FACTA UNIVERSITATIS
Series: **Physical Education and Sport** Vol. 12, N° 2, 2014, pp. 145 - 154

Original research article

THE RELATIONS BETWEEN MECHANISMS OF THE REGULATION OF MOVEMENT AND THE COGNITIVE ABILITIES OF HANDBALL PLAYERS OF VARIOUS RANKS OF COMPETITION

UDC 61.796.322

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Abstract. *On a sample of 180 handball players divided into 3 subsamples number 60 participants each, who belong to the I, II and republic handball league of Serbia, a system of 9 variables (6 motor and 3 cognitive) was applied with the aim of determining the statistically significant relations between the system of variables of motor and cognitive variables. The data were processed using a canonical correlation analysis. Using Bartlett's Chi-square test for handball players of various ranks of competition, we tested the statistical significance of the coefficients of the canonical correlation, which explains the linear combinations between the groups of variables, that is, the connection between two systems of variables. By solving the characteristic equations of the cross-correlation matrix we obtained, as the roots of these equations, the coefficients of the determination of the canonical correlation for I league handball players (Rc^2=.23, Rc^2=.10, Rc^2=.08), for II league handball players (Rc^2=.24) and national level handball players (Rc^2=.23). By analyzing the obtained canonical factors of both groups of variables we may say that the cognitive mechanisms have a certain significance for achieving success in handball, at the level of concrete, individual and isolated motor and cognitive abilities, and thus of the greatest importance for handball in general, irrespective of the level of the competition and level of success. A further more detailed study of the connection between the effectiveness of the parallel processor, which is responsible for the visual spatialization, and the factor of the structuring of movement is needed.*

Key words: *handball, intelligence, motor skills.*

Received March 20, 2014 / Accepted June 19, 2014
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INTRODUCTION

No sport, no matter how simple in content and structure it may be, is believed to exist in which cognitive skills, even to the slightest extent, do not take part, which can best be noticed in the field of the equation of the specification of the given sport (Stanković, 2001; Malacko and Stanković, 2011). The influence of cognitive regulatory mechanisms on success in a sports activity varies in intensity depending on the type of mechanism and type of sport, as well as on other predictable and unpredictable situations and circumstances, so that sports achievement could be optimum, considering the cognitive ability, sports knowledge, movement structure and training level of the athletes (Kirkendall and Gruber, 1970; Momirović, Gredelj and Hošek, 1980; Kornspan, 2009; Popović and Simonović, 2008).

Lazarević (1987) stated that in the psychology of sport the most acceptable theory is that of the existence of a general g factor and sequence of specific factors of intelligence, a claim also supported by Thurstone (1938) and Gardner (1983). The general factor includes all types of abilities and to the greatest extent contributes to the differences between individuals, while the specific factors serve to indicate the significance and level of development of specific abilities characteristic for a certain sport, which are directly related to sensorimotor abilities such as speed of visualization, perceptive differentiation, spatialization and diffuse perception. Momirović, Šipka, Wolf and Džamonja (1975), on the other hand, in their hierarchical theory of abilities of the cognitive dimension defined the structures which are responsible for the reception process, the retention and transformation for the purpose of reaching a conclusion and realizing activities which enable the adaptation of the variables of physical and social situations as functional.

In each sport, irrespective of whether we are dealing with a team or individual sport, there are requirements which refer both to intellectual and motor functioning. Handball is a polystructural, acyclic complex activity, a team sport game which places before the players numerous requirements defined by the rules and structure of the game. The required level of intellectual abilities is determined by the structural complexity of handball as a sport (the number of actions and their complexity, tactical variability) and the amount and frequency of making decisions which depend on the temporal structure of the game of handball.

Specific motor skills in handball are manifested within its specific situations and movement structures. Their determination is a result of the analysis of the game of handball, that is, of the classification and frequency of the technical-tactical elements and their spatial and temporal parameters, and thus the dominant motor skills which are keys for efficient performance. When performing technical-tactical elements in handball, the most frequent movement structures include: jumps, hits, changes in direction, stopping and turning, short sprints and increases in speed, throws and falls.

