Coll. Antropol. **29** (2005) 1: 79–84
UDC 796.85:572.512
Original scientific paper

Morphological Structures of Elite Karateka and Their Impact on Technical and Fighting Efficiency

Ratko Katić[1], Stipe Blažević[2], Saša Krstulović[1] and Rosanda Mulić[3]

[1] Faculty of Natural and Mathematical Sciences and Education, University of Split, Split, Croatia
[2] Faculty of Economics, University of Rijeka, Rijeka, Croatia
[3] Faculty of Medicine, Split, Croatia

A B S T R A C T

The aim of the study was to identify the morphological structures that determine achievement of top results in karate. The study included a sample of 85 karateka competing as senior category athletes within the Croatian Karate Society, aged 18–29 years. Sixteen morphological parameters were used; technical efficiency was assessed using 8 variables, i.e. evaluation of particular karate techniques, whereas fighting efficiency was estimated on the basis of results achieved at a number of contests. Factorial analysis of morphological space revealed the presence of four major factors: factor of muscle mass, followed by skeleton transverse dimensionality, factor of skeleton longitudinal dimensionality, factor of subcutaneous adipose tissue, and factor of shoulder width determining optimal trunk proportions (athlete type) in karateka. Regression analysis showed the isolated group of morphological factors to significantly determine both technical and fighting efficiency of karate athletes. Generally, skeleton longitudinality and muscle mass, followed by skeleton transverse dimensionality were found to exert favorable effects, and adipose tissue unfavorable effects according to both criteria. Also, each individual morphological factor influenced the performance of every karate technique applied. Adipose tissue had greatest unfavorable impact, whereas shoulder width and muscle mass had favorable impact on the performance of arm techniques (kicking). Considering performance of leg techniques, skeleton longitudinality had highest favorable impact, and adipose tissue greatest unfavorable impact. Of the techniques applied, combined karate kicks, i.e. jaku zuki-mawashi geri and kizame zuki-jaku zuki were found to be the best predictors of fighting efficiency.

***Key words**: senior karate athletes, morphological parameters, fighting efficiency*

Introduction

Mastering motor skills (techniques) in karate and their efficient use in fight require longstanding, strenuous training. The fight dynamics and high movement frequency are especially emphasized, necessitating a high level of motor and functional abilities, speed and strength[1], and coordination[2] in particular, of a karateka. Although of a relatively short duration, karate fights are characterized by maximal intensity, thus only the entities capable of enduring these demanding conditions can hold out in elite karate contests. Quite frequently, persistent and persevering training may prove inadequate, as specific predisposition is needed to achieve top-level results. All these reflect on the formation of an appropriate anthropologic complex of a karateka. Karate training leads to adjustment of the morphological subsegment of the anthropologic complex optimizing the morphological structure according to the requirements of this particular sport. As for the genetic determination of the skeleton longitudinal as well as transverse dimensions, karate training will result in an optimal muscle mass increase relative to the level of skeleton development, and in adipose tissue reduction.

High quality and elite karate selections are predominated by the karateka of the mesomorphic and ectomorphic constitution types[3,4], whereas endomorphic somatotype is rarely found, even in the heavyweight category.

Practical experience suggests that body height, and arm and leg length as skeleton longitudinal dimensions

Received for publication February 1, 2005

should be viewed as the fighter's advantage in any weight category, primarily because these measures enable him to fight at a greater distance, to lift legs higher on kicking (dynamic flexibility), and to perform a wider array of tactical variants.

In karateka, subcutaneous adipose tissue is a ballast mass that definitely slows the movement down and elicits unfavorable effect on the demanding dynamics of energy processes in the body. Muscle mass as a major component of the body volume dimension and body mass is substantial for contact duels with the opponent, and for performing throws, explosive and fast movements on attacks, defense or counterattack. A proportional constitution with pronounced extremity musculature is characteristic of elite karateka.

