STRUCTURAL ANALYSIS* OF THE VOLLEYBALL GAME ELEMENTS BASED ON CERTAIN ANTHROPOLOGICAL FEATURES

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Orginal scientific paper
UDK: 796.325:572.5
Received: October 15, 1997
Accepted: May 8, 1998

Abstract

The importance of the morphological features and motor, functional and specific cognitive abilities as regards successful performance of six elements of the volleyball game (SERVE, SERVE RECEIVING, SETTING, SPIKE, BLOCK and COURT DEFENSE) was assessed by 9 volleyball experts. Three groups were established by using hierarchical cluster analysis according to the playing distance from the net. Block and spike elements belong to group A hence this group is named 'playing above the net'; the serve receiving, setting and defense elements make group B, so it is named 'playing in one's half of the court'; the serve makes group C. Based on the arithmetic means of the judges' rating it might be concluded that group A is characterized by a very high level of explosive power, longitudinal dimensionality of the skeleton and coordination, and in general a higher level of power and endurance than in the other groups. Group B is characterized by a very high level of accuracy and coordination. The characteristic of this group is a very high level of anticipation, speed of reaction, agility, a highly developed sense of distance and flexibility. Group C is characterized by a very high level of accuracy and a highly developed sense of distance and explosive power though not so high as in the other groups.

Key words: volleyball experts, anthropological features, volleyball game elements, cluster analysis

Zusammenfassung:

DIE STRUKTURANALYSE DER SPIELELEMENTE IM VOLLEYBALL AUFGRUND EINIGER ANTROPOLOGISCHEN EIGENSCHAFTEN

Die Bedeutung der morphologischen Eigenschaften sowie der motorischen, funktionellen und spezifischen kognitiven Fähigkeiten für die erfolgreiche Ausführung von 6 Segmenten, bzw. Spielelementen im Volleyball (Aufgabe, Aufgabenannahme, Stellen, Schmetterschlag, Block und Feldverteidigung) wurden von 9 Volleyballexperten bewertet. Mittels der hierarchischen Clusteranalyse der Spielelemente wurden drei Gruppen ermittelt, die durch den Abstand des Ausführungsplatzes vom Netz definiert wurden. Die Gruppe A umfaßt den Block und den Schmetterschlag und wird "Spielen oberhalb des Netzes" gennant; die Gruppe B schließt den Aufgabenannahme, das Stellen und das Verteidigungsspiel ein und wird "Spielen im eigenen Feld" gennant und in der Gruppe C ist Aufgabe. Aufgrund der arithmetischen Mitte der Schiedsrichtersnoten für die einzelnen Gruppen, kann beschlossen werden, daß die Gruppe A durch ein hohes Explosivkraftsgrad, die longitudinale Skelettdimension und Koordination sowie im allgemeinen durch mehr Kraft und Aushaltung als die anderen Gruppen charakterisiert ist. Ein hohes Niveau der Präzision und Koordination kennzeichnet die Gruppe B, für die auch ein sehr hohes Antizipationsgrad sowie die Reaktionsschnelligkeit, Gewandtheit, das Spielraumgefühl und die Flexibilität spezifisch sind. Die Eigenschaften der Gruppe C sind ein sehr hohes Präzisionsgrad und ein hohes (obwohl nicht so hoch als in den anderen Gruppen) Grad des Spielraumgefühls und der Explosivkraft.

Schlüsselwörter: Volleyballexperten, anthropologische Eigenschaften, Spielelemente im Volleyball, Clusteranalyse

Introduction

Volleyball is a game composed of six interrelated segments or technical and tactical elements: serve, setting, spike, block and court defense. The basic playing positions in modern volleyball are: off-setter (1), main serve receivers and attackers from position 4 (2),

*The research was carried out in the scientific project entitled: "Models for identification and control of hindering factors in kinesiological activities" (No. 034006), funded by the Ministry of Science and Technology of the Republic of Croatia.

middle blockers and first tempo attackers (2), and an attacker, diagonally positioned to the setter (1). Each position demands of a player to perform many tasks which change according to the situation in a game. Most of the tasks are common to all players (block, serve, defense, spike), whereas the others are characteristic of particular roles, such as the serve receiving (2-3 players) and setting (1-2 players). The dimensions of the anthropological status (motor, functional, cognitive, anthropological and conative characteristics and social status), necessary for playing volleyball are not equally relevant for the different segments of the volleyball game. The dimension structure of anthropological status indispensable for the quality execution of each segment of the game should be established. These facts should be remembered when selecting and training volleyball players.