Motor skills included in the systems of movement structure and tonus regulation and synergy regulation are one of the factors which, with their high coefficient, have a clear influence on the high quality performance of handball players. However, at the elite level of competitions, if the competition is taking place at several levels and/or ranks and when the years of selection and training have singled out a model of the competitor which is, based on multiple abilities and characteristics, homogenous, (morphological characteristics, motor and functional skills, performance technique), what in fact determines the winner are the cognitive abilities and conative characteristics.

Bearing in mind the fact that handball players must solve motor and cognitive situations which can occur on the field, and which require evaluation, prediction and

reaction in relation to the constant changes and diversities of situations, one needs to start from the assumption that determining the relationship between basic motor and cognitive skills can be one of the most important indicators of the anthropological status of athletes, their mutual functioning and the harmony among the team members on the court (Malacko and Rađo, 2004). That is why the aim of this research was to use a sample of handball players of various ranks of competition to determine the statistically significant relations between the system of variables of motor skills, which are used to evaluate the mechanism of the regulation of movement, and cognitive variables for the purpose of forming rational procedures for the most optimal planning and programming of training content, as well as monitoring and controlling the transformation process of relevant anthropological characteristics.

THE METHOD

The sample of participants

The research sample included 180 handball players who were divided into 3 subsamples numbering 60 participants each, belonging to the I, II and national level handball league in Serbia. They were members of 8 handball clubs competing in the 1998-1999 season. A system of 9 variables was applied to the sample (6 motor and 3 cognitive).

The measuring instruments

To evaluate the motor skills, from the model of the structure of motor skills (Gredelj, Hošek, Metikoš, Momirović, 1975) defined as the mechanism for the regulation of movement, the following latent, or manifest variables were used: *structuring movement* - 1. coordination with a baton (KOP), 2. hand and foot drumming (BNR), 3. hand tapping (TAP), *tonus regulation and synergy regulation* - 4. hyperextensions (DPR), 5. standing on one leg (SJN), 6. shooting at a horizontal target (GHC).

For the evaluation of cognitive abilities from the KOG 3 battery (Wolf, Momirović, Džamonja, 1992) the following variables were used:

1. IT–1 test for the evaluation of the perceptive processor - taken from MFBT. It was constructed with the intention of measuring the perceptive ability, which represents a synthesis of the group of perceptive abilities of analysis, structuring and identification. It consists of 39 multiple-choice tasks. The participant needs to evaluate which of the 4 test-images is identical to the criterion one. The work time is limited to 4 minutes.

2. AL–4 test for the evaluation of the effectiveness of the serial processor– the synonym and antonym test, taken from the revised form of the ALFA battery of F.L. Wells. It was aimed at evaluating verbal understanding. It consists of 40 tasks or pairs of words. The participant was asked to determine whether the words in the pair have the same or opposite meanings. The test is a speed test. Work time is limited to 2 minutes.

3. S–1 test for the evaluation of the effectiveness of the parallel processor –it presents the essential part of the SVPN-1 battery. The intentional object of measuring is visual spatialization. It consists of 30 multiple choice tasks. Each includes a drawing of a tridimensional arrangement of a group of bricks, as well as 4 transversal projections of the group. The participant's task is to find the transversal projection which is related to the group of bricks viewed form a particular perspective. It belongs to the category of strength tests. The work time is limited to 8 minutes.

Data processing method

To calculate the relations between the systems of variables of basic motor variables and cognitive abilities the canonical correlation analysis was used. The hypothesis of the global connection between two different anthropological systems of variables was tested using: Rc- the canonical correlation coefficient of statistically significant canonical pairs, Rc^2- the squares of the canonical correlations, χ^2– Bartlett's Chi-square test.

THE RESULTS

Table 1 shows the results of the central and dispersion statistical parameters of the motor and cognitive variables. They indicate that the handball players of league I generally score higher results on all the tests of motor skills in comparison to the handball players from lower ranking competitions, except on the test of precision in which the best results were scored by the handball players from league II. In addition, the handball players of the highest rank of competition have higher scores on all the tests for the evaluation of cognitive abilities in comparison to the handball players of league II and the national rank of competition.