The aim of the study was to identify the morphological structures that determine achievement of top-level results in karate. To this end, morphological structures were identified, the factors influencing the criteria of technical and fighting efficiency and factors influencing performance of each particular technique, i.e. specific motor skills, and techniques influencing the criterion of fighting efficiency were determined. Thus, relations were established at three levels: (a) morphological structures – technical and fighting efficiency; (b) morphological structures – karate techniques (specific motor skills); and (c) karate techniques – fighting efficiency. The results obtained allowed for setting equations related to the selection, planning and programming of transformation procedures in elite karate.

Subjects and Methods

The study included a sample of 85 karateka competing as senior category athletes within the Croatian Karate Society, aged 18–29 years, at least brown belt owners. Anthropometrical variables were selected by assessment of the four-dimensional morphological space: skeleton longitudinal dimensionality, skeleton transverse dimensionality, body mass and volume, and subcutaneous adipose tissue. The following morphological measures were used: body height, arm length, leg length, biacromial diameter, bicristal diameter, elbow diameter, knee diameter, body weight, upper arm circumference in flexion, upper arm circumference in extension, forearm circumference, upper leg circumference, lower leg circumference, subscapular skinfold thickness, triceps skinfold thickness, and abdominal skinfold thickness. The measurement of anthropometrical characteristics in study subjects was done according to the International Biological Program recommendations[5], with all variables measured on three occasions.

Judgment by four independent karate experts was considered on assessing the karateka fighting success and technique. The experts were well informed on the subjects' activities, having followed them at numerous contests over a long period of time. Two criterion variables were set to estimate technical efficiency and fighting, i.e. competitive efficiency.

1) Technical efficiency – C1TECHN was determined on the basis of subjective evaluation by four judges calculating the first main judgment component in 8 karate techniques. The following techniques were evaluated: *jaku zuki, kizame zuki, ushiro mawashi geri* and *mawashi geri*, and in combinations *jaku zuki – mawashi geri, jaku zuki – uraken, ashi barai – ushiro mawashi* and *kizame zuki – jaku zuki.*
2) Fighting efficiency – CRESULT defined as an average of all competitive results achieved at world championships, world cups, European championships and national championships.

Factorial analysis was used to determine the karateka morphological structure. The algorithm consisted of oblimin transformation of latent dimensions obtained by orthoblique transformation of the characteristic vectors of the variable intercorrelation matrix. Classic regression analysis was used to determine the effect of the identified karateka morphological structures on their technical and fighting efficiency. Regression analysis was also employed to determine the relations between the morphological factors and performance of particular basic karate techniques, i.e. karate motor skills, and to determine the effect of karate techniques on the karateka competitive efficiency.

Table 1 shows basic statistical variable parameters (mean [$\overline{X}$] and standard deviation [SD]) and oblimin factor complex (OBL), while Tables 2, 3 and 4 present partial coefficients of regression (β), coefficient of predictor correlation with criterion (ρ) and coefficient of determination (δ), i.e. relevant results of regression analysis.

Results

In comparison with Croatian Army recruits[6,7], the karateka were found to show no substantial differences in the measures assessing the longitudinal skeleton dimensionality, but differed significantly according to the measures assessing the proportion of adipose tissue showing significantly lower values. When compared with the general population, the karateka are characterized by marked muscular mass (mesomorphy) with increased transverse skeleton dimensionality and minimal adipose tissue. It should be noted that the karateka are characterized by a considerably greater homoegeneity of the morphological measures applied than the general population, i.e. the variability is less pronounced, especially in the skinfolds observed.

Factorial analysis of the morphological space using the component model revealed the existence of four major factors.

First factor was a general one, defined by high projections of all circumference and diameter measures. Thus, muscle mass (mesomorphy) accompanied by transverse skeleton dimensionality was found to be a major characteristic of elite karateka.