Previous research

Most research in Croatia (Bosnar, 1983; Strahonja, 1983; Strahonja and Matković, 1983; Strahonja and Prot, 1983) dealt with the study of the relationship between the different dimensions of the anthropological status and the performance in the volleyball game. However, all the research was carried out using a sample of students studying at the Faculty of Physical Education who do not present a representative sample. Additionally, the specific features of particular elements of the game were not studied such as setting, spike, serve etc. The authors deem that the appropriate way of establishing the relevance of the individual dimensions of the anthropological status important for the execution of volleyball elements and for their structural analysis, is by obtaining data on the basis of subjective evaluation of volleyball experts.

The authors could not, unfortunately, find in the available literature, any article dealing with the evaluation of the individual dimensions of anthropological status relevant for the volleyball game as a whole or for any of its segments, done by volleyball coaches. Dizdar, Trninić and Bojan Matković (1995), however, carried out research of a sort relative to a basketball game. Five basketball coaches evaluated the relevance of motor and functional abilities and morphological features of players in different positions in a game.

The aim of research

The fundamental aims of the research are as follows:

1. to assess the relevance of certain fundamental motor and functional abilities, morphological features and specific cognitive capabilities necessary for the success of players in individual elements of a game: SERVE, SERVE RECEIVING, SETTING, SPIKE, BLOCK and DEFENSE by using expert advice of the competent volleyball experts;
2. to analyze the structure of the individual volleyball game segments on the basis of certain fundamental motor and functional abilities, morphological features and specific cognitive capabilities the relevance of which for each segment was assessed by selected volleyball experts.

Methods

Volleyball game fundamentals

The following volleyball game elements have been selected for the research:

* SERVE
* SERVE RECEIVING
* SETTING
* SPIKE
* BLOCK
* DEFENSE

Anthropological characteristics

The sample of anthropological characteristics contains: 12 motor characteristics, 3 functional characteristics, 4 morphological characteristics and 3 specific cognitive capabilities the relevance of which was assessed in particular game segments by volleyball experts on a scale from -5 to +5.

Motor abilities

1. AGILITY (AGL) - ability responsible for quick change of movement direction;
2. COORDINATION (KOR) - ability responsible for the efficiency of learning and execution of new and complex motor tasks and their successful application in a given situation;
3. ACCURACY (PRC) - ability responsible

for the efficiency of hitting the target (undefended part of the court) with a ball;

4. BALANCE (RAV) - ability responsible for keeping the body balanced;
5. FLEXIBILITY (FLK) - ability responsible for the execution of movements of maximal amplitude;
6. SPEED OF REACTION (BRR) - ability responsible for the quick response to hearing, visual and tactile stimuli;
7. SPEED OF A SINGLE MOVEMENT (BRP) - ability responsible for the execution of a single movement with maximal speed;
8. FREQUENCY OF A MOVEMENT (FRP) - ability responsible for the fast execution of repetitive movements of constant amplitudes;
9. EXPLOSIVE POWER (EKS) - ability responsible for the demonstration of maximal force in a unit of time;
10. MAXIMAL STRENGTH (APS) - ability responsible for demonstration of maximal strength of an attempted or executed movement;
11. REPETITIVE POWER (RPS) - ability responsible for continuous muscular work on the basis of alternate contraction and relaxation of individual muscles;
12. STATIC STRENGTH (STS) - ability responsible for the continuous isometric work.

