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Evaluation Models of Some Morphological Characteristics for Talent Scouting in Sport

Nenad Rogulj[1], Vladan Papić[2] and Marijana Čavala[1]

[1] Faculty of Kinesiology, University of Split, Split, Croatia
[2] Faculty of Natural and Mathematical Sciences and Education, University of Split, Split, Croatia

A B S T R A C T

In this paper, for the purpose of expert system evaluation within the scientific project »Talent scouting in sport«, two methodological approaches for recognizing an athlete's morphological compatibility for various sports has been presented, evaluated and compared. First approach is based on the fuzzy logic and expert opinion about compatibility of proposed hypothetical morphological models for 14 different sports which are part of the expert system. Second approach is based on determining the differences between morphological characteristics of a tested individual and top athlete's morphological characteristics for particular sport. Logical and mathematical bases of both methodological approaches have been explained in detail. High prognostic efficiency in recognition of individual's sport has been determined. Some improvements in further development of both methods have been proposed. Results of the research so far suggest that this or similar approaches can be successfully used for detection of individual's morphological compatibility for different sports. Also, it is expected to be useful in the selection of young talents for particular sport.

Key words: *morphological, sport, talent, scouting*

Introduction

Selecting children for appropriate sport is the most demanding and the most responsible task for sport experts and kinesiology in general Sport activities have significant differences regarding structural and substance features. Different sports are determined by authentic kinesiological structures and specific anthropological characteristics of an individual[1–3]. Success of an individual in particular sport activity is predominantly determined by the compatibility of his/her anthropological characteristics with the anthropologic model of top athletes in that sport[4,5].

Unfortunately, there is usually no systematic selection in sport. The selection is based on a subjective and non-scientific judgment with a low technological and methodological support. However, fast development of new information technologies as well as the introduction of new methods and knowledge provide a novel, systematic and scientifically based approach in selecting the appropriate sport for an individual.

Due to the importance of the objective selection of children for particular sport, an expert system for recognition of sport talents – TALENT[6,7] has been developed within the project »Talent scouting in sport«. Final goal of the project is to create a system that will be able to give reliable quantitative estimation of potential effectiveness of an individual for various sports. The system is based on the knowledge base that contains normative values of anthropological characteristics of school-age children in the Republic of Croatia along with the grades of these characteristics relevant for success in various sports. Morphological characteristics are undividable part of the anthropologic system and they significantly determine sport success. Morphological characteristics related to longitudinal and transversal dimensionality of bone system are predominantly genetically determined[8,9] and they have great importance in the process of athlete selection[10,11]. It has been recognized by numerous research teams[12,13] that top athletes in various sport activities possess different morphological characteristics. This is understandable because each sport activity is defined by authentic kinesiological structures that are conducted in specific conditions (space, time) requiring specific morphological characteristics of an athlete.

In this paper, as a necessary part of the expert system, two different methodological approaches for objective de-

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termination of particular morphological characteristics that contribute to various sport activities will be presented, evaluated and compared. A total of 14 different sport activities was involved in the evaluation process[6,7]: football, handball, basketball, volleyball, water-polo, swimming, rowing, gymnastics, athletics – sprint/jump, athletics – throwing, athletics – long distance running, martial arts of kicking type, martial arts of pulling and pushing type, tennis.

Materials and Methods

Evaluation based on the expert opinion and fuzzy approach

Bertrand Russell once said: »Everything is vague to a degree you do not realize till you have tried to make it precise«. Similar thoughts motivated the introduction of fuzzy sets and fuzzy logic by Lotfi A. Zadeh[14]. Fuzzy logic is basically a multi-valued logic. As opposite to the traditional logic and sets where set membership value of an object can only have two possible results (true or false), fuzzy logic and fuzzy sets allow partial set membership. Fuzzy sets are actually functions that map a value that might be an item of the set to a number between zero and one, indicating its actual degree of membership. A degree of zero means that the value is not in the set, and a degree of one means that the value is completely representative of the set. The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated comparably, and the order of the rules is unimportant. Fuzzy system makes a decision based on these rules and does not try to model a system mathematically. In fuzzy logic, the truth of any statement becomes a matter of degree. Because of the vagueness of human thoughts and expressions, fuzzy approach seems to be the natural choice in solution seeking. We can say that fuzzy reasoning systems attempt to emulate human thought, with no a priori restrictions on that thought[15].

