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# Early talent identification in tennis: A retrospective study

## Identificación temprana de talento en tenis: un estudio retrospectivo

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## Abstract

Talent identification often begins at the age of entry into a sport: even under the age of 9 years old (U9). However, the success of such early talent identification is questionable. Therefore, the aim of this long-term retrospective study is to examine whether today's more successful junior tennis players already differed from today's less successful junior tennis players in terms of physical fitness and motor competence when both groups were U9. If significant differences in performance characteristics between successful and less successful tennis players were already apparent at this young age, such characteristics could be used to forecast talent at an early stage. Based on their current tennis success, a total of 174 junior tennis players were divided into national *ranked players* (n = 16: players who achieved a place in the official national junior tennis ranking list of the German Tennis Federation) and *non-ranked players* (n = 158). All of these players had already participated in two anthropometric and nine physical fitness and motor competence tests at U9 (e.g., sprint, endurance run, ball throw). Using a MANCOVA and a correlation analysis, we retrospectively examined whether the two current performance groups had differed significantly in their U9 test scores and whether these athletes' U9 test performance scores correlated with their current playing success. No significant ($p < 0.05$) differences were found between ranked and non ranked junior players in terms of U9 body weight and height. However, with the exception of flexibility, all physical fitness tests and motor competence tests showed significant results. The ball throw was the most relevant test parameter, as it showed the highest prognostic validity (effect size $\eta^2$ = .157 and $r$ = .360). This test was followed by the two test tasks standing long jump (effect size $\eta^2$ = .081 and $r$ = .287) and endurance run (effect size $\eta^2$ = .065 and $r$ = .296). Overall, the U9 findings are in line with the results from other studies of U12–U18 tennis players. Therefore, it can be assumed that talent specific characteristics remain stable over a certain period of time and that U9 test performances may provide an early indication of later playing success.

**Keywords:** *talent, tennis, performance testing, prognosis, success.*

## Resumen

La identificación de talentos a menudo suele comenzar desde la edad de entrada al deporte, es decir, incluso por debajo de los 9 años (U9). Sin embargo, el éxito de dicha identificación de talento temprana es cuestionable. Por lo tanto, el objetivo de este estudio retrospectivo a largo plazo es analizar si los jugadores juveniles de tenis más exitosos hoy en día ya eran diferentes de los jugadores juveniles de tenis menos exitosos hoy en día en términos de aptitud física y competencia motora cuando los dos grupos eran U9. Si a esta temprana edad ya eran notables diferencias significativas en las características de desempeño entre los jugadores de tenis exitosos y menos exitosos, dichas características podrían usarse para predecir el talento desde una etapa temprana. Basados en su actual éxito en el tenis, un total de 174 jugadores juveniles de tenis fueron divididos en jugadores de clasificación nacional (n= 16: jugadores que obtuvieron un lugar en la lista oficial de clasificación nacional juvenil de tenis de la Federación Alemana de Tenis) y jugadores por fuera de la clasificación (n=158). Todos estos jugadores ya habían participado en dos pruebas antropométricas y nueve de aptitud física y competencia motora en U9 (ej. sprint, carrera de resistencia, lanzamiento de balón). Usando un análisis de correlación y el MANCOVA, analizamos retrospectivamente si los dos grupos de desempeño actual diferían

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significativamente de los puntajes en sus pruebas en U9, y si esos puntajes de las pruebas de rendimiento en U9 de estos atletas se correlacionaban con su éxito de juego actual. No se encontraron diferencias significativas ($p < 0,05$) entre los jugadores juveniles dentro la clasificación y por fuera de ella en términos de peso y altura en U9. Sin embargo, exceptuando la flexibilidad, todas las pruebas de aptitud física y competencia motora presentaron resultados significativos. El lanzamiento de balón fue la prueba más relevante ya que demostró la mayor validez pronóstica (tamaño del efecto $\eta 2$ = .157 y r = .360). A esta prueba le siguieron dos actividades de prueba, salto de longitud de pie (tamaño del efecto $\eta 2$ = .081 y r = .287) y carrera de resistencia (tamaño del efecto $\eta 2$ = .065 y r = .296). En general, los resultados en U9 están en línea con los resultados de otros estudios de jugadores de tenis en U12-U18. Por lo tanto, puede asumirse que las características de talento específicas permanecen estables durante cierto periodo de tiempo y que el desempeño en las pruebas en U9 puede ser un indicador temprano de futuro éxito en el juego.

**Palabras clave:** *talento, tenis, prueba de desempeño, pronóstico, éxito.*

## INTRODUCTION

With over 1.2 billion fans and more than 80 million players, tennis is one of the most popular sports in the world (International Tennis Federation, 2021). Tennis is also a highly complex sport that requires not only general endurance but also speed, agility, upper body power, and coordination (Filipcic & Filipcic, 2005; Kramer et al., 2017; Robertson et al., 2018). Apart from professional tennis players needing these performance prerequisites to defend their top positions in the world (Reid & Schneiker, 2008), it is also necessary to understand which performance characteristics are already relevant for tennis players at an early age. This may not only contribute to a successful future tennis performance (Till & Baker, 2020); it may also orientate a *best mover* to this particular sport according to the particular strengths of his or her individual performance profile. Importantly, the better the individual talent characteristics match the (future tennis) demands, the higher the chances that the beginners will achieve success and satisfaction in this complex sport. This assumption is underlined by Suppiah et al. (2015), who state that a wrong choice can never be compensated for by training. Engaging in an unsuitable sport might not only be detrimental to fun but also lead to drop outs ahead of time. Conversely, if children like a recommended sport, the talented athletes could transform their physical, physiological, and psychological gifts through a long term process of diligent learning, deliberate practice, and an extended amount of high quality training into optimal achievements (Davids & Baker, 2007; Pion, 2015).