Functional capacity

1. ANAEROBIC-ALACTACID CAPACITY (ANK) - maximal quantity of energy formed from ATP and CP;
2. ANAEROBIC-LACTACID CAPACITY (ALK) - maximal quantity of energy formed by anaerobic glycolysis;
3. AEROBIC CAPACITY (AEK) - maximal oxygen uptake or the maximal quantity of oxygen that the organism can use in a minute.

Latent dimensions of morphological features

1. LONGITUDINAL SKELETON DIMENSIONALITY (LDS) - latent dimension responsible for the longitudinal growth of bones;
2. TRANSVERSAL SKELETON DIMENSIONALITY (TDS) - latent dimension responsible for the circumferential bone growth;
3. VOLUME AND BODY MASS (VMT) - latent dimension responsible for circular dimension of the skeleton and body mass;
4. SUBCUTANEOUS FAT TISSUE (PMT) - latent dimension responsible for the quantity and distribution of subcutaneous fat tissue (ballast mass).

Specific cognitive capacity

1. PERIPHERAL SIGHT (PEV) - capacity responsible for the visual coverage of the court, including the ball, movements of one's team and the opposing players;
2. ANTICIPATION (ANT) - responsible for the anticipation of the opponent's or one's team actions;
3. PERCEPTION OF THE SPACE PERSPECTIVE (ODP) - responsible for a quick and accurate assessment of the ball direction because of the timely and accurate positioning in the court.

Methods of data collection

The data have been collected according to the subjective evaluations of 9 volleyball experts who have met the necessary criteria. The criteria were as follows:

* to be a graduate from the Faculty of Physical Education with a major in volleyball or a postgraduate at the postgraduate studies from the field of kinesiology at the Faculty of Physical Education, Zagreb; or

* to be a coach of high rank (A1 system of competitions).

The evaluation was conducted by specially designed questionnaires which enabled the rating of the relevance of the suggested anthropological features for individual elements of volleyball game. The rank list has a range of scores from -5 to +5 where:

- 5 means a very high negative impact on the success of the game;
- 4 means a high negative impact on the success of the game;
- 3 means a medium negative impact on the success of the game;

- 2 a slight negative impact on the success of the game;
- 1 means a negligible negative impact on the success of the game;

0 means no impact whatsoever on the success of the game;

+ 1 a very slight positive impact on the success of the game;
+ 2 a slight positive impact on the success of the game;
+ 3 a medium positive impact on the success of the game;
+ 4 a high positive impact on the success of the game;
+ 5 very high positive impact on the success of the game;

Data processing methods

In harmony with the primary aim of the research arithmetic means (AM) and standard deviations (SD) of the ratings of 9 volleyball experts on the relevance of anthropological features for individual segments of the game were computed.

Cronbach's α_c represents the measure of agreement of experts relative to the said anthropological features of volleyball players.

A matrix of the mean values of the ratings related to the anthropological features for each individual element of the volleyball game was used.

In harmony with the second aim hierarchical cluster analysis (Ward's method based on Euclidean distances, 1963) was used. The result is a tree diagram representation displaying the course of hierarchical formation of groups of elements of volleyball game and the level at which the element joined the group relative to its closeness. Thus, the hierarchical cluster analysis was used in order to obtain relatively homogenous groups of volleyball game elements which according to the experts' views require similar anthropological characteristics. Then the arithmetic means of the obtained groups were computed.

The data were processed by using the statistical package STATISTICA FOR WINDOWS version 5.0 at the Faculty of Physical Education, University of Zagreb.

