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Canonical relations between
cognitive abilities and specific motor abilities of sitting-volleyball players

Key words: **Cognitive abilities, Specific motor abilities, Sitting-volleyball, Canonic Correlation Analysis**
Ključne riječi: **Kognitivne sposobnosti, specifične motoričke sposobnosti, sjedeća odbojka, kanonička korelaciona analiza**

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Abstract
This research was conducted in order to assess the relations and the intensity of correlation between the cognitive abilities and the specific motor abilities of sitting-volleyball players. The sample consists of 68 subjects that are the best registered sitting-volleyball players in Bosnia and Herzegovina. This study is described using four variables for the estimation of cognitive abilities and eight variables for the estimation of specific motor abilities. The methods used for gathering data were a Cybernetic battery of tests KOG-3 and objectified tests for the estimation of specific motor abilities of the sitting-volleyball players. The correlation between the set of cognitive variables and the set of motor variables is estimated by means of using Canonic Correlation Analysis. Results of the research suggest that there does not exist a correlation between the cognitive and the specific motor abilities of sitting-volleyball players.

Sažetak
Istraživanje je provedeno u cilju utvrđivanja relacije i intenziteta povezanosti između kognitivnih sposobnosti i specifične motoričke spretnosti igrača sjedeće odbojke. Uzorak od 68 ispitanika, najboljih registriranih reprezentativnih igrača sjedeće odbojke u BiH, opisan je sa četiri varijable za procjenu kognitivnih sposobnosti i osam varijabli za procjenu specifične motoričke spretnosti. Prilikom prikupljanja podataka koristili smo se Kibernetičkom baterijom testova KOG-3 i objektiviziranim testovima za ispitivanje situacione motorike odbojkaša. Povezanost između seta kognitivnih varijabli i seta varijabli za procjenu specifične motoričke spretnosti procijenjena je korištenjem kanoničke korelacione analize. Rezultati istraživanja sugeriraju da ne postoji povezanost između kognitivnih i specifičnih motoričkih sposobnosti igrača sjedeće odbojke.

Introduction

During the competition and the training process an athlete performs movements that vary from those seemingly simple movements, like running, to movements of extreme complexity in structure. In addition, most sports include a necessary coordination of movements between two or more athletes. An athlete's performance then, demands skills at tasks which involve movement within a very limited time, and very often these movements involve an interaction with moving objects and opponents. Thus, it is of essential importance to understand the way in which an athlete accepts and processes information within their environment. The ability to quickly and efficiently process information that is specific to a certain sport task represents one of the defining characteristics of sport expertize. Given this situation, the reason to seek a foundation of explanation for the differences in motor skills within cognitive theories of information is important. In accordance to such a theoretical approach, an athlete is viewed as an intelligent receiver and translator of information that performs movements with various degrees of efficiency (Hodges, Starkes, MacMahon, 2006). Many authors claim that it is almost impossible to find significant differences among the factors that affect the acquisition of perceptual-motor functions and those that affect the acquisition of intellectual skills (Rosenbaum, Carlson, Gilmore, 2001; Schmidt and Bjork, 1992). To complicate this matter, neuroscience only offers more evidence of the similarity between the acquisition of perceptual-motor functions and intellectual skills. Even the early works of Holmes (1939) have shown that damage to the cerebellum usually results in low muscle tone, delayed initiation of movements, and motor planning defects and tremors, all of which draw us to the conclusion that the cerebellum controls and coordinates movement. In addition to this, numerous research has also shown that the cerebellum also affects cognitive functions.

Therefore, since the game of sitting-volleyball is of a very dynamic character, consisting of fast actions, and since it demands abilities of fast planning, decision making, and fast reactions to stimuli, we expect that the cognitive abilities of an athlete will be a major factor for successful motor performance for the game of sitting-volleyball.

Methods

Participants

The research consisted of 68 participants, all of whom were sitting-volleyball players from Bosnia and Herzegovina. The sample enfolds all of the best registered sitting-volleyball players from Bosnia and Herzegovina and among them were the members of the national sitting-volleyball team. We can consider these athletes to be elite athletes because the national team of Bosnia and Herzegovina is the current World Champion of sitting-volleyball, six-time champion of Europe, and winner of the Paralympic Games held in Athens, Greece in 2004.

