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# Reliability estimation for the lower bound of latent dimensions of morphological variables

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## Abstract

**Proposition 1.**

Coefficients $\gamma_p$ vary in the range (0,1) and can assume the value 1 if and only if $\mathbf{P} = \mathbf{I}$, so if all variables have been estimated without errors, and the value is 0 if and only if both $\mathbf{P} = \mathbf{0}$ and $\mathbf{R} = \mathbf{I}$, so if the total variance of all variables consists only of the variance of the errors of estimate, the variables from V have a spherical normal distribution.

**Proof:**

If the total variance of each variable from some set of variables consists only of the variance of the errors of estimate, it is then necessary that $\mathbf{E}^2 = \mathbf{I}$ and $\mathbf{R} = \mathbf{I}$, therefore all coefficients $\gamma_p$ equal zero. The first part of the Proposition is evident from the definition of coefficients $\gamma_p$; this means that reliability of each latent dimension, irrespective of the manner of defining that latent dimension, equals 1 if variables, from which that dimension has been derived, are estimated without errors.

However, the matrix of the reliability coefficients $\mathbf{P} = (\rho_j)$ is often unknown, and therefore the matrix of the variances of the errors of estimate $\mathbf{E}^2$ is also unknown. But, if variables from V are chosen so as to represent some universe of variables U with the same field of meaning, the upper bound for the variances of the errors of estimate is defined by the elements of the matrix $\mathbf{U}^2$ (Guttman, 1945; 1953), hence by the unique variances of those variables. Consequently, in that case, the lower bound for the latent dimensions' reliability can be estimated by the coefficients $\beta_p$… which have been derived by the procedure identical to that used to derive the coefficients $\gamma_p$ with the definition $\mathbf{E}^2 = \mathbf{U}^2$, therefore in the same way Guttman derived his $\lambda_6$ estimate.

**Key words:** / distribution / set / variable / coefficient / variance /

# 1. Introduction

The concept of morphological characteristics implies the system of the structure of morphological dimensions bounded by a limited number of the manifest, directly measurable anthropometric measures.

In the course of physical growth and development, each body part follows a different curve, reaching its maximum at different point of time. For this reason, the morphological structure of the body, which is based on mutual interactions between all anthropometric measures at different stages of development, can be different, that is, individual morphological characteristics can at different points of time participate with different coefficients of participation in a particular morphological structure of the body.

However, the development of individual morphological characteristics is also largely governed by the structure of endogenous and exogenous factors which determine different physiological age for different subjects in the same development period. In some morphological characteristics, especially those mostly affected by exogenous factors, variations within the population of the same chronological age can be very high.

On the basis of many to date studies carried out by applying the **factorial approach and procedures** (Momirović, Kurelić, Stojanović, Hošek, and others), it can be safely argued that morphological space is essentially four-dimensional, which means that we have a model of the structure of morphological characteristics that consists of the following four factors:

**L – longitudinal dimensionality of the skeleton,** responsible for the bone growth in length;

**T – transversal dimensionality of the skeleton,** responsible for the bone growth in width;

**V – body mass and volume,** responsible for total body mass and volumes;

**M – subcutaneous adipose tissue,** responsible for total body fat amount.

As the longitudinal dimensionality of the skeleton correlates most with the transversal dimensionality of the skeleton, and body mass and volume correlate with the subcutaneous adipose tissue, with respect to gender and age, these factors are sometimes connected to form two factors: **the dimensionality of the skeleton** (longitudinal and transversal) and **body volume** (body mass and volume and subcutaneous adipose tissue).

Interaction factorial procedures were used to also isolate **a general factor of growth** (E), responsible for the total growth of all morphological characteristics.

A great number of studies in kinesiological anthropology deal with **genetics and somatotypes.** Namely, in the literature the terms such as **constitutiology** (constitution, constitutional type, or body type or build) and **somatotypology** (somatotype) are often used in parallel.

Historically viewed, **constitutiology** is the oldest term used in anthropology to determine bodily individuality of man. Today, this term has a broader sense and denotes the wholeness of morphological and functional characteristics (inherited and acquired) that determines the features of body's reactivity (intensity of reaction) and dynamics of ontogenesis. Also, in the literature the concepts of general and individual (chromosomal, physical, biochemical, physiological, neurodynamic) constitution have been developed. Studying the body at different levels (micromorphological, macromorphological, biochemical, etc), one can observe that individual bodily constitutions have a common core (common line) connecting them in the form of genetic program which is realized during ontogenesis and under particular environmental conditions.

