Sustainability in Youth Sport Performance: A Study on Anthropometry and Motor Skills in Women's Tennis

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Abstract
In youth women's tennis, building a performance model requires linking physical traits and motor capacities to competitive progression without harming long-term development. Here, sustainability means guiding training and talent pathways through evidence-based, age-appropriate, and individually tailored criteria, limiting early-specialization bias and weak selection practices. This pilot study explores the anthropometric profile and selected motor indicators of U18 female tennis players to outline preliminary reference trends for a sustainable youth performance framework. An experimental field-based design was used, assessing basic anthropometrics (e.g., height, body mass) and tennis-related motor capacities through a sport-specific test battery. This work represents a first step toward an optimal youth performance model that supports talent identification and long-term athlete development using measurable, context-sensitive parameters. Results may help coaches align performance improvement with sustainable growth.
Keywords: youth tennis, sustainability, anthropometry, motor assessment, performance model.

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Introduction

Performance in tennis can hardly be explained by a single factor. It is built over time through the interaction between physical characteristics, motor skills, technical execution and tactical choices, which must then emerge in

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real race conditions (Brouwers et al., 2012). In youth tennis this picture is even more complex. Athletes are called upon to compete, but they are also in a development phase. In late adolescence, differences in biological maturation, training history and competitive exposure can be significant and often result in different performance profiles even among players in the same category (Kramer et al., 2017).

For this reason, building a performance model in youth tennis should not be understood as a rigid standard. It is more useful to consider it as an interpretative tool: a practical reference to understand which aspects tend to support progression, which indicators can be useful for monitoring development and how physical characteristics relate to the real demands of sport (Kolman et al., 2021). This is especially true in youth women's tennis. During adolescence, in fact, female athletes can go through significant changes in body composition, neuromuscular control and movement mechanics (Latino et al., 2019, 2023). These changes can affect performance, but they also affect the athlete's ability to tolerate progressively higher training loads (Susanto et al., 2024).

This perspective is naturally linked to the theme of sustainability, understood here as the sustainable development of the athlete (Aidar et al., 2022). In practical terms, sustainability means building progression paths compatible with long-term growth, reducing the risk of avoidable injuries and avoiding short-term solutions that can produce immediate results but limit future potential. In youth tennis, early selection processes and strong competitive pressure are frequent, which can make short-term results excessively decisive (Ulbricht et al., 2016). However, early success does not always predict progression in the long run. Athletes who mature earlier may appear to have an advantage in the short term, while "late developers" may need structured support so as not to be excluded too soon. Careful use of physical profiling can help reduce these biases and support more balanced decisions (Deng et al., 2023).

From a performance point of view, tennis is characterized by intermittent high-intensity activity. The race requires repeated acceleration, braking, rapid changes of direction and explosive actions performed in short time windows and repeated over often prolonged match durations. The athlete must initiate the movement quickly, reposition himself efficiently and maintain technical control under conditions of time pressure, fatigue and tactical variability (Girard, & Millet, 2009). On a physiological level, tennis alternates almost maximal actions with partial recoveries, requiring both neuromuscular readiness and the ability to repeat high-quality efforts during the entire match. On the biomechanical level, sport requires rapid force production and effective transfer along the kinetic chain during specific actions. In practice, it is not enough to possess isolated physical qualities: what matters is how these qualities are expressed in functional motor patterns that support technical-tactical execution (Fernandez-Fernandez et al., 2022).

In this context, anthropometric characteristics have long been considered an important component of tennis performance. They are easy to detect, relatively stable, and often interpreted as structural advantages. Height, in particular, has been widely discussed for its relationship to serve mechanics and the effectiveness of the "first strike". A higher point of impact can promote more advantageous trajectories, with possible benefits on speed, angles and margin above the net. Given the importance of serve and aggressive patterns in modern tennis, it's understandable that coaches pay attention to this variable (Fernandez-Fernandez et al., 2023).

