğe sahip olabileceği unutulmamalıdır. Bu nedenle, zihinsel dayanıklılığın sporda etkisini daha net anlayabilmek için çok yönlü değerlendirme araçlarına ihtiyaç vardır.

Antrenörler, yaş gruplarına göre farklı önceliklere sahip olduklarını ortaya koymuştur. U12 ve U14 kızlarda motor koordinasyon, temel teknik beceriler ve denge gibi özellikler ön plandayken; U14 erkekler ve U16 sporcularda zihinsel dayanıklılık öne çıkmaktadır. Bu değişim, gelişimsel sürecin ihtiyaçlarına uygun planlanmış bir antrenör yaklaşımıyla da örtüşmektedir. Antrenörlerin motor becerilerden psikolojik hazırlığa uzanan bu geçişi dikkate alarak programlarını yapılandırmaları, uzun vadeli başarı için önemlidir.

SINIRLAMALAR VE GELECEK ÇALIŞMALAR İÇİN ÖNERİLER

Bu çalışmanın bazı metodolojik ve uygulamaya yönelik sınırlamaları bulunmaktadır. Aşağıda belirtilen kısıtlılıklar, bulguların yorumlanmasında ve gelecekteki araştırmaların tasarımında dikkate alınmalıdır.

Bu çalışmada, müsabaka içi taktiksel davranışlara ilişkin veri toplanmamıştır. Oyun içi pozisyon alma, vuruş seçimi ve karar verme süreçleri gibi performansı doğrudan etkileyen taktik unsurlar analiz edilmemiştir. Oysa tenis gibi stratejiye dayalı sporlarda, taktik yeterlilik başarı üzerinde belirleyici olabilir. Bu nedenle, ilerleyen çalışmalarda maç içi oyun çözümlemeleri ve taktik zekâyı değerlendiren ölçütlerin dahil edilmesi önerilir.

Psikolojik değerlendirme yalnızca zihinsel dayanıklılık ölçeğiyle sınırlı kalmıştır. Konsantrasyon, motivasyon, öz düzenleme ve kaygı gibi diğer önemli psikolojik faktörler değerlendirme dışında bırakılmıştır. Genç sporcuların performansı, birçok psikolojik değişkenin etkileşimiyle şekillendiğinden, ileriki araştırmalarda daha kapsamlı ve çok boyutlu psikolojik test bataryaları kullanılmalıdır.

Çalışmada teknik beceri değerlendirmesi yalnızca servis hızıyla yapılmıştır. Ancak isabetlilik, vuruş çeşitliliği (forehand, backhand, vole, smaç vb.) ve oyun içinde bu becerilerin uygulanabilirliği ölçülmemiştir. Teknik performans, özellikle genç yaş gruplarında yalnızca kuvvet temelli bir göstergeyle değerlendirilemeyecek kadar karmaşıktır. Gelecek çalışmalarda, hem beceriye dayalı vuruş testleri hem de isabet ve karar verme temelli ölçümler dahil edilmelidir.

Bu çalışma, çok boyutlu bir çerçeve sunmasına rağmen, bazı kritik alanlarda daha detaylı ölçümlere ihtiyaç duyulduğunu göstermektedir. Bu eksikliklerin giderilmesi, genç tenisçilerin performansını daha kapsamlı biçimde analiz etmeye ve yetenek gelişim süreçlerini daha etkili yönlendirmeye katkı sağlayacaktır.

PRATİK ÇIKARIMLAR

Bu çalışmanın sonuçları, genç tenisçilerin gelişimini ve ulusal sıralamalardaki ilerlemelerini optimize etmeyi hedefleyen antrenörler, spor bilimciler ve tenis federasyonları için açık, kapsamlı ve kanıta dayalı bir rehber sunmaktadır. Bulgular, özellikle uluslararası düzeyde müsabaka deneyiminin, tüm yaş gruplarında üst sıralarda yer alma ile güçlü ve tutarlı bir ilişki gösterdiğini ortaya koymuştur. Bu nedenle antrenörler ve federasyonlar, oyuncuların erken yaşlardan itibaren üst düzeyde rekabet edebilecekleri yapılandırılmış müsabaka yolları oluşturmalıdır.

U12 yaş grubunda, özellikle kız sporcularda uluslararası turnuvalara katılım, daha üst sıralamalarla anlamlı düzeyde ilişkilendirilmiştir. Bu durum, erken yaşta uluslararası deneyimin oyuncu gelişimi açısından kritik bir unsur olduğunu göstermektedir. Ekipman tercihleri de performans üzerinde etkili olabilir; özellikle daha düşük tel gerginliğinin (muhtemelen artan güç üretimi sayesinde) daha iyi sıralamalarla ilişkili olduğu gözlemlenmiştir. Dikkat çekici şekilde, U12 kızlarda daha düşük kavrama gücü, esneklik ve motor koordinasyon puanlarının daha iyi sıralamalarla ilişkilendirilmesi, bu dönemde bu özelliklere aşırı odaklanmanın yararlı olmayabileceğini düşündürmektedir. Bu nedenle antrenmanlar, spora özgü hareket verimliliğinin geliştirilmesine ve müsabaka deneyiminin artırılmasına odaklanmalıdır. U12 erkeklerde ise turnuvalara daha erken yaşta katılımın, sıralamada daha üst pozisyonlara ulaşmakla anlamlı bir ilişkisi bulunmuştur. Bu durum, erken yaşta müsabık ortamlara girmenin uzun vadeli gelişim açısından değerli olabileceğini göstermektedir.

