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BODY STRUCTURE AND SOMATOTYPE IN PHYSICAL EDUCATION STUDENTS

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Abstract. From several studies it appeared that the predictive value of body measurements is fairly low for the mesomorphy component. In the present study on 51 physical education students we predicted the somatotype components from 25 body measurements and 9 tissue measurements taken on radiographs of the upper arm, thigh and calf. The somatotype was determined according to a modified anthroposcopic Sheldon technique.

The interrelationships between the somatotype components, body and tissue measurements were analysed by means of factor analysis (maximum likelihood, varimax, oblimin); stepwise multiple regression analysis was used to determine the predictive value of the body and tissue measurements. After oblique rotation four significant factors were extracted: *a general size factor*, a factor of *muscle development-mesomorphy*, a factor of *fat-endomorphy* and a fourth factor which we tentatively call *limb development*. The predictive value of a combination of body and tissue measurements amounted to R = .89 for endomorphy, R = .86 for mesomorphy and R = .90 for ectomorphy.

The inclusion of tissue measurements in the regression analysis seems to increase significantly the prediction of mesomorphy ratings.

Key words: physique, body measurements, tissue measurements on radiographs, somatotype, physical education students.

Introduction

Since SHELDON in 1940 proposed his method on somatotyping (SHELDON, STEVENS and TUCKER 1940) several modifications of his original work have been put forward (see e.g. CARTER and HEATH 1971). Most of these modifications concern the extension of the 7-point scale and the objectifications concerning the extension of the 7-point scale and the objectivity in somatotyping. To obtain a more objective system several authors attempted to predict the three components from body measurements by multiple regression techniques (DAMON et al. 1962, MUNROE, CLARKE and HEATH 1969, WILMORE 1970), while PARNELL (1954, 1958) and HEATH and CARTER (1967) proposed new methods based on anthropometry.

During the same period several authors have identified the structure of physique by means of factor analyses of body measurements. In a survey of these studies SIMONS and VAN GERVEN (1970—1971) concluded that most probably the structure of the head, hand and foot is independent of the structure of trunk and limbs and that in the trunk and limbs the following structure could be identified:

— size factor,
— limb-bone length,
— limb-bone width,
— fat thickness,
— muscle width.

These conclusions are in close agreement with the findings of TANNER who analysed the structure of physique by means of tissue measurements on radiographs (TANNER 1964).

In this study we analyse the factor structure of physique described by body measurements, tissue measurements on radiographs and somatotype components; furthermore, the predictive value of body and tissue measurements in identifying somatotype components was examined.

Material and Methods

Subject

The sample consisted of 40 male students who started Physical Education studies at the K.U. Leuven in 1973. Their chronological age varied between 18.1 and 25.7 years with a mean of 19.4 years.

Variables

The body measurements were taken by experienced anthropometrists. A description of the measurement techniques is given by SIMONS et al. (1978).

The soft tissue X-rays were taken in a standard position from the upper-arm, thigh and calf.

For the positioning of the subject the instructions given by TANNER (1962) were carefully followed. The measurements of the tissue components were taken in the middle between olecranon and acromion for the upper arm, half-way between the spina iliaca anterior superior and the upper border of the patella for the thigh; for the calf 1|3rd of the distance between the external epicondyle of the femur and the external malleolus below the external epicondyle. These points were marked with a lead marker and the limb was positioned so that the middle of the roentgen unit, the lead mark on the skin and the middle of the cassette which was also marked with a thin steel wire, were in the same horizontal plane.

The measurements on the X-rays were taken at the marked levels described above, with a sliding caliper for measurements on photographs with an accuracy of 1/10th of a millimetre (John Bull, British Indicators Ltd, St. Albans). The intraobserver reliability of the tissue measurements made on the same X-rays ranged from $r_{tt} = .90$ for the fat tissue to $r_{tt} = .999$ for the muscle tissue. These were no statistically significant systematic differences between the first and second measurements.

The somatotype ratings were carried out by the same observer (G.B.) according to a modified Sheldon technique developed for use in the Leuven Boys Growth Study (SIMONS et al. 1978) and described in detail by CLAESSENS et al. (1979). This method is essentially an anthropometric-anthroposcopic somatotype method based on the Atlas-technique of SHELDON (SHELDON, DUPERTUIS and MCDERMOTT 1954) whereby first estimates of endomorphy and ectomorphy are made using the tables developed by PARNELL (1958) and HEATH—CARTER (1967).

In Table 1 a list of the measurements is given.

