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COMPARISON OF PROBABILISTIC AND FUZZY APPROACHES TO EVALUATING THE LEVEL OF PERFORMANCE PRECONDITIONS IN TENNIS

PRIMERJAVA VERJETNOSTNEGA IN MEHKEGA PRISTOPA K OCENJEVANJU RAVNI USPEŠNOSTI V TENISU

ABSTRACT

Fuzzy theory emerged in the 1960s and since the 1990s several studies have been published dealing with fuzzy theory and how it can be used in data diagnosis in sports. While the classical theory operates with sharp borders between groups and the key concept is membership (an element either belongs to the set or does not), fuzzy theory enables the minimisation of issues that arise from the strict mathematical and statistical requirements of probability theory and defines the grade of membership in the interval <0, 1> with the aid of the membership function.

The aim of this research study is to present ways in which fuzzy logic can be used when evaluating tennis players' results using the TENDIAG1 test battery and for comparing tennis players' levels with the aid of the fuzzy approach and the probability approach. The research set consisted of 12-year-old tennis players (n = 88, age: 12.5 ± 0.3; height: 157.4 ± 7.0 cm; weight: 45.3 ± 6.3 kg). The research data were obtained using the TENDIAG1 test battery in the period 2000–2010. The test battery consisted of nine measurements and of somatic and motor preconditions tests. For individual tests, based on expert evaluations and the nature of the data the membership function sets L and Γ were identified. Results of the tennis players were then assigned various grades based on both the probability approach and the fuzzy approach. A comparison of the results obtained with these approaches showed their considerable mutual relationship (r = 0.92, p = 0.05).

Detailed analysis of the results showed that the fuzzy evaluation provides a significant differentiation of the results of individual tennis players. Especially for those

IZVLEČEK

Mehka teorija (t. j. teorija nejasno opredeljenih sistemov) je bila postavljena v 60. letih 20. stoletja in od 90. let naprej so bile o njej objavljene številne raziskave, vključno s tem, kako se jo uporablja pri diagnostiki podatkov v športu. Medtem ko ima klasična teorija jasno začrtane meje med skupinami in je ključni koncept ‚pripadnost' (nek element bodisi spada bodisi ne spada v nabor), pa mehka teorija omogoča minimaliziranje podatkov, ki izhajajo iz strogih matematičnih in statističnih zahtev teorije verjetnosti, in opredeljuje stopnjo pripadnosti od intervala <0, 1> s pomočjo funkcije pripadnosti.

Namen te raziskave je predstaviti možnosti uporabe mehke logike pri ocenjevanju rezultatov teniških igralcev z uporabo testne baterije in primerjave ravni uspešnosti teniškega igralca s pomočjo mehkega pristopa in verjetnostnega pristopa. Vzorec je zajemal 12-letne teniške igralce (n = 88, starost: 12,5 ± 0,3; višina: 157,4 ± 7,0 cm; teža: 45,3 ± 6,3 kg). Podatki za raziskavo so bili pridobljeni s testno baterijo TENDIAG1 v obdobju 2000 do 2010. Testna baterija je obsegala 9 meritev ter teste somatskih in motoričnih predpogojev. Na podlagi strokovnih ocen in zaradi narave podatkov so bili pri posameznih testih določeni nabori funkcije pripadnosti L, Γ. Rezultatom teniških igralcev so bile nato dodeljene ocene na podlagi verjetnostnega in mehkega pristopa. Primerjava rezultatov, pridobljenih s tema pristopoma, je pokazala močno medsebojno povezanost (r = 0,92, p = 0,05).

Podrobna analiza rezultatov je pokazala, da mehko ocenjevanje omogoča pomembno diferenciacijo rezultatov posameznih teniških igralcev. Zlasti pri tistih, ki so pri ocenjevanju dosegli enak rezultat, who obtained an equal score in the evaluation, the fuzzy evaluation gives a finer and more precise resolution of the overall level.

Key words: diagnosis, fuzzy theory, probability theory, test battery, tennis

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mehko ocenjevanje omogoča subtilnejši in natančnejši prikaz splošne ravni.