**Somatotypology** deals with classifying humans into constitutional types and such attempts date back virtually to the times of Hippocrates (2500 years ago) and his hypotheses about the existence of four structural elements of body type. Even though the systems for identifying the somatotype are numerous (their number equals the number of researchers dealing with this issue), body proportions, the amount of adipose tissue, the development level of the muscular system and skeleton are commonly taken for the criterion and classifications. In this regard, it should be highlighted that there is still no single realistic criterion, i.e. a model, which can be used to select relevant morphological variables, so as to reliably indicate, via an optimal condensation, that some morphological type exists.

On the grounds of different **typologies** (Kretschmer, Conrad, Sheldon), in recent studies the concept accepted by a larger number of authors (Burt, Thurstone, Conrad, and others) starts from the hypothesis that each subject takes a single, relatively stable position on each of several multivariate continuous taxonomic variables. In order to test this hypothesis, it was needed to exclude the classical procedures of 'cluster' analysis and apply the procedures based on the factorial or taxonomic model, the procedures belonging to the family of TAXOBOL algorithms, and thereby to achieve in an adequate way the typological goals of the study.

**Taxonomic (T) approach and procedures.** Despite a scarce number of studies are still applied (Hošek, Stojanović, and others), and regardless of the trends in constitutiology, a general morphological theoretical model is underpinned by the following taxons:

**δ – skeletomorphy,** responsible for skeleton longitudinality and partially bone width;

**π – pycnomorphy,** responsible for the prevalence of adipose tissue;

**α – athletomorphy,** responsible for the size and amount of muscle mass and skeleton dimensionality;

**ε – endomesomorphy,** responsible for the prevalance of muscle and adipose tissue.

Although all mentioned taxons are individually identified, they manifest themselves in an integrated manner and are, more or less, related to other characteristics of the anthropological status.

# 2. Methods

## 1.1.Subject sample

The sample was taken from the population of folk dancers, members of Serbian cultural artistic societies, aged 15-18 years.

Starting from the set up problem, subject and aim of the study, and taking into account the organizational and financial conditions required for conducting the study, the number of subjects included in the sample was maximum in order to make the study procedure regular and to obtain the results as much exact as possible.

The sample itself comprised 117 folk dancers, members of Serbian cultural artistic societies, which is an optimal number for the scheduled study. The subjects had to satisfy the following conditions: subjects' age was defined based on their chronological age, so that the study included the subjects aged 15-18 years, absence of organ and somatic diseases was another requirement, and still another was active membership in cultural artistic societies.

The study was conducted in the cultural artistic societies of Kraljevo, Čačak and Leposavić.

## 1.2.Variable sample

Subjects' morphological characteristics were estimated by applying 20 anthropometric variables, chosen according to the International Biological Program (IBP) to cover the 4D space defined as the longitudinal dimensionality of the skeleton, the transversal dimensionality of the skeleton, body mass and volume, and subcutaneous adipose tissue.

a) Longitudinal dimensionality of the skeleton: body height, sitting height, arm length, leg length, arm span.

b) Transversal dimensionality of the skeleton: biacromial range, bicristal range, wrist diameter, hand width, transverse thoracic diameter.

c) Body mass and volume: body mass, average thorax volume, upper arm volume, lower arm volume, upper leg volume.

d) Subcutaneous adipose tissue: upper arm skin fold, back skin fold, abdominal skin fold, armpit skin fold, lower leg skin fold.

## 1.3.Methods of data processing

The value of any research does not depend only on the sample of subjects and the sample of variables, i.e. on the value of basic information items, but also on the procedures applied to transform and condense information. Some scientific problems can be solved by the help of a larger number of different and sometimes equally valuable methods. However, different conclusions can be inferred from identical basic data and from the results obtained by different methods. That is why the problem of the choice of methods for data processing is rather complex.

To arrive at the satisfactory scientific solutions, the study employed, first of all, correct, adequate, objective and comparable procedures appropriate for the character of the set up problem, enabling the extraction and transformation of corresponding dimensions as well as setting up the regularities within the research area.

Taking into account above mentioned, the procedures chosen for the study were those considered to suit the nature of the problem and those not imposing the restrictions to information items.

In the past years a large number of researchers have misused their position and published an increasing number of quasi-scientific papers not founded primarily on mathematical artifacts. In addition, they are using the existing statistical products, but they have never had any basic understanding of the logic of the majority of multivariate models. That is why particular attention of this paper is directed to statistical data processing and to the choice of algorithms and programs that really have practical value.

