Coll. Antropol. **31** (2007) 3: 795–801
Original scientific paper

Biomotor Structures in Elite Female Handball Players

Ratko Katić, Marijana Čavala and Vatromir Srhoj

Faculty of Natural Sciences, Mathematics and Kinesiology, University of Split, Split, Croatia

ABSTRACT

In order to identify biomotor structures in elite female handball players, factor structures of morphological characteristics and basic motor abilities of elite female handball players (N=53) were determined first, followed by determination of relations between the morphological-motor space factors obtained and the set of criterion variables evaluating situation motor abilities in handball. Factor analysis of 14 morphological measures produced three morphological factors, i.e. factor of absolute voluminosity (mesoendomorph), factor of longitudinal skeleton dimensionality, and factor of transverse hand dimensionality. Factor analysis of 15 motor variables yielded five basic motor dimensions, i.e. factor of agility, factor of jumping explosive strength, factor of throwing explosive strength, factor of movement frequency rate, and factor of running explosive strength (sprint). Four significant canonic correlations, i.e. linear combinations, explained the correlation between the set of eight latent variables of the morphological and basic motor space and five variables of situation motoricity. First canonic linear combination is based on the positive effect of the factors of agility/coordination on the ability of fast movement without ball. Second linear combination is based on the effect of jumping explosive strength and transverse hand dimensionality on ball manipulation, throw precision, and speed of movement with ball. Third linear combination is based on the running explosive strength determination by the speed of movement with ball, whereas fourth combination is determined by throwing and jumping explosive strength, and agility on ball pass. The results obtained were consistent with the model of selection in female handball proposed (Srhoj et al., 2006), showing the speed of movement without ball and the ability of ball manipulation to be the predominant specific abilities, as indicated by the first and second linear combination.

Key words: *female handball players, morphological-motor status, specific motoricity, canonic relations*

Introduction

Previous studies have demonstrated that the formation of definitive conditions that are fundamental to achieve top performance in handball is predominantly determined by the initial state of anthropological characteristics[1–4], indicating the definitive state to be a function of all preceding states. Long-term training processes in handball, along with appropriate selection, lead to the formation of optimal, i.e. specific biomotor structures responsible for achievement of top performance in handball. This process requires thorough knowledge of the developmental patterns of anthropological features that are relevant for high achievements in the respective sports activity, including female handball. This in turn should include knowledge of the congenital and acquired components of the development of these anthropological features as well as of the sequence and magnitude of this development. The results achieved in any sports activity, including handball, cannot be simply explained by summing up individual abilities and characteristics responsible for these results but their inter-relationships should also be taken in consideration. It is therefore necessary to monitor development of the functions describing the anthropological structure of female handball players of a particular age group, i.e. according to stages of the performance quality formation.

Previous studies have revealed that handball is a very complex sports activity where successful performance depends on a number of basic motor abilities, mostly on the ability of cortical regulation of movement, explosive strength (of throwing type in particular), basic strength of the trunk, and psychomotor speed. Situation perfor-

Received for publication March 21, 2007

mance is predominantly determined by explosive strength because the conditions of elite handball impose the need of maximal jumping, throwing or sprint performance. The prognostic value of explosive strength tests to predict situation efficiency has been confirmed in many studies[2–6]. The accomplishment of specific motor skills is closely related to the development of specific motor abilities and basic motor abilities, which then results in the integration of specific and basic motor abilities into the locomotor system. Results of the studies performed in elementary school fifth- to eighth-grade female students included in handball training[3,4], and in elite female handball players[2,5,6], as well as in studies of motor development in general[7–12], are consistent with the statements above.

The studies conducted to date have mostly employed two methodological procedures and/or models to obtain relevant information on the factors determining the level of performance in a particular sports activity, i.e. regression model based on regression correlation analysis[2,3,13–16], and discriminative model based on discriminative analysis[1,4–6,17]. The use of either model depends on the data available. Thus, if results on the variables evaluating anthropological status of each individual and on his performance in the respective sports activity are available, then regression correlation analysis should be employed. Regression analysis yields specification equation for the respective sports activity, which contains three substantial elements, i.e. which factors influence performance, to what extent, and what is the relationship among factors influencing performance in this particular sports activity[1].