Ključne besede: diagnoza, mehka teorija, teorija verjetnosti, testna baterija, tenis

INTRODUCTION

Fuzzy theory has its historical roots in the second half of the 20th century. Professor Zadeh established its basics in 1965 and since then fuzzy theory has been applied in a variety of fields. Fuzzy set theory is based on the 'foggy' or 'uncertain' boundaries of its sets and on infinite-valued logic. The membership function, which assigns values to levels of performance, is partially a continuous function (generally, it can be any kind of continuous function) and there are no 'skips' in the evaluation as is the case with the classical method with 'sharp' numbers. Fuzzy controllers started the first wave of successful applications of fuzzy sets in the 1980s in the areas of engineering, the building industry, transport and electrotechnics. At the beginning of the 21st century, the second wave of applications came and affected the so-called soft fields such as economics, banking or personal logistics (Talašová, 2003, Zio, Baraldi, & Popescu, 2008). Unlike the classical probability approach, which is often limited by sharp boundaries that are not an optimal alternative for evaluating the goals of any activity (for example, school marks), fuzzy theory brings a new quality view of the evaluation.

In the 1990s, applications of fuzzy theory also appeared in sports (Zinner et al., 1994). Authors examined the interactions between the attack and defence in handball, bike riding, diagnostic data analysis in speed-skating, skiing and sport games, and exercise analysis of rock&roll acrobatic exercises and gymnastics (Schiebl, 2000). Rogujl, Papić and Čavala (2009) tested the application of fuzzy theory to talent identification when trying to find talents for various sports based on morphological characteristics. Bottoni, Gianfelici, Tamburri and Faina (2011) focused on identifying important factors through the selection of under-14 youth talent in the Olympic triathlon. Papić, Rogujl and Pleština (2008, 2011) created an expert system called "Sport Talent" for identifying talent in children aged 6 to 18 years in 14 different sports (gymnastics, athletics, basketball, volleyball, tennis and others). It is the first expert system that was developed for this purpose using fuzzy logic and the World Wide Web interface. Martinez, Ko and Martinez (2010) used fuzzy logic to evaluate service quality in a fitness centre using a questionnaire; it was the first time that fuzzy logic was used in sport management and marketing. The principles and applications of fuzzy theory in kinanthropology were first published in the Czech Republic by Blahuš (1999, 2000). Talašová (2003) provided an example of the application of fuzzy theory to the diagnostics of performance preconditions in tennis using the NEFRIT software (Nefrit-TENIS, 2000). The application of fuzzy theory to the diagnostics of performance preconditions in tennis and in a university entry examination were analysed by Zháněl et al. (1999, 2001).

In sports, a common research aim is to detect the level of performance preconditions (motor abilities and skills). Performance preconditions are based on the theory of motor constructs commonly used in German-speaking countries and cover motor skills and abilities considered as the preconditions of a sport performance (Bös, 2001; Zháněl et al., 2003). Diagnostics of the level of motor preconditions are based on an associative measurement principle where motor abilities and skills are considered as hypothetical constructs or latent features. Research data (rough score) obtained by using various diagnostic methods are analysed with statistic methods and are usually transformed into a derived score, which is then normed. This allows an easy evaluation of an athlete's level of performance preconditions (Beck, J., & Bös, 1995; Bös, 2001; Haag, 2010). We can distinguish these basic approaches for constructing norms: norms based on a calculation of basic statistical characteristics (arithmetic mean, standard deviation), norms based on percentiles, norms based on ages, and norms based on objectively justified standards

(Beck, J., & Bös, 1995; Haag, 2010). The most commonly used scales (norms) are e.g. free-steps, five-steps, seven-steps; there are often used standard (derived) scales for evaluation, e.g. z-scale, Z-scale, C-scale, T-scale, MQ-scale.

The application of fuzzy theory to the area of movement diagnostics has been frequently undertaken, although publications on this topic are more of an exception in the Czech Republic. Hence the purpose of this paper is the application of fuzzy sets for evaluating the level of performance preconditions in tennis based on previous research by Zhaněl et al. (1999, 2006).

Results of tests of individual tennis players were evaluated by a fuzzy approach with the aid of evaluation membership functions, in line with the procedures used by other authors (Papić et al., 2008, Zháněl et al., 2006; Zinner et al., 1994). The results were given values corresponding with degrees of membership obtained from the fuzzy evaluation functions. A similar fuzzy procedure was used by Papić, Rogujl and Pleština (2011) based on the fact that an athletic body can be characterised by authentic kinesiological structures and specific anthropological parameters that can be formulated in a membership function. Fuzzy evaluation functions were created for body height and BMI and the final value, represented by the degree of membership of the 'athletic body' set, was then compared to model types of anthropologic characteristics of sportsmen in various sports. Zinner et al. (1994) also assigned degrees of membership for evaluating the result diagnostics of skaters and constructed a membership function to assess the complex efficiency of the level of requirements.

