SECTION – SPORT SCIENCES

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EVALUATION OF THE USEFULNESS OF CLUSTER ANALYSIS IN THE IDENTIFICATION OF MOTOR ABILITY STRUCTURE IN LEADING POLISH BADMINTON PLAYERS FROM DIFFERENT AGE CATEGORIES

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Authors' contribution:
A. Study design/planning
B. Data collection/entry
C. Data analysis/statistics
D. Data interpretation
E. Preparation of manuscript
F. Literature analysis/search
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Abstract

Study aim. The main aim of the study was to identify clusters of players with similar motor ability profiles from a group of badminton players at different calendar ages. In addition, the level of significant differences was determined in terms of the analyzed variables between the particular groups.

Study design. The study was conducted among a group of at 30 most highly classified badminton players (youngsters 11–13 years, younger juniors 14–16 and juniors 17–19 years). The scope of research included 19 variables from the group of condition and coordination abilities. Statistical analysis used the k-means method as well as one-way ANOVA variance analysis.

Results and conclusions. On the basis of cluster analysis, the first cluster was assigned 6 juniors and 2 younger juniors (cluster 1 – juniors), the second: 7 younger juniors, 5 juniors and 1 youngster (cluster 2 – younger juniors), the third: 8 youngsters and 1 younger junior (cluster 3 – youngsters). The k-means method made it possible to identify separate clusters with similar motor capacity in the group of badminton players. On this basis, evaluation of the cluster content was conducted, as well as the affiliation of players from different calendar age categories. In the master model, a very important role is played by anaerobic and aerobic capacity as well as motor skill coordination with a higher degree of organization.

Introduction

Sport performed by children and youth is quite specific. This is reflected not only in the methodology used in the exercises, but is primarily concerned with the specific objectives of action. All proceedings carried out in successive phases of player development should therefore, be procedurally specified and create a closed cycle of high-class athlete development. It should be focused on achieving a championship level of sports in the future [1–4].

For the purpose of sports practice, it is necessary to isolate and identify the most important variables determining the efficiency of actions. However, the precise description and diagnosis of complex variables that determine success in sport it is extremely difficult. Thus, all disciplines of sports are trying to construct the so-called "Masters models" [5]. The basic criterion for the development of this type of model is always taking leading variables in a given discipline of sports into account, which at the same time are strongly genetically determined [6–8].

Analysis of literature indicates that such attempts have been undertaken to identify the characteristics of the leading features in badminton. Among these variables, typically emphasized are: somatic parameters [9, 10], maximum non-lactic-acidic anaerobic power and aerobic capacity, absolute force, speed abilities [11–13]. An important place in this model is also occupied by coordination motor abilities [14, 15]. Therefore, badminton, due to its high complexity of movements and the domination of open movement structures during the game, belongs to the third category of most difficult sports [16]. In the proposed model, psychological characteristics of players should also be taken into account [17, 18].

Starting each consecutive stage of training, one should place different and increasing demands on him/herself. This is determined by the specifics of the game, the level of a player's disposal, his/her developmental age and stage goals. In Poland, organization of training based on these assumptions closes in three specific calendar age categories, namely: youngsters (age 11–13 years), younger juniors (age 14–16 years) and juniors (age 17–19 years). This division seems to be debatable, since it does not take into account the inter-individual variability in terms of advancement in the development of physical, motor and mental health of the training players. The sizes of the leading characteristics, typical for different age groups, should be the starting point in the recruitment and selection process as well as planning and implementation of training in each age group [19–22].

The main objective of this study is to answer the following research questions:

1. Does the k-means method allow to identify three distinct clusters of players with similar motor skill profiles from the group of badminton players at different calendar ages?
2. What is the internal structure of the motor skill ability of the young badminton players in the particular clusters?
3. Are there any statistically significant differences between the profiles of motor efficiency indicators characterizing the particular groups?

Study design

The study was conducted starting at the end of April and the beginning of May 2009. This was the final stage of preparation for the key tournaments organized in Poland in three calendar age groups, namely: youngsters (11–13 years old), younger juniors (14–16 years) and juniors (17–19 years). 30 players were qualified for the study – the 10 best classified from each of the above categories. The criterion for selection was the current PZBat ranking list.

The general characterization of the players selected for the study included determining their calendar age, competing experience, body height, body mass and percentage of body fat. Arithmetic means of these values are given in Table 1.

