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Original research article

STRUCTURES AND DIFFERENCES OF THE COGNITIVE ABILITIES OF TOP HANDBALL, VOLLEYBALL, BASKETBALL AND SOCCER PLAYERS

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Abstract. *In modern sport, cognitive abilities are one of the key factors that affect the success rate of athletes. The goal of this study is to determine the statistically significant structures and differences in the area of cognitive abilities on a sample of top handball, volleyball, basketball and soccer players. The sample of participants consisted of 200 male athletes divided into four groups of 50 participants each. In order to assess the conative characteristics of the participants, the KOG 3 battery of tests was used. The structures and the differences in the athletes' test results were determined using the method of principal component analysis and canonical discriminant analysis. The observed structure of cognitive abilities indicates the existence of a single, general factor. The results of all the applied tests are significant at the entire sample level, predominantly on the input processor level, followed by serial and parallel processor test values which can be attributed to the requirements imposed by the top rank of the competition in which the participants perform. The differences in cognitive characteristics exhibited the isolation of one discriminant dimension. The values shown in the structure matrix suggest that the first discriminative function positively distinguishes the basketball and volleyball players from the other athletes based on the tests used to assess the efficiency of the input and the parallel processors. These results can be linked to the fact that volleyball and basketball are more dynamic sports, as well as that the specific nature of these sports requires solving complex tactical tasks.*

Key words: *handball, volleyball, basketball, soccer, cognitive abilities*

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INTRODUCTION

Cognitive abilities are one of the fundamental anthropological parameters which determine a human being, his behavior, the extent and quality of the functions performed in society. In sports, depending on the character and structure of motion activities, cognitive abilities to a lesser or greater extent have an influence on the quality and speed of mastering the required actions and represent an essential part of the success of a specification equation (Malacko & Rađo, 2004; Popović & Simonović, 2008). Although there is no general consensus in defining cognitive abilities, a number of studies, and the theoretical constructs based on them , indicate the existence of a general G factor, as well as certain specialized intelligence factors (Thurstone, 1938; Lazarević 1987; Carrol, 1993). This factor is usually interpreted as a general factor of intelligence and is defined as the ability to manage and resolve problems in new and unfamiliar situations (Malacko & Popović, 2001). Based on previously conducted studies, Momirović, Šipka, Wolf, & Džamonja (1978) proposed a model of the hierarchical structure of cognitive abilities, which in the category of the first order is characterized by: a factor of the perceptive reasoning, responsible for quick observation, spotting relations in space and memory; a factor of symbolic reasoning, which is responsible for the ability of operating with symbols; an education factor, responsible for determining the important characteristics of objects and occurrences. The general cognitive factor (G) is determined as a category of the second order, and is defined as the latent dimensions responsible for all the processes of reception, retention and transformation of information and solving complex problems, those that require the participation of various functional structures.

Modern studies in the field of cognitive abilities indicate that the precise definition of their preferred structure in certain sports activities, as well as the correlation with other anthropological characteristics, is of great importance in the process of predicting the effectiveness of athletes in a particular sport (Starkes & Ericsson, 2003; Mann, Williams, Ward, & Janelle, 2007; Voss, Kramer, Basak, Prakash, & Roberts, 2009). It has been proven that there is a high correlation between active sports engagement and improvement in cognitive abilities, as well as the structural and functional changes in the brain that are caused by these kinds of activities (Colcombe & Kramer, 2003; Etnier et al., 2006; Kramer & Erickson, 2007). Determining the structure and the correlation of intelligence with other anthropological characteristics, most of which are often general and specific motor skills, shows a high degree of interdependency of these anthropological parameters (Stojanović, Milenkoski, & Nešić, 2006; Blažević & Malacko, 2007; Stanković & Malacko, 2008; Blažević, 2009; Malacko, 2010; Malacko & Stanković, 2011; Alves, Voss, Boot, Deslandes, Cossich et al., 2013). An analysis of the cognitive abilities and competition rank indicates that athletes who compete at higher ranks of competition achieve better results on tests of cognitive abilities than those who compete in the lower ranks of competition (Ward & Williams, 2003; Moreau, Mansy-Dannay, Clerc, & Guerrien, 2011; Ruiz, Palomo, García, Navia, & Miñano, 2014; Stanković, 2014). Different sports with their rules and movement structures pose specific requirements, causing differences in the area of cognitive abilities, primarily between athletes regarding whether they engage in individual or team sports, but also between athletes in terms of individual and collective sports subgroups (Singh, 2007; Kaur & Sharma, 2015). As a result, the goal of this study is to determine the statistically significant structures and difference in the area of cognitive abilities on a sample of top handball, volleyball, basketball and soccer players, so that the

obtained knowledge could be applied in the selection process, the programmed plan and program of training activities, as well as contribute to the identification of the optimal model of an athlete in the studied sports.