U14 grubunda özellikle erkek sporcularda, ulusal ve uluslararası düzeyde oynanan tekler ve çiftler maç sayısının yüksek olması, sıralamayla güçlü şekilde ilişkilendirilmiştir. Bu bulgular, planlı müsabaka takvimi ve stratejik rekabet

yüklemesinin gerekliliğini ortaya koymaktadır. İlginç şekilde, bu yaş grubundaki erkek sporcularda vücut yağ yüzdesi daha yüksek olanların daha iyi sıralamalara sahip olduğu görülmüştür. Bu bulgu, her zaman daha düşük yağ oranının avantaj sağlamadığını ve bireyselleştirilmiş fiziksel gelişim planlarının uygulanmasının önemini göstermektedir. U14 kızlarda anlamlı istatistiksel ilişki saptanmamış olsa da uluslararası maç deneyimi arttıkça sıralama performansında pozitif bir eğilim olduğu görülmektedir. Bu grupta da koçların müsabaka katılımını teşvik ederken oyuncunun bireysel gelişim eğrisine uygun, aşamalı bir antrenman planı geliştirmeleri önerilmektedir.

U16 yaş grubunda, rekabet deneyiminin önemi güçlü biçimde devam etmektedir. U16 kız sporcularda toplam maç sayısının artışı, sıralamada üst pozisyonlara ulaşma ile doğrudan ilişkilidir. Ayrıca bu grupta, daha kısa boya sahip sporcuların daha yüksek sıralamalarda yer alması dikkat çekmiştir. Bu durum, başarıyı etkileyen faktörlerin sadece antropometrik avantajlara değil, oyun tarzı ve çeviklik temelli stratejilere de bağlı olabileceğini göstermektedir. U16 erkeklerde ise sağlık topu atışıyla ölçülen üst vücut gücü ve uluslararası çift maç sayısı ile sıralama arasında anlamlı ilişkiler bulunmuştur. Bu bulgular, güç temelli antrenmanların özellikle bu yaş grubunda programlara entegre edilmesi gerektiğine işaret etmektedir. Ayrıca, zihinsel dayanıklılık ile sıralama arasında istatistiksel olarak anlamlı olmasa da orta düzeyde bir ilişki saptanmıştır. Bu da psikolojik dayanıklılığın, performansa katkı sağlayan önemli bir unsur olabileceğini göstermektedir.

Paydaşlara Yönelik Öneriler

Bu bulgular, genç tenisçilerin gelişim süreçlerinde rol oynayan tüm paydaşlara yönelik mesajlar içermektedir:

Antrenörler: Uluslararası müsabaka deneyimini teşvik etmeli, antrenmanları yaşa özel ihtiyaçlara göre yapılandırmalı ve genel fiziksel gelişimden ziyade spora özgü beceri adaptasyonlarına odaklanmalıdır.

Ebeveynler: Fiziksel gelişimle ilgili gerçekçi beklentilere sahip olmalı, çocukların belirli fiziksel standartlara ulaşmaları için baskı yapılmamalı ve yapılandırılmış müsabaka takvimlerinin değeri konusunda bilgilendirilmelidir.

Federasyonlar, akademiler ve kulüpler: Özellikle U12 ve U14 yaş gruplarındaki oyuncular için erken uluslararası deneyim kazandıracak planlı ve erişilebilir rekabet yolları oluşturmalı, buna paralel olarak yaşa ve gelişim düzeyine uygun fiziksel ve zihinsel gelişim programlarını da desteklemelidir.

Kuvvet ve kondisyon uzmanları: Yaş grubuna özgü sıralama belirleyicilerine göre programlarını özelleştirmeli; örneğin genç yaş gruplarında esneklik ve kavrama kuvveti birinci öncelik olmayabilirken, ileri yaş gruplarında kuvvet gelişimine öncelik verilebilir.

Antrenman, müsabaka ve gelişim programlarının bu bilimsel bulgularla uyumlu hale getirilmesi, genç tenisçilerin performanslarını üst düzeye çıkarmalarına ve ulusal sıralamada daha üst düzey başarılara ulaşmalarına önemli katkılar sağlayacaktır.

SONUÇ

Bu çalışma, uygulanan testlerin genç tenisçilerdeki performans belirleyicilerinin bir kısmını açıklayabildiğini göstermiştir. Bulgular, ulusal sıralamaların yaş ve cinsiyete göre farklı faktörler ile ilişkili olduğunu ortaya koymuştur.