With the help of physical fitness and motor competence tests, young athletes are analyzed and their future potential is assessed (Kramer, Huijgen, Lyons, et al., 2016; Ulbricht et al., 2015). These so called sports orientation and talent identification (TID) campaigns have become increasingly common in recent years (Johnston et al., 2018). This is also due to national sports organizations investing more and more effort into the systematic identification of talented young players. In a professionalized competitive environment, a relaxed approach no longer appears acceptable (De Bosscher et al., 2008), and talent identification could become the key to national elite sport performance. Therefore, TID is designed to identify promising young athletes at an early stage (Hohmann & Seidel, 2003; Pion, 2015). Thus, the testing and scouting of athletes begin as soon as they enter a sport. On average, the general sport entry age of professional athletes is about 9 years (8.5 ± 2.5 years: Güllich & Emrich, 2014; 9.1 ± 3.7 years: Vaeyens et al., 2009). In this context, tennis and other racket sports are known to have an early starting age (5–8 years) (Faber et al., 2016). Studies by Li et al. (2020) have shown that 75% of all Top 300 tennis players began playing tennis between 3 and 7 years of age, and only 4% of the Top 300 tennis players started after the age of 10. This might be related to the fact that, firstly, the former group of athletes had more time to freely gain competitive experience, and secondly – particularly before puberty – there are sensitive learning phases that promote motor learning and thus offer the opportunity for the acquisition of technical skills (Knudsen, 2004). In addition, a tennis education starting at a young age gives the coaches a longer observation period; this reduces *talent selection* errors during early adolescence and enhances practitioners' talent identification decisions. Accordingly, it is not surprising that the evaluation of young athletes begins when they are under nine years (U9) of age (Potočnik et al., 2020; Tomkinson et al., 2017). However, because in many cases these young athletes have only little technical experience so far, these TIDs often consist of several generic test items rather than specific, more technically demanding skill tests (Hohmann et al., 2018; Niessner et al., 2020). This approach is supported by studies by Faber et al. (2020), who found a small but significant correlation between more sport specific, coordinative technical skills (e.g., speed while dribbling or aiming at a target) and previous training hours in racket players aged between 8 to 10 years old. In contrast, generic tests such as sprinting or standing long jump had no significant relationship with training volume.

While there are already some studies on the success of TID in other sports, such as soccer (see Sarmento et al., 2018), in tennis it is still questionable whether TID campaigns in the U9 age group (Hohmann et al., 2018; Pion, 2015) can provide any information whatsoever about later tennis performance. Although there are many studies on TID in junior tennis (U12–U18) and in professional tennis (Baiget et al., 2016; Van Den Berg et al., 2006), there are either no studies or hardly any on younger age groups (e.g., U9). This might be related to the fact that for this young age group, which lacks a developed tournament and ranking system, no proper differentiation of better and weaker performance groups can be established (Siener & Hohmann, 2019). The assessment of different tennis performance groups usually arises with the entrance into the junior ranking system of the U12 and is then often determined by the ranking position (Ulbricht et al., 2016). For this reason, it has been common practice to use as a template for TID in youth professional adult tennis players' profiles, collected from cross sectional studies (Hohmann & Seidel, 2003). This assumes that the same invariant skills are crucial for tennis success in both age groups. However, this has not yet been adequately demonstrated by long term studies (Baker et al., 2020). Therefore, for a prognostically valid evaluation of U9 test performances, either a prospective study design must be employed or these test performances must be considered retrospectively (see also Mostaert et al., 2020; Till et al., 2015). Either way, both approaches are highly time consuming and only possible in a longitudinal study.

The present study starts at the earliest possible point in time at which a distinction between different performance groups in tennis can be made. From U12, tennis players are able to qualify for the national junior tennis rankings of the German Tennis Federation and thus stand out from other athletes. These junior tennis rankings cover the age range up to U18 (Deutscher Tennis Bund [DTB], 2020). Within the group of junior tennis players, two performance groups – junior ranked players (RPs) and non ranked players (NPs) – can be distinguished. Based on these two performance groups, it is possible to retrospectively analyze the performance shown in the physical fitness and motor competence tests of the U9. Thus, the aim of this long-term retrospective study was to compare the initial U9 physical fitness and motor competence test performances of today's junior ranked and non–ranked tennis players from the national tennis ranking list of the German Tennis Federation (U12–U18) and, based on this, to address whether TID in U9 seems at all possible. Overall, this study makes the first attempt to close the gap in research on TID at U9 and to investigate the validity of talent prediction by physical fitness testing at this young age. If it transpires that at this young age, there are already significant differences in performance characteristics between later successful and less successful tennis players, these characteristics can be used to make a talent forecast for players when they are only 8 years old.

## MATERIALS AND METHODOLOGY

### General study design

In this retrospective (long-term) study, we examined whether there is a relationship between the playing success achieved by junior tennis players (U12–U18) and this cohort's general childhood performance (U9). For this purpose, 174 junior tennis players were divided into two groups based on their current playing success: (A) 16 players who have achieved a position in the official national tennis ranking lists of the German Tennis Federation (RPs); and (B) 158 players who have not achieved a position on the rankings (NPs).

All these players (A+B) had already been tested in the U9 category in two anthropometric tests, six physical fitness tests, and three motor competence tests (Fig. 1). This now allows us to analyze whether the two performance groups had already showed differences in their performance characteristics at the age of 8 and, if so, in which generic tests the differences were particularly evident. The results can then indicate whether certain characteristics/predictors detectable as early as U9 may point to later success at junior age and thus make TID worthwhile at this earlier stage.

