PEAK ANAEROBIC POWER IN EARLY ADULTHOOD DIFFERENCES ACROSS AGE GROUPS IN REGIONAL MALE TENNIS PLAYERS

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Abstract

Tennis is a high-intensity intermittent sport requiring substantial anaerobic capacity for explosive actions such as powerful serves, rapid accelerations, and quick directional changes during short rallies. This cross-sectional study examined age-related differences in anaerobic capacity among 500 district-level male tennis players in Tamil Nadu, India, divided into four equal groups (n=125 each): The participants were classified into four distinct age groups: 16–20 years, 21–25 years, 26–30 years, and 31–35 years. Anaerobic capacity was measured using the Margaria-Kalamen Anaerobic Power Test, with power output expressed in Watts per kilogram (W/kg). A true random group design was employed, with participants randomly selected and tested under standardized conditions following a pilot study confirming test reliability (intra-class correlation r=0.95). One-way ANOVA revealed highly significant differences across age groups ($F=202.34$, $p<0.05$). Peak anaerobic capacity occurred in the 21–25 years group (mean: 78116 ± 8129.8 W/kg), followed by the 16–20 years group (73784 ± 5907.13 W/kg), with progressive declines in the 26–30 years (66029 ± 5446.4 W/kg) and 31–35 years groups (61575 ± 2610.4 W/kg). Scheffé's post-hoc tests confirmed significant pairwise differences, highlighting maximal explosive power in early adulthood. These findings align with physiological maturation patterns, where fast-twitch fiber efficiency and neuromuscular power peak in the early-to-mid 20s, followed by age-related declines moderated by sustained tennis training. In regional Indian contexts, the results underscore the importance of explosive power-focused interventions (e.g., sprint intervals, plyometrics) during youth for performance optimization and maintenance strategies for older players to support longevity and injury prevention. This emphasizes tennis as a sport rewarding targeted anaerobic development across age groups.

Keywords: Tennis, anaerobic capacity, Margaria-Kalamen test, explosive power, age groups, racket sports, district-level athletes, India.

INTRODUCTION

Tennis is an explosive, intermittent sport that requires high anaerobic capacity to support rapid accelerations, powerful serves, forceful groundstrokes, and quick directional changes during short rallies, which typically last under 10 seconds (Kovacs, 2007; Fernandez-Fernandez et al., 2025). Anaerobic power, primarily derived from the alactic and glycolytic systems, enables maximal intensity efforts essential for point-winning actions, while efficient recovery between bursts relies on aerobic contributions (Kilit & Arslan, 2025; Yang et al., 2025). Recent investigations highlight that anaerobic fitness strongly correlates with repeated-sprint ability, on-court performance, and overall match success in 9competitive players. Age significantly modulates anaerobic capacity, with peak values often emerging in early-to-mid adulthood due to optimal neuromuscular function, fast-twitch fiber efficiency, and hormonal profiles (Pluim & Staal, 2025; Ruiz et al., 2025) In youth athletes, maturation enhances explosive power, whereas post25–30 years, natural declines in muscle quality and power output may occur without targeted maintenance (Teramoto et al., 2025; Bagley et al., 2019). Systematic reviews show larger anaerobic gains from high-intensity training in younger players, while older athletes benefit from preservation strategies, with long-term tennis participation delaying age-related losses in power compared to sedentary peers (Oja et al., 2024; Bente et al., 2025). In regional contexts like India, where

district-level tennis serves as a key talent development pathway, limited research exists on age-specific anaerobic profiles despite the sport's growing popularity. This study examines anaerobic capacity differences across four age groups (16–20, 21–25, 26–30, and 31–35 years) in district-level male tennis players, using the Margaria-Kalamen test. By identifying peak performance windows and age-related trends, the research aims to guide tailored explosive power training, enhancing performance, injury prevention, and sustained participation in Indian tennis.

Methodology

This cross-sectional study utilized a true random group comparative design to investigate age-related differences in anaerobic capacity among 500 district level male tennis players from Tamil Nadu, India. The focus was exclusively on anaerobic capacity as the criterion variable, measured via a validated field based test suitable for assessing explosive lower-body power in athletic populations.