If we exclude Mulaik's famous textbook of factor analysis, where there is something about reliability estimation of principal components (Mulaik, 1972) and the work by Kaiser and Caffrey who derived the method of Alpha factor analysis based on maximizing latent dimensions reliability (Kaiser and Caffrey, 1965), it seems that producers of various component and factor analysis and book writers in this area on the class of methods for the analysis of latent structures did not care about how much they can trust the real existence of the latent dimensions obtained by those methods. This fact also applies to the latent dimensions obtained by the orthoblique transformation of principal components, the method that has become a standard procedure for analyzing latent structures, employed by all those who have not acquired information about factor analysis using their fingers when reading seriously written texts in this area, or by those who do not analyze their data using some of poorly conceived, or even worse, written commercial statistical program packages, such as, but not exclusively, SPSS, CSS, Statistica, BMDP and Statgraphics, not to mention other products whose popularity is considerably smaller, but not always because they are essentially less good than those exclusively applied today by ignorant scientists and special type of human beings referred to as data processor species.

Indeed, one paper that proposes a competitive application of the semi-orthogonal transformations of principal components in exploratory and confirmatory analyses of latent structures suggests the use of a procedure for reliability estimation of latent dimensions founded on Cronbach's strategy for generalizability evaluation. However, that procedure is as justifiable as the assumptions from which the Cronbach $\alpha$ coefficient has been derived, today called after him for unknown reasons, despite the fact that totally identical measure, long before him, and with virtual assumptions, was offered by Spearman and Brown, Kuder and Richardson, Guttman, and in somewhat more simplified form described by Momirović, Wolf and Popović (1999), as well as by some psychometricians who worked in the nascent stage of the measurement theory development and in the age not caught in the PC revolution.

Therefore, the aim of this paper is to propose a measure for the lower bound of reliability of the latent dimensions obtained by the semi-orthogonal transformations of principal components.

All data collected in this study were processed at the Center for Multidisciplinary Studies, Faculty of Sports and Physical Education, University of Priština, using the system of data processing program developed by Popović, D. (1980; 1993) and Momirović, K. and Popović, D. (2003).

## Semi-orthogonal transformation of principal components

Let **Z** be the standardized data matrix obtained by the description of some set E of n entities on some set V of m quantitative, normally or at least elliptically distributed variables. Let **R** be the matrix of those variables inter-correlations. Assume that **R** is for certain a regular matrix and that the hypothesis that variables from V have a spherical distribution can be safely rejected, and therefore the matrix eigenvalues being the correlation in population P wherefrom the sample E has been extracted are equal. Let $\mathbf{U}^2 = (\mathbf{diag\ R}^{-1})^{-1}$.

Guttman estimation of unique variances of the variables from V, and let $\lambda_p$ , p = 1, …m be the eigenvalues of the matrix **R**. Let c = trag (I – $U^2$). Let us define scalar **k** such that $\Sigma_p^k \lambda_p > c$, $\Sigma_p^{k-1} \lambda_p < c$. Now, k is the number of principal components of the matrix **Z,** determined based on the Štalec and Momirović PB criteria (Štalec and Momirović, 1971).

Let $\Lambda = (\lambda_p)$; p = 1, … k be the diagonal matrix of the first eigenvalues of matrix **R** and let $\mathbf{X} = (x_p)$ be the matrix of eigenvectors appended to them, scaled such that $\mathbf{X}^t\mathbf{X} = \mathbf{I}$. Let **T** be some orthonormal matrix such that it optimizes the function $\mathbf{XT} = \mathbf{Q} = (\mathbf{q}_p)$ ; p (**Q**) = extremum, $\mathbf{T}^t\mathbf{T} = \mathbf{I}$ , where p(**Q**) is some parsimonious function e.g. ordinary Varimax function $\Sigma_j^m \Sigma_p^k q_{jp}^4 - \Sigma_p^k (\Sigma_j^m q_{jp}^2)^2$ = maximum, where the coefficients $q_{jp}$ are the elements of the matrix **Q** (Kaiser, 1958).