In some aspects of fuzzy logic implementation, proposed approach can be compared to the solution proposed by Weon and Kim[16] or the system developed by Bai and Chen[17] for the evaluation of students' learning achievement.

We cannot generally say »Tall is good« or »Heavy is bad« for every sport. The answer to the question »is the measured result good?« is sport specific and, in fact, it depends both on the measured value of an observed test (height of the person) and the measured value of the other test (weight of the person) and vice versa. In kinesiology, this is an issue known as athletic body model that is specific for particular sport. The evaluation of the body fitness of a tested person for the particular sport is calculated by using the rules with implementation of fuzzy logic.

For our particular problem, values obtained by the measurement of a person's height and weight are used as an input values in fuzzy module. Athletic body of a person is represented by two variables: height and body mass index (BMI). For the calculation of BMI, height and weight of a person are needed:

$$BMI = \frac{w}{h^2} \qquad (1)$$

where w is weight and h is height of a person.

A questionnaire was given to 45 experts in particular sport (at least 3 experts for each sport) and also to 52 general knowledge experts. After the analysis of the results from the (filled and returned) questionnaires, models of the ideal height and BMI were included into the expert system database.

Fuzzification of the measured height and calculated BMI has been done according to the fuzzy sets presented in Figures 1 and 2. Minimal and maximal values for the height (h_{min}, h_{max}) and BMI (BMI_{min}, BMI_{max}) used for the construction of the fuzzy sets and presented in Figures 1 and 2 were estimated by the authors on the basis of the available literature[18,19]. These values are not fixed; they depend on the gender and age of the observed individual.

Fuzzy grade vector for height (FH) can be presented as follows:

$$FH = \begin{bmatrix} FH_1 & FH_2 & FH_3 \\ \mu_{h1} & \mu_{h2} & \mu_{h3} \end{bmatrix}$$

where FH_1, FH_2, FH_3 denote the fuzzy terms »short«, »medium« and »tall«, respectively, μ_{hi} denote the membership value of the height belonging to the linguistic term FH_i, $\mu_{hi} \in [0,1]$, $1 \le i \le 3$.

Fuzzy grade vector for BMI (FB) can be presented as follows:

$$FH = \begin{bmatrix} FB_1 & FB_2 & FB_3 & FB_4 & FB_5 & FB_6 \\ \mu_{MBI1} & \mu_{MBI2} & \mu_{MBI3} & \mu_{MBI4} & \mu_{MBI5} & \mu_{MBI6} \end{bmatrix}$$

where FB_1, FB_2, FB_3 FB_4, FB_5 and FB_6 denote the fuzzy terms »very low«, »low«, »semi-low«, »semi-high«, »high« and »very high«, respectively, μ_{BMIi} denote the membership value of the BMI belonging to the linguistic term FB_i, $\mu_{BMIi} \in [0,1]$, $1 \le i \le 6$.

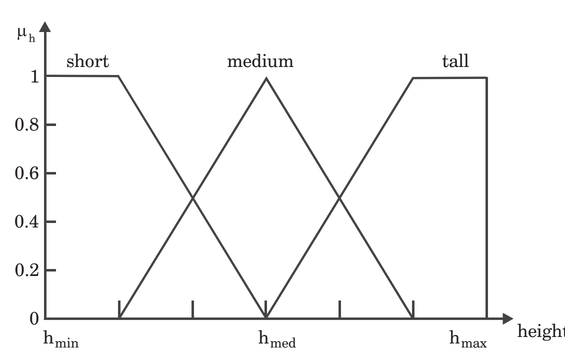

Fig. 1. Membership functions of the fuzzy sets »short«, »medium« and »tall« used for the calculation of fuzzy membership grade for height.