Scope of research

Measurements of morphological features were made using the Martin technique:

a) body height – measured in upright standing position (b-v),
b) body mass – measured in training outfit, without shoes, determined on the basis of results using the Tanita TBF-551 scale,
c) fat percentage – determined using the Tanita TBF-551 scale.

In accordance with the principles of the study, motor effects (related to abilities associated with energy and information) were taken into account in the research. In the selection of samples it was assumed that the tests should measure the comprehensive motor ability of a badminton player. In this context, seven tests for motor ability were conducted, namely:

Table 1. Numerical characteristics of calendar age and experience as well as basic somatic features of the studied badminton players.

Variable	Unit of measurement	Juniors (N = 10)	Younger juniors (N = 10)	Youngsters (N = 10)
		Mean ± SD	Mean ± SD	Mean ± SD
Calendar age	years	17.40 ± 0.52	15.30 ± 0.82	12.60 ± 0.84
Experience	years	7.90 ± 1.29	6.30 ± 1.95	4.05 ± 1.57
Body height	cm	179.78 ± 4.93	174.36 ± 4.69	152.54 ± 11.62
Body mass	kg	73.55 ± 6.03	66.91 ± 6.60	43.30 ± 11.09
% fat	%	15.13 ± 2.50	14.35 ± 4.35	17.03 ± 5.73

a) dynamometric measurement of the static force of the upper limb,
b) differentiation of muscle strength (determined – using a hand dynamometer – as the difference between the maximum strength and ½ of strength measurements) – differentiation of kinaesthetic force parameters;
c) throwing a 2 kg-medicine ball with both hands backwards, from over the head in open stance – explosive strength of upper limbs,
d) a zigzag run over an envelope-shaped track (analysed was the total time of three repetitions without interruption) – the ability to mobilise the muscles quickly,
e) sit-ups, according to the ICSPFT instructions [23] – the dynamic force of the abdomen,
f) standing long jump – explosive strength of the lower limbs [24],
g) endurance shuttle run – "Beep Test" [24] (the distance covered was measured in m) – cardio-respiratory endurance,
h) VO_2max value – calculated with "Beep Test".

Coordination motor abilities were also subjected to analysis and tested using a specially developed set of computer-based tests [25]:
a) the kinaesthetic differentiation – time parameters,
b) the frequency of hand movements,
c) the average visual response time,
d) the average auditory reaction time,
e) the average response time for a choice of visual/auditory stimulus,
f) rhythmisation of movements,
g) coupling of moves – maze to the left (number of errors and time were analysed),
h) hand-eye coordination – any mode,
i) the spatial orientation – any mode,
j) the spatial orientation – forced mode (the sum of correct responses was analysed).

Statistical methods of working on the material

The method of k-means was used to identify players with similar profiles of motor abilities; it belongs to methods of ordering and classifying objects (taxonomy). The method allows one to create k clusters differing from one another to as high a degree as possible. Computationally, this method may be regarded as the inversion of variance analysis [26]. In the present study, statistical analysis was performed for k = 3. Identification of groups was carried out with the number of players in different age groups taken into consideration.

In variance analysis, the F-test or Kruskal-Wallis H test were used depending on the distribution and homogeneity of variance. To study the differences between the averages of the individual groups, Tukey's HSD test (for uneven numbers) and Mann-Whitney U test were used. In the Mann-Whitney U test the Bonferroni correction was used, which involves dividing the significance $p \leq 005$ by the number of comparisons made. The Shapiro-Wilk test was used to test the normality of the distributions. Homogeneity of variance was tested with Levene's test [27].