Now, the transformation of principal components, defined by the vectors in the matrix **K = ZX**, into semi-orthogonal latent dimensions determined by the type II of the orthoblique procedure (Harris and Kaiser, 1964), is defined by the operation **L = KT = ZXT**. The covariance matrix of those dimensions is $\mathbf{C} = \mathbf{L'L}\ \mathbf{n}^{-1} = \mathbf{Q'RQ}$ $\mathbf{T}^t\mathbf{\Lambda T}$; let us denote with $\mathbf{S}^2 = (s_p^2)$ = diag **C** the matrix of their variances. If latent dimensions are standardized by the operation $\mathbf{D} = \mathbf{LS}^{-1}$, their inter-correlations will be in the matrix $\mathbf{M} = \mathbf{D}^t\mathbf{D}n^{-1} = \mathbf{S}^{-1}\mathbf{T}^t\mathbf{\Lambda T S}^{-1}$ ; note that neither **C,** and therefore nor **M,** can be the diagonal matrices, so thus obtained latent dimensions are not orthogonal in the entity space from E.

The correlations matrix, between the variables from V and latent variables, commonly referred to as the factor structure matrix, will be $\mathbf{F} = \mathbf{Z}^t\mathbf{D}n^{-1} = \mathbf{RXTS}^{-1} = \mathbf{X\Lambda TS}^{-1}$; since the elements of matrix **F** are orthogonal projections of the vectors from **Z** onto the vectors from **D**, those vectors coordinates in the space spanned by the vectors from **D** are the elements of the matrix $\mathbf{A} = \mathbf{FM}^{-1} = \mathbf{XTS}$

However, as $\mathbf{A}^t\mathbf{A} = \mathbf{S}^2$ the latent dimensions obtained by this procedure are orthogonal in the space spanned by the vectors of the variables from **Z**; quadratic norms of the vectors of those dimensions in the space of the variables equal the variances of these dimensions.

## Reliability estimation of the lower bound of latent dimensions

For simplicity and clear algebraic and geometric meaning and latent dimensions and identification structures appended to those dimensions, reliability of latent dimensions obtained by the orthoblique transformation of principal components can be determined clearly and unequivocally.

Let $\mathbf{G} = (\mathbf{g}_{ij})$; I = 1, … n; j = 1, …m and let us allow it be the unknown matrix of the errors of estimate in describing the set E on the set V. The true entities results matrix from E on the variables from V will then be $\mathbf{Y} = \mathbf{Z} - \mathbf{G}$.

If we assume, in accordance with classical measurement theory (Gulliksen, 1950; Lord and Novick, 1968; Pfanzagl, 1968), that matrix **G** is such that $\mathbf{Y}^t\mathbf{G} = \mathbf{0}$ i $\mathbf{G}^t\mathbf{G}n^{-1} = \mathbf{E}^2 = (\mathbf{e}_{jj}^2)$, where $E^2$ is a diagonal matrix, the true results covariance matrix will be $\mathbf{H} = \mathbf{Y}^t\mathbf{Y}n^{-1} = \mathbf{R} - \mathbf{E}^2$ if $\mathbf{R} = \mathbf{Z}^t\mathbf{Z}n^{-1}$ is the variables inter-correlations matrix from V defined on the set E.

Let us assume that the reliability coefficients of the variables from V are known; let **P** be a diagonal matrix, whose elements $\rho_j$ are those reliability coefficients. Then the variance of the errors of estimate for standardized results on the variables from V will be exactly the elements of the matrix $\mathbf{E}^2 = \mathbf{I} - \mathbf{P}$.

Now, the real values on the latent dimensions will be the elements of the matrix $\mathbf{\Gamma} = (\mathbf{Z} - \mathbf{G})\mathbf{Q}$ along with the covariance matrix $\mathbf{\Omega} = \mathbf{\Gamma}^t\mathbf{\Gamma}n^{-1} = \mathbf{Q}^t\mathbf{HQ} = \mathbf{Q}^t\mathbf{RQ} - \mathbf{Q}^t\mathbf{E}^2\mathbf{Q} = (\omega_{pq})$.

Accordingly, the latent dimensions true variances will be the diagonal elements of the matrix **Ω;** let us denote those elements with $\omega_p^2$. On the basis of formal definition of some variable reliability coefficient $\rho = \delta_t^2 / \delta^2$ where $\delta_t^2$ is the true variance of some variable and $\delta^2$ is the total variance of that variable, that is, the variance that also includes the error variance, then the latent dimensions reliability coefficients, if we know the reliability coefficients of the variables from which those dimensions are derived, will be $\gamma_p \boldsymbol{\gamma}_\mathbf{p} = \boldsymbol{\omega}_\mathbf{p}^\mathbf{2} / \mathbf{s}_\mathbf{p}^\mathbf{2} = 1 - (\mathbf{q}_p^t\mathbf{E}^2\mathbf{q}_p)(\mathbf{q}_p^t\mathbf{Rq})^{-1}$ p 1,.....,k

**Proposition 1.**

Coefficients $\gamma_p$ vary in the range (0,1) and can assume the value 1 if and only if $\mathbf{P} = \mathbf{I}$, so if all variables have been estimated without errors, and the value is 0 if and only if both $\mathbf{P} = \mathbf{0}$ and $\mathbf{R} = \mathbf{I}$, so if the total variance of all variables consists only of the variance of the errors of estimate, the variables from V have a spherical normal distribution.