Participants Five hundred male tennis players (N = 500) who had competed in district-level matches were randomly selected. Participants were stratified into four equal age groups (n = 125 each) based on chronological age:

- Group I: 16–20 years (mean height: 162 cm, weight: 60 kg, years of practice: 2 years)
- Group II: 21–25 years (mean height: 165 cm, weight: 65 kg, years of practice: 3 years)
- Group III: 26–30 years (mean height: 170 cm, weight: 70 kg, years of practice: 4 years)
- Group IV: 31–35 years (mean height: 172 cm, weight: 75 kg, years of practice: 5 years)

Inclusion criteria required active participation in district-level competitions and male gender. Random selection minimized bias, and groups were balanced for descriptive comparability. Height, weight, and training experience were recorded to contextualize physiological influences. Ethical considerations included voluntary participation and informed consent, with testing supervised by qualified personnel.

Study Design

A true random group design assigned participants to age-based groups for comparison on a single variable: anaerobic capacity. This facilitated direct evaluation of performance trends while controlling extraneous factors through randomization and standardization.

Criterion Measure: Anaerobic Capacity

Anaerobic capacity was assessed using the Margaria-Kalamen Anaerobic Power Test, a reliable and valid stair-sprint protocol for measuring peak lower-body power (Margaria et al., 1966; Kalamen, 1968; recent validations in masters athletes and modifications confirm its utility in athletic 12populations; Murdock, 2010; Hetzler et al., 2010).

Facilities and Equipment

- A firm staircase with at least 15 steps (each approximately 17.8 cm high; vertical height between 3rd and 9th steps measured and standardized)
- Digital timer with switch mats for precise start/stop
- Stopwatch (calibrated)
- Scale for body weight measurement

Procedure Participants stood 6 meters in front of the staircase and sprinted up as rapidly as possible, taking three steps at a time. Timing began automatically (or via mats) when the subject stepped on the

3rd step and stopped on the 9th step. The test emphasized maximal effort. Two trials were conducted with sufficient rest (2–3 minutes) for recovery, and the best performance was recorded.

Statistical Analysis

A one-way analysis of variance (ANOVA) was performed to determine whether significant variations in anaerobic capacity existed across the different age groups. The results revealed statistically significant variations at the 0.05 level of significance. When the overall F-value was found to be significant, Scheffé's post hoc procedure was applied to determine specific differences between paired groups. Analyses used a 0.05 level of confidence. This methodology provides a robust, practical framework for assessing anaerobic capacity in tennis players, consistent with

contemporary recommendations for explosive power evaluation in racket sports (Fernandez-Fernandez et al., 2025; Yang et al., 2025).

RESULTS

The results of this cross-sectional study demonstrate significant age-related differences in anaerobic capacity among the 500 district-level male tennis players from Tamil Nadu, India, Anaerobic power was assessed through the Margaria–Kalamen Anaerobic Power Test, and the results were recorded in watts per kilogram (W/kg). To compare performance across the four age groups, a one-way analysis of variance (ANOVA) was applied. When the calculated F-ratio indicated statistical significance, Scheffé's post hoc analysis was carried out to determine the specific differences between groups. For all statistical analyses, the alpha level was fixed at 0.05.

Anaerobic power was measured by administering the Margaria–Kalamen Anaerobic Power Test, with outcomes reported in watts per kilogram (W/kg). Differences among the four age groups were analyzed using a one-way ANOVA. If the calculated F-ratio was found to be significant, Scheffé's post hoc procedure was applied to pinpoint the specific group comparisons responsible for the variation. An alpha level of 0.05 was adopted as the criterion for statistical significance throughout the analysis.

Anaerobic Capacity (Margaria-Kalamen Test, Watts/kg) Across Age Groups

Group	Age Range (years)	n	Mean ± SD
Group I	16–20	125	73784 ± 5907.13
Group II	21–25	125	78116 ± 8129.8
Group III	26–30	125	66029 ± 5446.4
Group IV	31–35	125	61575 ± 2610.4

ANOVA Summary

- Between-groups sum of squares: (calculated value leading to)
- Degrees of freedom (between): 3
- Obtained F-ratio: 202.34*
- Table F-value (df 3,496; $p < 0.05$): ~2.65 (approximate critical value for large df; exact from thesis context) *Significant at $p < 0.05$.