Table 1 The descriptive statistics of the handball players of all three ranks of competition

Variables	Sample of I league handball players				Sample of II league handball players				Sample of national leaguehandball players			
	M	Min	Max	SD	M	Min	Max	SD	M	Min	Max	SD
KOP	67.65	48	100	11.86	98.15	58	200	34.63	101.50	60	250	27.60
BNR	9.016	4	13	2.17	9.98	7	16	2.39	10.75	3	16	3.45
TAP	36.45	28	49	4.21	34.50	30	40	3.02	35.98	22	52	6.97
DPR	49.13	39	61	5.64	46.43	35	56	4.51	43.40	6	62	9.76
SJN	38.26	16	79	15.62	30.06	11	70	11.90	32.38	10	87	12.63
GHC	22.58	5	60	8.83	24.35	17	34	4.36	16.38	3	80	12.01
IT1	25.00	12	38	5.56	23.38	12	38	6.45	25.78	8	39	7.30
AL4	35.53	22	40	5.46	34.70	24	40	3.81	34.41	26	40	3.77
S1	26.30	13	30	3.53	24.96	5	30	4.78	21.86	8	30	5.40

By analyzing the cross-correlation matrix between the system of motor and system of cognitive variables (Table 2) we can note statistically significant correlations between the pairs. Among league I handball players, between the cognitive variable S–1- the effectiveness of the parallel processors and the motor variables of KOP- coordination with a baton and DPR-hyperextensions and GHC - shooting a horizontal target there is a statistically significant correlation of a weak intensity. Among the handball players of the II, but also the national league, there is a statistically significant correlation of medium intensity between the cognitive variable AL–4-the effectiveness of the serial processor and motor variable BNR- hand and foot drumming, as well as a correlation of the weak intensity but also in a negative direction of the cognitive variable S–1-the effectiveness of the parallel processor and the motor variable KOP- coordination with a baton.

Table 2 The cross-correlations of the motor and cognitive variables of handball players

I league				II league				National league			
Variables	IT1	AL4	S1	Variables	IT1	AL4	S1	Variables	IT1	AL4	S1
KOP	-.07	.03	**-.32****	KOP	-.10	.13	**-.29***	KOP	-.06	-.09	**-.31***
BNR	.23	.21	-.07	BNR	.12	**.42****	.16	BNR	.23	**.36****	.08
TAP	-.06	.04	-.00	TAP	.05	.05	.24	TAP	.19	-.10	.04
DPR	-.15	.14	**.38****	DPR	-.11	.00	.07	DPR	-.09	.05	.17
SJN	-.09	.10	.12	SJN	-.10	.02	.13	SJN	-.17	.21	.06
GHC	-.12	.15	**.25***	GHC	.03	.20	.20	GHC	.03	.17	.21
Rc	**Rc^2**	**χ^2**	**p**	**Rc**	**Rc^2**	**χ^2**	**P**	**Rc**	**Rc^2**	**χ^2**	**p**
.48	.23	79.03	.00	.49	.24	50.36	.00	.48	.23	27.73	.05
.31	.10	33.37	.00								
.28	.08	15.01	.00								

Using Bartlett's Chi-square test for the handball players of the I league (χ^2=79,03, χ^2=33,37 and χ^2=15.01) the statistical significance of the canonical correlation coefficient was tested (Rc=.48, Rc=.31, Rc=.28), which explains the linear combinations between the groups of variables, that is, the connection between two different systems of variables. By solving the characteristic equations of the cross-correlation matrix we obtained, as the roots of these equations, the coefficients of the determination of the canonical correlation (Rc^2 =.23, Rc^2 =.10, Rc^2=.08), which explain a joint variance of the variables from two groups of the overall variability of the analyzed system of variables. Using Bartlett's Chi-square test for handball players from the II league (χ^2=50.36) the statistical significance of the canonical correlation coefficient was tested (Rc=.49) and for the handball players of the national rank for the obtained Bartlett's Chi-square test (χ^2=27,73) the statistical significance of the canonical correlation coefficient was obtained (Rc=.48) .

