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The Structure of Body Measurements for the Determination of Garment System for Young Croatian Men

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A B S T R A C T

The determination and promotion of garment size systems require a knowledge of the proportions of the human body i.e. of anthropometric measures of a certain population. In order to create and promote a garment size system it is necessary to establish a correct relationship between the body parts or body measures. Possible interregional body differences are often neglected in the process, although they can be considerable even in cases of sex- and age- limited populations. This has been confirmed by an investigation of body measures for determining garment sizes carried out on a randomly selected sample of 4,268 healthy and normally developed men aged 18–22. The investigation was performed in 1993 on five locations each one representing a definite region of the Republic of Croatia: Jastrebarsko (central), Koprivnica (northwest), Pula (southwest), Sinj (south) and Požega (northeast). The survey instruments were 50 body measures chosen according to ISO standards for garment sizes. Interregional differences were considerable in all body measures. The role of those measures and their contribution to the differences was confirmed by discriminative analysis with regions as a priori defined samples. Besides the differences in body size, significant differences in body build were established, mostly in the northeast region of Croatia and partly also in the northwest region. It is the difference in body build (besides the high number of necessary measurements) that makes the determination of garment size systems so complex. In order to establish an appropriate and purposeful garment size standard it is necessary to collect more information and also introduce the entity of target-population into previously determined categories in terms of chest circumference and body height.

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Introduction

In order to determine and promote the garment size system it is necessary to take into consideration the proportions of the human body, its anthropometric measures, various garment size systems as well as systems of designating those sizes. The size systems of garment items are of utmost importance for the manufacture of men's, women's and children' garments. If we wish to satisfy the largest population of buyers, it is necessary to develop and promote up-to-date systems which will make possible an optimal choice of garment sizes.

Considering the present-day situation in Europe and in the world, different garment size systems and different systems of designating those sizes pose a certain difficulty to the manufacturers, sellers and consumers of clothes, especially in international business transactions. However, in accordance with some new initiatives, the adoption of complete and unique garment size systems and systems of designating sizes could be expected in Europe and in the world[1].

Anthropometry is an anthropological method concerned with measuring the human body and determining the size relations between its parts. Proportions and relations can help us to establish a correct relationship between different body parts i.e. different measures. Based on these proportions the aberrations from normal body build (i.e. its deformations) can be noticed. By means of systematic anthropological measuring and statistical results processing of those measurements it is possible to determine groups of data essential for clothes manufacturing, such as:

- a system of designating clothes;
- standard and proportion measurements;
- the share of characteristic proportions of the human body as well as individual garment sizes.

The systems of designating clothes and standard body measures are an integral parts of every standard.

Anthropometric measurements, on which corrections and adaptations of the existing standards are based, are carried out in the world approximately every ten years on the average. This is necessary because of the conditions and lifestyles which directly affect the human body measures[2,3]. The results of anthropometric measurement point to the incidence of particular garment sizes in the tested population or in the population as a whole. This is crucial information for garment manufacturers so that they can know in what proportion a particular garment size is represented in the overall product. Since they work for a large population of buyers, that particular piece of information is a condition for the placement of their product on the market.

Considering that the latest anthropological measurements in this part of the world[4] were carried out in the early sixties of the last century and that the results are still used, the authors have – in accordance with ISO standards[5–8] and based on human body proportions – established a suitable basis and articulated recommendations for defining the new standard.

Materials and Methods

Investigation was carried out in 1993 at five locations each of which represented a region of Republic of Croatia: Jastrebarsko (C), Koprivnica (NW), Pula (SW), Sinj (S) and Požega (NE). 4,268 healthy and normally developed males aged 18 – 22 were randomly selected. Jastrebarsko was represented by 620 examinees on average 19.88 years old (SD 0.957); Koprivnica by 1,200 examinees 19.74 years old (SD 0.727); Pula by 1,221 examinees 19.77 years old (SD 0.988); Sinj by 618 examinees 19.91 years