Research subject and questions

As presented in the introduction, the aim of this study was to find and evaluate differences in the results of the performance requirements in tennis, using both the fuzzy and probability approaches. To be consistent with methodological practice (Bös, 2001; Haag, 2010), we formulated the following questions:

1. How can the fuzzy approach be used for evaluating the level of tennis results in the TENDIAG1 test battery?
2. How closely related are the evaluation results of the fuzzy approach and the probability approach?

MATERIALS AND METHODS

We used a comparative research method that works with elements of a methodology study as well as examines new approaches (methods) and their potential advantages in comparison to the current ones. It is quantitative and analytical research typically used to collect a certain set of data with the aim to identify and explain principles that can trigger or influence certain behaviour and actions (Haag, 2010; Hendl, 2008).

Research set

The set used to compare both evaluation methods consisted of 88 tennis players (age 12.5 ± 0.3; height: 157.4 ± 7.0 cm; weight: 45.3 ± 6.3 kg) who had participated in TENDIAG1 battery tests in the period 2000 to 2012. This research set was intentionally chosen, and the participants were the best Czech players and members of youth training centres.

Measurement procedures and data collection

The research data were obtained via the TENDIAG1 test battery (Zháněl et al., 2000), with testing having taken place twice a year in the period 2000–2012 within the framework of the Czech Tennis Union project "Complex diagnostics in tennis". Setting up the TENDIAG1 test battery was preceded by an extensive literature search of existing test batteries with respect to the importance of notable tennis game characteristics, the importance of individual motor abilities and requirement of a tennis-specific focus. The TENDIAG1 test battery included the measurement of basic somatic features, testing the fitness level and coordination requirements with the aid of field and lab motoric tests (Zháněl et al., 2000; Zháněl et al., 2003).

Aside from measuring the somatic features, the TENDIAG1 test battery consists of six motor ability tests. There are three field motor tests organised on the tennis court aimed at speed diagnostics ("Speed fan") and endurance diagnostics (Shuttle run, 60 timondectedes along a single baseline) and body flexibility (Fleishmann, 1964). An isometric hand strength test (measured with a Grip-D hand dynamometer, Takei, Japan) and reaction speed tests (reaction speed of the hands and legs to visual contact) can be considered lab tests, performed on FiTRONiC equipment and software: FiTRO Reaction Check and FiTRO Agility Check (http://www.fitronic.sk/en). An overview of the tests is given in Table 1.

Reliability of the TENDIAG1 test battery (bat $r_{xx'}$ = 0.98), just like the reliability of the individual tests (0.90 – 0.98), was high, the objectivity ratio was not questioned since the tests were conducted by trained and consistent personnel and the validity was in compliance with Böse (1987), attesting to the construct validity with the aid of expert theoretical justification (Zháněl et al., 2006). Following the test theory requirements (Bös, 2001) concerning the economy (in the sense of organisation, space, time) and construction of similar test batteries, the number of test items was set to be 3 + 6. The items of somatic features (height, weight, BMI) are only informative and not evaluated or included in the final score. The final score is given by the simple addition of points obtained by the tested conditional (speed, strength and endurance) and coordination (hand and leg reaction speed and body flexibility) items.

Table 1. Characteristics of motor tests for the age group 11–12 years (boys).

CODE	NAME OF THE VARIABLE	DIMENSIONS ASSESSED	MEDIUM LEVEL	UNIT
T1	Grip strength test (hand dynamometer)	Racket hand strength	24.7 – 28.7	kp
T2	Speed ('fan')	Multidirectional speed, agility	15.4 – 14.1	sec
T3	Shuttle run (60 přeběhů na single baseline)	Running endurance	154.8 – 147.3	sec
T4	Reaction speed (hands)	Eye-hand coordination	0.51 – 0.56	sec
T5	Reaction speed (legs)	Eye-leg coordination	0.39 – 0.44	sec
T6	Flexibility	Body flexibility	40 – 44	num/20 sec

Explanatory notes: T1 – T6 … individual tests

When creating the performance standards for evaluation of the TENDIAG1 test battery results, we took into consideration the above-mentioned views and consulted them with tennis experts. The three-degree standards employ the following categories – low level (0 points), medium level (1 point) and high level (2 points); in other words, below-average, average and above-average levels. The standards followed the classical probability approach calculating basic statistical features for individual age categories of tennis players. The total score in the TENDIAG1 test battery ranges from 0 to 12 points (out of 6 tested items). The three-degree evaluation standard for boys aged 11–12 is shown in Table 1 (the medium level gives the range constructed by the arithmetical average and prevailing deviation M ± s).