At the same time, the interpretation of anthropometric traits in youth categories requires caution. Late adolescence is still a developmental stage, and maturation can generate temporary differences that may appear as stable advantages. Anthropometry can help explain some performance trends, but it should not be treated as a definitive threshold for predicting future success. A selective approach that is too morphology-centric can become unsustainable, favoring female athletes who mature early and reducing opportunities for those who develop later, with possible consequences on long-term development and talent retention (Parpa et al, 2022).

In addition, anthropometry does not act in isolation. Height interacts with body mass, segmental proportions, and movement efficiency, and these interactions can produce different functional outcomes. Two athletes of similar stature may show different abilities to accelerate, decelerate or maintain balance in open stance situations, and these functional differences may matter more than "raw" anthropometric values. For this reason, anthropometric profiling becomes more informative when it is accompanied by motor and functional indicators (Luna-Villouta et al., 2021).

The evaluation of motor performance provides precisely this functional level. It offers a more direct reading of how the athlete moves, how effectively they produce and absorb force, and how they handle high-intensity repeated actions. In tennis, acceleration can determine whether the athlete reaches the ball in time to hit with control, while the ability to change direction influences court coverage and tactical stability (Rawat et al., 2026). The explosive force of the lower limbs supports rapid starts, braking and re-acceleration, as well as the production of the blow in both stable and unstable conditions. Joint flexibility and mobility can also play a role, allowing you to reach difficult balls, recover from extreme positions, and maintain quality of movement when the intensity increases. These qualities are trainable, so they are useful not only for describing, but also for planning development (Moreno-Apellaniz et al., 2024).

A further consideration concerns the dependence on the context of tennis performance. Playing surfaces, match pace and tactical preferences can change the relative importance of different physical qualities. Some contexts reward dominance on serve and first-shot play, while others require tolerance to prolonged exchanges and repeated defensive skills. This variability suggests that performance modeling should aim to define useful reference patterns, rather than rigid universal profiles (Pluim et al., 2023).

Despite the extensive literature on anthropometry and physical profiling in tennis, the evidence remains fragmented. Integrated approaches combining anthropometric features and functional motor indicators in the same framework are less frequent, especially in youth women's tennis and late adolescence. The U18 category represents a significant phase because it often coincides with a transition point: training loads increase, competitive demands approach senior levels and selection processes become more intense. At the same time, there is still variability in the state of maturation and in the age of training, which influences both performance outcomes and the interpretation of physical profiles. From an application point of view, many development contexts are based on "field-based" assessments, making it important to produce accessible, repeatable and interpretable data in real coaching environments.

On this basis, the present pilot study intends to contribute to a sustainable performance framework for youth women's tennis by combining basic anthropometric profiling with sport-relevant functional motor indicators. In particular, the study aims to describe the anthropometric profile of U18 players, evaluate some motor performance indicators through field tests, explore the variability within the sample to identify preliminary reference trends and contextualize the results through comparison with federal reference values for the same age group. This preliminary evidence can support data-driven decisions in training planning, monitoring, and long-term athlete development in youth women's tennis.

Materials and methods

Study Design

This research was designed as a pilot, cross-sectional observational study with an exploratory descriptive-comparative approach, aimed at outlining preliminary characteristics of the performance profile in youth women's tennis. Data collection was conducted through standardized field-based assessments performed in a single testing period (June 2025), in order to obtain an initial snapshot of anthropometric and motor indicators relevant to performance development and to contextualize these findings against federation reference benchmarks for the U18 category. Prior to participation, athletes and their legal guardians received detailed information about the aims and procedures of the study, and written informed consent was obtained. All procedures were carried out in accordance with the ethical principles for research involving human participants and were conducted in line with the Declaration of Helsinki.

Participants

The sample consisted of ten competitive female tennis players (n = 10) aged between 14 and 17 years, recruited through convenience sampling from the local competitive tennis environment. All athletes were actively engaged in systematic tennis training and regular competition at the time of testing. Inclusion criteria were: (i) female sex; (ii) age between 14 and 17 years; (iii) current participation in organized competitive tennis; (iv) regular training involvement during the season; and (v) availability to complete the full assessment protocol within the scheduled testing session. Exclusion criteria were: (i) the presence of acute musculoskeletal injury at the time of testing; (ii) any medical condition or health limitation that could compromise safe participation in maximal or near-maximal physical testing; (iii) recent surgery or rehabilitation interfering with normal training routines; and (iv) inability to complete all required measurements and field tests.

