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CONTENTS

DETERMINATION AND COMPARISION OF THE QUALITATIVE BIOMECHANICAL STATUS OF THE MOTOR STEREOTYPES IN HANDBALL WITH TWO METHODOLOGICAL APPROACHES

UDC: 796.322.012.1-057.874(497.711)

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Abstract
The knowledge of the biomechanical characteristics of the sports technique is one of the most important stages in the determination of the key aspects of the performance, through which more rational and more efficiant approach is enabled in its study and improvement.The objective of this research is to determine and compare the qualitative biomechanical status of the motor stereotypes from the sports game handball by applying two methogological approaches. The sample of motor stereotypes is analyzed with the method of qualitative biomechanical analysis through an application of binary and ordinal data, followed by determination and comparision of the biomechanicl intersimilarity, the complete biomechanical similarity, the adjacent biomechanical similarity, the force of the biomechanical connection and the biomechanical structure.The obtained results indicate presence of a similar interpretability in the two approaches for determination of the biomechanical status. Still, in terms of the biomechanical structure, the orthogonal and the skew solution provide a clearer structure and interpretability in the ordinal approach.Further research is required for more reliable generalizaton, which will also include other approcahes both in the qualitative biomechanical analysis, as well as in the methodology, through which the biomechanical status of the motor stereotypes would be determined and compared.

Key words: *qualitative biomechanical analysis, characteristics, strucutre, motor stereotype, binary, ordinal.*

Introduction

The qualitative biomechanical analysis is a process of systematic observation and introspective assessment of the quality of movements in the human, aimed at provision of the most appropriate intervention for their correction (Knudson, 2013), and its goal should be directed towards the achievement of the satisfactory level of performance in the trainee (McCaw, 2014).

The knowledge of the biomechanical principles and regularities provides very accurate determination of the key characteristics of the motor stereotypes (the elements) by determination and comparision of the engagement of specific muscle groups in the performance of the movements separately for each element, however also in the detection of their mechanical aspects.

The scientific research is in a constant intensive dynamics of search for new approaches which will enable more accurance, more efficient and more comprehensive analysis of the human movements. An attemot was made in the research to qualitatively assess the efficiency in the determination of the biomechanical status through two methodological approaches in the defining of the biomechanical status, which would provide a clearer understanding of the level of their optimality. The subject of research are the motor stereotypes of the sports game handball, and the goal of the research is to determine and to qualitatively compare the biomechanical status of the motor stereotypes from the sports game handball, that is, the biomechanical characteristics, the biomechanical intersimilarity, the complete biomechanical similarity, the adjacent biomechanical similarity, the force of the biomechanical connection and the biomechanical structure by applying two methodological approaches.

Method of Work

A sample of biomechanical variables that covers the elements of the sports game handball is an amount of 90, 5 of which are intended to define the goal, 12 are intended to define the initial and the final position, 48 are intended to define the functional-anatomic characteristics, and 25 in order to define the mechanical characteristics.

The sample of the elements is analyzed with the method of qualitative binary analysis, and the results from the biomechanical characteristics are presented in a binary matrix with values 1 and 0, and in the ordinal matrix with values 1; 5 and 0, where the motor stereotypes of the sports game are presented horizontally, and the biomechanical variables are presented vertically (Trajkovski, 2014). The obtained data from the qualitative biomechanical analysis of the motor stereotypes in both approaches are processed with several mathematical operations defined in the algorithm Heraclitus (Momirovic and associates, 1983) and ALPROBI (Tufekchievski and associates, 1988).

A binary, that is, an ordinal matrix is formed first, with basic biomechanical characteristics of the movements. A symmetric matrix of normalized measures of biomechanical similarity (intersimilarity) is obtained from this matrix, and then the other parameters of the biomechanical status of the model are determined. *The first parameter* so called coefficient of full biomechanical similarity (CFBS) indicates the level of homogenity of the elements and it is normalized from 0 to 1. *The second parameter* so called coefficient of adjacent biomechanical similarity (CABS) indicated the level of optimaility of the learning order of the elements. *The third parameter* so called coefficient of force of biomechanical connection (CFBC) indicates connection of one motor stereotype with all the others, and it determines the primary importance of specific motor stereotypes in the entire system, that is, the central role of motor stereotypes in the learning process.