Table 1

List of measurements taken on male physical education students

Anthropometry	*Tissue measurements*
— Height	— Fat width:
— Weight	. Arm
— Biacromial diameter	. Thigh
— Bi-iliac diameter	. Calf
— Transverse chest	— Muscle width:
— Chest depth expir.	. Arm
— Bicondylar femur	. Thigh
— Bicondylar humerus	. Calf
— Chest circumf. difference	— Bone width:
— Chest circumf. expir.	. Arm
— Abdominal circumf.	. Thigh
— Hip circumf.	. Calf
— Thigh circumf.	
— Calf circumf.	
— Upper arm circumf. flexed	*Somatotype components*
— Supra-iliac skinfold	
— Triceps skinfold	Endomorphy
— Sub-scapular skinfold	Mesomorphy
— Calf skinfold	Ectomorphy

Statistical procedures

The factor analysis was carried out according to the maximum likelihood principle using a computer program described by PEETERS (s. d.). The initial communalities are estimated by means of the squared multiple correlations. After the factors have been extracted, these are rotated to an orthogonal simple structure according to the Varimax method after which an oblique rotation into a simple oblique structure is carried out (Oblimin method).

The multiple correlations between the somatotype components and the anthropometric and tissue measurements were calculated by means of a step-wise multiple regression computer program described by BOECKX (1973). The partial variance of the dependent variable that could be explained by each independent variable to be entered in the equation, was tested by means of an F-test (significance level set at $\alpha = .05$).

Results

The factor analyses revealed that four significant factors could be extracted. The first factor could be identified as a *size factor*. Height, weight, and circumferences of the chest, abdomen and hip load high on this factor (see Table 2). On the second factor, which we call a *muscularity—mesomorphy factor*, a high loading is found for mesomorphy, the muscle tissue measurements taken at

the upper arm, thigh and calf, the circumferences of the limbs and ectomorphy. The third factor is called *adiposity—endomorphy*. Endomorphy loads highest on this factor, followed by the skinfold measurements, the fat tissue measurements and the circumferences. The fourth factor is not so clearly defined. We tentatively call this factor a *limb development factor* since the highest loadings are found for ankle breadth, bone tissue measurements, calf circumference and height and weight.

Table 2

Factor structure (maximum likelihood, varimax, oblimin) after oblique rotation of anthropometric measurements, tissue measurements and somatotype components on 40 male physical education students (only the highest factor loadings above .45 are reported)

Factor I size		Factor II muscularity — mesomorphy		Factor III adiposity — endomorphy		Factor IV limb development	
Weight	.871	Ecto	−.871	Endo	.941	Ankle breadth	.705
Abdom. circ.	.859	Meso	.779	Subscap. sk.	.820	Calf. circ.	.594
Hip circ.	.844	Up. arm circ.	.648	Suprail. sk.	.802	Weight	.540
Height	.841	Up. arm muscle	.641	Tric. sk.	.797	Height	.492
Chest circ.	.820	Calf muscle	.635	Thigh fat	.722	Up. arm bone	.483
Biacr. diam.	.751	Calf circ.	.594	Calf fat	.687	Calf bone	.456
Bic. fem.	.700	Thigh circ.	.547	Weight	.685	(Up. arm bone	.330)
Thigh circ.	.687	Thigh muscle	.422)	Chest circ.	.669		
Transv. chest	.637			Up. arm. fat	.666		
Bic. hum.	.620			Abd. circ.	.659		
Calf circ.	.573			Calf circ.	.543		
Up. arm circ.	.559			Thigh circ.	.542		
Sub. scap. sk.	.546			Hip circ.	.538		
Chest depth	.535			Calf sk.	.487		
Bi-il. diam.	.527			Up. arm circ.	.478		
Supra-il. sk.	.483			Biacr. diam.	.484		
Up. arm bone	.481			Chest depth	.467		
Ankle breadth.	478						
Endo	.455						
Thigh muscle	.454						

The intercorrelations between the four extracted oblique factors were very low, ranging from .431 between the size and adiposity–endomorphy factor to .110 betwen the adiposity—endomorphy and limb development factor.

In order to evaluate the predictive value of the anthropometric and the tissue measurements in predicting somatotype components a stepwise multiple regression analysis was carried out.

In Table 3 the coefficient of determination after each step of the stepwise regression analysis is reported for the three dependent variables. Only the variables that are added to those already present in the regression equation are mentioned together with the coefficient of determination for all variables in the regression equation.

It can be clearly seen that besides fat and skinfold measurements, bone breadth and length diameters enter the regression equation for the prediction of endomorphy. Five measurements account for 79% of the total variance in endomorphy. For mesomorphy the total variance explained, amounts to 74%. The tissue measurement of the upper arm is the most important predictor and here two measurements of skinfolds and of skeletal framework (transverse chest and bi-iliac diameter) enter the equation. Only three variables: height, weight and calf skinfold explain 82% of the total variance in ectomorphy.