Procedures

Data collection was carried out in June 2025 and followed a standardized protocol to ensure consistency across participants. Testing was conducted in a single assessment period and was organized to minimize fatigue effects and procedural variability. Anthropometric assessment was completed first, followed by the motor evaluation session based on the FITP protocol. All participants were assessed under comparable conditions and completed the full testing sequence during the scheduled session. After data collection, results were recorded and organized for subsequent analysis and comparison with available FITP reference values for U18 athletes of national interest.

Measures

Anthropometric measurements included stature and body mass, obtained using a stadiometer and a digital scale, respectively. Body Mass Index (BMI) was calculated from these measures using standard formulas. Motor performance was assessed through a FITP-based battery aimed at capturing physical qualities relevant to tennis, including linear speed, repeated change-of-direction performance, flexibility of the posterior chain and spinal mobility, and lower-limb explosive strength. Speed and shuttle performance were measured on court using spatial references and manual timing with a stopwatch. Flexibility was evaluated using the sit-and-reach procedure. Explosive strength was assessed through vertical jump tests, specifically squat jump (SJ) and countermovement jump (CMJ), performed on a dynamometric platform to obtain objective jump height values.

Statistical Analysis

Given the exploratory and pilot nature of the study, statistical analysis was primarily descriptive. For each anthropometric and motor variable, the main summary statistics were calculated, including mean values, minimum and maximum scores, and overall distribution trends within the group. BMI values were computed from measured height and body mass and interpreted according to standard classification criteria. The descriptive outcomes were then examined in relation to the initial research hypotheses, with particular attention to whether the observed profile appeared consistent with, or distant from, the reference standards reported by the FITP for U18 players of national interest. This descriptive-comparative approach was adopted to provide a preliminary interpretation of the sample's performance characteristics and to support future research development with larger cohorts and more advanced inferential designs.

Results

Motor performance outcomes are presented first, followed by anthropometric characteristics. The sample showed a clear inter-individual variability across all functional measures, with performance ranges that highlight meaningful differences even within a relatively homogeneous age category. In the 10-m sprint test, completion time ranged from 1.97 s to 2.20 s, with a mean value of 2.07 s (Fig. 1).

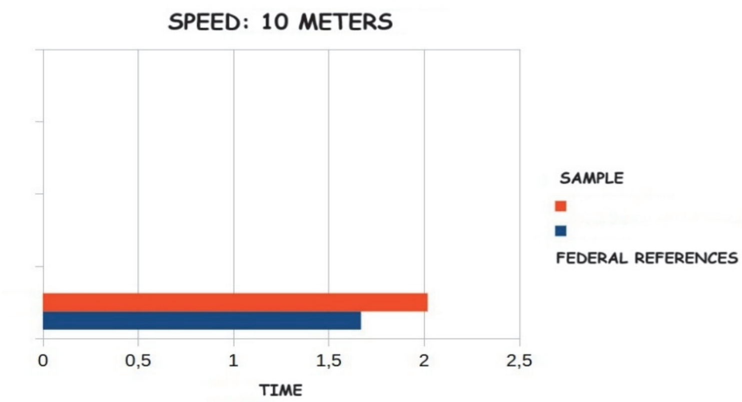

Fig. 1 - Quick 10mt results

The 8-m shuttle test (6 repetitions) showed a wider dispersion, with times ranging from 13.60 s to 15.97 s and an average performance of 14.77 s (Fig. 2).