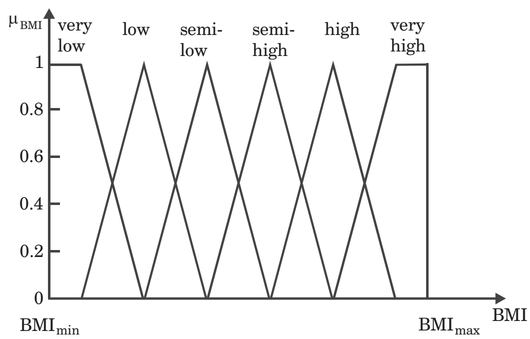

Fig. 2. Membership functions of the fuzzy sets »very low«, »low«, »semi-low«, »semi-high«, »high« and »very high« used for the calculation of fuzzy membership grade for BMI.

An example of a fuzzy rule matrix to infer the body model adequacy is presented in Table 1. Each sport has different rule matrix.

Based on the fuzzy grade vectors *FH*, *FB* and fuzzy rules which are partially shown in Table 1 (only for handball), fuzzy reasoning is performed in order to evaluate the athletic body adequacy for each sport. 18 rules can be elicited for each sport.

IF the sport is handball and the height is tall and BMI is semi-high THEN the model is matched

IF the sport is handball and the height is medium and BMI is semi-high THEN the model is semi-matched

Generally, we can write a fuzzy rule as follows:

IF the sport is S_k and the height is FH_i and BMI is FB_j THEN the model is M_l

where M_l can have three linguistic values: M_1 = »unmatched«, M_2 = »semi-matched« and M_3 = »matched«.

The elicitation of each rule as a result gives the membership grade of the model. Linguistic value (M_l) in the consequent part of the rule determines which linguistic variable the membership grade relates to. Result of each rule is calculated as follows:

$$\mu''_M(M_1) = 0.7 \times \mu_{Hi} + 0.3 \times \mu_{BMIj} \quad (2)$$

where M_l is the linguistic value in the consequent part of the rule. Other linguistic variables M_j, $j \neq l$ are not affected with the rule and their membership grades are zero. Because of the simplicity, in the equation (2), sport verification was left out in the antecedent part of the rule. In fact, in the expert system database, rules are grouped by sports and only rules related to the particular sport will be used. Also, weight values for height (0.7) and BMI (0.3) are introduced into the equation because of higher variability and easier changing of body mass index during time, as opposite to the height values. These weights are determined according to the opinion of the experts.

Model matrix (*M*) used for calculation of body model membership μ_M for each sport (S_1, …, S_p) is obtained after eliciting all the fuzzy rules and after the aggregation of their output for each linguistic value M_1, M_2 and M_3 by using the *Max()* function. Matrix elements μ_{11}, μ_{12}, ..., μ_{p3} are fuzzy values obtained by the evaluation of fuzzy rules.

$$M = \begin{array}{c} \\ S_1 \\ S_2 \\ \vdots \\ S_p \end{array} \begin{array}{c} \begin{array}{ccc} M_1 & M_2 & M_3 \end{array} \\ \begin{bmatrix} \mu'_{11} & \mu'_{12} & \mu'_{13} \\ \mu'_{21} & \mu'_{22} & \mu'_{23} \\ \vdots & \vdots & \vdots \\ \mu'_{p1} & \mu'_{p2} & \mu'_{p3} \end{bmatrix} \end{array}$$

Each element μ'_{ij} is calculated according to the fuzzy rules as follows:

$$\mu'_{ij} = Max[(\mu''_{M,1}(M_j), \mu''_{M,2}(M_j), \ldots, \mu''_{M,N}(M_j))] \quad (3)$$

where *N* is a total number of rules that as an output have membership grade of the linguistic value M_j.

Finally, the athletic body membership grade of the observed individual for particular sport is calculated as follows:

$$\mu_M(S_k) = Max(0.5 \times \mu'_{k2}, \mu'_{k3}), \mu_M(S_k) \in [0,1] \quad (4)$$

Evaluation based on morphological models of top athletes

Second approach for the evaluation of morphological characteristics is based on model values of morphological characteristics of top athletes in the observed sports since year 2000 until now. Model values are based on results of several research projects published in reputable scientific journals[20,21]. Values of particular morphological characteristic for 167 male and 149 female top athletes that are members of national teams and have achieved significant success on official international competition level during above mentioned period were collected after reviewing the research articles.