U12 kız sporcularda, uluslararası turnuvalara katılım sıralamayla pozitif ilişkili bulunurken; daha düşük tel gerginliği tercihinin de sıralama üzerinde olumlu etkisi olduğu gözlemlenmiştir. İlginç şekilde, kavrama gücü, esneklik, motor koordinasyon, vücut yağ oranı ve VKİ değerleri arttıkça sıralamanın düştüğü görülmüştür. Bu durum, bu yaş grubunda fiziksel parametrelere aşırı odaklanmanın performansla doğrudan örtüşmeyebileceğini düşündürmektedir. Antrenmanların, daha çok spora özgü hareket verimliliğini ve maç deneyimini geliştirmeye yönelik olması önerilmektedir. U12 erkeklerde, turnuvalara erken yaşta katılım, sıralama ile neredeyse mükemmel düzeyde ilişkilendirilmiştir. Bu, erken yaşta müsabaka ortamına girmenin gelişim üzerindeki olumlu etkisini vurgulamaktadır.

U14 kızlarda istatistiksel olarak anlamlı bir ilişki saptanmamış olmakla birlikte, eğilimler uluslararası maç deneyiminin sıralama üzerinde etkili olabileceğini

göstermektedir. U14 erkeklerde ise özellikle uluslararası düzeyde oynanan maç sayısı ile sıralama arasında güçlü negatif korelasyonlar saptanmıştır. Ayrıca, bu yaş grubunda daha yüksek vücut yağ yüzdesine sahip sporcuların daha üst sıralarda yer alması dikkat çekicidir. Bu bulgu, fiziksel kompozisyonun idealize edilmesinden ziyade bireysel farklılıklara dayalı yaklaşımların önemini göstermektedir.

U16 kızlarda toplam maç deneyimi sıralamayla pozitif ilişkili bulunmuştur. Bu, bu yaş grubunda düzenli olarak maç oynamanın gelişimi desteklediğini ortaya koymaktadır. Ayrıca, daha kısa boya sahip sporcuların sıralamada daha avantajlı olduğu gözlemlenmiştir. Bu durum, oyun tarzı tercihlerinde çeviklik ve hareket ekonomisinin öncelik kazandığını düşündürmektedir.

U16 erkeklerde ise uluslararası çiftler müsabaka deneyimi ile sağlık topu atışı performansı (üst vücut gücü) sıralamayla anlamlı ilişki göstermiştir. Zihinsel dayanıklılık ve VKİ de pozitif eğilim göstermiş ancak istatistiksel anlamlılığa ulaşmamıştır. Bu sonuçlar, performans belirleyicileri arasında fiziksel, psikolojik ve deneyimsel unsurların etkileşimini göstermektedir.

Katılımcıların %41,4'ü KTK testinde normalin üzerinde motor koordinasyon seviyeleri göstermiştir. Antrenör görüşleri, U12 sporcular ve U14 kızlar için motor koordinasyonu önemli bir performans belirleyicisi olarak vurgularken; U14 erkekler ve U16 gruplarında zihinsel dayanıklılık öncelikli faktör olarak değerlendirilmiştir. Bu, gelişim dönemlerine göre öncelikli performans alanlarının değişkenlik gösterdiğini ve antrenman programlarının buna göre yapılandırılması gerektiğini ortaya koymaktadır.

Bu bulgular, müsabaka deneyimi, motor koordinasyon ve zihinsel dayanıklılık gibi çok boyutlu unsurların bir araya gelerek başarıyı şekillendirdiğini göstermektedir. Genç sporcularda rekabet ortamına erken maruz kalmanın, hareket becerilerinin geliştirilmesinin ve zihinsel hazırlığın desteklenmesinin uzun vadeli gelişim için kritik olduğu anlaşılmaktadır.

Çalışmanın genel sonuçları, demografik bilgiler, antrenman geçmişi, ekipman tercihleri, fiziksel gelişim düzeyi, fiziksel yeterlilik, teknik beceriler, motor

koordinasyon, psikomotor yetenekler ve antrenör değerlendirmeleri gibi birçok bireysel değişkenin sıralamayla ilişkili olduğunu ortaya koymaktadır. Ancak bu ilişkilerin yaş gruplarına göre tutarlılık göstermemesi, her yaş grubu için farklı gelişim stratejilerinin gerekliliğine işaret etmektedir.

Turnuva deneyimi, incelenen tüm yaş kategorilerinde (U12, U14, U16) sıralamayla anlamlı ilişki gösteren tek değişken olmuştur. Bu bulgu, müsabaka ortamına daha fazla katılımın puan biriktirme, maç pratiği ve stresle başa çıkma gibi konularda kümülatif avantaj sağladığını göstermektedir.

Sonuç olarak, tenis performansı tek bir alan üzerinden değerlendirilemez. Bunun yerine, gelişimsel, fiziksel, teknik, bilişsel, psikolojik ve deneyimsel faktörlerin bütünsel şekilde dikkate alındığı çok boyutlu yaklaşımlara ihtiyaç vardır. Bu çalışma, genç tenisçilerin gelişiminin tüm aşamalarında uygulanabilecek kapsamlı bir bakış açısı sunarak, tenis branşında yetenek belirleme ve oyuncu gelişimi literatürüne anlamlı bir katkı sağlamaktadır.

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