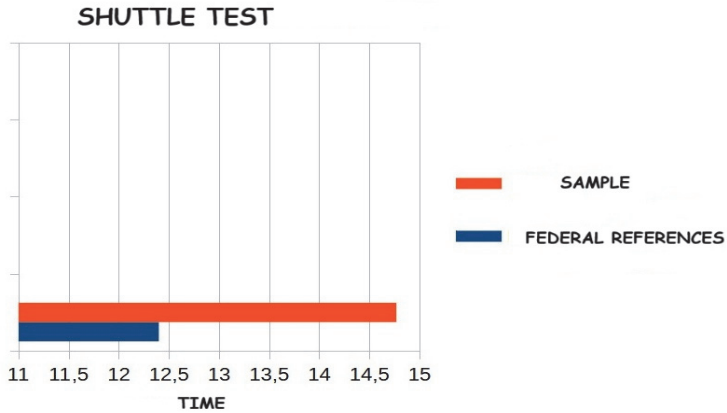

Fig. 2 - 8mt shuttle results

Regarding lower-limb explosive strength, squat jump (SJ) height ranged from 21.7 cm to 30.8 cm, with a mean jump height of 24.87 cm. Comparable values were observed in the countermovement jump (CMJ), with results ranging from 21.1 cm to 30.4 cm and an average of 24.41 cm (Fig. 3).

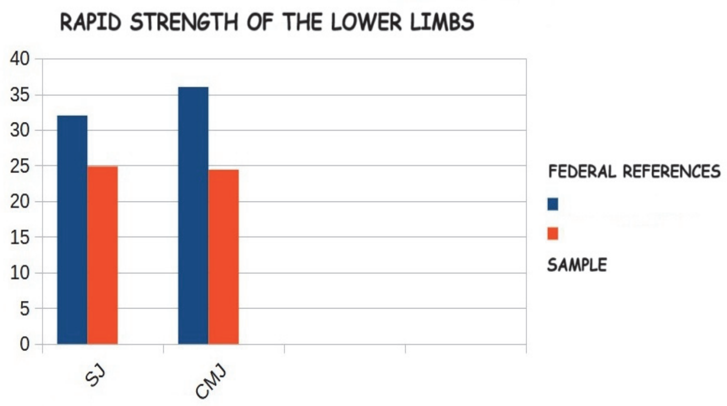

Fig. 3 - Results of rapid strength of the lower limbs

Flexibility, assessed through the sit-and-reach test, was generally positive across the group. Values ranged from − 9 cm to + 9 cm, with most athletes scoring above zero and a mean reach distance of + 9 cm (Fig. 4).

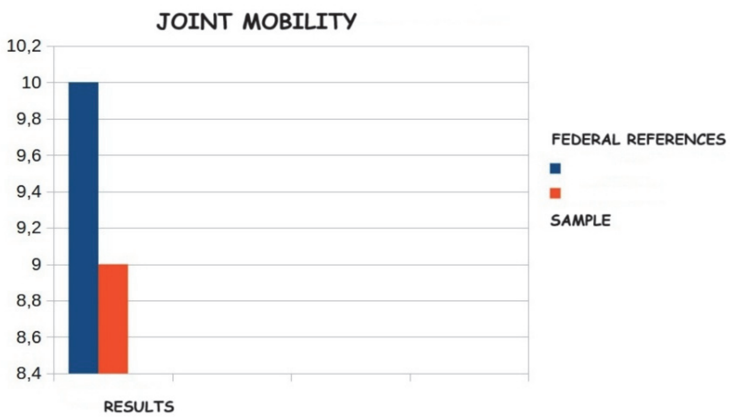

Fig. 4 - Sit and reach results

Anthropometric profiling indicated an average height of 159.7 cm and an average body mass of approximately 57.0 kg (Figs. 5-6). BMI values were largely consistent with a normal-weight profile, with 90% of participants classified within the normal range according to the adopted criteria (Fig. 7).