In practice, however, the level of performance in a sports activity may frequently be impossible to reliably define by using a single variable. Then the relationship between the set of predictor variables and the set of criterion variables is best evaluated by the use of canonic correlation analysis because all relations are calculated at the time. The use of a series of regression analyses between the two sets of variables will produce partial relations of predictor variables and a particular criterion in separate. In this way, the study phenomenon is analyzed and described by segments, while its function as a whole remains unknown. That is why canonic correlation analysis is the superior method for identification of optimal anthropological structures that determine the level of performance in a sports activity.

The general aim of this study was to diagnose anthropometric characteristics and basic motor abilities of elite female handball players, and to determine the structure and relations of these structures with the manifest variables evaluating performance in handball. Therefore, factor structures of both morphological characteristics and basic motor abilities of elite female handball players were determined first, followed by determination of relations of the morphological-motor space factors obtained with the set of criterion variables evaluating situation motor abilities in handball.

Subjects and Methods

Subject sample

Subject sample was defined as a group of female handball players playing in the Croatian Major Handball League for at least two years. The study included 53 subjects characterized as Croatian elite female handball players according to the level of handball technique training and experience.

Variable sample

The set of predictor variables were so chosen as to assess anthropometric dimensions and basic motor abilities. The choice of 14 morphological variables was based on the presumed existence of four dimensions, i.e. longitudinal skeleton dimensionality, transverse skeleton dimensionality, body volume and body mass, and subcutaneous fatty tissue (Katić et al., 1994)[7]. The following variables were chosen:

- measures for assessment of longitudinal skeleton dimensionality: body height, arm span, leg length, and hand length;
- measures for assessment of transverse skeleton dimensionality: knee diameter, wrist diameter, and hand diameter;
- measures for assessment of body mass and volume: body weight, upper arm circumference in relaxation, thorax circumference, and lower leg circumference; and
- measures for assessment of subcutaneous adipose tissue: midarm skinfold, back skinfold, and abdominal skinfold.

Fifteen motor tests were chosen for assessment of basic motor abilities:

- for assessment of agility (coordination factor): sidesteps, 8 with bending, and shuttle-run test;
- for assessment of movement frequency: hand tapping, foot tapping, wall foot tapping;
- for assessment of jumping explosive strength: standing long jump, standing high jump, and standing triple jump;
- for assessment of throwing strength: 2-kg medicine ball supine throw; 2-kg medicine ball standing chest throw, and 2-kg medicine ball bow throw; and
- for assessment of running strength (sprint): high start sprint 20 m, high start sprint 30 m, and high start sprint 40 m.

The set of criterion variables were so chosen as to evaluate situation efficiency in handball. The choice of situation variables was based on the presumed existence of five handball factors: situation precision, ball manipulation, speed of movement with ball, speed of movement without ball, and explosive strength of handball pass (Pavlin et al., 1982)[18]. In line with this study, a test defining best the respective factor was chosen for each handball factor, as follows:

- 9-m jump throw for precision,
- wall throwing and catching ball with one hand for ball manipulation,
- start speed with ball at 20 m for speed of movement with ball,
- speed of shuttle-run for speed of movement without ball, and
- handball distance jump throw for strength of throw.

Statistical analysis

Latent variables of the morphological and basic motor space were obtained by factor analysis on the model of main components, with direct oblimin rotations. The number of significant factors was determined by use of Guttman-Kaiser criterion, according to which a component with a variance exceeding 1.00 is considered significant.

Correlation between the set of predictor variables (factors of the anthropometric and basic motor space) and the set of criterion variables (variables of situation efficiency in handball) was determined by canonic correlation analysis by use of the classic Hotelling procedure. Significance of the canonic correlation coefficients was tested by Bartlet's χ^2-test at a level of $p<0.01$.

Results

Factorization of the morphological space manifest variables produced characteristic roots (Exp. Var.) explaining common variance of each factor. Three morphological factors explaining 71.52% of the common variance in total were isolated according to Guttman-Kaiser criterion from the overall space of variables.