This approach is based on quantitative analysis of differences between model morphological characteristics (height and BMI) of top athletes and morphological char-

TABLE 1
FUZZY RULE MATRIX FOR HANDBALL

Height	Body mass index (BMI)					
	Very low	Low	Semi-low	Semi-high	High	Very high
Short	Unmatched	Unmatched	Unmatched	Unmatched	Unmatched	Unmatched
Medium	Unmatched	Unmatched	Unmatched	Semi-matched	Unmatched	Unmatched
Tall	Unmatched	Unmatched	Semi-matched	Matched	Semi-matched	Unmatched

acteristics of particular individual. Average heights and BMI index values of top athletes in 14 different sports are proportionally scaled with respect to normative values of school children (aged 7–18) in Croatia[18]. As a result of this procedure, approximate model values of height and BMI were determined for each combination of age group and sport.

Scaling is done in two steps:

1. Calculation of the ratio between average height and BMI values for eighteen-year-old students (in this age, biological growth is mostly completed)[22,23] and average height and BMI values for all other age groups (7–17 year-olds).

$$k_{h,i} = \frac{h_i}{h_{18}^*}; k_{BMI,i} = \frac{BMI_i}{BMI_{18}^*} \quad (5)$$

where i is age of the observed group, h_{18}^* is average height of 18 year old students obtained from official normative tables and BMI_{18}^* is average BMI index of 18 year old students obtained from official normative tables[18].

2. Obtained coefficient for each age group is multiplied with top athletes' model values for each observed sport. In this way, the approximate height and BMI values are obtained.

$$M_i(S_k) = \{ k_{h,1} \cdot H(S_k), k_{BMI,i} \cdot BMI(S_k)\} = \\ = \{ M_{h,1}(S_k), M_{BMI,i}(S_k)\} \quad (6)$$

where $H(S_k)$ and $BMI(S_k)$ are average height and BMI values of top athletes in sport S_k, respectively.

This procedure calculates differences between the values of morphological characteristics of an individual and hypothetic model values of every sport for his/her age. Differences that are calculated using the equation (7) are used for grading the appropriateness of an individual's morphological characteristics for the models of various sports (P).

$$P(S_k) = \frac{\left(MD_h - |M_{h,i}(S_k) - h_{mes}|\right) \cdot K_h}{MD_h} + \\ \frac{\left(M_{BMI} - |M_{BMI,i}(S_k) - BMI_{mes}|\right) \cdot K_{BMI}}{MD_{BMI}} \quad (7)$$

where MD_h is maximal difference between model values for sport S_k and measured height of an individual (h_{mes}) calculated as follows: $MD_h = Max\{|M_{h,i}(S_k) - h_{mes}|\}$, $i = 1, ..., 14$, MD_{BMI} is maximal difference between model values for sport S_k and measured BMI of an individual (BMI_{mes}) calculated as follows:

$MD_{BMI} = Max\{|M_{BMI,i}(S_k) - BMI_{mes}|\}$, $i = 1, ..., 14$. K_h and K_{BMI} are the coefficients of estimated contribution of height and BMI in relation to other anthropological characteristics which were part of the expert opinion pool.

Comparison of proposed methodological approaches

The comparison of proposed methods was done on the sample of 31 young male students that are also successful athletes in various sports. System was configured separately for each of the proposed methodological approaches in order to conduct quantitative evaluation of student's morphological compatibility for 14 available sports.

For both approaches, average ratios between achieved score for student's favorite sport and sport with maximal score (Sport recognition index) have been calculated. Also, the ratio between probability that student's favorite sport will be in the top three sports with the highest scores as well as the probability that the favorite sport will be in group of three randomly chosen sports from the available set of sports (Recognition probability ratio) were calculated.

Measure of discrimination has been calculated by using the coefficient of variation which is expressed as the average ratio between standard deviation and average score of all tested individuals.

Results

The results of the evaluation of the proposed approaches are given in Table 2. It can be seen that the Sport recognition index (*SRI*) is relatively high. For the evaluation based on the expert opinion and fuzzy approach (Model I) *SRI* equals 0.81 and for the evaluation based on morphological models of a top athlete (Model II), *SRI* is slightly higher and equals 0.84.