Data analysis

The research data have physical values (kiloponds, seconds) or index-type dimensionless values; the test of body flexibility is evaluated by the number of correctly performed cycles which makes it discrete metric data. All of the data can be considered metric.

Normality of the distribution of the results was verified by the Kolmogorov-Smirnov test (K-S test). To measure aspects of the relationship between the variables, we used the Pearson or Spearman correlation coefficient. The research data were processed with the MS EXCEL and STATISTIKA 10 software.

Results

Results of the fuzzy and score evaluations are shown in Table 2. Based on the probability approach, we assigned points to the tennis players' results in the TENDIAG1 test battery, using the three-degree evaluation standard from the interval of <0;2>. The final sum of points made up the total score for each individual player. With the fuzzy approach, using the membership functions (Papić, Rogujl, & Pleština, 2011; Zadeh, 1965, 2008), we similarly calculated the grades of membership showing the level of results of individual tennis players (the aggregation method). The total of the membership grades in the test provides the final score of the test battery.

Based on the expert evaluation and the nature of the results acquired in individual tests for the membership functions we partially used the linear functions L, Γ. For tests where a lower value meant a better evaluation, we used membership function L (T2, T3, T4, T5) and for the other two tests (T1, T6) membership function Γ was used (Zinner et al., 1994).

To construct the membership function, v_i stands for the value of the result of a tested individual in test no. *I*, then c_i (where AP - s) for the result value that absolutely meets the requirements in test no *i*, d_i (where AP + s) for the result value that does not meet the requirements in test no *i*. Each of the results v_i between values c_i and d_i is given a point from zero to one, per function $A(v_i, d_i, c_i)$. The general formula for the L membership function (tests no. 5, 6, 7; which is. *i* Î {5, 6, 7}) is as follows:

$$A(v_i, d_i, c_i) \begin{cases} 0 & \text{for } v_i \geq d_i \\ \dfrac{(d_i - v_i)}{(d_i - c_i)} & \text{for } c_i \leq v_i \leq d_i \\ 1 & \text{for } v_i \leq c_i \end{cases}$$

Tests where high results value meant a better evaluation of membership, functions of Γ type were assigned (T1, T6). To construct the Γ membership function, v_i stands for the value of the result of a tested individual in test no. *i*, *a* (where AP - s) for the result value that does not meet the requirements in test no *i*, $b_{i\,i}$ (where AP + s) for the result value that absolutely meets the requirements in test no *i*. Each of the results v_i between values a_i and b_i is given a point from zero to one, per function $A(v_i, a_i, b_i)$. The general formula for the Γ membership function is as follows:

$$A(v_i, a_i, b_i) \begin{cases} 0 & \text{pro } v_i \leq a_i \\ \dfrac{(v_i - a_i)}{(b_i - a_i)} & \text{pro } a_i \leq v_i \leq b_i \\ 1 & \text{pro } v_i \geq \end{cases}$$

Conversion to the membership grade was calculated with a generic formula using the end values a_i , b_i, which are the border values of the point evaluation at the medium level. Since every membership function is only defined in the interval <0; 1>, the results of the total evaluation of the fuzzy approach had to be multiplied by a coefficient of 2 to be comparable to the score evaluation. In the classical score evaluation, using the probability approach, a tennis player can obtain three score values (0, 1, 2) in individual tests, which for the total of the six evaluated tests gives a range of 0 – 12 points. The fuzzy approach defines the evaluation of the tests in the interval <0; 1>, rounded up to 2 decimal places, the evaluation is significantly finer (0.01 – 1.0), but also ranges from 0 to 12 points.

The most common type of membership function used was that of the L type, its course and border values are given as an example for the item "*running speed*" in Figure 1. The function gives the value of 1 to a final time up to 14.07 ; then the evaluation follows the function (15.37 – x)/1.3; results higher than 15.37 are given a value of 0.