TABLE 1
LIST OF BODY MEASURES AND VARIANCE ANALYSIS RESULTS

Code	Variables	Sum of square	df	Mean square	F	p
V01	Head girth	104.8	4	26.2	10.5	<0.001
V02	Vertical head circumference	3244.3	4	811.1	169.4	<0.001
V03	Neck girth	1146.8	4	286.7	88.1	<0.001
V04	Neck-base girth	5930.2	4	1482.5	297.1	<0.001
V05	Chest girth	2606.1	4	651.5	16.8	<0.001
V06	Waist girth	1269.8	4	317.4	8.0	<0.001
V07	Hip girth	4095.5	4	1023.9	32.8	<0.001
V08	Shoulder length	1607.6	4	401.9	357.8	<0.001
V09	Shoulder width	11003.1	4	2750.8	371.2	<0.001
V10	Back width	7294.6	4	1823.6	229.4	<0.001
V11	Upper-arm girth	1640.0	4	410.0	57.9	<0.001
V12	Elbow girth	910.0	4	227.5	74.4	<0.001
V13	Wrist girth	41.5	4	10.4	14.2	<0.001
V14	Hand girth	59.3	4	14.8	13.4	<0.001
V15	Thigh girth	3238.0	4	809.5	43.3	<0.001
V16	Mid-thigh girth	6103.3	4	1525.8	90.8	<0.001
V17	Knee girth	571.3	4	142.8	32.5	<0.001
V18	Lower knee girth	265.4	4	66.4	14.7	<0.001
V19	Calf girth	458.6	4	114.6	17.9	<0.001
V20	Minimum leg girth	457.9	4	114.5	56.5	<0.001
V21	Ankle girth	2850.2	4	712.5	344.1	<0.001
V22	Height	8860.1	4	2215.0	51.3	<0.001
V23	Trunk length	13159.0	4	3289.7	348.5	<0.001
V24	Waist height	3597.9	4	899.5	34.0	<0.001
V25	Hip height	2525.2	4	631.3	30.1	<0.001
V26	Body rise	3843.9	4	961.0	194.8	<0.001
V27	Knee height	1606.2	4	401.5	60.9	<0.001
V28	Ankle height	180.4	4	45.1	129.7	<0.001
V29	Cervical height (sitting)	3356.7	4	839.2	99.2	<0.001
V30	Scye depth	11058.1	4	2764.5	678.5	<0.001
V31	Back waist length (cervical to waist)	7293.4	4	1823.4	346.0	<0.001
V32	Cervical to knee hollow	11296.8	4	2824.2	154.7	<0.001
V33	Cervical height	19625.4	4	4906.3	120.3	<0.001
V34	Frontal waist to length (neck shoulder point to waist)	3174.9	4	793.7	138.8	<0.001
V35	Cervical to waist (anterior)	807.3	4	201.8	43.4	<0.001
V36	Waist to hips	3632.9	4	908.2	268.8	<0.001

TABLE 1 (cont.)

Code	Variables	Sum of square	df	Mean square	F	p
V37	Trunk circumference	10836.9	4	2709.2	50.5	<0.001
V38	Total crotch length; lower trunk length	13425.4	4	3356.3	114.8	<0.001
V39	Armscye girth	8994.3	4	2248.6	264.6	<0.001
V40	Upper arm length (shoulder to elbow)	7904.6	4	1976.2	583.9	<0.001
V41	Arm length (shoulder to wrist)	11066.7	4	2766.7	330.8	<0.001
V42	7th-cervical-to-wrist length	4759.3	4	1189.8	90.7	<0.001
V43	Under-arm-length	306.5	4	76.6	11.4	<0.001
V44	Hand length	515.7	4	128.9	172.4	<0.001
V45	Outside leg length	2335.7	4	583.9	21.8	<0.001
V46	Thigh length	14388.0	4	3597.0	460.8	<0.001
V47	Inside leg length; crotch height	4248.1	4	1062.0	55.1	<0.001
V48	Foot length	197.0	4	49.3	31.5	<0.001
V49	Shoulder tilt	12997.2	4	3249.3	135.6	<0.001
V50	Body mass	6416.9	4	1604.2	17.3	<0.001

old (SD 1.248) and Požega by 609 examinees 19.46 years old (SD 0.992). Most examinees were between 20 and 21 (respectively 1,684 and 1,707) years of age and according to 1991 census they represent about 5% of Republic of Croatia's male population of the same age.