The biomechanical structure of the motor stereotypes of handball is determined with a factorization of the matrix of intersimilarity by applying the method of main compoents, where the Kaiser Guttman criterion for retention of significant main components is used (Aceski, 2009; Aceski, 2013; Jolliffe, 2002; Klincharov, 1997; Klincharov, 2001; Tufekchievski, et al. 2012; Tufekchievski, 1988). In order to compare the structure of the extracted main components between the binary and the ordinal approach, the Tucker's congruence coefficient was calculated (Lorenzo-Seva & Berge, 2006).

The data processing is performed with the statistical program package SPSS 16.

Results

On the basis of the obtained results from the conducted qualitative biomechanical analysis one can conclude that there is no difference between the two approaches, that is, 867 biomechanical characterisitcs are present, which have a value of 0. The total number of biomechanical characteristics with value 1 in the binary approach are 303, and in the ordinal approach there are 70. In the ordinal approach, the number of values that are less important and have a coefficient .5 is 233.

Table 1 and Table 2 present the normed measures of biomechanical similarity between the handball elements, the biomechanical similarity of the entire system of elements, the coefficient of adjacent biomechanical similarity in the binary, that is, the ordinal approach. The obtained coefficients of biomechanical similarity in the binary approach are within a range of 0 to .931, while in the ordinal approach they are within a range of 0 to .968. The coefficient of full similarity (CFBS) in the binary approach is .309, and in the ordinal approach it is .310. The coefficient of adjacent biomechanical similarity (CABS) in the binary approach is .547, while in the ordinal approach it is .562.

The coefficients of force of biomechanical connection (CFBC) of a motor stereotype with the others presented in Table 3 are within the limits from .149 to .403 in the binary approach and from .132 to .428 in the ordinal approach.

The unrotated factorial matrix is rotated in an ortogonal solution with Varimax rotation and a skew solution Direct Oblimin in both approaches (Table 4 and Table 5), whereby projects of the vectors of the motor stereotypes on the determined main components are defined, that is, groups of elements with related structure are defined, which have mutually expressed measures of biomechanical similarity. On the basis of the existence of important main components, 3 (three) groups of elements have been extracted in the two approaches.

The congruence coefficients in the ortogonal solution (Table 6) show very high values, while in the skew solution (Table 7), they are within the limits of acceptable to very high values.

Table 1. Normalized measures of biomechanical similarity between the elements of the sports game handball, coefficient of biomechanical similarity of the entire system of elements, and a coefficient of adjacent biomechanical similarity of all elements in the binary data.

No.	Motor stereotypes c	1 SMT	2 JSD	3 JSH	4 BP	5 BR	6 BL	7 COS	8 PS	9 ES	10 SE	11 RLBHL	12 RMCHL	13 RBBB
1	SMT	1												
2	JSD	.519	1											
3	JSH	.488	**.931***	1										
4	BP	.723	.371	.409	1									
5	BR	.453	.170	.213	.551	1								
6	BL	.483	.298	.298	.641	.429	1							
7	COS	.638	.417	.417	.490	.281	.491	1						
8	PS	.600	.576	.509	.402	.209	.390	.745	1					
9	ES	.450	.814	.746	.292	.168	.293	.522	.667	1				
10	SE	.140	.277	.277	.043	.147	.057	.131	.156	.272	1			
11	RLBHL	.046	.052	.052	.111	.191	.074	.113	.101	.101	.118	1		
12	RMCHL	.194	.044	.044	.236	.270	.252	.144	.129	.043	.101	.719	1	
13	RBBB	.099	**.000***	**.000***	.181	.208	.161	.062	.055	**.000***	.064	.836	.711	1

CFBS = 0.309

CABS = 0.547

Table 2. Normalized measures of biomechanical similarity between the elements of the sports game handball, coefficient of biomechanical similarity of the entire system of elements and a coefficient of adjacent biomechanical similarity of all elements in the ordinal data