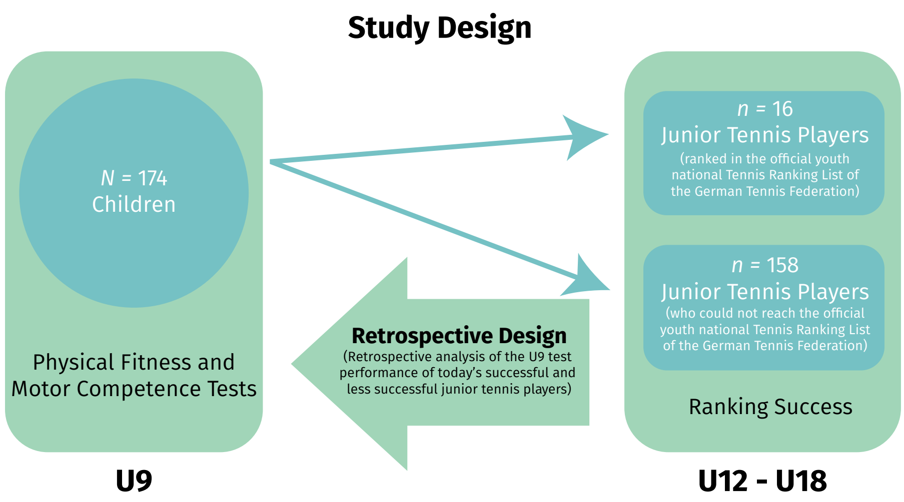


*Figure 1.* Study Overview

## Participants

A total of 174 junior tennis players (U12–U18; *M* = 156.3 months, *Min* = 132 months, *Max* = 206 months) were included in this study. The sample consists of 62 girls (♀) and 112 boys (♂). Among these junior tennis players, 16 RPs (*n*♂ = 11, *n*♀ = 5) achieved a place in the official national junior tennis ranking list of the German Tennis Federation (DTB, 2020). To be included in this junior ranking, a player must have at least 10 wins in junior ranking matches or have already earned a position in the adult rankings. All other junior tennis players (NPs; *n* = 158, *n*♂ = 101, *n*♀ = 57) were registered in clubs and actively participated in regional and local club competitions and tournaments but did not achieve the necessary number of wins in official ranking matches to earn a place on the official national junior ranking list of the German Tennis Federation.

As part of the study, all participants and their parents were fully informed about the content of the testing and the resulting studies, and their consent was obtained before the study began. The study and research design were in line with the Declaration of Helsinki and was approved by the ethics committee of the Municipality of Fulda (Germany), as well as the State Office of School Education of Fulda (Germany).

## Measurements

### *Physical Fitness and Motor Competence Tests of U9 Testing*

All junior tennis players were already tested at U9 with a test battery of two anthropometric (body weight and height) tests; six physical fitness tests (sprint, flexibility, arm and upper body strength, leg power, and endurance performance); and three mixed motor competence tests (coordination, balance, and ball throw performance). Each of the standardized tests was performed according to existing test protocols, which include a detailed description of the test items, the exact test set up, the demonstration of the test item, the execution of the test phases, and the measurements (Bös et al., 2009; Siener et al., 2021):

### *20-m Sprint*

The sprint performance was recorded using a 20-m sprint (~21.9 yards). In each of the two possible attempts, the test persons started 0.3 m before the starting line. The time was stopped by means of light gates (Brower Timing Systems; Draper, USA). The test met an objectivity value of .86 and a reliability value of .96 (Bös et al., 2009).

### *Sideward Jumping*

The number of two-legged jumps that a participant could perform between two 50-cm x 50-cm (1 cm ≈ 0.4 inches) squares within 15 s was measured. Only jumps where none of the boundary lines was touched counted. In total, two attempts were made, with a break of at least 2 min. between each attempt. The mean value of both tests was used for further calculations. The objectivity of this test is .99 and the reliability is .89 (Bös et al., 2009).

### *Balancing Backwards*

The participants balanced backwards on a 6-cm, 4.5-cm, and 3-cm wide wooden beam. Two attempts were made on each beam, and the number of steps (feet fully raised) before leaving the beam was counted. A maximum of eight steps/points could be achieved per beam, so that the total maximum number of points for this test task is limited to 48. The test achieved an objectivity of .99 and a reliability of .73 (Bös et al., 2009).

### *Standing Forward Bend*

In this flexibility test, the participants have to try to reach as low as possible with their hands. The ground height is evaluated as 0 cm, and everything that goes beyond that (below ground level) is entered as a positive value. The achieved value had to be held for at least 3 sec. in each of the two attempts. The test achieved an objectivity of .99 and a reliability of .94 (Bös et al., 2009).

### *Push-Ups*

In this test, the participants had to perform as many push-ups as possible over 40 sec. An execution was only evaluated if the technique was correct and the test person subsequently lay back down in the starting position. Only one attempt was performed. Bös et al. (2009) rated the objectivity with .98 and the reliability with .69.

### *Sit-Ups*

The sit-up test also evaluated the number of correctly performed sit-ups in 40 sec. Only one attempt was performed. The objectivity of this test was .92 and the reliability was .74 (Klein et al., 2012).

### *Standing Long Jump*

In the standing long jump test, the jumping distance was measured in centimeters. Each test person had two attempts, of which the better attempt was recorded. Between both attempts, a complete break was ensured. The test achieved an objectivity of .99 and a reliability of .89 (Bös et al., 2009).

### *Ball Throw*

In the ball throw test, the throw distance was measured in centimeters orthogonal to the line of release. The test persons threw with an 80-gm ball from a standing position three times in a row. As in the previous tests, the best value was evaluated. The test could be evaluated in our own studies ($n$ = 1800) with a reliability of .77.

#### *6 min Endurance Run*

In the endurance test, the participants tried to run as many laps as possible around a 9-m x18-m volleyball field in 6 min. The achieved distance was noted in meters. The test was carried out by a total of 15 people at the same time. The objectivity of this test is .87 and the reliability is .92 (Bös et al., 2009).

All tests were conducted by qualified personnel during regular school hours (8–12 am), and a uniform warm-up was held before starting. The 6-min endurance run was always the last test in the test series.

## STATISTICAL ANALYSES

For all analyses, the software SPSS (version 26; SPSS Inc, Chicago, IL, USA) was used.

A univariate ANOVA found that age affects the data and that the performance of U9 players increased significantly with age. In order to avoid this age bias, bivariate regressions to age in months were used to z standardize the test value residuals separately for both genders (Siener et al., 2021). Since this procedure poses the risk that in homogeneous groups certain test values are distorted by the group composition, the results of about 4000 children predominantly not from sporting clubs (see Hohmann et al., 2018; Tomkinson et al., 2017) were additionally used for z standardization. Thus, all data are available as age and gender independent z values. To ensure a better comparison of the sprint data, the z values were additionally multiplied by "–1", thus turning the better sprint results into positive z values.