Considering that the investigation is part of a more widely defined project, the anthropometric variables were chosen and their measurements performed in accordance with the methodology contained in International Biological Program (IBP)[9], International standards for garment (ISO)[10], the manual for applied anthropometry of the World Health Organization[11], the extended ergonomic list for projecting working places[12] and the proposal of a »uniform ergonomic anthropometric list«[13]. Thus the anthropometric list encompassed 130 measurements taken on each examinee. They can be divided into four functional groups: the group of measurements for assessing the morphological status, the group of measurements for clothes, the group of measurements for footwear and the group of measurements for ergonomy. Measurers were trained and taught to follow the measuring protocol. The object of this work is a group of measures for garments i.e. of anthropometric measures used for determining the dimensions of clothes and the size system of clothes encompassing 50 sizes (variables) given in Table 1 (descriptively and in code). All variables, except V2, V49 and V50, are measured according to ISO 8559[10].

In accordance with the subject of this work (the structure of body measures for determining garment sizes), statistical data processing and analysis were carried out covering 50 chosen anthropometric variables (Table 1) by means of univariate and multivariate methods. Since the emphasis is on structural distinctions, the variables are described by standardized values. Assumed regional differences *a priori* defined by investigated locations (Jastrebarsko, Koprivnica, Pula, Sinj and Požega), were tested by multivariate analysis of variance, whereas the position of each region within the variables was evaluated by discriminant analysis. It is important to emphasize that the observed variables are multivariate normally distributed which lends legitimacy to the applied methods. All statistical analyses were carried out by means of program package data analysis SPSS 9.0.

Results and Discussion

The differences between variables according to place of investigation i.e. according to regions of the Republic of Cro-

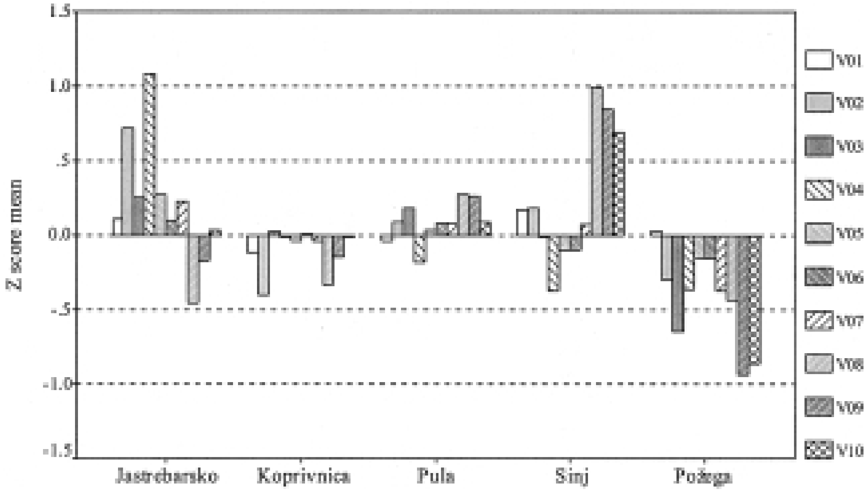

Fig. 1. Mean of standardized values of body measures V1 to V10 in terms of survey locations.