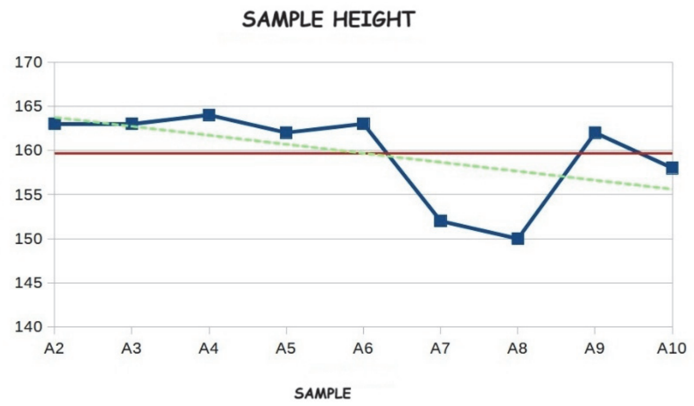

Fig. 5 - Sample height

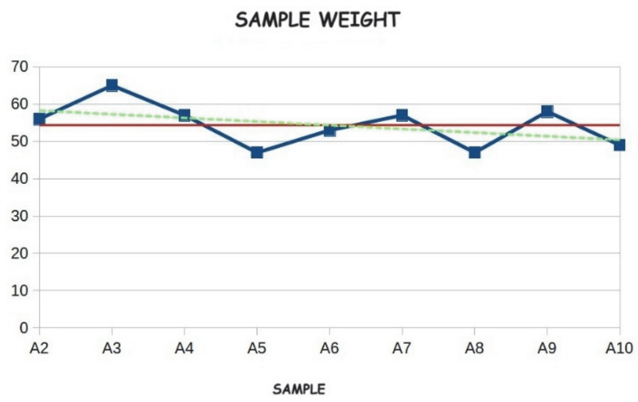

Fig. 6 - Sample weight

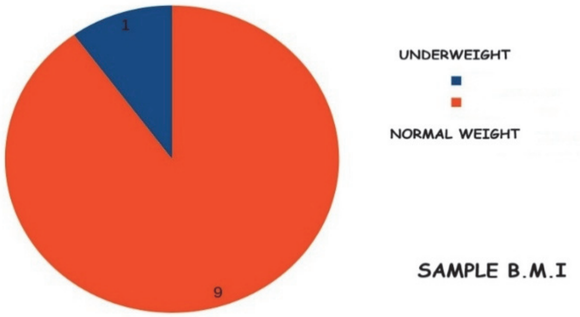

Fig. 7 - BMI of the sample

Table 1 - Descriptive statistics of anthropometric and motor variables (n = 10)

Domain	Variable	Unit	Mean	SD	Min–Max
Motor performance	10-m sprint time	s	2.07	0.07	1.97-2.20
Motor performance	8-m shuttle (6 reps) time	s	14.77	0.78	13.60-15.97
Motor performance	Squat Jump (SJ) height	cm	24.87	2.85	21.7-30.8
Motor performance	Countermovement Jump (CMJ) height	cm	24.41	2.72	21.1-30.4
Mobility/ Flexibility	Sit-and-reach	cm	+6.9	4.9	−9-+9
Anthropometry	Height	cm	159.7	5.8	151.0-169.0
Anthropometry	Body mass	kg	57.0	6.1	48.0-67.0
Anthropometry	BMI	kg/m²	22.3	1.8	19.1-25.8

Comparison with FITP reference benchmarks

To put the results in context, we compared the group data with FITP reference values for U18 athletes of national interest. In the 10-m sprint, the sample averaged 2.07 ± 0.07 s, while the FITP benchmark is 2.01 ± 0.05 s. This points to slightly weaker early acceleration. The same gap appears in repeated change-of-direction performance. Shuttle time was 14.77 ± 0.78 s in the present group, compared with 14.10 ± 0.60 s in the FITP reference, suggesting lower efficiency when directional changes are repeated at high intensity.

Jump outcomes were closer to the federation profile. Squat jump reached 24.87 ± 2.85 cm and countermovement jump 24.41 ± 2.72 cm, versus FITP values of 26.50 ± 2.60 cm (SJ) and 26.10 ± 2.50 cm (CMJ). The difference is small, but still present. Flexibility showed almost no discrepancy (sit-and-reach: +6.9 ± 4.9 cm vs +7.5 ± 4.0 cm), indicating no relevant limitation in posterior-chain mobility at group level.

Overall, the sample aligns more closely with FITP values in flexibility and explosive strength. Speed and repeated change-of-direction remain the main areas where the distance from the benchmark is clearer, and these qualities are key for court coverage and progression toward higher competitive levels.