TABLE 1
STRUCTURE OF LATENT VARIABLES OF MORPHOLOGICAL SPACE (F)

Variable	F1	F2	F3
Body height	0.19	0.94	0.18
Arm span	0.39	0.77	0.40
Leg length	0.13	0.93	0.13
Hand length	0.17	0.68	0.28
Hand diameter	0.14	0.39	0.90
Wrist diameter	0.27	0.41	0.83
Knee diameter	0.68	–0.07	0.33
Body weight	0.87	0.54	0.25
Upper arm circumference	0.86	–0.02	0.21
Thorax circumference	0.75	0.41	0.15
Lower leg circumference	0.74	0.35	0.11
Midarm skinfold	0.63	0.33	–0.43
Back skinfold	0.70	–0.10	–0.11
Abdominal skinfold	0.69	0.35	–0.08
Expl. Var.	5.65	2.82	1.55
Prp. Totl.	0.40	0.20	0.11

Expl.Var. – particular component variance, Prp.Totl. – total amount of the explained system variance

First oblimin factor (Expl. Var.=5.65) showed significant correlation body weight variables and all circumference measures, whereas the variables of subcutaneous fatty tissue showed lower yet relatively high projections upon the first latent dimension. It should be noted that this factor displayed a relatively high projection of knee diameter, a measure hypothetically belonging to transverse skeleton dimensionality. This is quite conceivable for the knee size and width, considering the fact that female handball players need stability while at the same time being capable to perform fast and explosive change in movement direction. These abilities can only be found in players with very strong knees. In the light of correlation with the mentioned variables, this factor could be interpreted as a mesoendomorphy factor and/or factor of total voluminosity. Generally, the factor describes 40% of total variance of the set of morphological variables applied.

Second oblimin factor (Expl. Var.=2.82) correlated significantly with all variables for assessment of longitudinal skeleton dimensionality (body height, arm span, leg length and hand length). This factor represents the dimension of longitudinal skeleton dimensionality and explains 20% of total system variance.

Third oblimin factor (Expl. Var.=1.55) was defined by hand and wrist diameter, thus it could be characterized as transverse hand dimensionality. Knowing the high relevance of hand size in ball manipulation, this factor is of special interest knowing. This factor describes 110% of total variance of the morphological set of variables applied. In the present study, three morphological factors were defined by use of factor analysis: factor of absolute voluminosity (mesoendomorphy), factor of longitudinal dimensionality, and factor of transverse hand dimensionality.

Factorization of the manifest basic motor variables yielded characteristic roots (Exp. Var.) explaining common variance of each factor. Five factors explaining 80% of common variance were isolated from the overall space according to Guttman-Kaiser criterion.

Analysis of the structure matrix (Table 2) showed the variables used for assessment of the agility type coordination to have highest projections (range, 0.87–0.94) upon the first oblimin factor (Expl. Var.=5.70). Some variables for assessment of explosive strength of the throw, jump and sprint type also had relatively high projections upon this factor, suggesting a conclusion that explosive strength and agility are dimensions that are tightly connected and correlated. This factor explained 37% of total variance of the basic motor set of variables applied, thus it could be termed agility factor.

Second oblimin factor (Expl. Var.=2.97) was defined by the tests of explosive strength of jump type, with highest projection of the variable describing vertical jump. Based on the results obtained, this factor could quite rea-

TABLE 2
STRUCTURE OF LATENT VARIABLES OF BASIC MOTOR SPACE (F)

Variable	F1	F2	F3	F4	F5
Sidesteps#	0.94	–0.16	–0.21	–0.20	0.15
8 with bow#	0.91	0.03	–0.29	0.10	0.13
Shuttle-run test#	0.87	–0.25	–0.23	–0.04	0.35
Hand tapping	0.18	0.14	0.07	–0.90	–0.01
Foot tapping	0.24	0.60	–0.68	–0.26	–0.33
Wall foot tapping	–0.17	0.17	–0.51	–0.68	–0.38
Standing long jump	–0.29	0.74	–0.01	–0.17	–0.41
Standing high jump	0.00	0.84	0.14	–0.16	–0.21
Standing triple jump	–0.64	0.51	0.28	0.29	–0.08
Supine medicine ball throw	–0.30	0.30	0.78	–0.14	–0.39
Standing medicine ball throw	–0.73	–0.12	0.63	0.36	0.20
Medicine ball bow throw	–0.63	0.28	0.75	–0.05	–0.08
High start sprint 20 m#	–0.05	–0.35	0.12	0.10	0.90
High start sprint 30 m#	0.74	–0.09	–0.45	0.13	0.63
High start sprint 40 m#	0.62	–0.26	–0.33	0.11	0.80
Expl. Var.	5.70	2.97	1.43	1.27	1.14
Prp. Totl.	0.37	0.19	0.09	0.08	0.07