T-Tests and a MANCOVA were used to check whether the test results differed significantly between the gender and tennis success groups. A covariate weight was chosen. Effect sizes for *partial eta squared* ($\eta^2$) smaller than 0.01 are interpreted as trivial, effect sizes between 0.01 and 0.059 are small, between 0.06 and 0.139 are moderate, and values higher than 0.14 are large.

To gain a better insight into the influence of the individual test items on later tennis success, *bivariate correlations* were also calculated. The Spearman correlations were classified according to the following pattern: trivial (0 – 0.1), small (0.1 – 0.3), moderate (0.3 – 0.5), and large (0.5 – 0.7).

## RESULTS

The initial U9 test results of the junior tennis players show that in almost all test tasks, RPs perform significantly better than NPs (Table 1). Particularly noteworthy here are the standing long jump, the sideward jumping, the balancing, the endurance run, and the ball throw, which all have values of $p < 0.001$ ($t$-Tests). In sideward jumping, the maximum value of the RPs was five jumps (12.5%) higher than the maximum value of the NPs. In the ball throw and the standing long jump, the later better athletes had a clear advantage in their youth. In both tests, approximately 84% of the NPs did not reach the average test result of RPs. In the sideward jumping, the balancing, and the endurance run, 84% of the RPs were also above the average result of the weaker performance group. For the forward bend test task ($p$ = 0.158) and body weight ($p$ = 0.910), no significant differences in the two performance groups could be found. In addition, the later ranked players are on average 4 months older than their weaker tennis colleagues ($p < 0.01$).

In examining the raw scores of the two performance groups separately by gender, it is notable that no significant group difference can be found for boys ($n$♂ = 112) in the test scores for body weight ($p$ = 0.149), height ($p$ = 0.8), sprint ($p$ = 0.106), push-ups ($p$ = 0.065), and forward bends ($p$ = 0.111). All other test results showed significant group differences ($p < 0.01$). *Girls* (n♀ = 62) showed comparable results. Only the test results for body height ($p$ = 0.044) and sprint ($p$ = 0.013) were also significant in contrast to the results for boys.

Also, after eliminating the age effect, RPs achieved better z-values than the NPs in all test items (Fig. 2). Except for the 20-m sprint, however, the ascending order of the single tests was almost identical in both groups. Also, in regard to the order of the RPs' tests, the ball throw ($M_z$ = 2.03) was in first place, followed by the standing long jump ($M_z$ = 1.53), the endurance run ($M_z$ = 1.42), and sideward jumping ($M_z$ = 1.41). For the ball throw, female tennis players ($M_z$ = 2.95, $n$ = 5) performed significantly better ($p < 0.05$) than their male counterparts ($M_z$ = 1.61, $n$ = 11). The same holds true for body height ($M_z$♀ = 0.92, $M_z$♂ = 0.07) and the standing long jump ($M_z$♀ =1.88, $z$♂ = 1.37). The anthropometric measures of the RPs were $M_z$ = 0.34 (body height) and $M_z$ = −0.30 (body mass). RPs at U9 were, therefore, on average slightly taller and lighter than the NPs. However, while in a t-test comparison, significant differences between the two performance groups can be found in almost all generic test items (with the exception of $p_{Forward\ bends}$ = 0.086), there are no significant differences in the anthropometric test values of body mass ($p$ = 0.078) and height ($p$ = 0.234).

Table 1.
– *Descriptive statistics for the former U9 test results of the junior tennis players.*

| | Groups | N | M | SD | 95% CL | | Min | Max | *p* |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | LL | UL | | | |
| Calendar age (months) | NPs | 158 | 93.8 | 5.0 | 93.0 | 94.6 | 83 | 110 | 0.007 |
| | RPs | 16 | 97.5 | 6.4 | 94.1 | 100.9 | 88 | 112 | |
| Test results | | | | | | | | | |
| Body height (cm) | NPs | 158 | 129.1 | 5.7 | 128.2 | 130.0 | 117 | 145 | 0.034 |
| | RPs | 16 | 132.3 | 4.5 | 129.8 | 134.7 | 127 | 143 | |
| Body mass (kg) | NPs | 158 | 27.2 | 4.1 | 26.6 | 27.9 | 20.0 | 39.3 | 0.910 |
| | RPs | 16 | 27.3 | 1.9 | 26.3 | 28.3 | 23.4 | 30.6 | |
| Sideward jumping (repeats) | NPs | 157 | 27.3 | 6.1 | 26.3 | 28.2 | 6.5 | 40.5 | 0.001 |
| | RPs | 16 | 33.0 | 5.1 | 30.3 | 35.7 | 27.0 | 45.0 | |
| Balance backward (steps) | NPs | 158 | 30.3 | 8.5 | 28.9 | 31.6 | 8 | 48 | 0.001 |
| | RPs | 16 | 38.3 | 5.7 | 35.2 | 41.3 | 28 | 48 | |
| Standing long jump (cm) | NPs | 157 | 135.1 | 16.2 | 132.5 | 137.6 | 82 | 190 | 0.001 |
| | RPs | 16 | 153.0 | 17.2 | 143.8 | 162.2 | 125 | 178 | |
| 20 m sprint (s) | NPs | 158 | 4.45 | 0.36 | 4.39 | 4.51 | 3.10 | 5.32 | 0.011 |
| | RPs | 16 | 4.21 | 0.34 | 4.03 | 4.39 | 3.50 | 4.72 | |
| Push ups (repeats) | NPs | 158 | 14.6 | 3.6 | 14.0 | 15.1 | 4 | 24 | 0.041 |
| | RPs | 16 | 17.1 | 5.2 | 14.3 | 19.9 | 9 | 25 | |
| Sit ups (repeats) | NPs | 158 | 19.2 | 5.1 | 18.4 | 20.0 | 2 | 30 | 0.002 |
| | RPs | 16 | 23.4 | 4.1 | 21.3 | 25.6 | 15 | 29 | |
| Forward bends (cm) | NPs | 158 | 1.98 | 5.94 | 1.05 | 2.92 | -11 | 18 | 0.158 |
| | RPs | 16 | 4.16 | 4.90 | 1.55 | 6.77 | -10 | 12 | |
| 6 min run (m) | NPs | 154 | 959 | 130.8 | 938 | 979 | 545 | 1259 | 0.001 |
| | RPs | 16 | 1078 | 80.7 | 1035 | 1121 | 891 | 1200 | |
| Ball throw (m) | NPs | 155 | 13.5 | 4.03 | 12.9 | 14.2 | 3.8 | 27.6 | 0.002 |
| | RPs | 16 | 18.8 | 5.35 | 15.9 | 21.6 | 9.2 | 28.3 | |