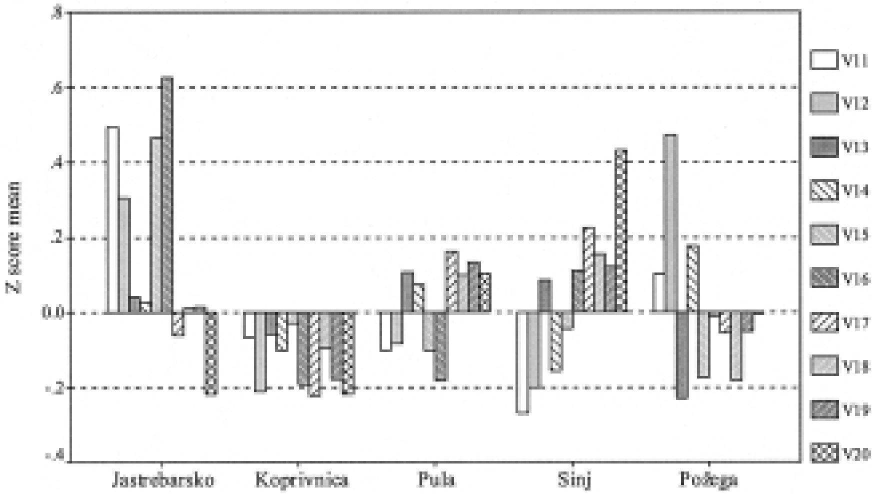

Fig. 2. Mean of standardized values of body measures V21 to V30 in terms of survey locations.

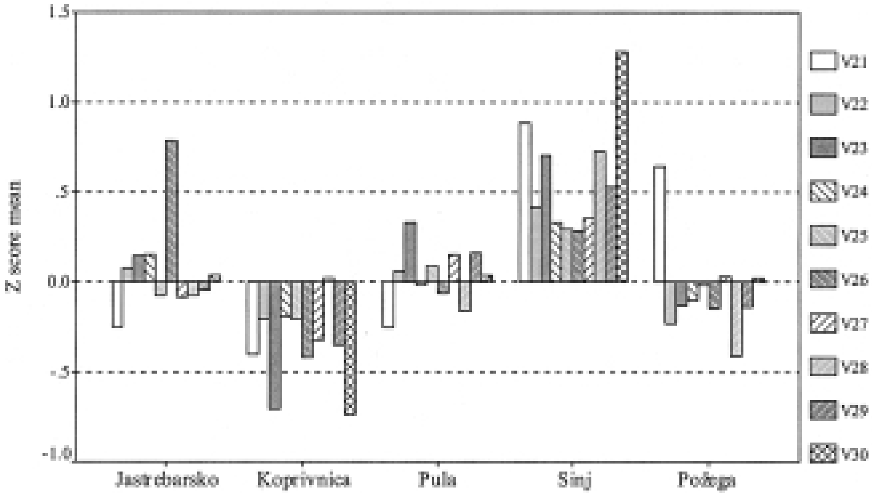

Fig. 3 Mean of standardized values of body measures V21 to V30 in terms of survey locations.

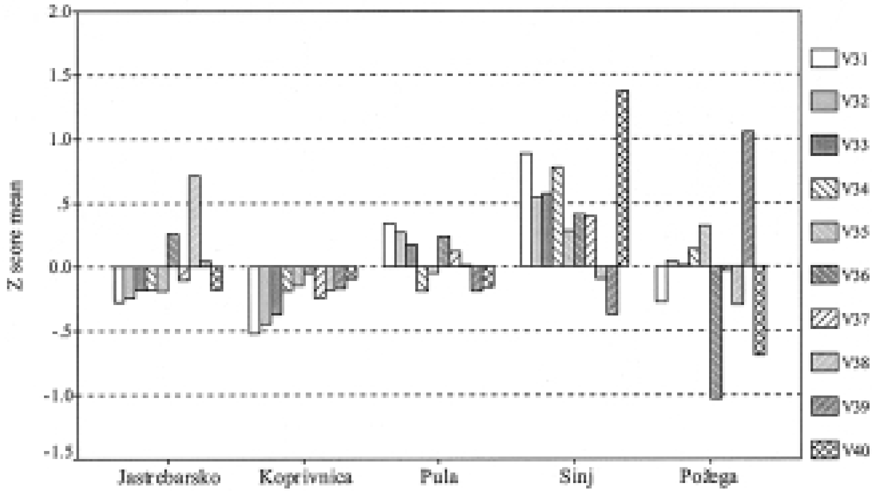

Fig. 4. Mean of standardized values of body measures V31 to V40 in terms of survey locations.

atia are represented on figures 1 to 5 by mean standardized values in such a way that differences can be read from the scale with units expressed by standard deviation. Thus for example the mean arm length (shoulder to wrist, V41) in Sinj differs from that in Požega for more than 1.5 standard deviation (Figure 5).