**Proof:**

If the total variance of each variable from some set of variables consists only of the variance of the errors of estimate, it is then necessary that $\mathbf{E}^2 = \mathbf{I}$ and $\mathbf{R} = \mathbf{I}$, and therefore all coefficients $\gamma_p$ equal zero. The first part of the Proposition is obvious from the definition of the coefficients $\gamma_p$; this means that reliability of each latent dimension, regardless of the manner of determining that latent dimension, equals 1 if the variables, from which that dimension has been derived, are estimated without errors.

However, the matrix of reliability coefficients $\mathbf{P} = (\rho_j)$ is often unknown, and therefore the matrix of the variances of the errors of estimate $\mathbf{E}^2$ is unknown. However, if variables from V are chosen in such way to represent some universe of variables U with the same field of meaning, the upper bound for the variances of the errors of estimate is defined by the elements of the matrix $\mathbf{U}^2$ (Guttman, 1945; 1953), hence by the unique variances of those variables. Accordingly, in that case, the lower bound for the latent dimensions' reliability can be estimated by the coefficients $\boldsymbol{\beta}_p = 1 - (\mathbf{q}_p^t\mathbf{U}^2\mathbf{q}_p)(\mathbf{q}_p^t\mathbf{R}\mathbf{q}_p)^{-1}$ $p = 1,..., \mathbf{k}$ which have been derived by the procedure identical to that used to derive the coefficients $\gamma_p$ with the definition $\mathbf{E}^2 = \mathbf{U}^2$ , therefore in the same way Guttman derived his $\lambda_6$ estimate.

## 3. Discussion

Morphological characteristics of human anthropological status most often imply a particular system of the basic anthropometric latent dimensions. Today, a serious scheduling of any moving activity cannot be done without knowledge about the morphological structure, its effects on the activity as well as the effects of that activity on the morphological characteristics development.

Morphological characteristics and somatotype features have always attracted researchers' interest on account of the need to identify the regularities of development in general, especially athlete's body, and therefore to establish the contribution of those characteristics to realizing particular motor abilities and habits.

THE MATRIX OF PRINCIPAL COMPONENTS OF ANTHROPOMETRIC VARIABLES

Tab. 1.

| | FAC1 | FAC 2 | FAC 3 | FAC 4 | $h^2$ |
|---|---|---|---|---|---|
| AVIS | ,84 | -,36 | ,24 | ,00 | .90 |
| ASV | ,81 | -,29 | ,15 | ,01 | .77 |
| ADR | ,74 | -,39 | ,26 | ,03 | .78 |
| ADN | ,77 | -,39 | ,33 | ,01 | .86 |
| ARR | ,86 | -,38 | ,17 | ,00 | .92 |
| AŠR | ,81 | -,08 | -,08 | ,11 | .69 |
| AŠK | ,81 | -,08 | ,05 | ,08 | .67 |
| ADRZ | ,75 | -,33 | -,19 | -.10 | .72 |
| AŠŠ | ,66 | -,30 | -,19 | -,30 | .66 |
| ATDGK | ,84 | ,15 | -,21 | -,07 | .78 |
| AMAS | ,18 | ,01 | -,51 | ,49 | .54 |
| ASOGK | ,86 | ,12 | -,30 | ,04 | .86 |
| AONADL | ,85 | ,24 | -,28 | ,02 | .87 |
| AOPODL | ,86 | ,11 | -,35 | ,00 | .88 |
| AONATK | ,57 | ,35 | ,00 | ,11 | .46 |
| AKNN | ,56 | ,63 | ,17 | -,16 | .76 |
| AKNL | ,67 | ,59 | ,00 | -,03 | .81 |
| AKNT | -,01 | -,02 | ,21 | ,76 | .63 |
| AKNPAZ | ,50 | ,47 | ,36 | ,19 | .63 |
| AKNPOT | ,50 | ,63 | ,34 | -,12 | .77 |
| Charcte. roots | 10.18 | 2.49 | 1.31 | 1.05 | |
| % | 50.94 | 12.48 | 6.56 | 5.28 | |
| Cumula. % | 50.94 | 63.43 | 69.99 | 75.28 | |

