CORRELATIONS OF BODY MEASUREMENTS IN WOMEN ATHLETES AND FEMALE STUDENTS

by

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In the course of research focused on one of the main problems of physical anthropology, the manners and causes of individual variations and differentiation correlations relected to body measurements and proportions have arisen interest. There are only a few such studies which facilitate a better, more exact understanding of the *feminine* physique (Félice 1958, Tittel 1965, Moeschler 1966 and 1968, Félice and Vassal 1968). Therefore the presentation of this study seems to be necessary.

Material and Methods

The author performed the anthropometric measurements on the most eminent women athletes of Europe, on girls admitted to the Physical Education College of Budapest, and on the female students of the Teachers College of Szombathely. The first group developed to such a level as the measurements indicated under the influence of special intensive physical training (athletic activity on European level). The second group contained selected individuals, while members of the Teachers College represented the average population. Within the first group one can differentiate several subgroups among the participants of the various athletic events.

The author used these groups as *models* in his examinations.

The measurements of the women athletes were obtained in the "Olympic village" of Gödöllő during the VIIIth Euporean Athletic Championship held in Budapest in 1966. A total of 125 representatives of the following countries were measured: Albany, Belgium, Denmark, France, the German Democratic Republic, the German Federal Republic, Great Britain, Greece, Hungary, Iceland, Italy, the Soviet Union and Yugoslavia. Their age varied between 15 and 36 years (mean: 23·8 years). All belonged to the Europid race.

To obtain comparative material the author measured 139 girls admitted to the Physical Education College of Budapest in 1966. Their age varied between 18 and 25 years (mean: 18·7 years). The same measurements were taken in 1964 on 179 female students of the Teachers College of Szombathely, West-

Hungary (E i b e n 1965). — These girls were all between 18 and 22 years of age (mean: 19·9 years).

For the measurements the M a r t i n technique was used.

The data were processed by a computer.

The results are the usual parameters of 53 measured and calculated anthropometric characterics, calculation of (A) total and (B) partial correlations and analysis by generalized coordinates.

The purpose of this study is the presentation of the *correlations*. Description of the general anthropometric-constitutional characteristics and analysis by generalized coordinates are subjects of the author's other studies (E i b e n 1969, a; 1969, b).

In the course of the above examinations the author obtained 53 body measurements from each member of the three main groups (and the nine subgroups of the women athletes), and calculated the total correlations of the data. It was possible to make partial correlation analysis with all the women athletes and the femal students of the Physical Education College.

In the multiple correlation analysis the common correlation coefficient between any two variates was colled *total correlation coefficient* (t.c.c.), to differentiate it from the partial correlation coefficient.

In the case of more than two variates (body measurements) the *partial correlation coefficient* (p.c.c.) characterizes connection between two variates, as far as it eliminates the effect of the other variates from the connection of these two ones. It can happen e.g. that connection can be seen between two variates only because they are connected with a third one (or perhaps with some more variates). On the other hand it can happen too, that a given connection between two variates under certain conditions is eliminated by the effect of the other variates. (For the analysis of such cases the conditional distribution of the two variates is used.)

The author employed the following formula for the *total correlation calculations:*

$$r_{ik} = \frac{c_{ik}}{\sigma_i \sigma_k},$$

where $\sigma_i = D(\xi)_i$ and $\sigma_k = D(\xi)_k$. Here ξ represents the i^{th} and k^{th} variates respectively, D represents their standard deviation.

$$c_{ik} = M[(\xi_i - m_i)(\xi_k - m_k)],$$

where m_i and m_k are the arithmetic means of ξ_i and ξ_k, respectively. M indicates the expected value.

The following formula expresses the *partial correlation:*

$$\varrho_{ik} = -\frac{R_{ik}}{\sqrt{R_{ii} R_{kk}}},$$

where R_{ik} equals the cofactor of the correlation matrix

$$R = (r_{ik}) = \frac{C_{ik}}{\sigma_i \sigma_k}$$

The author also analyzed the significance of the correlations expressed by the correlation coefficients. Since the r correlation coefficient generally does not follow a normal distribution, one must normalize it with z-transformation according to the following formula:

$$z = \frac{1}{2} \log \text{ nat} \frac{1+r}{1-r} .$$

The expected value on the $\cdot 001$ level is

$$z_{.001} = 3.29 \sqrt{\frac{1}{N-3}}$$

where N is the sample size and $3 \cdot 29$ is the normal deviate. The result then must be transformed back to r in order to obtain the correlation coefficient belonging to the 1/1000 significance level (P e a r s o n – H a r t l e y 1958. Table 14, page 139).