Discussion

The present study aimed to clarify performance-related profiling in youth women's tennis by combining basic anthropometric description with field-based motor indicators linked to athletic readiness. Results were then interpreted through a descriptive comparison with FITP reference benchmarks for U18 athletes of national interest. The goal was not to generate predictive claims. Rather, the study provides an initial snapshot that may support monitoring practices and a more sustainable approach to development in late-adolescent female players.

Overall, the group showed a physical profile compatible with healthy development and regular competitive participation, while some motor qualities displayed a clearer distance from federation benchmarks. From an anthropometric standpoint, mean height (159.7 cm) and body mass (≈57 kg) described a typical profile for the age range, with BMI values mostly within a normal-weight range. These measures are not intended to define an "ideal" body type. They are useful mainly as context for reading the functional outcomes. This point matters in applied settings, where anthropometric traits can still influence informal selection decisions, especially in tennis, where height is often associated with serving advantage and first-strike effectiveness. In the present sample, however, anthropometry alone does not explain the variability observed in motor performance. This supports a key developmental message, namely taht in adolescence, morphology should not be treated as a gatekeeping criterion. Maturation-related differences can be temporary, and their apparent "advantage" may change over time. A more sustainable approach is to consider anthropometry as background information that interacts with trainable qualities and movement efficiency (Reid et al., 2009).

Motor performance results showed a more differentiated pattern. Short sprint performance (10 m) averaged 2.07 s, while repeated change-of-direction performance (8 m shuttle ×6) averaged 14.77 s. Compared with FITP benchmarks, both outcomes appear slightly lower, pointing to a potential margin in early acceleration and repeated high-intensity movement efficiency. These qualities are central in tennis because they directly affect court coverage and time-to-ball. Even a small delay in early acceleration can reduce shot options and increase the likelihood of defensive play. Similarly, less efficient repeated directional changes may reduce movement quality over longer rallies and multiple games, potentially increasing fatigue-related technical errors. From a practical standpoint, the results do not suggest poor performance. They highlight an area where training could be more targeted, especially through neuromuscular work aimed at acceleration mechanics, braking control, and re-acceleration quality. This fits well with a sustainable development framework: improvements in speed and COD should be built progressively, with technical emphasis and injury-prevention priorities, rather than through excessive loads or early specialization (Chapelle et al., 2022).

In contrast, explosive lower-limb strength appeared closer to the federation profile. Squat jump and countermovement jump values (24.87 cm and 24.41 cm) showed only a modest gap compared with FITP references. This is relevant because vertical jump tests are commonly used as practical proxies for neuromuscular readiness and explosive capacity in field settings. At the same time, it would be reductive to interpret SJ and CMJ as a complete representation of tennis-specific power. Tennis requires explosive force in horizontal and multi-directional patterns, often under asymmetrical and rapidly changing conditions. Still, SJ and CMJ remain useful monitoring tools. In applied terms, the combination of relatively "closer" jump values and slightly lower sprint/shuttle outcomes may suggest that training priorities should focus less on increasing generic power and more on how force is expressed in tennis-relevant movement tasks (movement efficiency, acceleration quality, repeated directional changes) (Zurano et al., 2025).

Flexibility outcomes, assessed through the sit-and-reach test, were broadly comparable to FITP values, with most athletes scoring in the positive range. Flexibility is not always discussed as a primary performance driver, yet in tennis it can influence reach, stability in extreme positions, and recovery during defensive phases. In youth female athletes, mobility can also interact with injury risk, particularly during periods of growth and movement reorganization. In the present group, posterior-chain flexibility does not appear to be a major limitation (Chapelle et al., 2023). Still, the variability observed at individual level remains relevant, because even one athlete with reduced mobility may be exposed to higher risk when training volumes increase or when repeated high-intensity actions accumulate. In this sense, flexibility screening may be more useful as an individual monitoring tool than as a group-level performance determinant.