Second factor included highest measure projections, i.e. body height, and arm and leg length, thus this factor

TABLE 1
DESCRIPTIVE STATISTICS AND STRUCTURE OF OBLIMIN FACTORS IN THE SPACE OF MORPHOLOGICAL VARIABLES (N=85)

Variable	$\overline{X}$	SD	OBL1	OBL2	OBL3	OBL4
Body height (cm)	178.17	6.84	0.04	0.87	–0.02	0.20
Leg length (cm)	102.51	6.34	0.04	0.95	0.04	–0.22
Total arm length (cm)	78.82	4.70	–0.08	0.96	0.00	0.07
Biacromial diameter (cm)	37.40	3.96	–0.10	–0.02	–0.05	0.95
Bicristal diameter (cm)	28.64	1.72	0.41	0.30	0.03	0.36
Elbow diameter (cm)	7.07	0.44	0.66	0.28	–0.09	–0.07
Bicondylar femur diameter (cm)	10.38	0.99	0.57	0.30	0.16	–0.32
Upper arm d. in extension (cm)	30.34	3.11	1.00	–0.20	–0.07	–0.03
Upper arm d. in flexion (cm)	32.42	3.23	0.96	–0.05	0.05	–0.05
Forearm circumference (cm)	27.36	2.15	0.92	0.01	0.07	0.03
Upper leg circumference (cm)	56.16	4.88	0.59	0.13	0.27	0.11
Lower leg circumference (cm)	37.22	2.43	0.59	0.16	0.28	0.11
Body mass (kg)	75.38	9.90	0.40	0.33	0.25	0.42
Subscapular skinfold (mm)	9.04	2.33	0.04	0.02	0.91	0.03
Triceps skinfold (mm)	7.37	2.08	0.01	–0.11	0.95	–0.03
Abdominal skinfold (mm)	7.75	2.21	–0.08	0.03	0.98	–0.05
LAMBDA			8.54	2.14	1.58	1.09
Variance %			53.40	66.77	76.65	83.49

being responsible for longitudinal skeleton dimensionality.

Third factor was determined by all skinfold measures and could be interpreted as a subcutaneous adipose tissue factor.

Fourth factor exhibited a structure specific for a part of elite karateka, in which bisacromial diameter determines optimal trunk proportions (athletic type). The structure of this factor defines the level of trunk development in terms of length and width, i.e. a proportional, optimal relation of the two horizontal body axes and trunk length.

Upon identification of the morphological structures, it appeared logical to assess the relations of these morphological structures and the criterion variables defining technical and performance efficiency of the karateka.

Regression analyses were significant at a level of 0.001, indicating the isolated group of morphological factors to be a good predictor of the karateka success (Table 2). Therefore, the success in karate cannot be observed in separate from the karateka morphological characteristics.

A higher multiple correlation was obtained for fighting efficiency assessed from competition scores recorded over the last few years relative to the criterion of technical efficiency. Obviously, there was considerable mutual saturation among the criteria analyzed, thus the karateka quality appears to be most reliably and most easily assessed by following their results from as many contests as possible.

The coefficients of regression (β) also indicated high determination of the morphological criteria and the criteria defining the karateka success, i.e. quality. All regression coefficients were significant, indicating that each of the isolated morphological factors influenced the karateka quality achieved, while taken together they defined the morphological complex that is optimal to achieve best results in karate. In this complex, skeleton longitudinality stood out as a positive predictor, and adipose tissue as an interfering factor in performing motor tasks in karate. Skeleton longitudinality enables the karateka to fight at a greater distance, thus making it more difficult for the opponent to strike. Along with

TABLE 2
RESULTS OF REGRESSION ANALYSIS FOR TECHNICAL AND FIGHTING EFFICIENCY IN THE FACTORIAL MORPHOLOGICAL SPACE IN KARATE

Factor	C1TECHN	CRESULT
	β	β
Muscle mass	0.26[a]	0.27[a]
Skeleton longitudinality	0.36[c]	0.34[c]
Adipose tissue	–0.41[c]	–0.34[c]
Biacromial diameter	0.31[c]	0.38[c]
ρ	0.63[c]	0.65[c]
δ	0.40[c]	0.42[c]

C1TECHN = first main component of eight karate techniques; CRESULT = overall competitive efficiency over a few years; β = regression coefficients; ρ = multiple correlation; δ = coefficient of determination
[a] $p<0.05$; [b] $p<0.01$; [c] $p<0.001$

skeleton longitudinality, the morphological factor based on shoulder width and trunk length has the same effects, i.e. it also facilitates various techniques to be performed at a greater distance (shoulder width for arm techniques, and trunk length for leg techniques). Bisacromial diameter as a crucial determinant of athletic somatotype is associated with body stability on movements (agility), which is a precondition for supreme technique performance. In addition to the factors of skeleton longitudinality and bisacromial diameter, the volume factor based on muscle mass associated with skeleton transversality is also a good positive predictor of a karateka success.