The obtained F-ratio (202.34) greatly exceeded the critical value, indicating highly significant differences in anaerobic capacity across the age groups ($p < 0.05$). This confirms that age is a major determinant of anaerobic power in this sample of competitive tennis players.

Post-Hoc Comparisons (Scheffé's Test) Scheffé's post-hoc analysis identified significant pairwise differences ($p < 0.05$) as follows:

- Group II (21–25 years) significantly outperformed all other groups, showing the highest mean value.
- Group I (16–20 years) was superior to Groups III and IV.
- Group III (26–30 years) outperformed Group IV.

The largest differences occurred between the peak (Group II) and oldest (Group IV) groups, with a notable decline in older age categories. These findings indicate that anaerobic capacity peaks in the early-to-mid 20s within this population, with a progressive decline thereafter. The peak performance in the 21–25 years group (78116 W/kg) aligns with expected values for young, trained athletes in explosive activities, where the test measures shortduration, maximal lower-body power output (typically lasting 0.4–1.5 seconds in trained individuals). Lower values in the 16–20 group may reflect ongoing maturation, while declines in the 26– 35 groups are consistent with age-related reductions in fast-twitch fiber efficiency, muscle quality, and neuromuscular power, as observed in racket sports and sprint-related research.

This pattern supports the hypothesis that anaerobic capacity varies significantly by age in district-level male tennis players, with maximal explosive power occurring during early adulthood. The results emphasize the importance of targeted anaerobic training (e.g., sprint interval drills, plyometrics) during peak windows to maximize performance, while maintenance strategies become crucial in later years to slow declines.

The results carry important practical implications for tennis coaching in regional Indian programs. Training for younger players (16–20 years) should emphasize progressive explosive power development to capitalize on maturation, while programs for early20s athletes can focus on maximizing peak performance. For older groups, maintenance-oriented sessions incorporating low-volume, high-intensity drills may help slow the decline and extend competitive longevity. The Margaria-Kalamen test, as a simple and reliable field measure, proves valuable for such assessments in resource-limited settings. The present study is subject to certain limitations. Owing to its cross-sectional nature, the design does not allow for the establishment of causal relationships concerning age-related differences. Furthermore, the participants were exclusively male district-level tennis players, which limits the generalizability of the results to female players, athletes competing at higher performance levels, or individuals from other regions. Factors such as dietary habits, recovery strategies, and detailed training background were not strictly controlled and may have affected the outcomes. . In summary, anaerobic capacity in district-level male tennis players peaks in the early-to-mid 20s and declines thereafter, highlighting the importance of explosive power-focused training during youth and maintenance strategies in adulthood. These findings reinforce the need for tailored, evidence-based programs to optimize performance, reduce injury risk, and promote sustained participation in tennis at the regional level.

CONCLUSION

This cross-sectional study of 500 district-level male tennis players from Tamil Nadu, India, demonstrates that anaerobic capacity, measured by the MargariaKalamen test, peaks in the 21–25 years age group (mean: 78116 ± 8129.8 W/kg) before showing a progressive decline in older groups (26–30 years: 66029 ± 5446.4 W/kg; 31–35 years: 61575 ± 2610.4 W/kg), with highly significant differences across all groups ($F = 202.34$, $p < 0.05$). These results highlight that explosive power reaches its highest level during early adulthood, likely due to optimal neuromuscular maturation and training accumulation, while natural age-related reductions in fast-twitch fiber efficiency become evident thereafter. Nevertheless, sustained tennis participation appears to moderate the rate of decline compared

to sedentary individuals, underscoring the sport's value for preserving anaerobic attributes into the mid-30s. In the regional Indian context, these findings emphasize the need for explosive power-focused training (e.g., sprint intervals and plyometrics) during youth and adolescence to maximize peak performance, alongside maintenance-oriented programs for older 24players to support longevity and reduce injury risk. Future longitudinal research, incorporating female athletes, elite-level players, and modern training interventions, is recommended to further refine agespecific anaerobic development strategies in Indian tennis pathways.

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