In the three samples the numerical limit value is the following:

women athletes	(N = 125)	$r_{.001} = \pm \cdot 29$,
girls admitted to the Physical Education College	(N = 139)	$r_{.001} = \pm \cdot 27$,
female students of the Teachers College	(N = 179)	$r_{.001} = \pm \cdot 24$.

Therefore, if the value obtained for correlation is equal to the expected value, or in case of r positive it is higher than $r_{.001}$, in case of r negative it is lower than $r_{.001}$ then the deviation from 0 at the $\cdot 001$ level is significant.

It is notable that there is ample occurence of much higher values than the ones obtained in the above three groups; this fact indicates the homogeneity of the samples.

Results

Tables I – X. illustrate the correlation coefficients; for the sake of greater clarity the author also added a few sketches (Figures 1 – 6).

The data – on account of their multitude – have been grouped so as to illustrate the relationships best. In grouping the data the author utilized the principles of T a n n e r (1953) which he published based on his factor analysis classification of physique. Following this pattern the author grouped the linear and non-linear body dimensions separately, and considered these groups as separate blocks. Further analysis was made within each block and among the separate blocks, respectively. Certain correlations occur in different Tables; these repetitions seemed necessary to facilitate fuller understanding of the material.

First of all the correlations of the women athletes will be discussed.

A) T o t a l c o r r e l a t i o n s

1. Total Correlations of Length Measurements

In general the length measurements of *women athletes* show a high correlation with themselves (Table I). Stature – except the height of ankle and the total head height – yields a correlation of $r > \cdot 8$. The results also indicate

Table I.

Total correlations of the length measurements with themselves

The upper rows refer to the women athletes, the lower ones (in italics) refer to the female students of the Physical Education College in Budapest. The asterisks indicate non-significant correlations. This way of marking occurs in all of the Tables of this paper.

Measurements		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Weight	1	1.00	.644 *.636*	.649 *.683*	.575 *.535*	.470 *.585*	.622 *.678*	.622 *.572*	.584 *.516*	.547 *.416*	.584 *.623*	.382 *.458*	.167* *.291*	.692 *.525*	.677 *.689*	.491 *.317*
Stature	2		1.00	.966 *.955*	.912 *.787*	.849 *.837*	.973 *.922*	.903 *.869*	.880 *.755*	.851 *.718*	.904 *.858*	.777 *.730*	.342 *.334*	.850 *.741*	.819 *.800*	.462 *.319*
Suprasternale height	3			1.00	.876 *.797*	.834 *.853*	.955 *.945*	.902 *.897*	.863 *.792*	.830 *.732*	.885 *.882*	.742 *.774*	.278* *.349*	.814 *.723*	.819 *.810*	.436 *.305*
Omphalion (navel) height	4				.100	.855 *.845*	.902 *.829*	.848 *.792*	.813 *.703*	.814 *.643*	.841 *.836*	.732 *.721*	.279* *.321*	.750 *.484*	.726 *.662*	.398 *.254*
Symphysis height	5					1.00	.836 *.872*	.738 *.800*	.702 *.699*	.696 *.622*	.795 *.880*	.693 *.721*	.211* *.323*	.671 *.474*	.676 *.774*	.297 *.284*
Acromiale (shoulder) height	6						1.00	.926 *.948*	.897 *.853*	.867 *.791*	.907 *.855*	.775 *.770*	.305 *.395*	.795 *.689*	.804 *.793*	.419 *.303*
Radiale (elbow) height	7							1.00	.927 *.921*	.900 *.879*	.828 *.772*	.691 *.744*	.287* *.413*	.755 *.707*	.701 *.652*	.399 *.246**
Stylion (wrist) height	8								1.00	.949 *.921*	.813 *.632*	.658 *.629*	.291 *.335*	.757 *.694*	.626 *.475*	.385 *.257**
Dactylion height	9									1.00	.785 *.564*	.636 *.576*	.278* *.330*	.724 *.684*	.535 *.349*	.326 *.189**
Spina iliaca height	10										1.00	.787 *.784*	.304 *.348*	.709 *.444*	.781 *.813*	.413 *.284*
Tibiale (knee) height	11											1.00	.282* *.430*	.604 *.410*	.649 *.654*	.269* *.237**
Ankle height	12												1.00	.338 *.216**	.231* *.246**	.219* *.054**
Sitting height	13													1.00	.701 *.484*	.459 *.345*
Span	14														1.00	.494 *.303*
Total head height	15															1.00

high crrelations both among points located beneath each other in the sagittal plane of the body and laterally, especially on the upper limb (Figure 1).