#variable with opposite metric orientation, Expl. Var. – particular component variance, Prp. Totl. – total amount of explained system variance

sonably be termed factor of explosive strength of the jump type. This factor explained 19% of total variance of the set of variables applied.

Third oblimin factor (Expl. Var.=1.43) was defined by two variables that hypothetically belong to the factor of explosive strength of the throw type, thus it could well be termed so. The variables of explosive strength of the jump type were opposed by the variables of the lower extremity movement frequency. This factor explained 9% of total variance of the set of the basic motor variables applied.

Fourth oblimin factor (Expl. Var.=1.27) showed significant and predominant correlation (0.90) with the variable for assessment of upper extremity movement frequency. The variable of wall foot tapping also showed quite a high projection upon this factor (0.68), therefore this factor could be termed factor of movement frequency. The third variable of foot tapping that hypothetically belongs to the latent dimension of movement frequency showed highest correlation with the factor of explosive strength of take-off, suggesting a conclusion that this test measures other abilities in addition to measuring movement frequency. It should be noted that the variables mentioned above had negative sign (–), indicating that the factor was defined by poorer test results. This should be taken in consideration when explaining results in forthcoming analyses. This factor described 8% of total variance of the motor variables applied.

Fifth extracted oblimin factor (Expl. Var.=1.14) correlated significantly with two variables assessing sprint speed, whereas the variable of 30-m high start sprint that hypothetically belongs to this space showed somewhat lower projection upon this factor. The results obtained indicated that the dimension thus obtained could be presented as factor of explosive strength of running type, which explained 7% of total variance of the variables applied.

Accordingly, factor analysis produced five basic motor dimensions: factor of agility, factor of explosive strength of jumping type, factor of explosive strength of throwing type, factor of movement frequency, and factor of explosive strength of running type (sprint). Based on the results of canonic correlation analysis, illustrated in Table 3, four significant canonic correlations explained the association between the set of eight latent variables of the morphological and basic motor space, and five variables of situation motoricity. Canonic correlation coefficients between particular pairs of dimensions were statistically significant, ranging from 0.64 to 0.93.

Canonic correlation between the first pair of dimensions was responsible for the most part of common variability of morphological-motor factors and situation motor variables (Can R^2=0.87). The correlation in this pair of canonic dimensions was underlain by the favorable impact of the factors of agility/coordination on the ability of fast movement without ball. This is quite logical because on playing handball there is much swift movement without ball as a basis to perform all tasks in handball.

Second pair of canonic dimensions explained 65% of common variability (Can R^2=0.65). The correlation of structures in this pair of canonic dimensions could be attributed to a combination of the motor and morphologi-

TABLE 3
CANONIC RELATIONS BETWEEN THE SET OF LATENT MORPHOLOGICAL-MOTOR VARIABLES AND SET OF SITUATION-MOTOR VARIABLES

Morphological-motor factors	CAN1	CAN2	CAN3	CAN4
Mesoendomorphy	0.04	0.14	0.02	0.14
Longitudinality	0.05	–0.34	0.31	–0.06
Transverse hand dimenzionality	0.16	0.49	0.45	–0.16
Coordination/agility#	–0.70	0.42	0.08	–0.53
Explosive strength jump type	0.21	0.63	–0.30	0.41
Explosive strength throw type	0.14	0.02	0.35	0.50
Speed of movement#	–0.53	–0.26	–0.35	0.43
Explosive strength running type#	–0.56	–0.34	0.58	0.07
Factors of situation motoricity				
Throw precision	0.20	0.53	0.48	0.01
Speed of movement with ball#	–0.42	–0.52	0.71	–0.20
Speed of movement without ball#	–0.94	0.27	–0.03	–0.20
Ball manipulation	0.50	0.59	0.46	–0.28
Strength of throw	0.59	0.17	0.17	0.77
Can R	0.93	0.81	0.75	0.64
Can R^2	0.87	0.65	0.57	0.41
P	0.00	0.00	0.00	0.01