Sample of variables

The sample is described by eleven variables. Variables for the estimation of the cognitive abilities (efficiency of perceptive processing -GVT1, efficiency of successive processor - GVL4, effi-

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ciency of simultaneous processor – GVS1 and general intellectual efficiency – GOIQ) were measured by a Cybernetic battery of tests of intelligence KOG-3 (Wolf, Momirović and Džamonja, 1992). The other eight variables pertain to the situational-motor abilities area of the research. These eight variables are:
The ability to consecutively suppress the ball with the fingers (SMUP), the ability to consecutively suppress the ball by passing or bumping the ball (SMUO), the precision in suppressing the ball with the fingers (SMPP), the elevated precision of suppressing the ball with the fingers (SMLP), the elevated precision of suppressing the ball by passing or bumping the ball (SMOL), the ability to alternately suppress the ball by passing or bumping the ball (SMLD), the precision of a tactical serve of the ball (SMPT), and lastly, the efficiency in spiking the ball (SMLZ). All of these variables are measured using objectified tests designed for estimating the situational-motor abilities of sitting-volleyball players.

Results

Table 1 indicates the values of the basic parameters of descriptive statistics, the values of Skewness, Kurtosis, and the Kolmogorov-Smirnov test. The values of the Kolmogorov-Smirnov test indicate that only two variables in the distribution of results have a statistically relevant variation from a normal distribution. These two variables are the ability to consecutively suppress the ball with the fingers and the ability to consecutively suppress the ball by passing or bumping the ball. Aside from these two variables, since the greatest difference between the relative and the theoretical cumulative frequency of all of the other variables (D max) is lower than the constant (K-S test) 0.20 the other variables are normally distributed. However, since the variation of those two variables is not very large we have decided to use these obtained results within our analysis.

High results obtained of cognitive tests were scaled in such a way that the high results imply highly developed abilities. Pertaining to the variables for estimation of situational-motor abilities, higher results mean better motor performance, while lower results represent weaker motor performance. Both, canonical correlations and statistical significance of the sets of canonical correlations and canonical coefficients are shown in Table 2. They indicate that there is no statistically significant correlation between the cognitive and the motor abilities given the levels of statistical significance of $p<0.01$ and $p<0.05$.

Discussion

Although our research has not shown there to be a relationship between the intellectual and the motor abilities of these athletes, some research has shown that there is a relationship between these abilities; and the most evident case of this relationship occurs when athletes perform motor tasks of high levels of complexity.
In simple situations, as in the testing situation of this research, motor performance demands a significantly lower representation of a cognitive component for these performances; whereas, in the process of performing taks in a situation that is more complex motor performance becomes more and more cognitive. Such a complex cognitive behavior aims at producing a maximal state of economy between the efficiency in the usage of adequate effectors and the manifesting of some other inner components of motor behavior (e.g. personal characteristics and emotions during solving specific motor problems, which is recognized in a style of actualizing motor abilities).
Based on the results of his research Bala (1999) generates the general conclusion that relations between cognitive and motor

***Table 1**. Descriptive Statistics of Basic Parameters*

	N	Min	Max	Dx	M	SD	Skew	Kurt	Dmax	KS-z
GVT1	68	-2.14	350.65	0.17	0.54	0.73	-0.78	187.19	0.07	0.20
GVL4	68	-0.62	160.72	0.103	399.04	0.43	-1.90	227.98	0.13	0.20
GVS1	68	-1.68	244.73	0.22	0.24	0.92	-0.31	399.05	0.07	0.20
GOIQ	68	90.00	123.00	303.17	109.22	250.20	-0.48	399.96	0.07	0.20
SMUP	68	17.00	210.00	326.90	44.37	33.16	398.75	13.22	0.23	0.20
SMUO	68	11.00	115.00	307.73	26.75	20.38	237.74	265.43	0.22	0.20
SMPP	68	10.00	300.00	13.81	67.60	58.12	399.35	286.72	0.08	0.20
SMLP	68	6.00	40.00	197.25	32.01	176.85	-1.64	198.76	0.10	0.20
SMOL	68	3.00	35.00	146.11	399.86	326.29	-0.39	431.91	0.04	0.20
SMLD	68	2.00	26.00	400.57	447.43	216.41	295.87	319.29	0.10	0.20
SMPT	68	1.00	10.00	0.43	278.51	299.52	0.57	154.01	0.04	0.20
SMLZ	68	10.00	40.00	463.88	30.40	132.71	-1.45	143.97	0.09	0.20