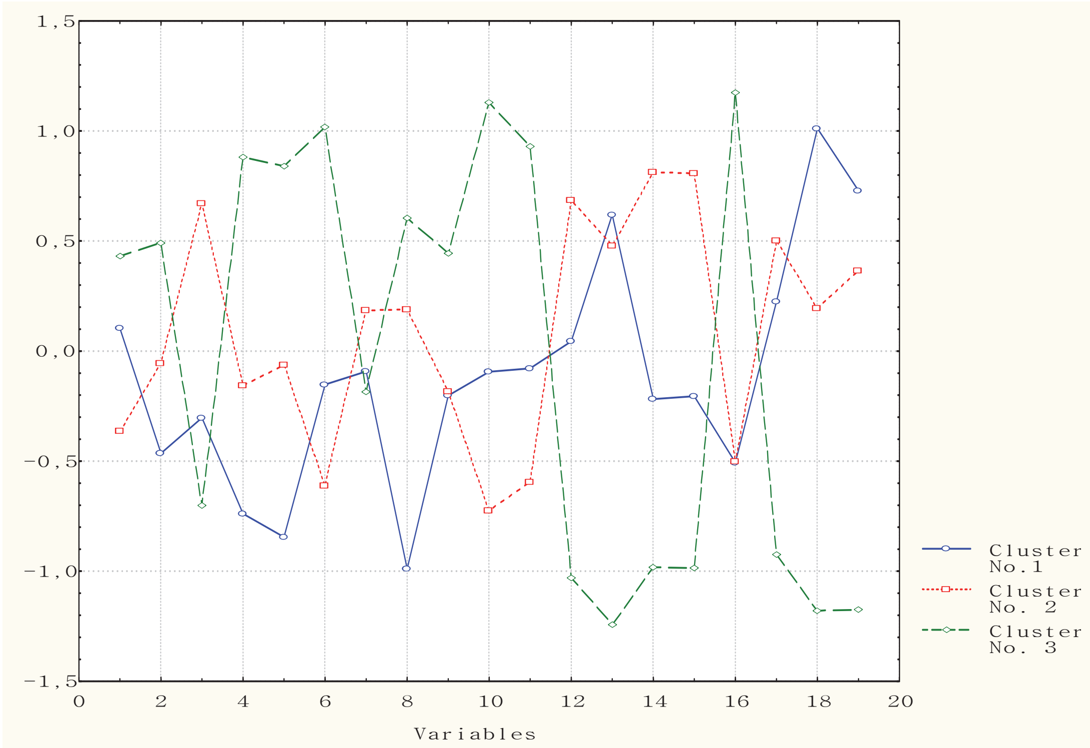
The STATISTICA 10.0 PL Suite was used to work out the results of the study.

Results

Thanks to the statistical procedure used it was possible to extract, from a group of 30 highest ranked players (differing from one another in terms of age), three fractions of badminton players similar to one another in the structure of the motor potential (conventionally called "motor age"). Based on cluster analysis (k = 3), 6 juniors and 2 younger juniors were assigned to "1st cluster – juniors"; 7 younger juniors, 5 juniors and 1 youngsters were assigned to "2nd cluster – younger juniors"; and 8 youngsters and 1 younger junior were assigned to "3rd cluster – youngsters". The identification of groups was carried out with the number of players in different age groups taken into account. The first cluster was dominated in number by juniors, with the second and third clusters being dominated by younger juniors and youngsters, respectively. Figure 1 illustrates a graph of the standardised means of each cluster.

By far the largest inter-cluster variability (over 2 SD) was observed for the maximal anaerobic power of the upper limbs. Variability oscillating around 1.8 SD was noted for running endurance, eye-hand coordination, aerobic capacity, spatial orientation (in forced mode) and the response time to auditory stimulus. Inter-cluster variation of 1.6 SD was observed during the following tests: response time to visual stimulus, response time with selection, spatial orientation (any mode) and the power of the lower limbs measured with a zigzag run over an envelope-shaped track.

On the other hand, an analysis of diversity within each cluster reveals that in the 3rd cluster (youngsters), the variation between the variables introduced into the model is about 1.22 SD. A slightly smaller diversity of the participation of individual variables in shaping the motor model is observed in younger juniors; for the totality of variation in this cluster of badminton players is 1.08 SD. Yet another structure of the tested model is observed in the cluster of juniors. The diversity of individual variables forming a module is the biggest here: it amounts to 1.49 SD.



Note: variable designation as in Table 2.

Figure 1. Standarized arithmetical means of motor ability in three seperate clusters

In addition, by analysing the differences between particular motor performance indices, statistically significant differences were found in 15 out of 19 cases (Table 2).

By comparing the arrangement of means it can be concluded that Tukey's procedure allowed to determine statistically significant differences between the first and third clusters, and between the second and third clusters. Such regularities were obtained for the following variables: average visual response time, the average reaction time with selection; eye-hand coordination; spatial orientation in any mode; spatial orientation in forced mode; standing long jump; VO_2max; run over an envelope-shaped track; a backward medicine ball throw; static force. On the basis of multiple comparisons the following homogeneous groups were created:

- juniors and younger juniors,
- youngsters.

Higher results were characteristic for the first and second cluster, in relation to the values of the variables in the third cluster.