The assumption of equality of centroids in Croatia can be rejected with high certainty ($p<0.001$) on the ground of results obtained by multivariant variance analysis in the area constituted by 50 variables for determining garment sizes. Thus it is possible to verify the corresponding hypotheses by univariate anal-

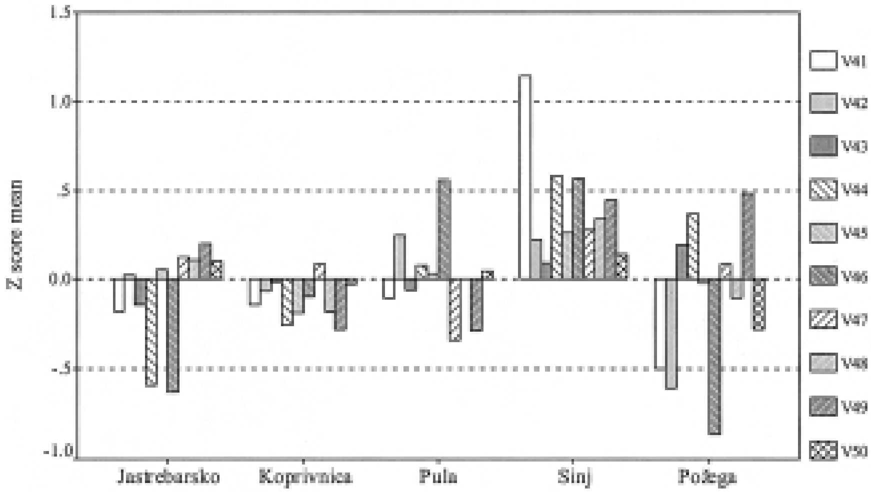

Fig 5. Mean of standardized values of body measures V41 to V50 in terms of survey locations.

TABLE 2
EIGENVALUES

Function	Eigenvalue	% of Variance	Cumulative %	Canonical correl.
1	4.263	39.3	39.3	0.900
2	3.186	29.3	68.6	0.872
3	2.233	20.6	89.2	0.831
4	1.177	10.8	100.0	0.735

ysis of variance, variable by variable. As it is evident from Table 1, Croatian regions differ in all dimensions (variables) for determining garment sizes.

The role and contribution of individual variable to the confirmed differences between regions can be explained on the basis of performed discriminative analysis with regions as *a priori* defined samples. Five groups i.e. five regions can be represented in four-dimensional discriminative space all of which being significant for discriminating the groups. The first discriminant function explains 39.3%, the second 29.3%, the third 20.6%, and the fourth the remaining 10.8% of total variance (Tables 2 and 3).

The contents of individual discriminant functions can be recognized on the grounds on their correlation with starting variables i.e. with original body measures for determining garment sizes. Table 4 presents those correlations arranged according to their absolute value. As it is evident, the first discriminant function is defined by the thigh length (V46), the shoulder width (V09), the shoulder length (V08), the back waist length (cervical to waist, V31), the armscye girth (V39), the back width (V10) and the waist to hips (V36). The second discriminant function is defined primarily by the ankle girth (V21), the hand length (V44), the cervical to knee hollow (V32), cervical

TABLE 3
WILKS' LAMBDA (Λ)

Test of functions	Wilks' Λ	χ^2	df	p
1 through 4	0.006	21382	200	<0.001
2 through 4	0.034	14342	147	<0.001
3 through 4	0.142	8272	96	<0.001
4	0.459	3297	47	<0.001

TABLE 4
POOLED WITHIN-GROUPS CORRELATIONS BETWEEN DISCRIMINATING VARIABLES AND STANDARDIZED CANONICAL DISCRIMINANT FUNCTIONS (STRUCTURE MATRIX)