METHOD

The sample of participants

The sample of participants consisted of 200 athletes who compete in handball, volleyball, basketball and soccer, divided into four groups of 50 participants, based on the sport they compete in. The participants had to meet the following conditions: they are male; aged 18 to 35 ± 0.5; they are registered players of clubs competing in the top two national competitions ranks; they all took part in the regular training process.

The measuring instruments

In order to make an adequate assessment of the cognitive abilities of the participating athletes, the following variables from the KOG3 battery of tests were used (Wolf, Momirović, Džamonja, 1992): the IT-1 test for assessing the efficiency of the input processor, i.e. perceptive reasoning. It is designed to evaluate perceptual identification and discrimination. The test contains 39 tasks, and the test duration is limited to 4 minutes; the AL-4 test for assessing the efficiency of the serial processor, i.e. symbolic reasoning. This synonyms-antonyms test contains 40 tasks, and is meant to assess the identification of the significance of verbal symbols. The time provided for the completion of the test is 2 minutes; the S-1 test for assessing the efficiency of the parallel processor, i.e. noticing relations and correlates. The test contains 30 tasks, and is intended to assess visual spatialization. The time allotted for solving the test is 8 minutes. All of the tests were conducted before the afternoon workout.

Statistical analysis

The structures and the differences of the obtained results for the group of tested athletes were determined using the method of principal component analysis and canonical discriminant analysis, using the system of programs developed by Momirović and Popović (Popović, 1993; Momirović & Popović, 2003), implemented and executed using the statistical packages SPSS 16 (SPSS Inc., Chicago, IL.) and SAS 9 (SAS Institute Inc., Cary, NC).

RESULTS

The results of the descriptive statistical analysis of the variables obtained by the applied tests are shown in Table 1. Based on the presented parameters, it can be concluded that volleyball players have the highest average values in all tested categories, while the values of the basketball players are a close second. The handball players occupy third place in all the tested categories, while soccer players have the lowest average values in all the tested categories.

Table 1 Descriptive statistics of the athletes' cognitive abilities parameters

Sport		Range	Min	Max	M	S
Handball	IT1	32	5	37	23.02	6.61
	AL4	25	15	40	29.42	7.41
	S1	23	6	29	20.62	6.57
Volleyball	IT1	23	12	35	25.00	5.72
	AL4	29	11	40	31.78	6.19
	S1	20	10	30	22.92	5.84
Basketball	IT1	25	9	34	24.34	5.61
	AL4	25	15	40	31.32	6.21
	S1	25	5	30	20.74	5.90
Soccer	IT1	28	9	37	21.20	5.18
	AL4	25	15	40	28.54	6.07
	S1	23	6	29	19.94	5.87

Legend: Min - minimum, Max - maximum, M - mean, S - standard deviation.

Looking at the values obtained by the method of principal component analysis shown in Table 2, the isolation of a single latent dimension is observed. The projections of all three measuring instruments are significant at the level of the entire sample. The highest values of the projections on the main component are determined in the test for the evaluation of the efficiency of input processors (IT-1): for handball players .91, volleyball .83, basketball .88, and soccer players .91. The projection values of the test for the evaluation of the efficiency of the serial processor (AL-4) are significant for athletes of all four studied sports: for handball players .87, volleyball .81, basketball .79, and soccer players .88. The projection of the measuring instrument for assessing the efficiency of the parallel processor (S-1) demonstrated lower, but still significant values among all groups of athletes: for handball players .65, volleyball .76, basketball .69, and soccer players .79.

Table 2 The principal component analysis of the athletes' cognitive abilities

	Handball		Volleyball		Basketball		Soccer	
	FAC1	h2	FAC1	h2	FAC1	h2	FAC1	h2
IT-1	.91	.81	.83	.69	.88	.77	.91	.87
AL-4	.87	.76	.81	.66	.79	.64	.88	.78
S-1	.65	.42	.76	.58	.69	.48	.79	.67
Eigenvalue		1.56		1.93		1.99		2.37
% of Variance		52.04		64.48		61.77		68.81
Cumulative %		52.04		64.48		63.91		68.81

Legend: % of Var. – percent of variance, Cum. % - cumulative percent.