Table 1: Arithmetic means (AM) and standard deviations (SD) of the assessment of the anthropological features regarding the relevance for the success of players in performance of individual segments of volleyball game

	AM-serve	SD-serve	AM-receiving	SD-receiving	AM-setting	SD-setting	AM-spike	SD-spike	AM-block	SD-block	AM-defense	SD-defense
LDS	2.67	1.41	1.44	1.67	2.00	2.29	4.78	0.44	4.78	0.44	1.00	2.12
TDS	0.22	2.28	0.22	2.17	-0.22	1.92	1.44	2.35	1.11	2.26	0.56	2.60
VOL	0.56	2.35	0.00	2.40	-0.33	2.29	1.11	2.67	0.78	2.44	-0.33	2.74
PMT	-1.78	1.79	-1.11	2.26	-2.44	2.07	-3.11	2.42	-2.22	3.35	-2.11	2.15
MSN	0.89	2.42	0.44	2.51	1.33	2.78	3.11	2.47	3.00	2.40	1.56	2.01
RSN	2.67	1.73	2.00	1.94	3.44	0.73	3.89	0.60	4.00	0.50	3.56	0.88
EKS	4.11	1.36	3.33	1.32	4.11	1.05	5.00	0.00	4.89	0.33	4.44	0.88
SSN	0.22	1.20	1.89	2.98	0.33	1.94	1.44	1.67	1.89	1.36	2.56	1.24
BRR	3.00	2.12	4.22	0.67	4.33	0.50	4.00	0.87	4.22	0.67	4.78	0.44
BPP	3.44	1.42	3.89	0.93	3.33	1.22	4.00	1.00	3.56	1.24	4.33	0.71
FRP	2.00	2.12	3.11	1.76	3.67	1.66	3.56	1.59	3.56	1.51	3.67	1.58
KOR	3.56	1.42	4.56	0.53	4.67	0.50	4.67	0.50	4.67	0.50	4.56	0.53
RAV	2.22	2.22	3.56	1.88	4.11	1.69	3.44	1.59	3.67	1.66	3.33	1.80
PRE	4.78	0.44	4.89	0.33	5.00	0.00	4.67	0.50	3.44	1.81	4.00	1.12
AGI	2.44	2.24	3.89	1.76	4.78	0.44	4.33	0.71	4.33	0.71	4.56	0.53
FLE	2.89	1.90	3.89	1.27	4.00	1.41	4.11	1.05	3.78	1.39	4.67	0.50
AAK	2.56	1.67	3.00	1.58	3.56	1.33	4.00	1.12	3.67	1.12	3.33	1.66
ALK	2.33	1.58	2.78	1.30	3.22	1.09	3.67	1.22	3.56	1.13	3.33	1.50
AEK	2.78	1.30	2.78	1.09	3.56	0.88	3.22	0.83	3.22	0.83	3.11	1.05
PEV	1.78	1.86	2.89	2.03	5.00	0.00	4.56	0.53	3.89	1.27	3.33	1.41
ANT	2.00	1.87	4.11	1.45	4.44	0.73	4.11	0.60	4.78	0.44	5.00	0.00
ODP	4.22	1.30	4.44	0.73	4.44	0.73	3.89	1.05	2.56	1.67	4.11	0.78
α	0.86		0.89		0.95		0.94		0.91		0.94	

Results and discussion

Descriptive parameters of assessing the relevance of anthropological features for individual segments of volleyball game

In Table 1 arithmetic means (AM) and standard deviations (SD) of the assessment of relevance of the said anthropological features of players' characteristics for each individual segment of volleyball game are displayed. The assessment was performed by 9 volleyball experts.

Cronbach's measure of reliability (α_c) ranges in the interval from 0.86 to 0.95 indicating a relatively high level of agreement among the judges regarding the relevance of the said anthropological features for the success of players in performing the fundamentals of the game. A slightly less agreement of the ratings of the judges (0.86 & 0.89) was achieved in the segments serve and *receiving the serve*. In the remaining segments (*setting, spike, block and defense*) a slightly higher consensus of the ratings of the relevance of the said anthropological features was achieved, with the coefficient of reliability ranging in the interval from 0.91 to 0.95.

The Table 1 shows that according to the assessment of volleyball experts some features of the anthropological status are essential for all technical fundamentals of volleyball. Variable *accuracy* exercises a very high or high positive (5,4 respectively) impact on all segments of the volleyball game except *block*. In the volleyball game the ball should be neither carried nor held by the fingers, but bearing in mind the small contact area of only the palms and forearms, the very high speed of the ball (over 100 km/h during a spike and jump serve) and the relatively small court, then the requirements for high accuracy of a movement become even harder to achieve.