THE MATRIX OF ANTHROPOMETRIC VARIABLES TAXON

Tab. 2.

| | OBL1 | OBL2 | OBL3 | OBL4 |
|---|---|---|---|---|
| AVIS | ,97 | ,02 | ,08 | ,04 |
| ASV | ,85 | ,05 | -,00 | ,01 |
| ADR | ,94 | -,03 | ,11 | ,09 |
| ADN | ,99 | -,01 | ,17 | ,10 |
| ARR | ,97 | -,01 | ,01 | ,01 |
| AŠR | ,58 | ,18 | -,29 | -,00 |
| AŠK | ,63 | ,23 | -,14 | ,03 |
| ADRZ | ,69 | -,10 | -,24 | -,24 |
| AŠŠ | ,61 | -,09 | -,12 | -,41 |
| ATDGK | ,34 | ,40 | -,34 | -,23 |
| AMAS | -,10 | -,09 | -,76 | ,19 |
| ASOGK | ,34 | ,35 | -,48 | -,17 |
| AONADL | ,24 | ,47 | -,46 | -,18 |
| AOPODL | ,33 | ,32 | -,50 | -,23 |
| AONATK | ,08 | ,56 | -,20 | ,05 |
| AKNN | -,07 | ,89 | ,07 | -,17 |
| AKNL | -,04 | ,84 | -,16 | -,09 |
| AKNT | ,10 | -,00 | -,19 | ,79 |
| AKNPAZ | ,10 | ,74 | ,08 | ,28 |
| AKNPOT | -,03 | ,91 | ,21 | -,00 |

THE MATRIX OF THE STRUCTURE ANTHROPOMETRIC VARIABLES

Tab. 3.

| | OBL1 | OBL2 | OBL3 | OBL4 |
|---|---|---|---|---|
| AVIS | ,94 | ,39 | -,25 | -,12 |
| ASV | ,87 | ,40 | -,31 | -,14 |
| ADR | ,87 | ,31 | -,19 | -,06 |
| ADN | ,90 | ,34 | -,15 | -,05 |
| ARR | ,96 | ,38 | -,32 | -,15 |

Table continued on next page...

| ... Table continued from previous page | | | | |
|---|---|---|---|---|
| AŠR | ,76 | ,49 | -,53 | -,15 |
| AŠK | ,77 | ,52 | -,42 | -,11 |
| ADRZ | ,77 | ,26 | -,48 | -,38 |
| AŠŠ | ,68 | ,22 | -,35 | -,53 |
| ATDGK | ,67 | ,65 | -,58 | -,37 |
| AMAS | ,08 | ,01 | -,68 | ,14 |
| ASOGK | ,69 | ,63 | -,70 | -,32 |
| AONADL | ,64 | ,70 | -,68 | -,32 |
| AOPODL | ,68 | ,61 | -,72 | -,37 |
| AONATK | ,38 | ,64 | -,36 | -,04 |
| AKNN | ,29 | ,86 | -,12 | -,20 |
| AKNL | ,38 | ,88 | -,36 | -,19 |
| AKNT | ,02 | -,00 | -,15 | ,75 |
| AKNPAZ | ,33 | ,74 | -,10 | ,19 |
| AKNPOT | ,26 | ,85 | ,00 | -,07 |

INTER-CORRELATIONS BETWEEN OBLIMIN FACTORS

Tab.4.

| | OBL1 | OBL2 | OBL3 | OBL4 |
|---|---|---|---|---|
| OBL1 | 1,00 | ,41 | -,34 | -,18 |
| OBL2 | ,41 | 1,00 | -,23 | -,10 |
| OBL3 | -,34 | -,23 | 1,00 | ,09 |
| OBL4 | -,18 | -,10 | ,099 | 1,00 |

The start matrix for identifying the structure in component analysis is the total matrix of inter-correlations. From the thus obtained matrix of inter-correlations 75.28% of variability of the applied system of variables is interpreted by the component analysis. Using Guttman $\lambda_6$ criterion, four principal components were obtained with characteristic roots fulfilling the specified criterion (Tab. 1).

The first principle component with the characteristic root of 10.18 and variance of 50.94% is explained by all variables of longitudinal, transversal and circular dimensionality, as well as two variables for estimating dancers' back and armpit adiposity (AKNL and AKNPAZ). Based on high correlations between mentioned variables and the first principal component, it can be safely assumed that it behaves as a general factor of young dancers' growth and development.