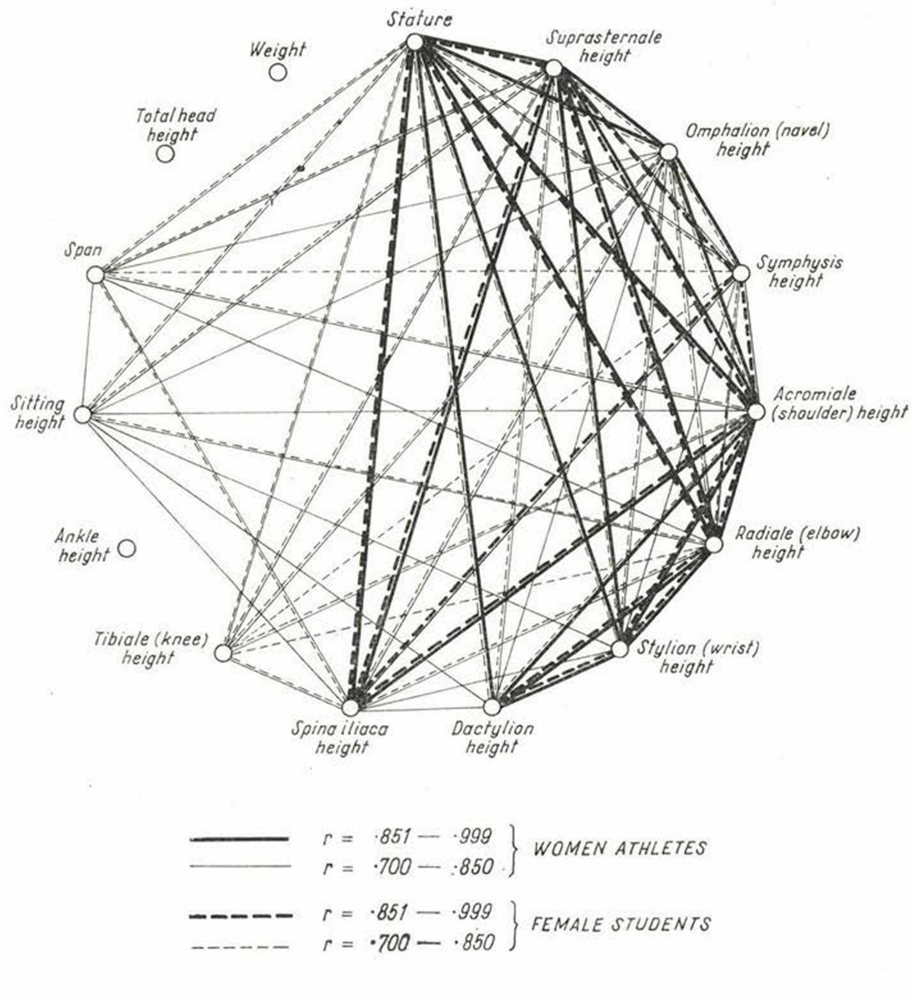

Fig. 1. A schematic representation of some important total correlations of the length measurements with themselves
(This way of marking occurs in all of the Figures of this paper)

Among the correlations of the length measurements and body proportions the high correlation values of the upper and lower limbs with the length measurements are notable (except the height of ankle), r is greater than ·6 in almost all cases (Table II, Figure 2).

Table II.