No.		1	2	3	4	5	6	7	8	9	10	11	12	13
	Motor stereotypes	SMT	JSD	JSH	BP	BR	BL	COS	PS	ES	SE	RLBHL	RMCHL	RBBB
1	SMT	1												
2	JSD	.685	1											
3	JSH	.668	**.968***	1										
4	BP	.761	.523	.542	1									
5	BR	.306	.144	.168	.346	1								
6	BL	.545	.416	.416	.646	.291	1							
7	COS	.645	.490	.490	.494	.175	.535	1						
8	PS	.642	.605	.568	.462	.136	.472	.780	1					
9	ES	.543	.738	.700	.386	.113	.430	.667	.775	1				
10	SE	.102	.168	.168	.029	.107	.036	.087	.109	.197	1			
11	RLBHL	.029	.027	.027	.065	.121	.041	.066	.092	.064	.201	1		
12	RMCHL	.148	.093	.093	.139	.173	.141	.085	.079	.027	.173	.701	1	
13	RBBB	.059	**.000***	**.000***	.100	.124	.084	.034	.063	.033	.206	.930	.717	1

CFBS = 0.310

CABS = 0.562

Table 3. The coefficient of force of biomechanical connection (CFBC) of one motor stereotype with the others by applying binary and ordinal data from the biomechanical analysis of the sports game handball

Motor stereotypes	1	2	3	4	5	6	7	8	9	10	11	12	13
	SMT	JSD	JSH	BP	BR	BL	COS	PS	ES	SE	RLBHL	RMCHL	RBBB
CFBC – binary	**.403***	.372	.365	.371	.274	.322	.371	.378	.364	**.149***	.209	.241	.198
CFBC – ordinal	**.428***	.405	.401	.374	.184	.338	.379	.399	.389	**.132***	.197	.214	.196

Table 4. Projections of the elements on the defined components (C), communalities (h²), size of explained part of total variance of each component and coefficient of an explained part of total variance (Total) of each component (% of Variance) in the two approaches VARIMAX

No.	Motor stereotypes	VARIMAX							
		Binary				Ordinal			
		C1	C2	C3	h²	C1	C2	C3	h²
1	SMT	.382	**.768**	.008	.736	**.696**	.026	.537	774
2	JSD	**.902**	.232	-.035	**.868***	**.887**	.018	.116	.801
3	JSH	**.858**	.251	-.032	.800	**.863**	.017	.143	.766
4	BP	.144	**.866**	.085	**.778***	.480	.035	**.725**	**.757***
5	BR	-.012	**.678**	.212	.505	.009	.138	**.687**	.491
6	BL	.108	**.778**	.083	.624	.438	.028	**.661**	.630
7	COS	.449	**.633**	.008	.603	**.720**	.025	.321	.622
8	PS	**.636**	.482	.004	.637	**.819**	.055	.188	.710
9	ES	**.878**	.220	-.013	.820	**.895**	.039	.018	**.802***
10	SE	**.464**	-.087	.170	.252	.293	**.350**	-.258	.275
11	RLBHL	.104	.012	**.933**	**.881***	.009	**.946**	.031	.895
12	RMCHL	.013	.218	**.856**	.780	.020	**.840**	.176	.737
13	RBBB	-.012	.103	**.921**	.858	-.024	**.948**	.083	**.906***
	Total	5.061	2.544	1.538	/	5.332	2.612	1.220	/
	% of Variance	38.930	19.568	11.833	/	41.017	20.093	9.388	/

Table 5. Projections of the elements on the defined components (C), communalities (h²) - DIRECT OBLIMIN

No.	Motor stereotypes	DIRECT OBLIMIN							
		Binary				Ordinal			
		C1	C2	C3	h²	C1	C2	C3	h²
1	SMT	.266	-.050	**-.742**	.736	**.694**	-.003	.409	.774
2	JSD	**.898**	-.076	-.100	**.868***	**.909**	-.042	-.050	.801
3	JSH	**.850**	-.072	-.126	.800	**.884**	-.040	-.019	.766
4	BP	.001	.029	**-.878**	**.778***	.463	.029	**.638**	**.757***
5	BR	-.130	.172	**-.699**	.505	-.029	.166	**.686**	.491
6	BL	-.022	.033	**-.792**	.624	.423	.023	**.583**	.630
7	COS	.359	-.043	**-.589**	.603	**.728**	-.014	.187	.622
8	PS	**.579**	-.044	-.401	.637	**.834**	.003	.034	.710
9	ES	**.876**	-.052	-.090	.820	**.920**	-.025	-.151	**.802***
10	SE	**.496**	.162	.174	.252	.289	**.320**	(-.326)*	.275
11	RLBHL	.099	**.934**	.055	**.881***	-.056	**.952**	-.001	.895
12	RMCHL	-.031	**.847**	-.179	.780	-.044	**.851**	.147	.737
13	RBBB	-.037	**.920**	-.059	.858	-.093	**.959**	.058	**.906***