Code[a]	Function[b]			
	1	2	3	4
V46[a]	**0.304**	0.006	–0.126	–0.047
V09	**0.280**	–0.021	0.065	0.045
V08	**0.253**	0.135	0.043	0.034
V31	**0.222**	0.160	0.017	0.164
V39	**–0.203**	0.147	–0.026	0.044
V10	**0.203**	–0.066	0.107	0.022
V36	**0.200**	–0.135	0.048	0.124
V42	**0.127**	–0.058	–0.020	0.067
V18	**0.051**	0.001	0.001	0.048
V50	**0.049**	–0.031	0.023	0.040
V13	**0.047**	–0.020	–0.008	0.046
V21	0.022	**0.279**	0.179	0.025
V44	0.068	**0.208**	0.000	–0.060
V32	0.114	**0.148**	–0.018	0.127
V33	0.105	**0.129**	0.021	0.102
V03	0.082	**–0.120**	–0.013	0.083
V35	0.001	**0.110**	0.030	–0.010
V20	0.077	**0.091**	0.014	0.029
V37	0.073	**0.077**	0.016	0.069
V25	0.053	**0.060**	0.011	0.060
V43	–0.011	**0.050**	0.011	–0.040
V06	0.010	**–0.038**	–0.022	0.035
V40	0.282	0.067	**0.292**	–0.060
V41	0.211	0.076	**0.212**	–0.027
V28	0.121	0.009	**0.157**	–0.060
V49	–0.041	0.131	**0.157**	0.095
V34	0.068	0.136	**0.152**	–0.021
V47	–0.024	0.011	**0.143**	–0.053

Code[a]	Function[b]			
	1	2	3	4
V23	0.159	0.150	0.032	**0.351**
V26	0.017	–0.012	0.142	**0.340**
V02	0.043	–0.040	0.079	**0.335**
V30	0.204	0.273	0.224	**0.306**
V04	–0.077	–0.207	0.114	**0.275**
V38	–0.004	–0.095	0.058	**0.246**
V16	–0.031	–0.026	0.126	**0.192**
V12	–0.098	0.049	0.012	**0.134**
V11	–0.076	–0.048	0.032	**0.130**
V29	0.107	0.085	0.032	**0.127**
V15	–0.016	–0.069	0.068	**0.109**
V27	0.066	0.090	0.001	**0.104**
V24	0.045	0.028	0.067	**0.095**
V22	0.082	0.027	0.054	**0.094**
V05	–0.001	–0.047	0.007	**0.085**
V48	0.049	0.030	0.061	**0.082**
V07	0.050	–0.060	0.016	**0.082**
V19	0.037	0.028	–0.015	**0.081**
V17	0.058	0.050	–0.016	**0.081**
V45	0.036	0.041	0.035	**0.076**
V01	0.010	0.025	0.043	**0.053**
V14	–0.028	0.023	–0.044	**0.052**

[a] Variables ordered by absolute size of correlation within function

[b] Bold font style denote largest absolute correlation between each variable and any discriminant function

height (V33) and the neck girth (V03). The third discriminant function that is worth analyzing is determined by the length of the upper arm length (shoulder

TABLE 5
CLASSIFICATION RESULTS[a]

Original		Predicted Group Membership					Total
		Jastrebarsko	Koprivnica	Pula	Sinj	Požega	
Jastrebarsko	Count	581	35	3	0	1	620
Koprivnica		48	1111	37	2	2	1200
Pula		6	37	1175	2	1	1221
Sinj		0	4	29	585	0	618
Požega		2	1	3	0	603	609
Jastrebarsko		93.7	5.6	0.5	0.0	0.2	100.0
Koprivnica		4.0	92.6	3.1	0.2	0.2	100.0
Pula	%	0.5	3.0	96.2	0.2	0.1	100.0
Sinj		0.0	0.6	4.7	94.7	0.0	100.0
Požega		0.3	0.2	0.5	0.0	99.0	100.0

[a] 95.0% of original grouped cases correctly classified

to elbow, V40), the arm length (shoulder to wrist, V41), and to a lesser degree by the ankle height (V28) and by the shoulder tilt (V49).