M = mean; SD = standard deviation; SE = standard error; CL = confidence limit; LL = lower limit; UL = upper limit; Min = minimum; Max = maximum; NPs = non-ranked players; RPs = ranked players; p = *p*-value of the *t*-test

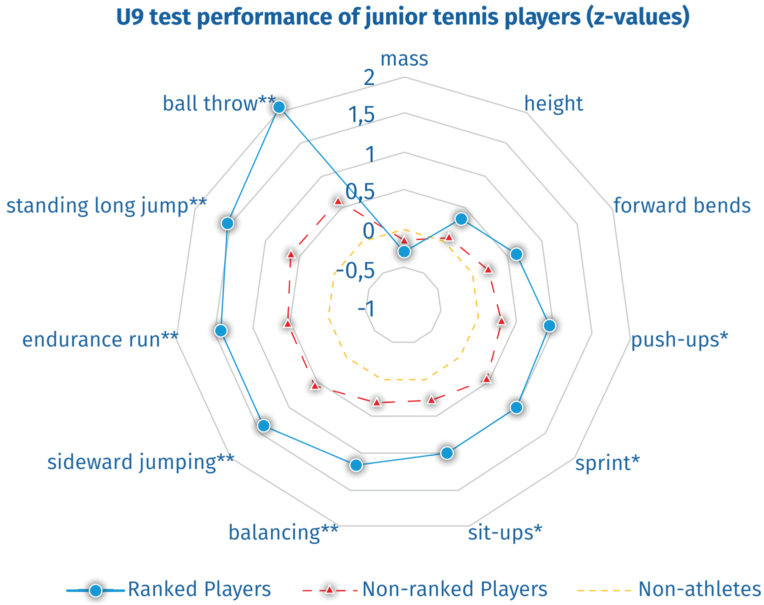


*Figure 2.* Initial U9 test performances (z-values) of junior ranked tennis players, non- ranked tennis players, and non-athletes (* p ≤ 0.05; ** p ≤ 0.01).

The MANCOVA (Table 2) shows that body mass only had a significant ($p < 0.05$) influence on the test values of balancing, sit ups, and the endurance run. Gender only had a significant influence on the ball throw in the analyses ($p_{Gender}$ = .012; $p_{Performance*Gender}$ = .056). All other hypotheses concerning a difference between the genders had to be rejected. As already suspected in *Fig. 2*, a *partial Eta squared* of $\eta^2$ = .157 shows the strongest effect size of group differences in the ball throw. The standing long jump, the endurance run, and sideways jumping show moderate effect sizes, while all other effects are small. It is notable that the standard deviation (SD) for the RPs fluctuates strongly. For the NPs, on the other hand, the SD of almost 1, which is usual for z values, is achieved.

Looking at the box plots of RPs and NPs for the different test tasks (*Fig. 3*), it is notable that the RPs have the biggest advantage, especially in the ball throw. Nevertheless, not all of the 16 RPs can show very high values. There is also one athlete with a *z*-value of *z* = −1.2 and three athletes with z values below *z* = 1.0 (range of 6.06). All other RPs show above-average throwing performances. Such large fluctuations in performance cannot be seen in test items the endurance run (range of 2.3) and balancing (range of 2.16). Here the results are comparatively close to each other, and none of the RP values is below a *z*-value of *z* = 0. Also, in body mass, no major fluctuations can be detected in the RPs (range of 1.15). The results show that in the ranked player group 75% (12/16) of the tennis players at the age of 8 yrs achieved a very good test result ($z \geq 1.0$) in the standing long jump, the endurance run, and the ball throw. In addition to the three tests mentioned, more than 50% of the ranked junior tennis players were initially (when U9) able to achieve a very good test score in the sideward jumping (68.8%) and sit ups (56.3%).

Table 2.
*– Results of the MANCOVA for the different former U9 test disciplines*

| | NPs (Mean ± SD) | RPs (Mean ± SD) | F | Sig. | Partial Eta Squared (η2) |
|---|---|---|---|---|---|
| Ball Throw | 0.639 ± 0.999 | 2.033 ± 1.553 | 29.943 | .0001 | .157 |
| Standing Long Jump | 0.634 ± 0.874 | 1.532 ± 0.906 | 14.175 | .0001 | .081 |
| Sideward Jumping | 0.558 ± 0.949 | 1.407 ± 0.773 | 11.401 | .001 | .066 |
| Endurance Run | 0.537 ± 0.975 | 1.423 ± 0.564 | 11.239 | .001 | .065 |
| Sit-Ups | 0.281 ± 0.908 | 1.010 ± 0.710 | 9.697 | .002 | .057 |
| Balancing | 0.300 ± 0.938 | 1.157 ± 0.605 | 9.542 | .002 | .056 |
| Sprint | 0.440 ± 0.912 | 0.987 ± 0.851 | 5.468 | .021 | .033 |
| Push-Ups | 0.288 ± 0.927 | 0.924 ± 1.360 | 5.090 | .025 | .031 |
| Forward Bends | 0.198 ± 0.952 | 0.634 ± 0.564 | 2.548 | .112 | .016 |

SD = standard deviation; NPs = junior non ranked tennis players; RPs = junior ranked tennis players; Effect sizes (η2): 0.01 ≤ small, 0.06 ≤ medium, 0.14 ≤ strong

Apart from the forward bends, no significant results can be seen for the correlations of tennis ranking success with body height or body mass (Table 3). All other test values achieved significant correlations, mostly in the moderate range.