Total correlations of the length measurements with the proportions of the body

Measurements	Trunk length	Length of the upper limb	Upper arm length	Fore-arm length	Hand length	Length of the lower limb	Thigh length	Leg length	Ankle height
Weight	.395 .479	.517 .671	.315 .658	.358 .339	.227* .342	.565 .613	.556 .564	.357 .411	.167* .291
Stature	.338 .658	.799 .769	.618 .718	.446 .593	.300 .233*	.863 .830	.694 .713	.728 .699	.342 .334
Suprasternale height	.423 .718	.790 .793	.575 .722	.476 .586	.307 .300	.847 .859	.697 .715	.707 .744	.278* .349
Omphalion (navel) height	.167* .417	.711 .690	.551 .630	.457 .508	.222* .280	.795 .824	.638 .690	.696 .696	.279* .312
Symphysis height	−.147* .289	.722 .784	.605 .720	.400 .542	.198* .320	.751 .870	.601 .753	.671 .694	.211* .323
Acromiale (shoulder) height	.338 .655	.835 .822	.638 .761	.465 .582	.294 .310	.965 .833	.701 .676	.735 .723	.305 .395
Radiale (elbow) height	.405 .675	.677 .665	.302 .520	.584 .573	.317 .272*	.797 .747	.655 .575	.652 .689	.287* .413
Stylion (wrist) height	.396 .633	.592 .478	.378 .424	.247* .209*	.379 .367	.795 .607	.661 .451	.617 .581	.291 .335
Dactylion height	.345 .629	.485 .306	.356 .345	.286* .268*	.133* −.021*	.768 .536	.638 .391	.597 .524	.278* .330
Spina iliaca height	.281* .444	.753 .808	.604 .740	.409 .610	.284* .287	.975 .996	.834 .884	.747 .758	.304 .348
Tibiale (knee) height	.194* .482	.653 .665	.546 .563	.394 .546	.220* .260*	.756 .774	.316 .406	.975 .956	.282* .430
Ankle height	.151* .258*	.233* .314	.189* .208*	.135* .330	.127* .079*	.264* .341	.217* .186*	.060* .163*	1.00
Sitting height	.361 .746	.629 .432	.474 .414	.337 .316	.283* .144*	.678 .404	.549 .342	.549 .381	.338 .216*
Span	.360 .447	.823 .909	.605 .807	.474 .632	.390 .397	.737 .798	.621 .704	.620 .644	.231* .246*
Total head height	.289* .209*	.392 .282	.248* .307	.228* .079*	.260* .213*	.393 .276	.394 .234*	.228* .257*	.219* .054*

The correlation of the lower limb is high not only with the stature but also with the acromiale (shoulder) height. The conspicuous connection between the lower limb and the spina iliaca ant. sup. height and between the leg length and ankle height is a natural result.

In the group of the women athletes among the correlations of the length measurements and dimension of width of the trunk there are exceptionally numerous non-significant values. High correlations occur between weight and dimensions of width; among these especially those which are measured on the muscles or on soft spots including connective tissue and fat (Table III). Naturally, the correlations are smaller among weight and measurements of width taken directly over bone structures.