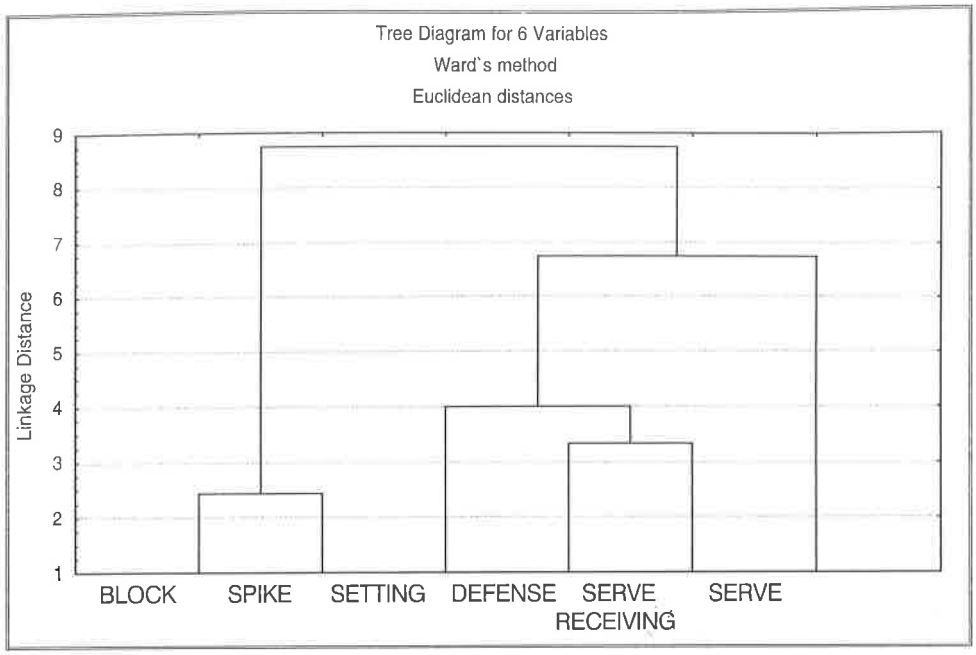
Due to the aforesaid and the technical complexity of the volleyball game elements, *coordination* exercises a very high positive impact in all the volleyball game elements, except the serve which is executed without the opponent's interference and with the ball hit by the server himself/herself thus decreasing the technical complexity and consequently the importance of coordination regarding successful execution of that element.

As we have already said, the speed of the spiked or served ball (with a jump serve) exceeds 100 km/h so the high positive impact of the variable *reaction speed* on the successful execution of defense, block and receiving the serve was to be expected. However, very often the reaction speed itself is not sufficient for the successful execution of an individual element, but it is necessary to anticipate the intention of the opponent spiker, server, blocker or setter. During spike and block it is important to execute these segments as high above the net as possible. Due to this fact the variables *longitudinal dimensionality of the skeleton and the explosive power* have, according to the opinion of the volleyball experts a very high positive impact on the execution of these elements. The Table 1 shows that the variable perception of the space perspective exercises a high positive impact on the successful execution of the serve, the serve receiving, setting and defense. When serving and setting accurate space perspective is crucial for regulating the power regarding the passing of the ball to one's own team or opponent player, and during the reception of serve and defense this ability is very important for the evaluation of the ball direction and the right positioning in the court, respectively. Due to the need of changes of direction, the variable *agility* exercises a very high positive impact on the success at setting, and high at spike, block and defense.

With regard to functional capacities, volleyball is, according to the experts' opinion a both anaerobic and aerobic sport with a slight predominance of anaerobic-alactacid capacity. from the energetic point of view the most demanding elements are *spike* and *block*.

The only variable with a negative impact on all the fundamentals of volleyball game is subcutaneous fat tissue. Any increase of weight on the account of fat and not muscles has a negative impact since it aggravates the movement of a player in the court and the impact is particularly negative as regards their ability to jump.