By analyzing the results of the discriminant analysis of cognitive variables shown in Table 3, it is determined that only one discriminative dimension is isolated. There was a statistical significance at the p = .04 * level, with a values of Wilks' Lambda value of λ = .08 and a canonical correlation of Rc = .33. This indicates the significance of the discriminant function and is a major indicator of the quantitative and qualitative structure. The significance of the canonical correlation was tested using Bartlett's χ^2 test (15.44).

Table 3 Discriminant analysis of the athletes' cognitive abilities

Func	Eigenvalue	% of Var	Cum%	Rc	λ	χ2	Df	p
1	.01	82.1	82.1	.33	.08	15.44	9	.04*
Var	Matrix structure		Var			Group centroids		
	FUN1					FUN1		
			Handball			-.09		
IT-1	.77		Volleyball			.11		
AL-4	-.08		Basketball			.17		
S-1	.59		Soccer			-.04		

Legend: % of Var. – percent of variance, Cum. % - cumulative percent, Rc – canonical correlation coefficient, λ – Wilks' Lambda, χ^2 – Bartlett's Chi-square, df – degrees of freedom, p – significance.

The values shown in the structure matrix suggest that the first discriminant function distinguishes the athletes based on the test of perceptive reasoning IT-1 (.77), and the test for the evaluation of the efficiency of the parallel processor S-1 (.59). By analyzing the group centroids, it was observed that the values for all four groups are largely unified, but also that the perception on the court and the ability to parallel process a large amount of information is primarily the characteristic of the participant subsamples of basketball and volleyball players.

DISCUSSION

The results obtained by using the principal components analysis show the existence of a single, general factor of cognitive abilities, which is consistent with theories about the structure of the cognitive space, which define the existence of this factor and its relations with other subfactors (Thurstone, 1938; Momirović et al., 1978; Lazarević 1987; Carrol, 1993). The values of all three tests of cognitive parameters in the studied groups of athletes are statistically significant. The highest correlation with the isolated cognitive dimension was determined for the variable of the assessment of perceptive abilities IT-1. The identified high values of the factors of perceptive reasoning, which are responsible for quick observation, spotting relations in space and memory, are expected, given that handball, volleyball, basketball and soccer are sports characterized by rapid, dynamic situational changes in the game, which require the ability to adopt and adequately apply acquired tactical and technical knowledge in a limited time interval. The isolated cognitive dimension is also clearly defined by the AL-4 test, with a relatively high projection for the assessment of the efficiency of the serial processor, responsible for operating with symbols. The test used to assess the efficiency of the parallel processor (S-1) showed a satisfactory value in the entire test sample of athletes, which can be linked to the fact that all of the studied sports are characterized by diversity and a variety of technical and tactical elements, as well as the movement of the whole body and limbs in different directions with variable rhythm and pace of movement.

Given the rank of competition in which the tested athletes compete, the established high values of cognitive abilities are in accordance with previously conducted studies, which determined that athletes who perform in the top ranks of competition show higher values of cognitive abilities compared to those that compete in the lower ranks (Stanković, 2014). The observed results can be attributed to the positive selection and high intellectual demands that are imposed at this level of competition in the process of

detecting dynamic changes of situation parameters in the game, as well as the need for understanding and adequate application of different technical and tactical actions.

The structure of cognitive abilities that Malacko (2010) determined in his research is in accordance with previously presented results. A battery of nine motor and three cognitive (KOG3) tests was applied on a population of 136 elite soccer players, aged 18 to 27 years. The determined structure of cognitive abilities shows that only one latent dimension was isolated, which behaves like the general factor. Furthermore, the results of all three tests for the assessment of the efficiency of input, parallel and serial processors show statistical significance, which is identical to the results presented in this study.

The research conducted by Stanković, Ilić, & Bojić Stanković (2014) on a sample of handball players of different competitions ranks showed that there is a difference in the structure of cognitive abilities in relation to the rank of the competition. It included handball players who participate in two national and republic-level leagues. By using different statistical methods for determining the structure of the cognitive space of the handball players of two national ranks of competition, one latent variable was isolated that describes the test area, and which is interpreted as a general factor. The principal component analysis shows the statistical significance of all three examined subfactors, which is consistent with the results obtained in this study.