One of the main contributions of this pilot work is the emphasis on variability, even within a small and relatively homogeneous group. Performance ranges were not narrow, especially in repeated movement tasks. This aligns with a common principle in youth sport science, namely that late adolescence is not a uniform stage. Players of the same age can differ in readiness due to maturation timing, training exposure, and movement quality (Hizan et al., 2011). The practical implication is straightforward. Development pathways should be individualized. A sustainable performance model is not one that identifies a single "ideal athlete" profile, but one that provides reference ranges and indicators that help guide decisions without forcing all athletes into the same template (Skorodumova et al., 2022).

The descriptive comparison with FITP benchmarks adds an applied layer to this interpretation. It helps clarify where the sample aligns with higher-level expectations and where the distance is more evident. In this dataset, the clearest margins appear in speed and repeated change-of-direction performance, while explosive strength and flexibility are closer to the federation profile. For coaches, this kind of information can support prioritization. It also promotes a more rational development approach, rather than relying on non-trainable traits or general impressions, practitioners can focus on qualities that are relevant for tennis and responsive to structured training. From a sustainability perspective, this is important. Youth programs should aim to build a broad and resilient athletic base, limit early specialization, and reduce the temptation to chase short-term gains through excessive loading. A more sustainable route emphasizes progressive improvement in movement quality, neuromuscular control, and repeatability of high-intensity actions.

Anthropometry deserves a final note. Although height and body mass were reported descriptively and BMI suggested a generally healthy status, these measures should not be interpreted as predictors of elite potential. Tennis literature often highlights stature as a serving advantage, but women's tennis is tactically diverse, and movement efficiency can be decisive. Moreover, in youth categories, maturation can distort the relationship between body size and performance. For this reason, the present findings support an approach where anthropometry is used as contextual information for training and monitoring, not as a selection filter. This is consistent with the broader logic of sustainable athlete development, which aims to keep development opportunities open and to support progression through trainable qualities and skill acquisition (D'Hondt, & Chapelle, 2024).

Future research should build on these exploratory results with larger samples and stronger designs. Integrating maturation status and training history would help interpret variability more precisely, separating differences driven by biological development from those linked to training adaptation (Montesano et al., 2013). Longitudinal monitoring across a season would also be valuable, as sustainability is reflected not only in absolute values but in the capacity to improve while remaining healthy and consistently available for training and competition (Di Palma et al., 2025). Finally, a more complete performance model would benefit from integrating match-related variables and technical–tactical indicators, which remain essential components of tennis performance (Kramer et al., 2016).

Several limitations should be acknowledged. The sample size was small (n = 10), limiting generalizability and restricting the strength of inferential conclusions. Recruitment was based on convenience sampling, so the profile may reflect local characteristics rather than the broader population of youth female tennis players. The design was cross-sectional, providing a snapshot rather than developmental evidence. Sprint and shuttle timing relied on manual stopwatch procedures, which may introduce measurement error compared with electronic systems. FITP benchmarks offer a useful reference, but they may vary depending on testing conditions and selection criteria, and should be interpreted as indicative rather than absolute. Finally, the study focused on physical and functional indicators and did not include technical, tactical, or match-analysis measures, which would be required for a fully comprehensive performance model.

Conclusions

This pilot study describes the physical and functional profile of competitive female tennis players aged 14–17 years using field-based assessments, and it compares the results with FITP reference values for U18 athletes of national interest. The sample showed a generally healthy anthropometric profile. Flexibility and lower-limb explosive strength were broadly close to federation standards, whereas sprint and repeated change-of-direction performance were lower. This gap points to acceleration and movement efficiency under repeated high-intensity efforts as potential priority areas for development in this age group.

From a practical standpoint, combining basic anthropometric monitoring with functional performance testing may support more individualized training decisions. It also encourages a longer-term view of development, based on progressive improvement, appropriate load management, and attention to movement quality. At the same time, the variability observed within a small group confirms that players of similar age can differ in readiness, and may therefore require different training priorities rather than uniform prescriptions. Future research should extend these findings with larger samples and longitudinal designs, and should include maturation status, training history, and match-related indicators to improve the interpretation of performance profiles and support a more comprehensive and sustainable performance model for late-adolescent female tennis players.

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