In the remaining data processing, three statistically significant structures of the canonical factors were found, on the one hand, in the system of motor variables, and on the other hand, in the system of cognitive variables for handball players of the I league, and one statistically significant canonical factor structure each for the handball players of the II and national league.

Table 3 The canonical structure of the motor and cognitive variables of the handball players

	Sample of I league handball players			Sample of II league handball players	Sample of national league handball players
Variables	**Fc - 1**	**Fc - 2**	**Fc - 3**	**Fc – 1**	**Fc - 1**
			Motor variables		
KOP	**.58***	-.22	**.71***	-.27	-.13
BNR	.22	**-.93***	-.26	**.71***	**.87***
TAP	-.04	-.04	.27	**.42***	-.09
DPR	**-.73***	-.01	.32	.10	-.02
SJN	**-.32***	-.12	.32	.22	**.30***
GHC	**-.61***	-.12	.33	**.52***	**.30***
			Cognitive variables		
IT1	.22	-.48	**-.84***	.28	.29
AL4	-.31	**-.90***	.27	**.72***	**.94***
S1	**-.95***	-.02	-.29	**.85***	.19

The first isolated canonical factor can be defined as a canonical factor for the regulation of tonus and synergy regulation. The second canonical factor can be defined as single canonical factor of non-rhythmic drumming. The third canonical factor can be defined as a canonical factor of body coordination.

The first canonical factor is presented by only one cognitive variable (S–1), thus it can be defined as the effectiveness of the parallel processor, that is, the determination of the relations and correlates. Considering that the second canonical factor is also presented by only one cognitive variable (AL–4), it can be defined as the effectiveness of the serial processor, that is, symbolic reasoning. The third canonical factor can be interpreted as the effective input of the processor, that is, perceptive reasoning.

For the sample of II league handball players, the only isolated canonical factor in the space of motor skills can be defined as one complex canonical factor of non-rhythmic drumming and precision. The matrix of the structure of the canonical factors of cognitive abilities can thus be defined as the effectiveness of the parallel processor, that is the determination of the relations and correlates and effectiveness of the serial processor, i.e. symbolic reasoning.

For the sample of handball players from the republic league, the only isolated canonical factor in the space of motor variables was defined as the canonical factor of the central regulation of movement. The matrix of the structure of the corresponding canonical factor of cognitive abilities indicates that there is a very high projection of the cognitive variable AL-4 (.72*), and thus it can be defined as the effectiveness of the serial processor, that is symbolic reasoning.

DISCUSSION

In this study three factors each were isolated from the analyzed spaces for the I league handball players (regulation of tonus and synergy regulation, non-rhythmic drumming and body coordination), while for the II and national league handball players one statistically significant factor each was isolated in these two spaces, the single canonical factor of non-rhythmic drumming, that is the factor of the central regulation of movement among the national league handball players. The situation is quite similar with the cognitive canonical factors, which are in a statistically significantcorrelation with the isolated motor factors. In this study, three factors in the cognitive space of league I handball players each were isolated (the effectiveness of the parallel processor, that is the identification of the relations and correlations, the effectiveness of the serial processor, that is symbolic reasoning and effectiveness of the input processor, that is perceptive reasoning), while for the handball players of the II and national league one statistically significant factor each was isolated in these two spaces, the effectiveness of the parallel processor, that is the identification of the relation and correlation and the effectiveness of the serial processor, that is symbolic reasoning for the II league handball players, that is the factor of the effectiveness of the serial processor, that is symbolic reasoning of the handball players of the national league. These results are in agreement with the research of Stanković and Malacko (2008) who, also on the sample of handball players, obtained three isolated canonical factors in these two systems. These results are in favor of the assumptions which the authors Rushall and Siedentop (1972) obtained in their work on the possibility of differentiating athletes based on their cognitive abilities and personality traits not so much on the type of sport as on their success in the sport.