The contribution of particular segments of the morphological complex to the performance of different motor skills, i.e. karate techniques, varies. Therefore, the karateka tend to use those techniques that are consistent with their morphological features. In order to acquire relevant information on the effect of morphological characteristics on the performance of particular basic karate techniques, results of regression analysis between isolated morphological factors and each technique as performed by elite karateka are presented in Table 3.

All multiple correlations were significant, implying that success in the performance of all karate techniques, performed either alone or in combination, could be predicted by use of a group of isolated morphological factors. Accordingly, karate techniques were concluded to be significantly determined by the morphological structure where skeleton longitudinality, muscle mass (mesomorphy) and shoulder width exerted favorable effects, whereas adipose tissue elicited unfavorable effects on the performance of these specific movements.

Relations between specific motor skills, i.e. techniques, and the criterion of fighting, i.e. competitive efficiency are presented in Table 4. It should be noted that motor skills in this case refer exclusively to the kicks performed individually or in combination, thus providing information on the impact of particular karate kicks on the fighting success.

Multiple correlation was high and significant, indicating the group of the karate kicks applied to be a good predictor of the karateka fighting success. Of the techniques applied, the *zuki-mawashi geri* and *kizame zuki-jaku zuki* karate kicks performed in combination were found to be the best predictors of fighting efficiency. These two combinations predominantly determined the karateka fighting efficiency, whereas quality, i.e. the level of mastering the kicks performed individually had no major impact on the karateka fighting efficiency. Accordingly, the ability of integrating different motor skills, i.e. mastered routines, into a unique structure appeared to be the main precondition for the karateka fighting success.

Discussion

Elite karateka have an ectomesomorphic constitution with minimal adipose tissue values. The basic parameters and factorial structure of the morphological variables revealed the karateka constitution to be equally predominated by the mesomorphic and ectomorphic components, which is consistent with literature data[3,4]. However, the mentioned studies were performed in small samples, with a small group of morphological measures, and using univariate data processing. Comparison of their results with those obtained in the present study suggests the average karateka to be predominantly characterized by mesomorphy, the above average karateka by mesoectomorphy, and elite karateka by ectomesomorphy as compared with the general population.

Longstanding karate training leads to ever increasing harmonization between the karateka acquisition of specific motor skills, i.e. techniques, and fighting efficiency. As illustrated in Table 2, the specific morphological factor predominated by bisacromial diameter is determined by the criterion of fighting efficiency over a prolonged period of time rather than the criterion of technical efficiency, and to a lesser extent by the adipose tissue. This finding points to the role of the specific mor-

TABLE 3
RESULTS OF REGRESSION ANALYSIS FOR PARTICULAR KARATE TECHNIQUES IN THE FACTORIAL MORPHOLOGICAL SPACE

Factor	TA1	TA2	TL3	TL4	TK5	TK6	TK7	TK8
	β	β	β	β	β	β	β	β
Muscle m.	0.30[c]	0.26[a]	0.19	0.19	0.20	0.31[c]	0.18	0.34[c]
Skeleton l.	0.25[a]	0.39[c]	0.32[c]	0.42[c]	0.40[c]	0.21[a]	0.40[c]	0.32[c]
Adipose t.	–0.50[c]	–0.47[c]	–0.28[b]	–0.38[c]	–0.31[c]	–0.38[c]	–0.31[c]	–0.47[c]
Biacrom. d.	0.41[c]	0.32[c]	0.23[a]	0.19	0.30[c]	0.33[c]	0.16	0.36[c]
ρ	0.68[c]	0,68[c]	0.50[c]	0.57[c]	0,61[c]	0.58[c]	0.52[c]	0.69[c]
δ	0.46[c]	0.46[c]	0.25[c]	0.33[c]	0.37[c]	0.34[c]	0.27[c]	0.48[c]