Table 3

Multiple correlations (only coefficients of determination are reported) between somatotype components and anthropometric and tissue measurements on 40 male physical education students (for each dependent variable the independent variables entered the regression equation in each step are mentioned)

Dependent variables					
Endomorphy		Mesomorphy		Ectomorphy	
Subscapular skinfold	.61	Up. arm muscle	.27		
Calf fat	.66	Height	.41	Height	.56
Bi-iliac diam.	.72	Transv. chest	.50	Weight	.79
Supra-iliac skinfold	.76	Up. arm circ.	.58	Calf skinfold	.82
Thigh bone	.79	Supra-iliac skinf.	.70		
		Bi-iliac diam.	.74		

Discussion and Conclusions

The somatotype distribution of the physical education students examined in this study was very similar to the distributions reported earlier by Carter (1964) and Swalus (1967—1968).

These distributions show striking similarities with the distributions of outstanding male athletes.

The factor structure found herein is in general in agreement with the structure found in similar studies. Tanner (1964) using a maximum likelihood method extracted five significant factors. Three of them are of the same nature as the ones we found. He could, however, differentiate between a limb-bone length and a limb bone breadth factor.

In a study on 336 pre-adolescent and 318 adolescent boys Van Gerven (1976) identified three maximum likelihood factors, namely a *length–muscle–width* factor, a *fat* factor and a *mesomorphy–muscle* factor.

Skibinska (1977) too, reported nearly the same three factors. From her studies she concluded that irrespective of sex, number of measurements and population under investigation the three following factors are found:

— a size factor,
— a mesomorphy–muscularity factor,
— an endomorphy–adiposity factor.

Our findings seem to confirm this conclusion. That it was not possible to differentiate in this study between a limb-bone length and limb-bone breadth factor is most probably due to the lack of length measurements of different parts of the body. However, in a separate analysis of the 12 tissue measurements it could be demonstrated that the three tissue components loaded highly on their respective tissue factors, namely a *fat*, a *muscle* and a *bone* factor.

From the factor analysis on all measurements it is also clear that endomorphy and mesomorphy load on a separate factor while ectomorphy loads negatively on the muscularity–mesomorphy factor. Although it is convenient to think of the three somatotype components as three independent or orthogonal components this need not to be true. Probably the interdependency of the components can be explained by some physiological or genetical factors.

From the analysis also appears that muscle and bone width are independent. Mesomorphy is related to muscle width development but not to limb-bone breadth. This confirms the findings of WILMORE (1970) and SLAUGHTER and LOHMAN (1977).

In comparison with the findings of other authors a fairly high percentage of the variance in mesomorphy could be explained using tissue measurements and anthropometric measurement (see Table 4).

Table 4

Coefficients of determination among anthropometric measurements, body composition, tissue components and somatotype components as reported by several authors (males)

Author	Sample measurements	Dependent variables			
		Method	Endo	Meso	Ecto
DAMON et al. (1962)	225 soldiers (anthropometry)	Sheldon, atlas	.61	.44	.81
MUNROE et al. (1969)	207 boys 12Y. (anthropometry)	Heath	.82	.60	.95
SLAUGHTER and LOHMAN (1977)	45 boys 7–12Y. (anthropometry and body composition)	Sheldon trunk index	.78	.21	.74
		Heath–Carter	.83	.74	.81
BEUNEN and VAN HELLEMONT	40 phys. ed. students (anthropometry and tissue measurements)	Modified Sheldon atlas	.79	.74	.82

This leads to the conclusion that the inclusion of tissue measurements in the regression equation adds significantly to the predictive value. Although we would not recommend taking X-rays for somatotyping, it reveals that mesomorphy as defined by the modified Sheldon-technique (CLAESSENS et al. 1979) is closely related to muscle development. As already established, endomorphy can be fairly accurately predicted from skinfold measurements while ectomorphy is closely related to the ponderal index (a correlation coefficient of .90 was found in this study).

Considering the sample involved which shows a specific somatotype distribution, as mentioned above, it could probably be expected that higher predictive values will be found in a normal healthy population of the same age and sex. Since, in the present sample, the variance in each of the somatotype components is reduced in comparison with a representative sample of a total population of the same age and sex.

It should also be noted that in the regression equation for predicting mesomorphy measurements taken at the limbs (upper arm muscle, upper arm circumference) as well as measurements taken at the trunk (transverse chest, suprailiac skinfold and bi-iliac diameter) contribute significantly.

Nevertheleless, neither PARNELL (1954, 1958) nor HEATH—CARTER (1967) include trunk dimensions in the estimation of mesomorphy whereas the discrimination between endomorphy and mesomorphy in Sheldon's trunk index method (1968) is solely based on trunk measurements.

This analysis suggests that in estimating mesomorphy one should take into account the dimensions of the trunk and the limbs as well.

Moreover, as stated at the beginning of this paper, the structure of head, hand and foot is most probably fairly independent of the structure of trunk and limbs. Therefore, we conclude that the separation into different body regions, as proposed by SHELDON et al. (1940) seems to have a statistical meaning. This does not imply that one has to estimate the somatotype for each body region separately but it suggests that, in estimating the somatotype components, one has to take into account the different aspects of the different body regions.

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