***Table 2**. Canonical Correlations and Significance Levels for Sets of Canonical Correlations.*

NO.	R	R2	HI	DF	WILKS	PROB.
1	0.5467	0.2989	44.9800	32	0.4784	0.0677
2	0.4877	0.2378	23.3198	21	0.6823	0.3293
3	0.2562	0.0657	6.7521	12	0.8952	0.8731
4	0.2046	0.0419	2.6096	5	0.9581	0.7622

abilities indicate the existence of a general ability of adaptation during the solving of motor tasks in motor-cognitive problem situations. This general ability of adaptation Bala defines as *motor behavior*, and some even call it *motor intelligence*. The level of motor behavior depends on the complexity of the motor task and the motor-cognitive problem; i.e. his results indicate that as a situation is more simple the cognitive component will be minimally represented in motor behavior. A complex situation on the other hand, according to Bala, transforms into cognitive behavior and aims at producing a maximal state of economy between the efficiency in the usage of adequate effectors and the manifesting of some other inner components of motor behavior.

It is well-known that any acquisition of motor skills has its cognitive stage, and because of this, in this stage motor skills are tightly related to cognitive skills. Motor skills rely on the same principles as intellectual skills during their acquisition, and both have their basis within cognitive functions. That is to say, during motor performance higher mental processes are used in order to analyze goals and the way in which to achieve those goals. Thus, in this stage it is possible for an athlete to recognize the mental processes involved in a movement, during the process of acquiring motor skills. However, once a mental program has been acquired, as a final instance in the process of every kind of learning, even a motor one, there is a stage of automatization in which there is needed less of a conscious effort for the performance of motor skills. By becoming automatized a movement acquires a certain autonomy related to the cognitive abilities, especially if we are talking about movements estimated in this research. Due to this occurence it is safe to speak about the nonexistence of a correlation between cognitive skills and motor skills at the executive phase of movement. This is supported insofar as while describing the process of the acquisition of movement and its execution, Bala (1999) claims that such is accomplished thanks to the activity of the Central Nervous System, and that it is a necessary activity of the cortex during the process of acquiring motor tasks, since the given tasks need to be comprehended in advance.

During the acquisition of motor tasks a process of regulation gets activated through a system of feedbacks (through various receptors that are very important in those muscles that are kinestetic for movements of joint and those which react for tasks such as speeding up and a change in balance). However, when motor tasks become automatic a process of regulation is not needed anymore; only a system of control is needed. In short, if the task is simple only a system of control is necessary, and if the task is complex the priority of performing the task is favored by a process of regulation which includes cognitive functioning.

Maybe the most significant explanation of relation between cognitive and motor abilities was given by Fitts and Posner (1967). They claim that during the process of acquisition of motor skills an individual is progressing through the cognitive stage, then the associative stage, and finally the individual reaches the level of an automatic (autonomous) stage. To describe this progression, the cognitive stage is characterized by an intellectual approach, in which a person relies more on instructions and feedback from their environment. Performance at this level is characterized by the conscious control of different elements of the motor skill and it lacks the fluidity which characterizes later levels of performance. Next, coordination is developed through the associative phase; during this phase the elements of a motor skill are getting integrated into more polished actions that can be rapidly and flexibily appointed. In the autonomous phase, performance finally becomes more independently releated to cognitive control and the role of attention becomes significantly low. At the same time, the performance of the individual gets less sensitive to interference from enviromental information. Hence, according to Fitts and Posner, when athletes acquire high skill levels the level of attention and cognitive control decreases. Similar results have been presented by Schiffrin and Schneider (1977). In their model, Schiffrin and Schneider confirm that automatic processing has low levels of attention, which is contrary to controlled information processing, which demands attention. In contrast to controlled information processing then, automatic processing is fast, easy, and its not under conscious control (Williams, A.M., Davids, Williams J.G., 2000). Thus many authors often speak about conscious and subconscious processes within this context (Shiffrin and Schneider 1977, Schneider, Dumais and Shiffrin, 1984). And by this principle many different motor performances in sport can be explained. For example, a skillful athlete usually uses subconscious processes when performing tennis serves or hitting a golf ball. According to this distinction, automatic control arises when an athlete starts to move from the level of conscious processing to the level of subconscious information processing. This further indicates that motor skills can be performed with a very limited scope of attention and contribution of cognitive abilities; as such, athletes can focus their attention on other tasks. Fischman and Oxendine (1993) give an example of Michael Jordan who was able to carry out the dribbling of a basketball at full speed and change direction without conscious effort, which has left him space to focus on the positions of other players and assign the best strategy to reach the basket. Smith (1996) claims that both sorts of information processing are an integral part of the behavioral repertoir of an athlete from the moment a movement has been acquired to its final and independent execution. Some authors have also indicated that the sole reflection on motor skills and a conscious try to accelerate them generally aggravate performance (Jarvis, 2004). Elite skiers usually don't reflect on sequential movements that they perform during skiing. On this level of performance, attention can be focused solely on the ski flags or the terrain. The remaining performance of these athletes is performed without any effort and conscious reflection about any other separate aspect of the motor technique (Williams, A.M., Davids, Williams J.G., 2000).