The centroid position of individual regions at the level of the first two discriminant functions (Figure 6) corresponds to the size of the body expressed particularly by the length of the upper leg and the measures in shoulder and back area, except the circumference of the armpit which acts in the opposite way from the rest of the measures defining the first discriminant function (the mean value is the highest in Požega and the lowest in Sinj). The order of regions in terms of body size – northeastern, central, northwestern, southwestern and southern – is disarranged only by the northeast region (Požega) showing the relatively highest mean values in measures defining the second discriminant function. The remaining regions follow the growth of the body size on the level of the second discriminant function in the same order as in the first discriminant function. There is a certain difference in the fact that the northwestern and the southwestern regions have switched places. A possible ex-

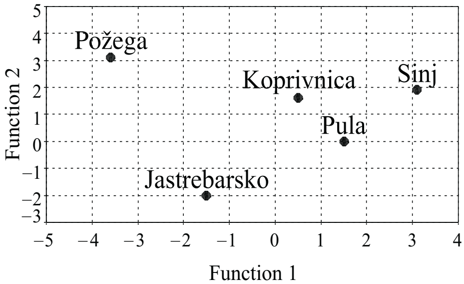

Fig. 6. Positions of regions at the level of the first and second discriminative function.

planation of this can be found in the robustness of the southeast region examinees' body build expressed primarily by the circumference of the ankle and the size of the hand; this region stretches to the west overlapping the northwestern region.

The results of the classification of examinees by means of discriminative analysis confirm the significance of interregional body differences: namely, 95% of all examinees were correctly categorized. The lowest percentage of correctly categorized examinees was in northwest Croatia (Koprivnica, 92.6%), while the northeast region (Požega) which is the most remote (Figure 6) from other regions, contains 99% correctly categorized examinees (Table 5).

The above considerations lead to the conclusion that the determination of the system of garment sizes is rather complex, not only due to a large number of necessary measurements but also due to interregional body differences even in cases of sex- and age-limited population segments, in this case men aged 19 to 20. Namely, garment manufacturers can obtain (and demand) much more information than is indispensable for establishing a system of garment sizes for a definite target population e.g. classifying it in terms of chest circumference or of body height.

Acknowledgements

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STRUKTURA TJELESNIH MJERA ZA ODREĐIVANJE ODJEVNIH VELIČINA MLADIH MUŠKARACA HRVATSKE

S A Ž E T A K

Određivanje i unapređivanje sustava odjevnih veličina odjeće zahtijeva upoznavanje proporcije čovječjeg tijela odnosno antropometrijskih mjera određene populacije. Za stvaranje ili unapređenje sustava odjevnih veličina potrebno je ustanoviti pravilan međusobni odnos pojedinih dijelova tijela odnosno pojedinih tjelesnih mjera. Pri tome se često zanemaruju moguće međuregionalne (interpopulacijske) tjelesne različitosti koje mogu biti znatne i u slučajevima spolno i dobno ograničenih populacija. Pokazuje to i provedeno istraživanje tjelesnih mjera za određivanje odjevnih veličina na slučajno odabranom uzorku 4268 zdravih i normalno razvijenih muškaraca u dobi od 18 do 22 godine. Istraživanje je realizirano na pet lokacija 1993. godine od kojih svaka predstavlja određenu regiju Republike Hrvatske: Jastrebarsko središnju, Koprivnica sjeverozapadnu, Pula jugozapadnu, Sinj južnu i Požega sjeveroistočnu. Kao mjerni instrument odabrano je 50 tjelesnih mjera prema važećim ISO standardima za odjevne veličine. Međuregionalne razlike su značajne u svim tjelesnim mjerama. Uloga i doprinos pojedinih mjera tim razlikama utvrđena je diskriminacijskom analizom s regijama kao a priori definiranim uzorcima. Pored razlika u veličini tijela ustanovljene su značajne razlike u građi tijela ponajprije sjeveroistočne regije Hrvatske i djelomično sjeverozapadne. Osim velikog broja potrebnih mjerenja upravo razlike u građi tijela čine određivanje sustava odjevnih veličina veoma kompleksnim. Za uspostavu prikladnog i svrhovitog standarda za odjevne veličine nužno je osigurati više informacija umjesto uvrštavanja entiteta ciljane populacije u unaprijed određene razrede po opsegu grudi i visini tijela.