The second principal component explains the total of 12.48% of the common variance. It is a dual factor of measures for estimating the upper arm subcutaneous adipose tissue (AKNNAD) and the lower leg subcutaneous adipose tissue (AKNPOT), and based on this factor it can be concluded that mentioned ballast fat tissue is a significant but not dominant characteristic of selected young dancers.

The third principal component is also single, i.e., the factor of body mass (AMAS), and the fourth component, also a single one, is the factor of abdominal skin fold (AKNT).

The communality size for all variables is satisfactory.

In order to obtain the parsimonius structure, to make such clear structure even more simplified, the obtained initial coordinate system was transformed into an oblique oblimin position, with the same number of factors retained afterwards. For the reason that the applied transformation method yields the total of three matrices, the matrix of parallel variable projections onto the factors (Tab. 2), the matrix of orthogonal variable projections onto the factors (Tab. 3) and the matrix of obtained factors inter-correlations (tab. 4), all three matrices were simultaneously interpreted.

The first oblimin factor of the largest projections has longitudinal and transversal dimensionalities with the variables. It can be interpreted no doubt as a general factor of the skeleton growth in young, selected dancers.

The second oblimin factor is defined by the variables for adipose tissue estimation in young dancers. The highest saturation of this factor is provided by the variables such as lower leg skin fold (AKNPOT), upper arm skin fold (AKNN), back skin fold (AKNL), armpit skin fold (AKNPAZ) as well as by a single variable for estimating the skeleton circular dimensionality of the upper leg volume (AONAT). This is a factor not generated by several years' training process, because the sample of subjects consists of young dancers and the factor is the result of endogenous effects. This factor can be defined as the factor of subcutaneous adipose tissue or endomorphy.

The third oblimin factor is also easy to interpret. It represents the factor of the volume and body mass, i.e., the variables that have an important role in the total body mass percentage.

The fourth oblimin factor is a single factor of abdominal skin fold, so this must be the product of hyperfactorization.

Of the isolated factors, statistically significant correlations exist between the first three oblimin factors, which makes sense because the young selected dancers have somewhat larger accumulation of subcutaneous adipose tissue and voluminosity which correlate with a general factor of growth.

Some morphological characteristics of dancers have a considerable correlation level with folk dancing achievement. In a series of studies it has been found that tall dancers and those with longer legs and arms have the advantage over shorter dancers, that is, those with short extremities, their moves in dancing look more elegant, whereas dancers having higher amount of adipose tissue are superior in rhythmic structures. The impact level of specific morphological structure in folk dancing achievement should be identified by determining the correlation degree between total anthropometric test battery and dancing achievement. It can be expected that the length of arm, leg, foot, biacromial range, weight, volume of thorax, upper arm, lower arm and upper leg, hand and foot width, wrist diameter, abdominal and back skin fold are all in a more significant correlation with dancing achievement than other measures. From all above mentioned it follows that the structure obtained in the morphological space corresponds to the body build of folk dances performers.

# 4.Conclusion

The aim of the study was to identify the structure of morphological dimensions in dancers performing folk dances.

In order to identify the structure of the treated anthropometric dimensions, 117 dancers, members of Serbian cultural artistic societies, were examined.

To estimate the subjects' morphological characteristics, 20 anthropometric variables were applied, chosen according to the International Biological Program (IBP) to cover the four-dimensional space defined as the longitudinal dimensionality of the skeleton, the transversal dimensionality of the skeleton, body mass and volume, and subcutaneous adipose tissue.

All data collected in this study were processed at the Center of Multidisciplinary Studies, Faculty of Sport and Physical Education, University of Priština, using the system of programs for data processing developed by Popović, D. (1980), (1993) and Momirović, K. and Popović, D. (2003).

To identify the latent morphological structure in dancers, the method of the Principal Components Factor Analysis was applied. Using the Guttmann $\lambda_6$ criterion, four principal components were obtained, whose characteristic roots fulfill the specified criterion (Tab. 1).

The first principal component with a characteristic root of 10.18 and variance of 50.94% is interpreted by all variables of longitudinal, transversal and circular dimensionality, as well as by two variables for the estimation of back and armpit adiposity in boxers (AKNL and AKNPAZ). On the grounds of high correlations between mentioned variables and the first principal component, it can be safely assumed that that it behaves as a general factor of growth and development in young dancers.