These changes arise due to a decreased attentional scope that is necessary for the performance of motor tasks. Such an advancement in technique enables an athlete to direct their attention on other aspects within their environment and for them to develop more subtley strategies of performance (Glencross, 1978, prema Williams, A.M., Davids, Williams J.G., 2000). In other words, if an elite athlete thinks too much about his movements while skiing it can deteriorate his performance (Baumeister, 1984; Gallwey and Kriegel, 1977). From a cognitive perspective, the direction of conscious attention towards different parts of a motor skill can derange an acquired motor program of control over an action. This result of an excessive usage of the conscious feedback mechanism or of a redirection towards some other form of control during performance of the motor task is called *paralysis by analysis*.

The results of our research have probably been affected by the type of motor tasks performed in testing. Specifically, in the research we have analyzed *closed movements*. The degree to which we consider motor skills to be closed is due to being restricted to the environment in which the motor skill is performed, an environment that is predictable and unchangeable (Jarman, 2004). Although sitting-volleyball is a sport which demands *opened skills*, the testing situation created conditions which have been controled by the researcher so circumstances were predictable. The sense of control then, over the situation and the predictability of the motor tasks performed, decreased the level of impact of cognitive abilities on the performace of motor tasks. The testing motor tasks were very simple in structure and were automatically performed; thus, it is hard to expect more significant intellectual engagement while responding to motor tasks of this type without bigger situational changes. We can also expect that the characteristics of the sample, which is small in size and particularly selected, has contributed to the cause of an absence of a correlation, especially if we have in mind that one of the canonic correlations occurs at the border of statistical significance ($p=0.07$). It is possible that results would reach a level of statistical significance if there had been a greater number of participants in the research.

In addition, the analysis of motor abilities has been conducted in testing conditions and not in a realistic situation of sport competition. It is therefore safe to say that such a method of collecting data affected the results of the research. Whereas, during a competition a significant dynamic of movement, which is performed without predefined order and routine, is present. What was absent then is the characteristic of the situation of competition that possesses a factor of uncertainty. This uncertainty manifests a significant use of perceptive abilities, e.g. the need for fast planning, decision making, and the ability to anticipate the reactions of opponents. Certainly, our discoveries would be more valid if our testing would have been conducted in an authentic sport situation, which is a recommendation for future research.

Conclusion

A statistical significant correlation between cognitive abilities (intellectual abilities, perceptive abilities and successive information processing) and specific motor abilities has proven to be nonexistant. This result indicates the conclusion that the examined athletes have acquired a high level of competency of performing motor tasks because they do not rely on cognitive abilities during the performance of movements. We can say that the performance of motor skills is automated because when these elite sitting-volleyball athletes perform movements they do not rely on cognitive abilities. The control over motor skills and the performance of these movments is a very important factor in achieving a successful performance, not only when the demand for processing consists of a small amount of information, but also in more complex situational circumstances that require decision making abilities. In such circumstances, althetes only need to make a choice of which technique to use in a given situation.

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