The ball throw reaches the highest correlation value with r = .360, followed by the standing long jump (*r* = .287), and the endurance run (*r* = .296). However, these two values cannot be considered a moderate result. Also, all other test values have small correlation effects.

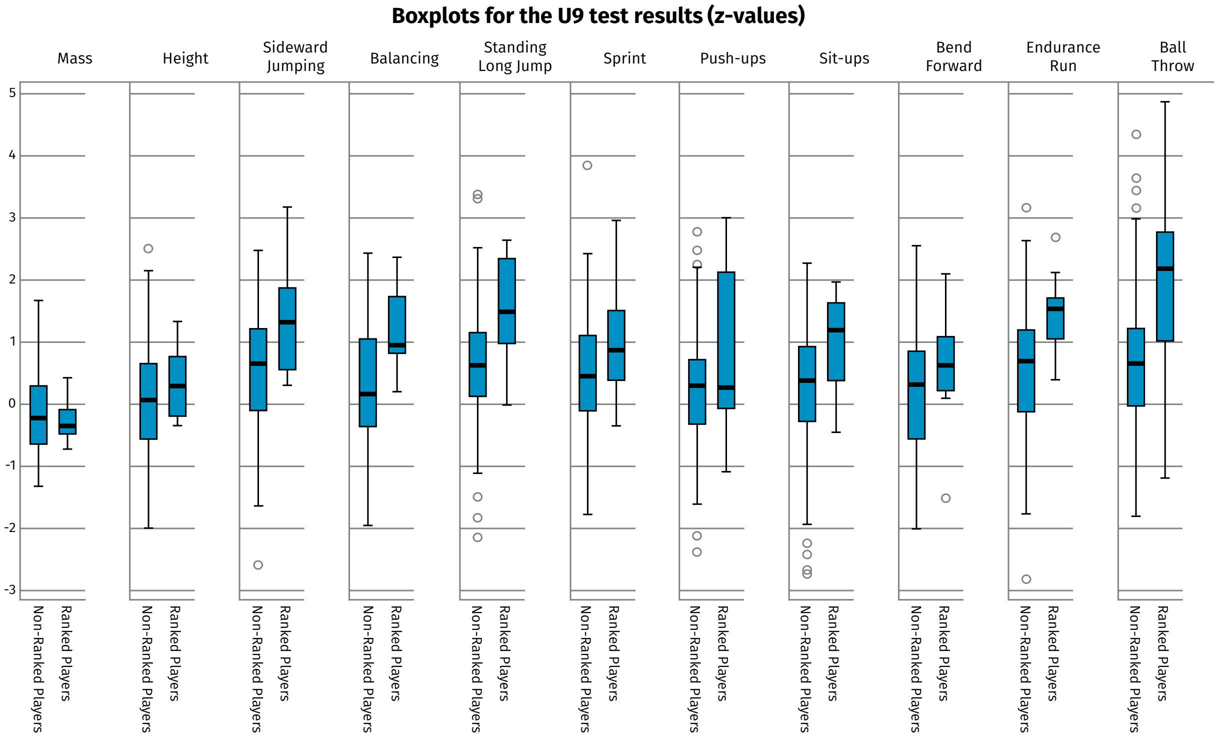


*Figure 3.* Boxplots of the former U9 test results (z-values) of junior non-ranked tennis players and ranked tennis players.

Table 3.
*– Bivariate correlations of the different U9 test results and the chance to achieve a ranking position in the official youth national ranking lists of the German Tennis Federation (* p ≤ 0.05; ** p ≤ 0.01).*

| | Mass | Height | Sideward Jumping | Balancing | Standing Long Jump | Sprint | Push-ups | Sit-ups | Forward Bends | Endurance run | Ball Throw |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tennis Ranking Success | -.077 | .091 | .256** | .263** | .287** | .226** | .187* | .231** | .130 | .296** | .360** |

## DISCUSSION

The aim of this study was to investigate whether TID in tennis is already possible in the U9 age group and whether physical fitness tests and motor competence tests provide an early indication of later junior success. For this purpose, a long-term study retrospectively investigated the initial U9 test performances (based on physical fitness and motor competence tests) of today's junior tennis players in the official junior ranking list of the German Tennis Federation, as well as the weaker tennis players without a successful placement in the ranking list. If measurable differences in certain physical fitness and motor competence characteristics/predictors between these two current junior performance groups can already be identified at U9, then conversely, a prediction of later junior success can also be prospectively made at U9 on the basis of these characteristics, and the validity of early TID can be evaluated.

It was shown that the group of junior ranked tennis players were already significantly superior to the group of non ranked players in almost all test items at the age of 8 (U9). Looking at the results of the U9 tests more closely, it is noticeable that the differences are particularly high in test tasks the ball long throw, the endurance run, and the standing long jump, while U9 body height and body weight did not show any significant difference between the two groups of junior tennis players.

In *Table 1*, it can be assumed that the RPs as children (U9) had a clear advantage over their peers. The mean values of all test items are higher for the later group of more successful athletes than for the later group of NPs. With the exception of body weight and flexibility, the raw values already show significant differences between the two performance groups. However, the values still cannot be interpreted well, as age can also have an effect on performance. Considering the age in months, it is also notable that the later RPs are, on average, about 4 months older than the NPs. This is consistent with various studies on the *relative age effect*, according to which older athletes of a given age group have an advantage over their younger peers (Musch & Grondin, 2001). According to the data, this advantage does not seem to vanish even after about 5 years (Smith et al., 2018). Also, comparing the results of similar tests by Tomkinson et al. (2017) and Bös et al. (2009), it is of note that the participants tested in this study performed better in certain test items than the comparison groups of the other studies. Therefore, it can be assumed that regional differences influence performance. For this reason, too, it makes sense to standardize the **raw scores**. For the *z*-value standardization, in addition to the gender and age in months of the tennis players, the data of about 2000 non athletes of the same region were also used. This prevents regional test bias from blurring the results (Hohmann et al., 2018). In addition, **male and female** athletes can be evaluated together, as is usual in talent identification campaigns (Pion, 2015). While the raw scores of female and male tennis players still differ significantly in the four test tasks the sprint, the forward bends, the endurance run, and the ball throw, the MANCOVA of *z*-values only shows significant differences between the genders in the ball throw, with girls scoring comparatively better than boys. Overall, however, it must be noted that with this exception, the sample is still relatively homogeneous at this age (Siener & Hohmann, 2019).