Table 6. Congruence coefficients between the two approaches for the isolated componetns with the ortogonal solution

C1-C1	C2-C3	C3-C2
0.951	0.958	0.989

Table 7. Congruence coefficients between the two approaches for the isolated componetns with the skew solution

C1-C1	C2-C2	C3-C3
0.905	0.994	0.91

Discussion

From the analysis of the obtained results presented in the matrix of intersimilarity (Table 1 and Table 2), one can conclude that in both approaches, the greatest similarity is present between jump shot in distance (JSD) and a jump shot in the height (JSH), in the binary approach with a coefficient .931, and in the orginal approach with a coefficient .968.

The coefficient of full biomechanical similarity (CFBS) is .309 in the binary approach, which indicates relatively low biomechanical homogenity in regard to the defined biomechanical characteristics of the dynamic stereotypes. In the ordinal approach, this coefficient is .310, whereby essentially there is almost no difference in regard to the biomechanical homogenity in these two approaches. The coefficient of adjacent biomechanical similarity (CABS) in the binary approach is .547, that is, .562 in the ordinal approach. The greatest force of biomechanical connection (CFBC) in both approaches is present in the element 7-meter throw (SMT) with a coefficient .403, that is, .428, and this would mean that it has the greatest similarity with all the others in regard to the defined biomechnical characteristics. In both approaches, the lowest force of biomechanical connection, and accordingly, the least similarity with the others is present in the element spreadeagle with a coefficient .149, that is, .132.

In regard to the factor structure, the vectors of motor stereotypes jump shot in distance (JSD), jump shot in height (JSH), picker shot (PS), drift (eret) shot (ES), spreadeagle (SE) have important projections on the *first component* in the *binary approach*.

On the basis of the biomechanical classification (Tufekchievski, 2003; Tufekchievski and Aceski, 2009), the above mentioned stereotypes are: jump shot in distance – acyclical movement with generalized asymmetrical anatomical structure, jump shot in height - generalized asymmetrical anatomical structure, picker shot-acyclical movement with generalized asymmetrical anatomical structure, drift (eret) shot-acyclical movement with generalized asymmetrical anatomical structure, spreadeagle (SE)-acyclical movement with a generalized symmetrical anatomic structure. This group of motor stereotypes can be defined as a group of shots, excluding the element spreadeagle. The element jump shot in distance has the highest communality on the first component, h^2=.868.

The vectors of the motor stereotypes 7-meter throw (SMT), jump shot in distance (JSD), jump shot in height (JSH), cross-over step (COS), picker shot (PS), drift (eret) shot (ES) have the greatest important projections on the *first component in the ordinal approach*.

On the basis of the biomechanical classification, these motor stereotypes are: 7-meter throw-acyclical movement with asymmetrical anatomic structure of the hands, jump shot in distance-acyclical movement with generalized asymmetrical anatomic structure, jump shot in the height – acyclical movement with generalized asymmetrical anatomic structure, picker shot- acyclical movement with generalized asymmetrical anatomic structure, drift (eret) shot- acyclical movement with generalized asymmetrical anatomic structure. This group of motor stereotypes can be defined as a group of shots. The element drift (eret) shot has the highest communality on the first component, h^2=.802.

The motor stereotypes 7-meter throw (SMT), ball pass (BP), ball reception (BR), ball lead (BL), cross-over step (COS) have the most important projections on the *second compoent (C2)* in *the binary approach.*

According to the biomechanical classification, these motor stereotypes include: 7-meter throw-acyclical movement with asymmetrical anatomic structure of the hands, ball pass-acyclical movement with generalized asymmetrical anatomic structure, ball reception-acyclical movement with symmetrical anatomic structure, ball lead-cyclical movement with generalized asymmetrical anatomic structure, cross-over step-acyclical movement with generalized asymmetrical anatomic structure. This group of motor stereotypes can be defined as a group of ball kick, pass, reception and lead. The element ball pass (BP) has the highest communality on the second component, h^2=.778.