The obtained results differ in comparison to those obtained by Malacko (2010) on a sample of 136 national league soccer players, age 18 ± 27 after applying a system of 9 tests of motor skills and the KOG 3 battery, considering that he determined that there was a positive canonical correlation between the isolated canonical factor of general cognitive abilities and the first canonical factor of the system of motor skills, which was interpreted as the canonical factor of the structure of movement, the regulation of intensity and the duration of excitation, which indicates that soccer players who achieve very good results on basic motor skills at the same time achieve high scores on the tests of cognitive abilities and vice versa. In our research we determined that there was no unique general factor either in the motor or cognitive space on a sample of the national league handball players, while one factor each in these areas, but of a completely different structure, was isolated among the handball players who compete at lower-level competitions. Nevertheless, in the space of cognitive functioning, considering that in all three groups there was effectiveness of the serial processor it is possible to isolate it as an independent sample, we can agree with Malacko's (2010) conclusion that cognitive mechanisms have a general significance on the successful performance of motor skills among soccer players, but that the effectiveness of the serial processor has a defining influence on it, considering that the serial processor is responsible for the ability to operate with symbols, which is especially prominent among the system of movement structuring, which represents the most dominant ability of the soccer players, and probably handball players. The differences in the structure and number of isolated factors compared to earlier research should primarily be sought in the nature of sport, that is, the diversity of motor requirements which are placed before the soccer players and handball players, and accordingly, the necessary motor skills. Undoubtedly great significance was also attached to the quality and rank of the competition, which with it brings not only different motor and cognitive factors, but also conative space which could have a defining influence on these differences, along with the presence both of morphological differences which cannot be neglected considering that in the first league of any sport there was a significantly greater number of older and more experienced athletes in comparison to the lower ranks of the competition.

The research results of Stanković and Malacko (2008) also indicated that there is a positive, statistically significant correlation with a weak intensity between the scores on the hand and foot drumming test and the test of the effectiveness of the perceptive processor IT–1, which is not in accordance with the results of this study, considering that the score on the hand and foot drumming test was in a statistically significant correlation of modest intensity with AL–4 - the effectiveness of the serial processor also among the handball players at lower ranks of competition. Stanković and Malacko (2008) determined for the AL–4-effectiveness of the serial processor that there is a statistically significant correlation of mild intensity and a positive direction with the motor variable of shooting at a horizontal target and hyperextensions, as well as the statistically significant correlation of mild intensity and a negative direction in the score of the test of coordination with a baton. These authors did not obtain any statistically significant correlations between the applied system of motor variables and the effectiveness of the parallel processor (S–1) while in this study it was determined that it was connected in a statistically significant manner with the motor variables of KOP – coordination with a baton among all the handball players of all levels of competition and the correlation of moderate intensity with a positive direction connected to the motor variables of DPR - hyperextensions and GHC – shooting at a horizontal target and only among the handball players of the first

league. These results have confirmed the hypothesis that there is a positive correlation which varies from low correlations to correlations of moderate intensity between intelligence and complex motor tasks (in the field of coordination and balance).

For this reason we can presume that the cognitive mechanisms have a certain importance for the achievement of success in handball, at the level of specific, individual andisolated motor and cognitive skills, and thus that the greatest significance in handball in general, irrespective of the level of competition and success, the connection with the effectiveness of the parallel processor which is responsible for visual spatialization should be studied in more detail, which is based on the test of strength and the factor structure of movement measured using the test of coordination with a baton. A weak but negative connection between this motor task and cognitive functioning indicates that during its performance there is an additional influx of information which needs to be detected on time, properly understood, cognitively processed, realized and thus performed in as short a period of time as possible. The greater the influx of visual information in the field, the more time it takes to realize each of the individual tasks. Naturally, under the condition that each component of the receptors of the eyes, via the working memory and the centers in the cortex, all the way to the effectors, that is, the upper extremities, and during the game itself, including the whole body, are used to their maximum potential. This entire process takes place in an exceptionally dynamic situation and during a fast game which is full of many details, which should adequately be interpreted in a short period of time. The performance of these complex movements, among which the order of performance is very important, requires among other things the memory of the order of movement, and the connection of a greater number of separate movements into a new whole, can be realized only after a certain short period of learning through gaining insight. It is precisely in the process of learning motor tasks, which are very complex in handball, that there is significant involvement of the parallel processor, whose role it is to process the new information at various levels, and thus analyze them in comparison to previous experience with the aim of making more effective decisions, which is especially important for coordination, the most complex motor skill.