In terms of frequency of movements and the strength of the abdominal muscles the following homogeneous groups were formed on the basis of multiple comparisons:

- younger juniors,
- juniors and youngsters.

Taking into account the means in each group of players it was noted that younger juniors obtained better results than juniors and youngsters.

In the case of coupling movements (the maze to the left test – time trial), Tukey's procedure allowed for the creation of the following homogeneous groups:

- juniors,
- younger juniors and youngsters.

Comparing the means enabled the observation that the best results of this test were achieved by juniors, and worse by younger juniors and youngsters.

In terms of mean auditory response time, Tukey's procedure allowed for the creation of the following homogeneous groups:

- juniors,
- younger juniors,
- youngsters.

Thus, it can be concluded that the best results occurred in the juniors group, and the worst in the youngster group.

As to the shuttle run time, following homogeneous groups were created:

- younger juniors,
- juniors,
- youngsters.

Table 2. Mean values of motor ability indices in clusters of players of similar motor potential profiles

No.	Variable	Unit of measurement	1st Cluster – Juniors (N = 8)	2nd Cluster –Younger juniors (N = 13)	3rd Cluster – Youngsters (N = 9)
			Mean ± SD (1)	Mean ± SD (2)	Mean ± SD (3)
1	Kinaesthetic differentiating, force parameters	% error	20.77 ± 11.57	14.50 ± 11.44	24.03 ± 14.24
2	Kinaesthetic differentiating, time parameters	pixel	24.29 ± 8.64	32.54 ± 15.85	41.60 ± 27.51
3	Movement frequency **	n- number	38.71 ± 5.59 (2*)	48.54 ± 5.58 (3**)	38.80 ± 8.88
4	Average time of visual response **	ms	219.00 ± 16.24 (3**)	234.77 ± 14.02 (3**)	257.20 ± 28.01
5	Average time of auditory response **	ms	183.14 ± 11.04 (2*, 3**)	201.00 ± 16.44 (3*)	217.10 ± 15.16
6	Average time of reaction w/ selection**	ms	394.57 ± 24.88 (3**)	366.38 ± 47.53 (3**)	487.40 ± 77.47
7	Rhythmisation	ms	127.86 ± 93.61	156.77 ± 77.40	135.90 ± 57.19
8	Movement coupling, maze to the left **	s	43.43 ± 5.29 (2*, 3**)	52.15 ± 7.21	53.90 ± 6.74
9	Movement coupling, maze to the left	n- errors	12.86 ± 7.73	13.15 ± 7.66	18.20 ± 10.49
10	Eye-hand coordination**	s	38.86 ± 2.34 (3**)	35.92 ± 1.55 (3**)	46.20 ± 5.41
11	Spatial orientation, in any mode**	s	57.43 ± 7.83 (3##)	53.85 ± 6.97 (3##)	78.20 ± 14.88
12	Spatial orientation, forced mode**	n- correct	37.86 ± 6.94 (3##)	43.08 ± 4.75 (3##)	20.00 ± 11.55
13	Standing long jump **	cm	238.86 ± 16.30 (3**)	233.46 ± 11.37 (3**)	190.90 ± 22.74
14	Shuttle run **	m	1928.57 ± 255.83 (2*, 3*)	2272.31 ± 187.89 (3**)	1626 ± 264.84
15	VO_2max **	ml/kg/min	50.53 ± 3.78 (2*, 3*)	55.55 ± 2.70 (3**)	45.93 ± 4.11
16	"Envelope" run **	s	22.43 ± 0.92 (3**)	22.48 ± 0.73 (3**)	24.50 ± 1.12
17	Abdominal muscles strength **	n-number	33.57 ± 1.40	35.23 ± 4.07 (3**)	29.70 ± 4.57
18	Backward medicine ball throw **	m	17.59 ± 2.87 (2*, 3**)	13.62 ± 2.14 (3**)	8.26 ± 3.19
19	Static force **	kG	47.57 ± 8.16 (3**)	43.00 ± 9.33 (3**)	25.50 ± 10.41

*: $p < 0.05$; **: $p < 0.01$. When conducting multiple comparisons using Mann-Whitney test - # : $p < 0.016$; ## $p < 0.01$.

Taking into account the means in each group, it was observed that the best results were obtained by younger juniors, and the worst by the youngsters.

On the other hand, no significant difference was observed between the clusters for the following variables: kinaesthetic differentiation of force and time parameters, rhythmisation of movement and movement coupling (maze to the left errors).