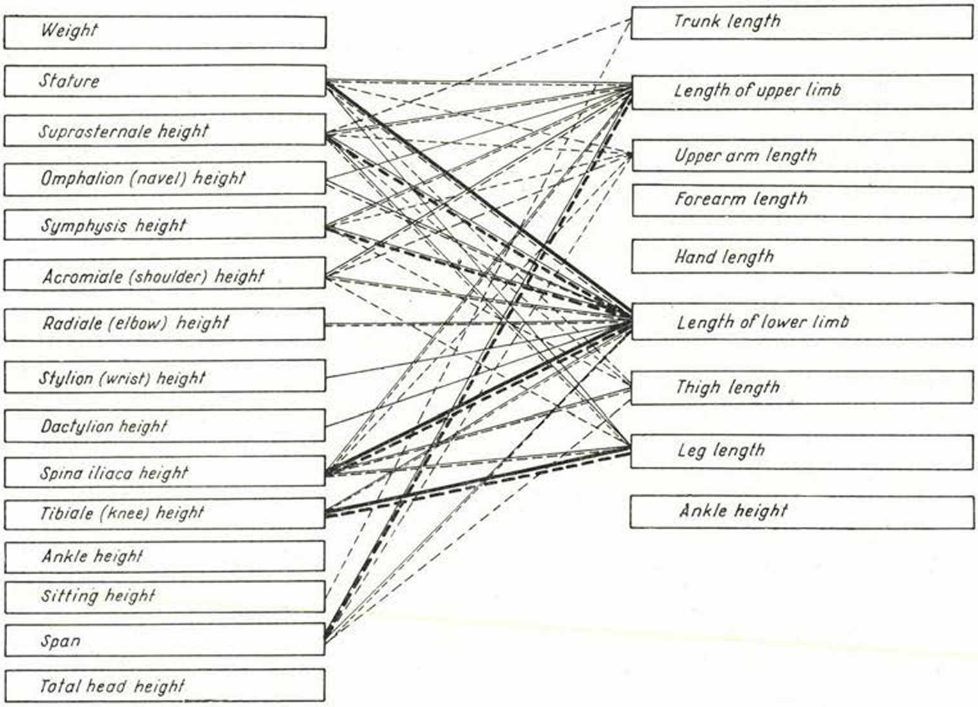

Fig. 2. A schematic representation of some important total correlations of the length measurements with the proportional body measurements

The same tendency is conspicuous in the analysis of correlations between length measurements and measurements of girth: a higher coefficient than ·7 occurs only in relation to weight (Table IV), while in Tables I and II one finds low r values for weight. The relatively high correlation coefficients between the length measurements and the ankle circumference must be mentioned.

Table III.

Total correlations of the length measurements with the breadth measurements of the trunk

Measurements	Biacromial breadth	Bideltoid breadth	Chest breadth	Chest depth	Waist breadth	Bispinal breadth	Bitrochanteric breadth	Breadth of the back
Weight	.619 .548	.772 .752	.824 .696	.585 .616	.743 .623	.388 .325	.780 .735	.721 .649
Stature	.420 .403	.365 .396	.438 .377	.266* .418	.421 .262*	.264* .244*	.535 .447	.240* .346
Suprasternale height	.398 .383	.372 .402	.451 .357	.283* .475	.420 .274	.285* .280	.558 .518	.253* .327
Omphalion (navel) height	.371 .265*	.334 .334	.387 .311	.215* .372	.410 .257*	.259* .207*	.474 .381	.208* .357
Symphysis height	.289* .327	.235* .371	.318 .358	.172* .324	.303 .279	.192* .241*	.389 .437	.121* .311
Acromiale (shoulder) height	.387 .371	.338 .420	.427 .390	.272* .429	.407 .262*	.294 .248*	.517 .485	.241* .367
Radiale (elbow) height	.376 .259*	.316 .321	.420 .316	.225* .364	.437 .159*	.308 .196*	.496 .368	.231* .307
Stylion (wrist) height	.394 .168*	.278* .270	.383 .242*	.201* .350	.386 .047*	.289* .132*	.465 .283	.211* .251*
Dactylion height	.347 .129*	.245* .215*	.336 .190*	.191* .311	.337 .005*	.264* .080*	.450 .227*	.163* .210*
Spina iliaca height	.409 .397	.356 .387	.427 .359	.336 .394	.474 .394	.282* .247*	.543 .481	.272* .337
Tibiale (knee) height	.250* .238*	.218* .252*	.267* .291	.129* .282	.271* .242*	.208* .208*	.358 .366	.061* .248*
Ankle height	.043* .136*	.047* .106*	.090* .120*	−.046* .110*	.105* .201*	.034* .015*	.031* .216*	−.004* .199*
Sitting height	.427 .254*	.454 .256*	.530 .230*	.269* .426	.473 .071*	.247* .130*	.538 .327	.310 .229*
Span	.492 .564	.524 .532	.545 .506	.448 .340	.510 .429	.320 .353	.605 .585	.393 .421
Total head height	.456 .286	.423 .243*	.382 .290	.174* .090*	.336 .211*	.280* .052*	.450 .108*	.327 .192*

Table IV.

Total correlations of the length measurements with the girth measurements of the trunk and limbs