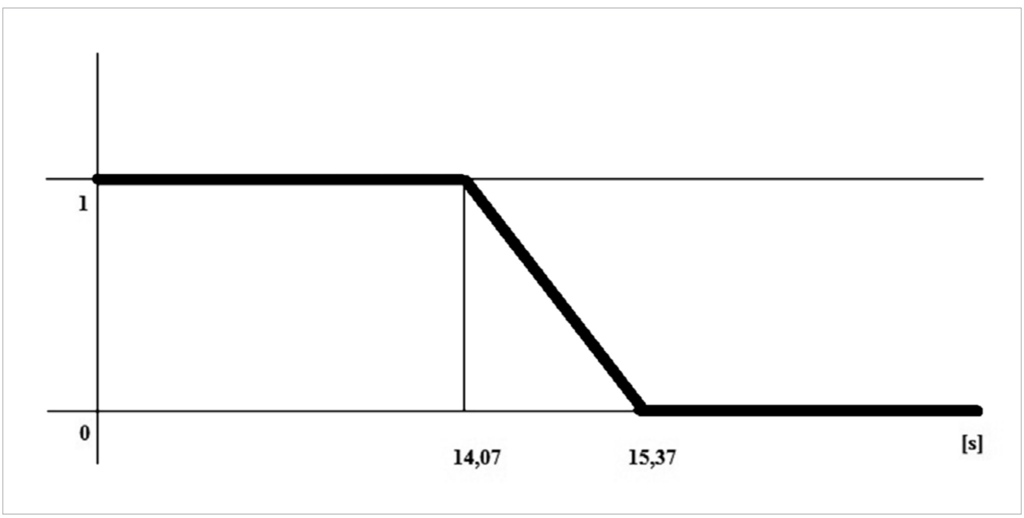

Figure 1. Membership function of type L for the evaluation of running speed

To demonstrate this procedure in the given wide range of our set (n=88), we only show as an example the results of the first and last two participants (ordered by age).

Table 2. Degrees of membership of individual subtests and comparison of scoring with fuzzy approach

PROBAND	T1	T2	T3	T4	T5	T6	FUZZYx2	Σ POINTS	DIFFERENCE
1	0.48	0.28	0.28	0.25	0.24	0.58	4.22	6	-1.78
2	0.19	0.49	0.35	0.37	0.75	0.25	4.80	6	-1.20
…	…	…	…	…	…	…	…	…	…
87	1	0.77	0.43	0.75	0.91	1	9.72	8	1.72
88	0.84	1	1	1	0.66	0.66	10.32	9	1.32

A finer differentiation of the fuzzy evaluation is demonstrated by a comparison of randomly selected tennis players (Figure 2). The total score (upper scale) of a player is connected by an arrow to the total score of 'fuzzy points' (lower scale) of the same player. The same procedure was used with tennis players scoring the highest (Figure 3). The advantage of using the finer evaluation can be seen with tennis players with a total score of 9 points.

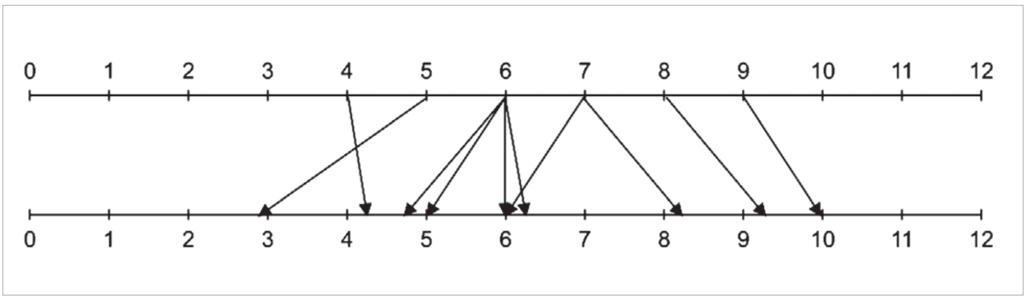

Figure 2. Comparison of the final evaluation of a subset for randomly chosen tennis players