The results obtained by using a discriminant analysis indicate the existence of only one discriminant function which is satisfactory in explaining the space of cognitive abilities. Based on the values presented in the matrix structure and the group centroids of the cognitive variables, we can conclude that volleyball and basketball are more dynamic sports which take place on courts of smaller dimensions. The outcome is that the execution of offensive and defensive actions is realized in a smaller area and results in the constant need for perceptive processor utilization, which is responsible for the observation, perception, anticipation, and navigation in dynamic situations, i.e. in the process of receiving and decoding information and solving problems whose elements are directly given in a field of perception. In addition, the expressed high value of the parallel processor indicates that visual spatialization is more emphasized with basketball and volleyball players compared to handball and soccer players, which can be explained by the specific nature of these sports that requires the solution of complex tactical tasks.

These results to some extent correspond to those found by Kaur & Sharma (2015), who determined differences in the field of conative abilities on a test sample of 157 athletes, aged 17 to 23, 64 of whom competed in individual sports (judo, athletics, gymnastics, badminton) and 93 in team sports (kho kho, volleyball, cricket, handball, basketball, soccer, kabadi). The results obtained by using the ANOVA and post hoc analysis showed that statistically significant differences were observed between the cognitive abilities of basketball, volleyball and soccer players.

CONCLUSION

In modern sport, cognitive abilities represent an essential factor in the planning process that leads to sports success. Their importance is especially emphasized in team sports, which are characterized by interaction with teammates and the execution of complex, simultaneous movement structures.

This study determined the structure of cognitive abilities, which indicates the existence of one general factor which has been confirmed in practice and is in line with

existing theories in this field. The obtained statistically significant values of all three tests indicate that the quality of the sample of participants is top level and confirms that the complexity of the tasks imposed by performing in the highest ranks of competition requires extraordinary cognitive abilities . The observed differences speak in favor of the specific requirements of tested sports and suggests that athletes who perform their actions on courts of smaller dimensions have a more pronounced ability of perception and visual spatialization. It can be concluded that cognitive abilities are highly developed among handball, volleyball, basketball and soccer players who participate in top national competition ranks. The goal of the future studies can be reflected in the qualitative expansion of the sample of participants and a comparison of the dominant cognitive abilities with other team and individual sports. This determination of the optimal cognitive abilities structure would help in the establishment of the preferred model of athletes in the analyzed sports, and thus contribute to the selection process in the younger age categories, as well as improve the determination of the current competitive qualities of individuals.

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STRUKTURE I RAZLIKE KOGNITIVNIH SPOSOBNOSTI VRHUNSKIH RUKOMETAŠA, ODBOJKAŠA, KOŠARKAŠA I FUDBALERA

U modernom sportu kognitivne sposobnosti predstavljaju jedan od ključnih faktora koji utiču na uspeh sportista. Cilj ovog istraživanja je utvrđivanje strukture i razlika u domenu kognitivnih sposobnosti na uzorku vrhunskih rukometaša, odbojkaša, košarkaša i fudbalera. Uzorak ispitanika obuhvatio je 200 sportista muškog pola, podeljenih u četiri jednake grupe od po 50 ispitanika. Za utvrđivanje konativnih karakteristika primenjena je KOG3 baterija. Struktura i razlike prikupljenih rezultata posmatranih sportista utvrđeni su primenom metode glavnih komponenata i kanoničke diskriminativne analize. Opažena struktura kognitivnih karakteristika ukazuje na postojanje jednog faktora, koji se može tumačiti kao generalni kognitivni faktor. Rezultati sva tri primenjena testa značajni su na nivou celokupnog uzorka, pre svega na nivou input procesora, a zatim i serijalnog i paralelnog procesora, što se može pripisati potrebama koje nameće vrhunski rang takmičenja u kome ispitanici nastupaju. Razlike kognitivnih karakteristika ispitivanih sportista utvrđene su primenom diskriminativne analize, gde je izolovana jedna diskriminativna dimenzija. Posmatranjem matrice strukture i centroida grupa utvrđeno je da prva diskriminativna funkcija separiše košarkaše i odbojkaše na osnovu testova za procenu efikasnosti input i paralelnog procesora. Dobijeni rezultati se mogu dovesti u vezu sa činjenicom da su odbojka i košarka nešto dinamičniji sportovi, kao i da karakteristična priroda ovih sportova nameće rešavanja složenih taktičkih zadataka.

Ključne reči: *rukomet, odbojka, košarka, fudbal, kognitivne sposobnosti*