However, the *z*-standardization to the non athletes also has the disadvantage that the *z*-values are comparatively higher than usual. This is especially noticeable in the **ball throw**, where individual tennis players can show *z*-values of $z$ = 4 and more. Therefore, the results must always be seen in relation to the regional non athletes. Nevertheless, the differences in the individual test items now can be better seen. In this study, the ball throw is also the most important U9 test value. Both the NPs and RPs achieved the highest average test values of $z$ = 0.64 and $z$ = 2.03. It is not surprising that the ball throw, as a combined exercise of technique and strength, has such a high influence on subsequent success in tennis, since the two movements, the tennis serve and throwing abilities, have similar characteristics (Fett et al., 2020). The serve is of particular importance in tennis, as it lays the foundation for the rally and can put pressure on the opponent right from the beginning to achieve a point win. As early as 1992, Roetert et al. could prove a significant correlation between national tennis success and striking speed (correlations: $r_{forehand}$ = 0.68, $r_{backhand}$ = 0.59, $r_{serve}$ = 0.57). Similar results have been shown in recent studies by Ulbricht et al. (2016) on the influence of fitness characteristics on tennis performance. They showed that in 902 tennis players aged from 11 to 16 years, serve velocity (correlations: $r_♀$ = −0.43 to −0.64, $r_♂$ = −0.33 to −0.49) and upper body power (medicine ball throw; $r_♀$ = −0.26 to −0.49; $r_♂$ = −0.20 to −0.49) have the greatest impact on tennis performance. We were able to demonstrate a significant correlation between the ball throw and the RP of r = 0.360 ($p < 0.01$), which is comparable to the studies described above. *Table 2* also shows the highest effect size for the ball throw, with a *partial eta squared* of $\eta^2$ = 0.157. This is the only one of the various test items that can demonstrate a strong effect. A high influence on tennis performance could be proven not only for the serve but also for the upper body strength in general. In cross-sectional studies by Kramer et al. (2017) on 86 Dutch junior elite tennis players, a significant correlation between the combined upper body strength abilities of the ball throw and two medicine ball throws with the ranking of the male U13 players (Pearson correlation: *r* = −0.5*) was demonstrated. This is supported in studies by Fett et al. (2017) on U16 *Davis Cup* players and regional squad tennis players, who demonstrated a large effect size (*Cohen's d* = 1.04) for the throwing performance (forehand medicine ball throw) in *t*-tests.

In college tennis competitions, Kovacs (2007) measured an average playing time of about 1.5 hr. With such a long game duration, it is not surprising that due to exhaustion, hitting accuracy can drop as low as 81% (Davey et al., 2002). Thus, **endurance** has an important impact on tennis success and in our study reaches a moderate effect strength of $\eta^2$ = 0.065. Box plots also show that the range of results is relatively small, which is also shown in *Table 2* in SD = 0.564. A certain level of endurance seems to be indispensable for achieving rankings. For example, in a study with 40 male RPs (ranked 1 to 40) at the age of 15 years, a 20-m shuttle run (number of laps) correlated significantly with the achieved ranking (Meckel et al., 2015). However, the achieved correlation of *r* = −0.581* is much higher than the correlation value of *r* = 0.296** proven here. In addition to Meckel and colleagues (2015), other authors demonstrated the importance of endurance performance for tennis success in the U15 category (Filipcic et al., 2010). While in older athletes good endurance, due to the shifting of the fiber distribution, can have a rather negative effect on sprint ability, at the age of 8 years a significant correlation between the two abilities is still evident (*r* = 0.331**). Nevertheless, the influence of **sprinting** is weaker compared to endurance and has a correlation value of only *r* = 0.226** (Sprint–Tennis Ranking Success). The *partial eta squared* also turns out to be only a *small* effect, with $\eta^2$ = 0.03. This seems surprising at first sight, since studies by Girard and Millet (2009) on male U15 tennis players showed correlation values between the 20-m sprint performance and the ranking of *r* = 0.74**. However, their study was based on a small sample, with only 12 participants. Nevertheless, Filipcic et al. (2010) also demonstrated similar results in a larger sample (*N* = 159, U16–U19). In investigations by Ulbricht et al. (2016), correlations of $r_♂$ = 0.31** and $r_♀$ = 0.19* were found in the U14 category (*N* = 431), but in contrast to the serve velocity (*r* = 0.33 to 0.64 of U12–U16), these values were rather low. Also, the effect size between national and regional athletes was mostly small ($d_{Cohen}$ = 0.00 to 0.21 for U14–U16; exception: $d_{Cohen}$ = 0.63** for ♂ U12). Ulbricht explains the low significance of the classic linear sprint tests by the fact that typical movements in tennis are limited to a radius of 3 to 4 meters. The maximum speed would therefore never be reached. This fact is even more relevant for the U9 players, where the 20-m sprint is more dependent on speed endurance than in older research groups. Therefore, at a second view, the weak performance of the 20-m sprint is understandable.

The two test tasks **sideward jumping** and **standing long jump** have moderate effect size of a *partial eta squared* of 0.066 and 0.081. The standing long jump is also in second place in the overall U9 motor skills profile, and both RPs and NPs were able to achieve very good values at a young age. The explosive power of the leg muscles is also of great importance for short fast starts and quick first steps. Both exercises were investigated in a series of agility tests (see Girard & Millet, 2009; Ulbricht et al., 2016). Roetert et al. (1992) was one of the first to point out the significant correlation between the hexagonal test and the tennis ranking position. Although a classical agility test is missing in our study, the high value in the standing long jump may be an indication of corresponding abilities in tennis.