Discussion

These observations were designed to fill the gap in the area of complex explorations of the multi-faceted conditions of sport class of young badminton players. A pragmatic way of resolving this priority issue was sought after: the method of k-means was used initially for identifying groups of leading badminton players having similar motor performance profiles. The method applied allowed to distinguish three uniform clusters of players significantly different in terms of the levels of motor ability complexes.

For it is essential for coaching practice to set the values of the variables characteristic for particular age groups.

The level of particular condition and coordination abilities – as important elements of technical and tactical training – determines the efficiency of sports competition [28-30]. Following only age as the criterion, false conclusions may be drawn since the indices of individual players may be significantly different from the values characteristic for a particular group; the consequence may be targeting training at higher levels of particular indices than recommended [1–3].

It seems that the correct solution is to select subjects for uniform teams in terms of their motor potential. Then, exercises suited to the structural and functional capabilities of young players may be chosen. Additionally, the availability of model motor performance profiles facilitates the evaluation and selection at various levels of players' training. In practice, wrong decisions and distortions often occurs in this respect. Not taking into account the biological and motor age of young athletes in applying training is a major mistake. Overload and "early specialisation" are very often the cause of eliminating talented (albeit developing more slowly) candidates from sports in general. The so-called acceleration do not hold promise either and should, if possible, practice in groups of higher age category. Exercise that is unsuited to the developmental age of the trainees sometimes leave a lasting mark on their psyche and have a negative effect on their bodies. Waddell and In Hong pointed to these problems to some extent [31]: they pointed to the necessity of adjusting the applied exercises for young badminton players to development potential of training children, as well as to reasonable shaping of competition technique that would stay in accordance with the physical capability of badminton adepts. Pursuit of championship at an early stage is bad forward thinking and often limits full development of the player [3, 32].

Training children and youths must therefore be subordinated to supporting individual development processes. It should be characterized by versatility turning to specialisation gradually and systematically. This versatility is based on selective stimulation of those abilities that, during the period of the development of a child's organism, are characterized by the greatest susceptibility to physical activity [33].

Trainers – despite the modest amount of literature on the subject – formed a view that badminton belongs to the group of sports of non-standard properties and requires high level of motor coordination [16]. Elements mentioned most often include: simple and complex reaction time, coupling and diversification of movement, balance, orientation, rhythmisation and adaptation [14, 15]. It would seem that each of these elements play an essential role in badminton as far as the quality and effectiveness of the motor tasks on the pitch are concerned, diverse in spatial and temporal terms. Given the class of the studied group it should be assumed that the highest variables recorded for a particular group are directly connected with the class of their achievements. In the younger juniors group, highest values were recorded for movement frequency, abdominal muscles strength and shuttle run time. For juniors, the highest values were recorded for coupling moves/maze to the left (s) and the average auditory reaction time. It seems that emphasis should be put on shaping these players' motor preparation variables during the training periods in question. However, it should be noted that training in the younger age groups should be subordinated to achieving high results in seniors groups. As it was already mentioned, in this age group the importance is attributed to coordination motor abilities. Taking into account the sensitive periods of coordination motor abilities, training at youngster levels should focus on shaping these particular abilities. The importance of hand-eye coordination and reaction time for the game is also confirmed in research by Yuan et al. [34]; the role of these abilities in teaching technique is emphasized, among others, by Chin et al. [35] Sakurai and Ohtsuki [36] and Mooney and Mutrie [37].

The variables determining the energy-related abilities (including Maximal Aerobic Power) proved to have a very significant share in shaping sport class, especially in groups who were older in terms of motor abilities. The observed facts correspond to the opinions of other authors classifying badminton as a speed/strength discipline[11, 13, 38].

Great importance in this regard should also be attributed to aerobic endurance, especially among younger juniors; it probably affects maintaining high efficiency in the final phase of the play, as well as in subsequent matches. In studies on judokas, it was found that high VO_2max values were associated with increases in activity of players in the second half of the fight and during extra time [39].

Conclusions

1. The k-means method made it possible to identify distinct clusters with similar motor capacity potential profiles from the group of badminton players.
2. Usage of this method also allowed to assess the level of development of the analyzed variables in the different clusters.
3. The structure of variables construing the sports level at various stages of training, marks a certain trend in shaping the model of a future champion. The ideal is an individual with high anaerobic and aerobic exercise capacity and higher degree of organization and specifics of motor coordination.

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