Recognition probability ratio (RPR) is equal for both models (RPR = 3.03) and that confirms that presented models have significantly improving probability of recognition of the sport that is adequate for the observed individual.

The expressed coefficient of variation is higher (36.92%) for Model II than for Model I (32.75%) suggesting that the range (min to max) of the obtained results of sport compatibility for each individual is slightly larger for Model II.

TABLE 2
COMPARISON OF THE EVALUATION PARAMETERS

Evaluation parameters	Model I	Model II
Sport recognition index (SRI)	0.81	0.84
% of probability that favorite sport is in top three sports	65 %	65 %
Recognition probability ratio (RPR)	3.03	3.03
Coefficient of variation	32.75%	36.92%

Discussion and Conclusion

Two new approaches have been proposed: approach based on the kinesiology experts' opinion on the compatibility of proposed hypothetical morphological model of particular sport (subjective approach – Model I) and the approach based on detection of differences between morphological characteristics of tested individuals and morphological characteristics of top athletes in various sports (objective approach – Model II). Presented approaches achieved similar results in the recognition of a sport compatible for tested individuals.

Approach based on the expert opinion has lower coefficient of variation due to the smaller number of models used for the comparison of morphological characteristics of the tested individual as opposite to the second approach that uses larger number of models. This difference in number of used models occurred because some sports had identical ideal models considering height and BMI in the first approach due to the methodological constrains, while second model used one unique model for each sport.

Improvements in performance of expert opinion approach are expected after increasing the number of experts involved in research, modeling and the adjusting of the membership functions as well as updating the normative values used for the specification of fuzzy sets.

Further improvements for the second approach (Model II) are expected after exact determination of top athletes' anthropometrical characteristics for each age group and gender. So far, interpolation has been done since only the data on senior top athletes was available.

For both cases, in further versions of expert system more precise categorization of sports activities should be done. Some sports (e.g. athletics) should be divided into larger number of disciplines while other sport games (e.g. basketball, handball) should be analyzed for each player's position separately.

Results of the conducted research suggest that both proposed methods are capable of successful recognition of the sport compatible for the tested individual based on his/her morphological characteristics and that future development of the expert system for recognition of morphological compatibility of athletes has real prospects.

At this stage, we prefer approach based on the morphological characteristics of top athletes because of its higher precision and the fact that it is based on the real models as opposite to the hypothetical models used in expert opinion approach.

Of course, presented models dealing only with one segment of complete anthropological status. Therefore, for more reliable prognosis of potential sport success by using the expert system, evaluation should include other variables of anthropologic space as well, especially motor and functional abilities.

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N. Rogulj

Faculty of Natural and Mathematical Sciences and Education, Teslina 12, Split, Croatia
email: nrogulj@pmfst.hr

EVALUACIJSKI MODELI NEKIH MORFOLOŠKIH KARAKTERISTIKA ZA ODABIR TALENATA U SPORTU

S A Ž E T A K

U ovom su radu za potrebe evaluacije ekspertnog sustava u okviru znanstvenog projekta »Otkrivanje talenata u sportu» prezentirana, evaluirana i komparirana dva različita metodološka pristupa za prepoznavanje morfološke kompatibilnosti sportaša za pojedine sportove. Prvi se pristup zasniva na fazi logici i ekspertnom mišljenju o kompatibilnosti ponuđenih hipotetskih morfoloških modela za 14 različitih sportskih aktivnosti koje su zahvaćene ovim ekspertnim sustavom. Drugi se pristup zasniva na utvrđivanju razlika između morfoloških karakteristika ispitanika i modelnih morfoloških karakteristika vrhunskih sportaša u tom sportu. Prezentirane su logičke i matematičke osnove obiju metodoloških pristupa te izvršena njihova evaluacija i komparacija. Utvrđena je dobra prognostička efikasnost prepoznavanja sporta kojim se ispitanik bavi. Predložena su određena unapređenja obiju postupaka u narednim inačicama. Rezultati istraživanja ukazuju da se ovakvi i slični pristupi mogu uspješno koristiti za detekciju morfološke kompatibilnosti ispitanika za različite sportove, odnosno za odabir mladih talentiranih sportaša za pojedini sport.