Figure 1: The tree diagram presentation of hierarchical grouping of volleyball game elements



Hierarchical cluster analysis of the volleybal game elements determined by anthropological features

Three homogenous groups have been obtained by using hierarchical cluster analysis in the space of the volleyball game elements. The diagrammatic presentation of hierarchical grouped elements of volleyball game based on the assessed anthropological features is displayed in Figure 1.

GROUP A:

BLOCK

SPIKE

GROUP B:

SETTING

DEFENSE

SERVE RECEIVING

GROUP C:

SERVE

The analysis of the dendrogram of the hierarchical volleyball elements grouping (Fig.1) shows the grouping of volleyball game elements on the basis of the distance from the net from which they are executed:

- Block and spike are game elements which are executed quite close to the net, moreover while blocking it is desirable to throw one's arms over the net as far as possible into the opponents half of the court. Spikes are usually executed from 50 cm to 2 m from the net.
- The elements setting the ball for the spike, defense of the court and receiving the serve are executed farther from the net. It is desirable to execute the setting at a distance of 50 cm to 1m from the net, however it is very often necessary to set the ball from deep in the court due to an inaccurately received or defended ball. Defense and the reception of serve are most frequently executed at the distance of 4 to 8m from the net.
- Serve is a segment of volleyball game executed from the most distant position from the net (9-17m), only during a jump serve the contact of the palm and the ball may be closer to the net (less than 9m).

On the basis of the obtained results it is possible to name the groups as follows:

- group A as *elements played above the net,*
- group B as *elements played in one's own half of the court,*
- group C as *serve*, which is characteristically executed behind the baseline.

Additionally, it is characteristic of group A to attempt to pass the ball into the opponent's half of the court in such a way that the opponent is unable to return it. It is characteristic of group B that the ball passed

by the opponent (*defense* and *serve receiving*) or one's own team player (setting) comes into one's own half of the court. The opponent is not in a position to intercept the execution of the action. For group C it is characteristic that the same player serves and throws the ball. This is the only element of volleyball game which is executed without the cooperation of one's own team players, and the opponent, the same as in group B, is not in a position to hinder the execution of the action.

The execution of certain groups of volleyball game elements from different distances from the net is also determined by the differences in the level of the players' anthropological status dimensions necessary for their successful execution.

Table 2: Arithmetic means of evaluations of anthropological features for the obtained groups - group A: elements played above the net; group B: elements played in one's own half of the court; group C: serve

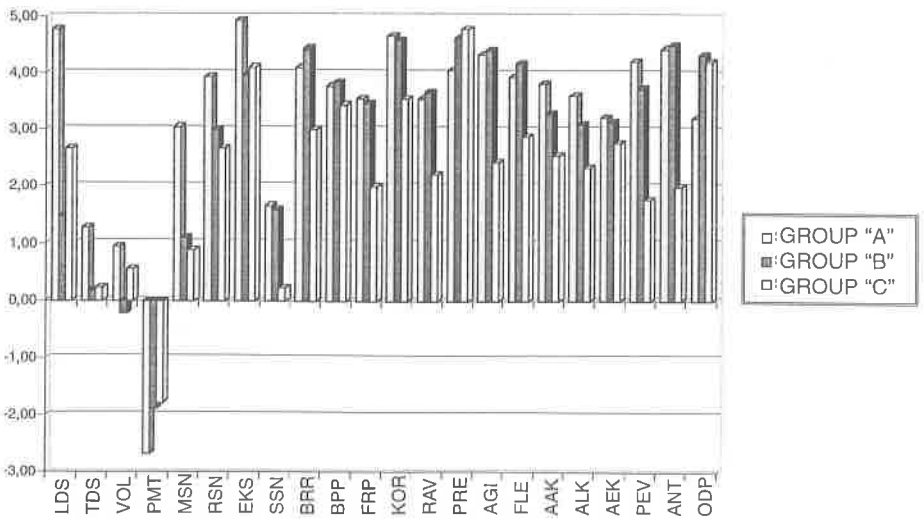
	Group "A"	Group "B"	Group "C
LDS	4.78	1.48	2.67
TDS	1.28	0.19	0.22
VOL	0.94	-0.22	0.56
PMT	-2.67	-1.89	-1.78
MSN	3.06	1.11	0.89
RSN	3.94	3.00	2.67
EKS	4.94	3.96	4.11
SSN	1.67	1.59	0.22
BRR	4.11	4.44	3.00
BPP	3.78	3.85	3.44
FRP	3.56	3.48	2.00
KOR	4.67	4.59	3.56
RAV	3.56	3.67	2.22
PRE	4.06	4.63	4.78
AGI	4.33	4.41	2.44
FLE	3.94	4.19	2.89
AAK	3.83	3.30	2.56
ALK	3.61	3.11	2.33
AEK	3.22	3.15	2.78
PEV	4.22	3.74	1.78
ANT	4.44	4.52	2.00
ODP	3.22	4.33	4.22