#variable with opposite metric orientation, CAN – structure of canonic variables, Can R – coefficient of canonic correlation, Can R^2 – coefficient of canonic determination, p – level of significance

cal factors, explosive strength of jump type and transverse hand dimensionality on the one hand, and criterion variables of throw precision and ball manipulation on the other hand. Obviously, the players with higher explosivity of the jump type and more pronounced hand dimension will be more successful on performing test tasks that require precise jump throw, precise pass and ball catching.

Third pair of canonic dimensions was responsible for 57% of common variability. The correlation of structures in this pair of canonic dimensions could be ascribed to the impact of explosive strength of running type (sprint) and situation motor variable of the speed of movement with ball. Accordingly, the players with a more pronounced ability of explosive strength of running type (sprint) would move faster with ball, and *vice versa*, slower players will move more slowly with ball. Accordingly, ball manipulation should not pose any problems to the study sample consisting of elite female handball players that have mastered ball manipulation thoroughly and profoundly.

Fourth pair of canonic dimensions showed somewhat weaker correlation and considerably lower coefficient of canonic determination (Can R^2=0.41). The structure of this pair of canonic dimensions shows that this correlation could be ascribed to the effect of explosive strength of throw and jump type, and of agility on the strength of ball throw. It is concluded that a player would throw the ball more strongly and to a greater distance if she has developed a higher level of explosivity, agility and strength in arms and shoulder girdle, as it is known that all motor abilities are intertwined and that good performance in this criterion variable requires a spectrum of motor abilities. This implies coordinated and concerted activity of all parts of the body, i.e. muscle groups involved in the kinetic chain that ensures progressive transfer of the muscle strength over to the ball directed in the desired throw direction.

Discussion

Canonic correlation analysis (Table 3) produced four significant linear combinations between the set of eight latent variables of the morphological and basic motor space, and five variables of situation motoricity.

First linear combination showed general correlation of the basic motor ability of agility/coordination saturated with explosive strength in terms of sprint and movement frequency rate with specific abilities of the speed of movement without ball, strength of throw, ball manipulation, and to a lesser extent with the ability of movement with ball. Results indicated the general factor of specific motor abilities to be predominantly defined by the speed of movement without ball. This implies specific agility, i.e. speed of changing direction while playing handball. The strength of ball throw ranked second, ball manipulation third, and speed of movement with ball fourth in defining the general factor of specific abilities. Throw precision had a negligible contribution in defining the specific general factor. The first canonic dimension in the space of specific motor abilities of female handball players was found to completely fit the model of selection and formation of performance quality proposed (Srhoj et al., 2006)[1]. Accordingly, the speed of movement without ball has a crucial role, followed by the strength of throw and ball manipulation. Then, integration of these abilities into the ability of movement with ball occurs. The development of throw precision probably requires further integration of all the previously mentioned specific abilities, along with appropriate development of other anthropologic features. Thus defined general specific ability is determined by agility (factor of coordination), running speed (explosive strength of running type) and rate of movement frequency.

The first linear combination established determination of basic motor efficiency underlain by agility, which in turn integrates speed of running and speed of movements, in the general handball performance predominated by the speed of movement without ball. The second linear combination revealed the players with above-average explosive strength of jump type and above-average transverse hand dimensionality but with below-average agility and skeleton longitudinality to achieve above-average results in specific abilities of ball manipulation, throw precision and speed of movement with ball. Accordingly, in this type of players, integration of jump explosivity and hand transversality was decisive for their high handball performance.