TA1 = jaku zuki; TA2 = kizame zuki; TL3 = ushiro mawashi geri; TL4 = mawashi geri; TK5 = jaku zuki – mawashi geri; TK6 = jaku zuki – uraken; TK7 = ashi barai – ushiro mawashi; TK8 = kizame zuki – jaku zuki; β = regression coefficients; ρ = multiple correlation; δ = coefficient of determination
[a] $p<0.05$; [b] $p<0.01$; [c] $p<0.001$

TABLE 4
RESULTS OF REGRESSION ANALYSIS FOR FIGHTING EFFICIENCY IN THE SPACE OF TECHNIQUE VARIABLES IN KARATE

Technique	CRESULT
	β
Jaku zuki	–0.14
Kizame zuki	0.28
Ushiro mawashi geri	–0.14
Mawashi geri	–0.28
Jaku zuki – mawashi geri	0.55[b]
Jaku zuki – uraken	0.07
Ashi barai – ushiro mawashi	0.08
Kizame zuki – jaku zuki	0.42[a]
ρ	0.84[c]
δ	0.71[c]

CRESULT = overall competitive efficiency over a few years; β = regression coefficients; ρ = multiple correlation; δ = coefficient of determination
[a] $p<0.05$; [b] $p<0.01$; [c] $p<0.001$

phological factor identified in the achievement of top results by the karateka.

Table 3 shows that all isolated morphological factors influence the performance of each technique used in karate. The contribution of particular factors in the performance of particular techniques clearly varies. Adipose tissue (endomorphy) has the greatest unfavorable impact, whereas bisacromial diameter and muscle mass (mesomorphy) have the greatest favorable impact on the performance of arm techniques (kicking). Skeleton longitudinality has the greatest favorable effect and adipose tissue (endomorphy) the greatest unfavorable effect on the performance of leg kicks. Bisacromial diameter along with arm length has favorable effects on the performance of arm kicks, because the longer levers allow for greater strength manifestation. The kicks are faster and stronger, striking the opponent at a greater distance. It can also be presumed that the blocks are faster and stronger, thus initially neutralizing the opponent's kicks, which will eventually facilitate the performance of counterattack.

The data presented in Table 4 show that the karateka fighting success is not warranted by appropriate performance of individual kicks but by the ability to perform a combination or series of kicks. Of individual kicks, however, only *kizame zuki* has some favorable impact on the fighting success. Similar to straight punch in boxing, *kizame zuki* enables control of the opponent's attack, i.e. prevents and interferes with the opponent's attack and allows for better preparation of the own attack or counterattack.

In karate, top results can only be achieved by the karateka who have developed potentially above average motor abilities, primarily those of explosive strength, coordination and flexibility, which are integrated into the general motor efficiency through karate training. This integration is the basis for proper development of motor functioning[8].

Technique performance is considerably saturated by cognitive abilities, because the karateka must be able to identify the situation in the shortest possible lapse of time and to choose the most appropriate reaction to achieve the goal[8], i.e. to win the fight.

Sforza *et al.*[9] analyzed technique quality, i.e. efficiency on the basis of deviation – variability in technique performance (*mae-geri-keagea*) through 10 repeats, whereby trajectories in three-dimensional space with 13 body points were recorded by use of a photoelectronic device. The hips and head showed lower variability, while the ankle and knee of the predominant extremity showed poorer quality on repeats. The authors conclude that this method can be used to detect especially talented karateka, and can help in identification of the parts of the body that fail to repeat the movement with a desired precision. This method is useful in learning, i.e. mastering, then in training particular karate techniques. In 2001, Sforza *et al.*[10] found the experienced karateka to achieve highest quality on repeating two different standardized counterattack techniques.

Mastering of the karate techniques is a longstanding process that depends both on basic motor abilities and on specific motor abilities. The karate motor skills as well as the general and specific motor abilities are being integrated into the morphological system over time[8,11], by optimizing the magnitude and relationships of the karateka somatotype components. The fighting efficiency of the karateka is significantly determined by the level, i.e. the quality of integration of the specific motor skills into the morphological system.