None of the RPs was extremely light or heavy at the age of 8. Accordingly, no significant results could be found in **body mass** comparing the two performance groups. Also, the **body height** did not lead to a significant result (*t*-test: p = 0.24). This is surprising, since a larger person has an advantage over smaller persons in the serve and also in the range of covered space on the court. Due to the higher hitting position of the ball, the relative field size to be hit in the opponent's field is larger than from a lower hitting position of the ball (Vaverka & Cernosek, 2013). A higher hitting position also allows the ball to be played at greater speed, so it should not be surprising that coaches give larger athletes a higher chance of success (Robertson et al., 2018). Nevertheless, the height of the junior tennis players tested in the U9 had no direct influence on their tennis ranking success.

Overall, U9 results are comparable to results from other performance studies of U11–U16 tennis players (Fett et al., 2017; Ulbricht et al., 2016). Therefore, it can be assumed that talent specific characteristics remain stable over time (Hohmann et al., 2018) and that athletes who tend to perform better later on already emerge in U9. However, the results cannot consistently confirm the prognostic validity of TID in U9, as a high association with later ranking success could be found in only a few test items. Future TID predictions could therefore benefit from more test items or holistic talent assessments (e.g., motivation; Zuber et al., 2016). Nevertheless, for coaches, the results demonstrated can serve for a first cautious assessment of their training groups.

## LIMITATIONS

The **test battery** used here covers a wide range of generic motor tests and almost all basic abilities (speed, strength, flexibility etc.). These tests intentionally correspond to the physical fitness and motor competence tests often used in TID campaigns in Europe (Niessner et al., 2020; Pion, 2015; Potočnik et al., 2020). Nevertheless, it should be noted that the results of the study shown here also depend to a large extent on the tests used. According to the retrospective design, the U9 tests here were already given up to 9 years ago; accordingly, it was not possible to draw on the latest test developments of recent years (Faber et al., 2017; Faber et al., 2018; Fernandez-Fernández et al., 2014). However, although Koopmann et al. (2020) were able to highlight the use of sport specific tests in the context of TID for the junior level, it is questionable whether similar successes in TID can be already predicted in U9 through sport specific tests in tennis. This is because the use of sport specific tests can quickly overburden children without many years of sport specific technical experience and, accordingly, would presumably over recommend early specialized athletes. However, specialization as early as 8 years of age is at the same time considered critical in the eyes of many scientists (LaPrade et al., 2016). Therefore, for future testing of the U9 players, sport-specific tests should only be used to a small extent. Nevertheless, the study shown here could have benefited from an additional *change of direction agility test, a stroke velocity test, or* a *handgrip test* (Ulbricht et al., 2016). However, tennis success does not only depend on physical fitness. Zuber et al. (2016) have therefore made initial attempts to integrate *psychological tests* into TID campaigns. In the future, it will be interesting to see how TID develops further.

The small **sample size** is another limitation of the study. With only 174 participants and also only 16 ranked players, the sample is very small. The results shown here are therefore not generalizable and must always be interpreted in relation to group size. Following Gagné (2010), only about every $10^{th}$ athlete can be described as talented. Accordingly, if a group of 50 ranked players were to be studied, a total sample of approximately 500 participants would be needed. However, investigating such large sample sizes is highly time-consuming and cost-intensive, especially for long-term studies, which is why only a few studies have made this effort (Bergkamp et al., 2019; Gonaus & Müller, 2012; Höner et al., 2017; Höner & Votteler, 2016).

Another problem could be the joint consideration of genders. In Germany, it is common to train girls and boys together at a young age and thus to screen them together in the initial TID. However, various studies (Fernandez-Fernández et al., 2014; Kramer, Huijgen, Elferink-Gemser, & Visscher, 2016; Sannicandro et al., 2012; Ulbricht et al., 2016) suggest that boys' physical fitness and motor competence (in relation to tennis) may differ from that of girls. Usually, these differences do not emerge until puberty (Grosser et al., 2008). In the U9 sample used here, no significant differences in age-adjusted z-scores between the genders were found except for ball throwing (where ranked girls were slightly better than ranked boys). Nevertheless, even the same test values could have a different effect for the different genders later. However, our calculations showed that the results for test items with the strongest effect values were almost identical for both genders. Unfortunately, due to the even smaller sample size (especially for the 62 girls), these results are difficult to evaluate. Therefore, in future studies, the differentiation of the genders should be considered again more intensively.

## CONCLUSION

This long-term retrospective study shows that TID appears possible even at U9 and that early test performance can be used to predict later junior tennis success. Today's junior tennis players in the national tennis ranking list of the German Tennis Federation were already superior in U9 to current weaker junior players in almost all early test items. This is especially evident in throwing performance, endurance running, and the standing long jump. Throwing performance is the most important factor. In all analyses (MANCOVA and correlation), it was shown to have the greatest influence. All other test items could only show medium to small effect sizes. Retrospective body height and weight at the time of U9 testing did not show any difference between the groups. Nevertheless, the study demonstrates that a valid talent prognosis seems to be possible even at the U9 level.

## PRACTICAL APPLICATION

The results show that TID can be successful as early as U9. Coaches should particularly focus on throwing power in their search for talent, as this has the greatest effect on reaching the national youth rankings later on. Namely, every second person with a throwing performance of $z \geq 2$ reached the rankings. In addition to throwing power, endurance and jumping power were also good indicators of later success. In both parameters, with one exception, later RPs reached above-average values ($z \geq 0$). However, the results also show that even weaker athletes ($z_{ball\ throw}$ = −1.3) can still achieve success. Therefore, physical fitness and motor competence should not be used alone for TID but should be considered in addition to the coach's opinion.

## CONFLICT OF INTERESTS

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript. Also, the authors did not conduct any studies with animal participants for this article. As for other studies citied in this article, information on ethical guidelines may be found in the respective sources. All experiments comply with the current laws of the country in which they were performed.

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