Table 2 shows that, according to the evaluations of volleyball experts, the positive impact of variables explosive power, longitudinal dimensionality of the skeleton, and coordination on the successful execution of the elements played above the net is very high (group A). This is logical since a higher reach above the net (height, jumping ability), speed, strength and both the accurate and versatile technique are necessary if one wants to spike and block successfully. At the same time in groups B and C these variables have a considerably lower positive impact, since these elements are not executed above the net. Table 2 also shows that elements in group A and in contrast to the elements in group B and C, demand a higher level of functional abilities (particularly alactacid and lactacid capacity) and the maximum of repetitive, explosive and static strength. The reason is a great number of maximally high jumps into block and for the spike per match (up to 200).

Group B, on the other hand, is characterized by a very high positive impact of the variables accuracy and coordination, however lower than in group C or A respectively.

The characteristic of this group is, according to the experts' views, a very high positive impact of the variable anticipation, and a high

Figure 2: Arithmetic means of evaluations of anthropological features of the obtained groups of volleyball segments



positive impact of the variables reaction speed, agility, a highly developed sense of distance and flexibility, because of high speeds and the difficulty in predicting the directions of the spiked and served balls.

The group C is characterized by a very high positive impact of the variable accuracy, whereas the impact of the other variables is much lower than in groups A and B. Consequently, according to the volleyball experts, the essential characteristic of a good server is accuracy, however the speed of the passed ball to the opponent is also important.

Conclusion

Nine volleyball experts evaluated the relevance of morphological features and motor, functional and specific cognitive abilities for the successful execution of the 6 fundamental elements of volleyball game (*serve, receiving the serve, setting, spike, block and defense*). Arithmetic means and standard deviations of evaluations of the relevance of certain anthropological features for each segment were computed. Cronbach's α is in the range of 0.86 to 0.95, indicating a relatively high degree of agreement among the judges. According to the criterion *execution distance from the net* three groups were obtained by using hierarchical cluster analysis. Group A consists of *block* and *spike*, and is consequently named *playing above the net*; group B consists of *the serve receiving, setting* and *defense*, and is appropriately named *playing in one's own half of the court*; and the group C *serve* for which it is characteristic that it is played outside one's own half of the court. Arithmetic means of the evaluations were computed for all groups. On the basis of the obtained results one might conclude that group A is characterized by a very high level of *explosive power, longitudinal dimensionality of the skeleton and coordination*, and in general a higher level of *strength* and *endurance* in comparison with the other groups. Group B is characterized by a very high level of accuracy and coordination, and the specific feature of this group is a very high level of anticipation, a high level of *reaction speed, agility, perception of the space perspective* and flexibility, necessary for the ball reception passed at very high speeds. Group C is characterized by a very high accuracy level, however, not as high as in the other two groups, next the level of the *perception of the space perspective* and *explosive power*. The only variable having a negative impact on all groups is the variable subcutaneous *fat tissue*. It would be useful to research in further studies the similarities and differences between male and female volleyball players according to the evaluations of volleyball experts.

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