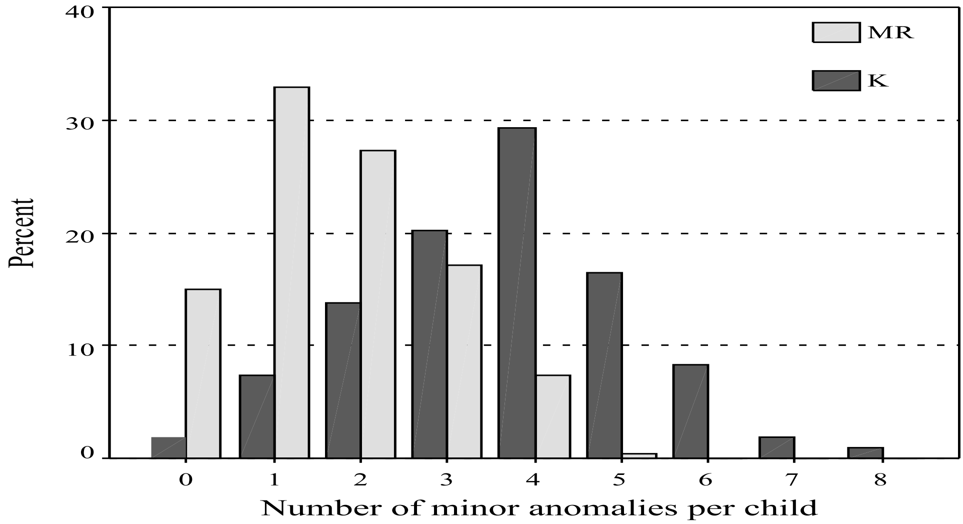

Fig. 1. Mentally retarded and control children groups according to the number of minor anomalies per child after Waldrop. MR = mentally retarded children (N = 109), K = control group (N = 246).

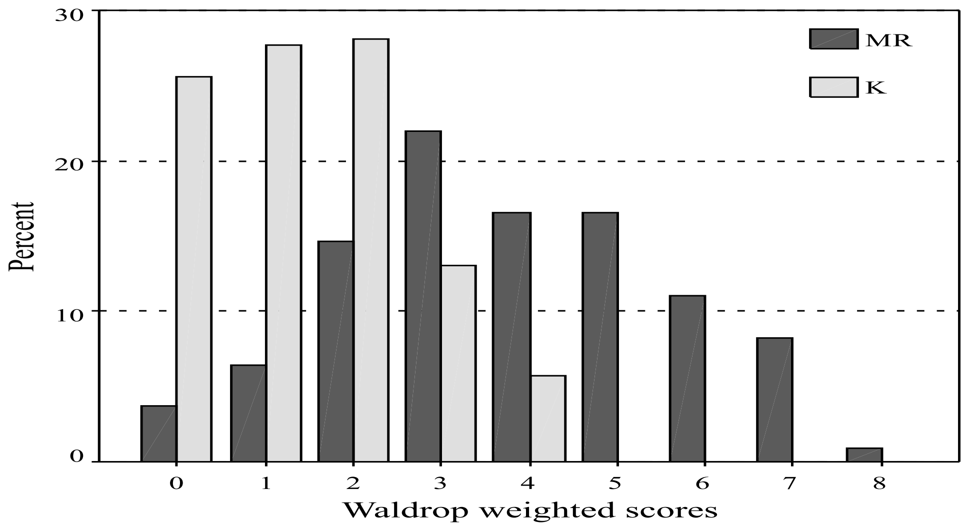

Fig. 2. Waldrop weighted scores for mentally retarded children and their controls. MR = mentally retarded children (N = 109), K = control group (N = 246).

children. In well children, however, lower weighted scores (from 0 to 2) predominated. High weighting scores (5 or higher) were found in 36.7% of MR children. Not a single child in the well-child group had a weighting score 5 or higher. Among

MR children, the average frequency of ffff fffff ccccc k k k kkkkkkk k kkk kk kkkkk kkkkk kkkk kkkkk kkkk kkkk kkkkk kkkkk