Acknowledgment

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).

REFERENCES

1. RAVIER, G., F. GRAPPE, J. D. ROUILLON, Science & Sports, 18 (2003) 134. — 2. WEINBERG, R., T. SEABOURNE, A. JACKSON, J. Sport Psychol., 3 (1981) 225. — 3. BERTINI, I., A. PUJIA, M. GIAMPIETRO, Acta Diabetol., 40 (2003) 142. — 4. GIAMPIETRO, M., A. PUJIA, I. BERTINI, Acta Diabetol., 40 (2003) 145. — 5. WEINER, J. S., J. A. LOURIE: Practical human biology. (Academic Press, London, 1981). — 6. MALEŠ, B., R. KATIĆ, D. ROPAC. In: Proceedings. (The 4th Int. Congr. Phys. Antrop., Zagreb, 1998). — 7. MALEŠ, B., D. SEKULIĆ, R. KATIĆ, Mil. Med., 169 (2004) 65. — 8. KATIĆ, R., A. PEJČIĆ, N. VISKIĆ-ŠTALEC, Coll. Antropol., 28 (2004) 261. — 9. SFORZA, C., M. TURCI, G. P. GRASSI, V. F. SHIRAI, G. PIZZINI, V. F. FERRARIO, Percept. Motor Skills, 95 (2002) 433. — 10. SFORZA, C., M. TURCI, G. P. GRASSI, N. FRAGNITO, G. SERRAO, V. F. FERRARIO, Percept. Motor Skills, 92 (2001) 1230. — 11. KATIĆ, R., Coll. Antropol., 27 (2003) 351.

R. Katić

Faculty of Natural and Mathematical Sciences and Education, University of Split, Split, Croatia

MORFOLOŠKE STRUKTURE VRHUNSKIH KARATISTA I NJIHOV UTJECAJ NA TEHNIČKU I BORBENU EFIKASNOST

S A Ž E T A K

Cilj rada je bio identificirati morfološke strukture koje determiniraju postizanje vrhunskih rezultata u karateu. U tu svrhu istraživanje je izvršeno na uzorku od 85 karatista, natjecatelja u borbama seniorske kategorije Hrvatskog karate saveza, a starosna dob ispitanika kretala se u granicama 18–29 godina. Na ispitanicima je primijenjeno 16 morfoloških mjera, te izvršena procjena tehničke efikasnosti s 8 varijabli, tj. ocjena iz pojedinih karate tehnika, kao i procjena borbene efikasnosti na temelju postignutih rezultata s većeg broja natjecanja. Faktorska analiza morfološkog prostora utvrdila je postojanje četiri značajna faktora i to: faktor mišićne mase, praćen transverzalnom dimenzionalnosti skeleta, faktor longitudinalne dimenzionalnosti skeleta, faktor potkožnog masnog tkiva i faktor po kojem širina ramena determinira optimalne proporcije trupa (atletski tip) kod karatista. Regresijska analiza je pokazala da izolirani skup morfoloških faktora značajno determinira kako tehničku tako i borbenu efikasnost karatista. Generalno, u odnosu na oba kriterija, longitudinalnost skeleta, te mišićna masa koju prati transverzalna dimenzionalnost skeleta, ima pozitivan utjecaj, a masno tkivo negativan utjecaj. Svaki pojedini morfološki faktor utječe i na realizaciju svake primijenjene tehnike u karateu. U realizaciji ručnih tehnika (udaraca) najveći doprinos u negativnom smislu ima masno tkivo, a u pozitivnom smislu širina ramena i mišićna masa. U odnosu na realizaciju nožnih udaraca najveći doprinos u pozitivnom smislu ima longitudinalnost skeleta, kao i masno tkivo u negativnom smislu. Od primijenjenih tehnika najbolji prediktori borbene efikasnosti su karate udarci koji se izvode u kombinaciji i to: jaku zuki-mawashi geri i kizame zuki-jaku zuki.