CONCLUSION

In every sport, irrespective of whether it is a group or individual sport, there are requirements which refer to intellectual and motor functioning. In order to successfully outplay the other athletes we would have to have highly developed abilities both in the motor and intellectual space. The differences in the quality and use of these potentials are especially pronounced in the various levels of competition. The obtained differences in the relations of handball players of various ranks of competition are the result of numerous factors which influence the differences in the quality of the players (talent, persistence, selection and the material, staff and other conditions). This was also confirmed in this study.

In the study it was determined that there is no unique general factor either in motor or cognitive space on the sample of first league handball players, while each factor in these spaces, but of a completely different structure, was isolated among the handball players who compete at lower-level competitions. However, in the space of cognitive abilities, we can conclude that the cognitive mechanisms have a great significance for the successful performance of complex motor tasks. In the successful performance of these motor tasks,

decisive importance lies in the effectiveness of the serial processor, considering that among I and II league handball players it has been shown that the effectiveness of the serial processor can be isolated either as an independent canonical factor or as a dominant skill. The serial processor is responsible for operating with symbols, but also visual spatialization, where it is the test of strength, in which the tasks were ordered from the simplest to the most demanding degree of cognitive data processing. That is why it represents a unique plan of coordination as the most complex motor skill which is especially dominant in the system of movement structure, which represents the most dominant latent ability of handball players, since the motor tasks of handball players are primarily the result of the function of coordination, speed and the success of manipulating a ball. That is why we cannot avoid the assumption on the transfer of acquired knowledge and the patterns of learning from the system of motor variables into the system of cognitive variables and vice versa, considering that a better result for the evaluation of the parallel processor is accompanied by the quicker and more precise performance of the test of coordination with a baton, which has confirmed the hypothesis that the more complex the motor task, the greater its correlation with intelligence which is equally important for the achievement of top sports results in both anthropological domains.

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RELACIJE MEHANIZMA REGULACIJE KRETANJA I KOGNITIVNIH SPOSOBNOSTI KOD RUKOMETAŠA RAZLIČITIH RANGOVA TAKMIČENJA

Na uzorku 180 rukometaša podeljenih u 3 subuzorka po 60 ispitanika koji pripadaju I, II i republičkoj rukometnoj ligi Srbije bio je primenjen sistem od 9 varijabli (6 motoričkih i 3 kognitivne) saciljem da se utvrde statistički značajne relacije između sistema varijabli motoričkih i kognitivnih varijabli. Podaci su obrađeni pomoću kanoničke korelacione analize. Pomoću Bartlettovog Hi-kvadrat testa za rukometaše različitih rangova takmičenja testirana je statistička značajnost koeficijenta kanoničke korelacije koja objašnjava linearne kombinacije između skupova varijabli, tj. povezanost dva različita sistema varijabli. Rešavanjem karakterističnih jednačina kroskorelacione matrice dobijeni su, kao korenovi tih jednačina, koeficijenti determinacije kanoničke korelacije za rukometaše I lige (Rc^2=.23, Rc^2=.10, Rc^2=.08), rukometaše II lige (Rc^2=.24) i za rukometaše republičkog ranga takmičenja (Rc^2=.23). Analizom dobijenih kanoničkih faktora oba skupa varijabli se može zaključiti da kognitivni mehanizmi imaju određeni značaj za postizanje uspeha u rukometu, na nivou konkretnih, pojedinačnih i izdvojenih motoričkih i kognitivnih sposobnosti, te da je od najvećeg značaja u rukometu generalno, bez obzira na nivo takmičenja i uspešnosti, potrebno detaljnije izučiti vezu efikasnosti paralelnog procesora koji je zadužen za vizuelnu spacijalizaciju i faktora za strukturiranjekretanja.

Ključne reči: *motoričke sposobnosti, inteligencija, relacije, rukomet*.