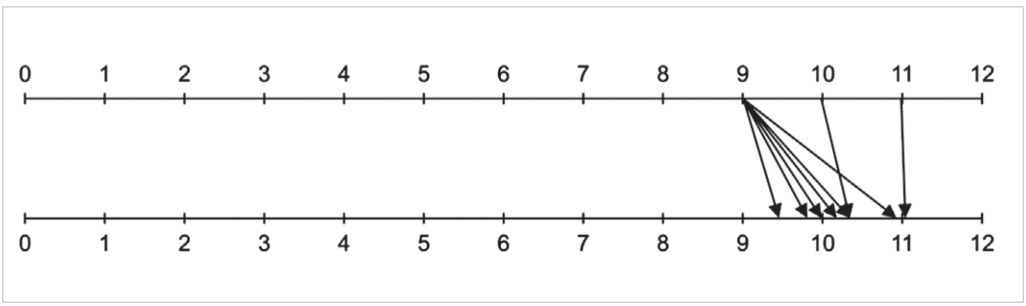

Figure 3. Comparison of tennis players with the best scores

Assessment of the dependency ratio of the evaluations with the aid of the probability and fuzzy approaches in the set of tennis players (n=88) with Pearson's correlation coefficient showed that the value r = 0.92 is statistically significant (p = 0.05) and indicates the considerable relationship of the results of both approaches. To make a detailed analysis of the relationship between the score evaluation and the fuzzy approach, we looked for a correlation between both approaches in each category (low, medium, high level), with corresponding score intervals <1 to 4>, <5 to 8>, <9 to 12> and calculated Spearman's correlation coefficient. When examining the relationship between the evaluations of both approaches, it was found that in the subsets with lower level scores (1 to 4 points) or even medium level ones (5 to 9 points) the correlation between the results was statistically significant. However, in the subsets of a higher level (9 to 12 points) the results correlated insignificantly (Table 3).

Table 3. Values of the Spearman correlation coefficient in individual groups (p = 0,05).

Evaluation groups (subsets)	law (n = 15)	medium (n = 64)	high (n = 9)
r_S	0.60*	0.78*	0.64

Explanatory notes: r_S … Spearman's correlation coefficient (* … significant at p=0.05) n … range of the set

DISCUSSION AND CONCLUSIONS

The evaluation method of the degree of membership of individual tests and comparison of the evaluation scores with the fuzzy approach is presented in Table 2, where the last column shows the difference in scores between the two evaluation methods. If the result is negative, then the subject obtained a better result using the classical probability approach, with the positive difference showing the better result of the fuzzy approach. Verifying the normality of the distribution of the results of individual tests and the overall score acquired by both the probability and fuzzy approaches was tested with the aid of the Kolmogorov-Smirnov test, and the hypothesis of the normality of the distribution cannot be dismissed (p = 0.05).

To demonstrate both approaches, we chose 10 tennis players from the set of players (n=88) using a random number generator (nos. 2, 5, 6, 53, 58, 65, 70, 71, 78, 82) and compared the final scores obtained with both approaches. This is demonstrated in Figure 1 (the upper axis shows the range of final values, the lower axis shows the range of the total scores obtained by the fuzzy approach; for comparability reasons, the values of the fuzzy approach were doubled). Using both evaluation approaches, the total scores of the tennis players are connected with an arrow. Figure 1 shows that the finer evaluation with the fuzzy approach provides a distinct differentiation of the final results. To make the results more significant, we purposely chose two more groups of players. Tennis players who received 6 points with the probability approach are the best example.

Assessment of these evaluation approaches (Table 3) led us to the assumption (despite the small range of subsets) that a more precise and finer evaluation will be the most pronounced with the 'high level' evaluation groups. A graphic image of the results of this subset (Figure 2) shows that the 'fuzzy evaluation' gives a finer and more precise resolution for those tennis players who obtained an equal score in the evaluation. This increases the differentiation of the total evaluation of the results of individual tennis players in the TENDIAG test battery with the aid of the fuzzy approach and, therefore, of the overall level of fitness and coordination requirements. In future, the results of individual tests could be weighted based on an expert assessment referring to their importance for tennis.

Based on the expert evaluations and the nature of the results acquired in the individual tests, the following membership functions were assigned to individual items of the TENDIAG1 test battery: for tests T2, T3, T4, T5 we used the L type of membership function, for tests T1 and T6 the Γ type, and for the overall evaluation of the results the method of aggregation of individual degrees of membership was used. The results showed that the fuzzy evaluation provided a significant differentiation of the tennis players' individual as well as overall results.

Assessment of the dependency ratio of the overall results with the aid of the probability and fuzzy approaches in the set of tennis players (n=88) showed the statistically significant dependency of both approaches ($r = 0.92$, $p = 0.05$). Individual evaluation groups (low, medium, high) showed a statistically significant correlation in the subsets of tennis players with a 'low' and 'medium' level of results and a statistically insignificant correlation in the subsets with a 'high' level of overall results (9 to 12 points). The graphic image of the results of this subset indicates that for tennis players with equal results the 'fuzzy evaluation' enables a finer and more exact resolution of the overall level of results in the TENDIAG1 test battery.

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