The motor stereotypes spreadeagle (SE), rejection of low balls with hand and leg (RLBHL), rejection of medium balls with hand and leg (RMCHL), rejection of balls bounced from a base (RBBB), have the most important projections on the *second component (C2)* in the *ordinal approach.*

From the biomechanical classification these motor stereotypes are: spreadeagle-acyclical movement with symmetrical anatomic structure generalized, rejection of low balls with hand and leg-acyclical movement with asymmetrical anatomic structure of the hands and the legs, rejection of medium balls with hand and leg-acyclical movement with asymmetrical anatomic structure of the hands and the legs, rejection of balls bounced from a base - acyclical movement with asymmetrical anatomic structure. This group of motor stereotypes can be defined as a group of ball defenses. The element rejection of balls bounced from a base has the highest communality on the second component, h^2=.906.

The motor stereotypes rejection of low balls with hand and leg (RLBHL), rejection of medium balls with hand and leg (RMCHL), and rejection of balls bounced from a base (RBBB) have the most important projections on the *third component* (C3) in the binary approach. From the biomechanical classification, these motor stereotypes are: rejection of low balls with hand and leg- acyclical movement with asymmetrical anatomic structure of the hands and the legs, rejection of medium balls with hand and leg- acyclical movement with asymmetrical anatomic structure of the hands and the legs, rejection of balls bounced from a base- acyclical movement with asymmetrical anatomic structure. This group of motor stereotypes can be defined as a group of ball defenses. The element rejection of low balls with hand and leg (RLBHL) has highest communality on the third component, h^2=.881.

The motor stereotypes ball pass (BP), ball reception (BR), ball lead (BL) have the most important projections on the *third component (C3)*. From the biomechanical classification, these motor stereotypes are: ball pass-acyclical movement with generalized asymmetrical anatomic structure, ball reception-acyclical movement with symmetrical anatomic structure, ball lead-cyclical movement with generalized asymmetrical anatomic structure. This group of motor stereotypes can be defined as a group of ball pass, reception and lead. The element ball pass has the highest communality on the third component, h^2=.757.

The biomechanical characteristics of the handball elements have similar values in the two approaches, which is confirmed through the coefficients of biomechanical similarity, the coefficient of complete biomechanical similarity and the coefficient of adjacent biomechanical similarity.

The values of the congruence coefficients indicate that in the skew transformation, with the exception of the first and the third compoenent which are within the limits from 0.85 to 0.94, the other components have values higher than 0.95 and practically they can be treated as same (Lorenzo-Seva & Berge, 2006). In regard to the interoperability, one can conclude that the ortogonal and the skew solution in the ordinal approach give a clearer biomechanical structure in regard to the definition of the groups of elements and their interpretability.

Similar results are obtained in other researches that refer to the determination of the biomechanical status of the motor stereotypes represented in the lectures in physical and health education VI-IX grade (Argiroski, 2015), as well as the determination of the biomechanical status of the motor stereotypes of basketball, handball, volleyball and football (Trajkovski, 2014).

Conclusion

The human movement has an exceptionally complex form of manifestation, which is perceived through the infinite number of movements a person can make. The qualitative definition of the biomechanical status is only one segment of the multitude of approaches that are being used in the analysis of the human movement. Its determination is not a simple and quick process, and it does not imply only a detection of the biomechanical characteristics, but also a selection of an appropriate methodology which will provide the most accurate and the most efficient way to obtain results through which the biomechanical status will be interpreted. An attempt is made in the research to determine and compare the biomechanical status of the motor stereotypes of handball through different approaches. The obtained results indicate similar interoperability in both approaches, however in regard to the biomechanical structure, the orthogonal and skew solution give a clearer structure and interpretability in the original approach.

Still, many such researches are required in the future, which would move in the direction of determination of the biomechanical status in other motor stereotypes as well, which will also include other approaches, in the qualitative biomechanical analysis, as well as in the methodology, which would enable more reliable generalization for the justification of its application.

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