The third linear combination was bipolar, differentiating two types of handball players. The players with above-average sprint ability accompanied by moderate projection of explosive strength of jump type, but with below-average transverse hand dimensionality and somewhat below-average explosive strength of throw type and skeleton longitudinality were more successful in the specific ability of the speed of movement with ball but less successful in throw precision and ball manipulation. The players with opposite characteristics, i.e. with moderately above-average values of hand transversality, skeleton longitudinaltiy, explosive strength of throw type and speed of movement, but with below-average ability of sprint and explosive strength of jump type, showed above-average results in throw precision and ball manipulation but below-average results in the speed of movement with ball. Accordingly, explosive strength of running type is decisive for the manifestation of the speed of movement with ball in a significant proportion of female handball players.

The fourth linear combination revealed the above-average agility and explosive strength of throw and jump type but with below-average rate of movement frequency to determine the specific ability of throw strength in some female handball players.

Study results pointed to the existence of an optimal morphological motor structure for the manifestation of all relevant specific abilities of elite female handball players (first linear combination) as well as to the existence of appropriate biomotor structures for the manifestation of particular specific abilities, and thus for successful accomplishment of certain tasks in handball game.

The results obtained are consistent with the model of selection in women's handball proposed (Srhoj et al., 2006), indicating that the specific abilities of the speed of movement without ball and of ball manipulation are of utmost importance for top performance in handball, just as described by the first and second linear combination. The first linear combination predominates in the phase of defense and counter-attack, whereas second linear combination prevails in the phase of attack upon defense.

Acknowledgement

This research is a part of a project of the Ministry of Science, Education and Sport of the Republic of Croatia (No: 0177190 head researcher: Prof. R. Katić).

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R. Katić

Faculty of Natural Sciences Mathemathics and Kinesiology, University of Split, Teslina 12, 21000 Split, Croatia
e-mail: katic@pmfst.hr

BIOMOTORIČKI SKLOPOVI VRHUNSKIH RUKOMETAŠICA

S A Ž E T A K

U cilju identifikacije biomotoričkih sklopova u ženskom vrhunskom rukometu, najprije su utvrđene faktorske strukture kako morfoloških karakteristika, tako i bazičnih motoričkih sposobnosti vrhunskih rukometašica (n=53), a zatim su utvrđene relacije dobivenih faktora morfološko-motoričkog prostora sa skupom kriterijskih varijabli, koje procjenjuju situacione motoričke sposobnosti u rukometu. Faktorskom analizom 14 morfoloških mjera dobivena su tri morfološka faktora: faktor apsolutne voluminoznosti, tj. mezoendomorfije, faktor longitudinalne dimenzionalnosti skeleta i faktor transverzalne dimenzionalnosti šake, dok je faktorskom analizom 15 motoričkih varijabli dobiveno pet bazičnih motoričkih dimenzija: faktor agilnosti, faktor eksplozivne snage tipa skočnosti, faktor eksplozivne snage tipa bacanja, faktor brzine frekvencije pokreta i faktor eksplozivne snage tipa trčanja (sprinta). Četiri značajne kanoničke korelacije, tj. linearne kombinacije, objasnile su povezanost između skupa od osam latentnih varijabli morfološkog i bazično motoričkog prostora i pet varijabli situacijske motorike. U osnovi prve kanoničke linearne kombinacije je pozitivan utjecaj faktora agilnosti/koordinacije na sposobnost brzog kretanja bez lopte. U osnovi druge linearne kombinacije je utjecaj eksplozivne snage tipa skočnosti i transverzalne dimenzionalnosti šake na baratanje rukometnom loptom, preciznost šutiranja, te na brzinu kretanja s loptom. U osnovi treće linearne kombinacije je determiniranost eksplozivne snage tipa trčanja s brzinom kretanja s loptom, a u osnovi četvrte determiniranost eksplozivne snage bacanja i skoka, te agilnosti na snagu izbačaja rukometne lopte. Dobiveni rezultati su u skladu s predloženim modelom selekcije u ženskom rukometu (Srhoj i sur. 2006), a pokazuju kako su za postizanje vrhunskih rezultata u rukometu dominantne specifične sposobnosti brzine kretanja bez lopte i sposobnost baratanja loptom, upravo kako to opisuje prva i druga linearna kombinacija.