The second principal component interprets the total of 12.48% of the common variance. It represents a dual factor of measures for estimating the upper arm subcutaneous adipose tissue (ANN) and the lower leg subcutaneous adipose tissue (AKNPOT), on the basis of which it can be deduced that this ballast tissue represents a significant but not dominant characteristic of young, selected dancers.

The third principal component is also a single factor of body mass (AMAS); the fourth component is a single factor of abdominal skin fold (AKNT). The size of communality for all variables is satisfactory. To obtain the parsimonious structure and to make such a clear structure even more simplified, the obtained initial coordinate system has been transformed into an oblique oblimin position, retaining the same number of factors after that. For the same reason that the applied method for transformation yields the total of three matrices, the matrix of parallel projections of variables onto the factors (Tab. 2), the matrix of orthogonal projections of the variables onto the factors (Tab. 3) and the matrix of inter-correlations between the obtained factors (Tab. 4), all three matrices were simultaneously interpreted.

The first oblimin factor of the largest projections has longitudinal and transversal dimensionalities with the variables. It can be interpreted no doubt as a general factor of the skeleton growth in young, selected dancers.

The second oblimin factor is defined by the variables for adipose tissue estimation in young dancers. The highest saturation of this factor is provided by the variables such as lower leg skin fold (AKNPOT), upper arm skin fold (AKNN), back skin fold (AKNL), armpit skin fold (AKNPAZ) as well as by a single variable for estimating the skeleton circular dimensionality of the upper leg volume (AONAT). This is a factor not generated by several years' training process, because the sample of subjects consists of young dancers and the factor is the result of endogenous effects. This factor can be defined as the factor of subcutaneous adipose tissue or endomorphy.

The third oblimin factor is also easy to interpret. It represents the factor of the body mass and volume, i.e., the variables that have an important role in the total body mass percentage.

The fourth oblimin factor is a single factor of abdominal skin fold, so this must be the product of hyperfactorization. Statistically significant correlations among the isolated factors exist between the first three oblimin factors, which makes sense because the young selected dancers have somewhat larger accumulation of subcutaneous adipose tissue and voluminosity which correlate with a general factor of growth.

The author leaves an open issue of further studies on anthropological dimensions, especially the dimensions of musicality and functional mechanisms as well as the quality of acquired techniques in dancers performing folk dances, not involved by this study.

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# *Procena pouzdanosti donje granice latentnih dimenzija morfoloških varijabli*

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## *Sažetak*

*Propozicija 1.*

*Koeficijenti* $\gamma_p$ *variraju u rasponu (0,1) i mogu poprimiti vrednost 1 onda i samo onda ako je* $P = I$, *dakle ako su su sve varijable izmerene bez greške, a vrednost 0 onda i samo onda ako je i* $P = 0$ *i* $R = I$, *dakle ako se cela varijansa svih varijabli sastoji samo od varijanse greške merenja, a varijable iz V imaju sferičnu normalnu distribuciju.*

*Dokaz:*

*Ako se cela varijansa svake varijable iz nekog skupa varijabli sastoji samo od varijanse greške merenja, onda je nužno* $E^2 = I$ *i* $R = I$, *pa su svi koeficijenti* $\gamma_p$ *jednaki nuli. Prvi deo propozicije očigledan je iz definicije koeficijenata* $\gamma_p$ *; to*

*znači da je pouzdanost svake latentne dimenzije, bez obzira kako je ta latentna dimenzija određena, jednaka 1 ako su varijable iz kojih je ta dimenzija izvedena izmerene bez greške.*

*Međutim, matrica koeficijenata pouzdanosti* $P = (\rho_j)$ *je često nepoznata, pa je nepoznata i matrica varijansi greške merenja* $E^2$ *. Ali, ako su varijable iz V izabrane tako da reprezentuju neki univerzum varijabli U sa istim poljem značenja, gornja granica varijansi greške merenja definisana je elementima matrice* $U^2$ *(Guttman, 1945; 1953), dakle uniknim varijansama tih varijabli. Zbog toga se, u tom slučaju, donja granica pouzdanosti latentnih dimenzija može proceniti koeficijentima* $\beta_p = 1 - (q_p^t U^2 q_p)(q_p^t R q_p)^{-1}$ $p = 1,..., k$ *koji su izvedeni postupkom koji je identičan postupku kojim su izvedeni i koeficijenti* $\gamma_p$ *uz definiciju* $E^2 = U^2$*, dakle na isti način na koji je Guttman izveo svoju meru* $\lambda_6$ *.*

***Ključne reči:*** */ distribucija / skup / varijabla / koeficijenti / varijansa / plesači /*

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