Measurements	Head circum- ference	Neck circum- ference	Chest circum- ference	Waist circum- ference	Abdomen circum- ference	Trochan- ter circum- ference	Upper arm circum- ference	Forearm circum- ference	Wrist circum- ference	Thigh circum- ference	Leg circum- ference	Ankle circum- ference
Weight	.625 *.430*	.540 *.560*	.831 *.786*	.784 *.808*	.773 *.668*	.848 *.773*	.750 *.752*	.863 *.774*	.564 *.692*	.820 *.859*	.723 *.570*	.757 *.590*
Stature	.448 *.329*	.447 *.244**	.413 *.384*	.383 *.338*	.377 *.388*	.483 *.458*	.320 *.184**	.458 *.314*	.359 *.290*	.392 *.377*	.346 *.378*	.494 *.326*
Suprasternale height	.427 *.338*	.421 *.240**	.456 *.408*	.387 *.372*	.403 *.411*	.504 *.513*	.345 *.245**	.486 *.367*	.386 *.309*	.396 *.427*	.367 *.337*	.503 *.344*
Omphalion (navel) height	.402 *.269**	.392 *.201**	.369 *.313*	.359 *.338*	.331 *.328*	.431 *.436*	.253* *.185**	.392 *.267**	.287* *.233**	.362 *.304*	.296 *.208**	.424 *.199**
Symphysis height	.282* *.285*	.335 *.182**	.294 *.341*	.269 *.374*	.267* *.371*	.355 *.457*	.178* *.227**	.298 *.275*	.264* *.238**	.270* *.343*	.204* *.253**	.358 *.245**
Acromiale (shoulder) height	.412 *.336*	.437 *.197**	.416 *.441*	.387 *.338*	.383 *.397*	.479 *.508*	.304 *.265**	.451 *.381*	.360 *.329*	.382 *.427*	.337 *.349*	.480 *.325*
Radiale (elbow) height	.386 *.292*	.409 *.131**	.408 *.369*	.425 *.273*	.444 *.310*	.491 *.427*	.346 *.181**	.460 *.287*	.399 *.235**	.386 *.336*	.370 *.282*	.518 *.283*
Stylion (wrist) height	.362 *.225**	.355 *.111**	.368 *.322*	.363 *.204**	.410 *.246**	.441 *.359*	.337 *.187**	.406 *.263**	.370 *.225**	.368 *.313*	.343 *.212**	.495 *.231**
Dactylion height	.318 *.190**	.345 *.080**	.334 *.277*	.354 *.124**	.386 *.187**	.431 *.296*	.332 *.135**	.368 *.167**	.308 *.153**	.369 *.254**	.322 *.248**	.470 *.220**
Spina iliaca height	.365 *.279*	.369 *.244**	.407 *.389*	.359 *.442*	.380 *.455*	.466 *.508*	.284* *.226**	.401 *.329*	.288* *.239**	.370 *.359*	.332 *.270*	.405 *.255**
Tibiale (knee) height	.315 *.165**	.318 *.048**	.271* *.291*	.168* *.320*	.164* *.314*	.291 *.364*	.150* *.133**	.233* *.197**	.130* *.103**	.221* *.214**	.217* *.188**	.255* *.164**
Ankle height	.228* *.161**	.162* *.025**	.009* *.178**	.018* *.180**	.053* *.076**	.086* *.213**	.101* *.130**	.131* *.202**	.175* *.220**	.122* *.232**	.120* *.373*	.150* *.281*
Sitting height	.514 *.382*	.457 *.245**	.468 *.344*	.461 *.170**	.396 *.219**	.547 *.306*	.435 *.144**	.522 *.271*	.397 *.312*	.480 *.359*	.417 *.368*	.544 *.348*
Span	.509 *.339*	.570 *.291*	.544 *.469*	.441 *.493*	.464 *.485*	.563 *.537*	.389 *.315*	.564 *.426*	.432 *.376*	.449 *.458*	.407 *.301*	.505 *.339*
Total head height	.446 *.294*	.293 *.169**	.351 *.211**	.337 *.194**	.322 *.186**	.320 *.037**	.342 *.151**	.363 *.220**	.273* *.107**	.319 *.192**	.268* *.185**	.322 *.147**

Table V.

Total correlations of the proportional body measurements with themselves

Measurements		1	2	3	4	5	6	7	8	9	10	11	12	13
Weight	1	1.00	.644 *.636*	.677 *.689*	.692 *.525*	.395 *.479*	.517 *.671*	.315 *.658*	.358 *.339*	.227* *.342*	.565 *.613*	.556 *.564*	.357 *.411*	.167* *.291*
Stature	2		1.00	.819 *.800*	.850 *.741*	.338 *.658*	.799 *.769*	.618 *.718*	.446 *.593*	.300 *.233**	.863 *.830*	.694 *.713*	.728 *.699*	.342 *.334*
Span	3			1.00	.701 *.484*	.360 *.447*	.823 *.909*	.605 *.807*	.474 *.632*	.390 *.397*	.737 *.798*	.621 *.704*	.620 *.644*	.231* *.246**
Sitting height	4				1.00	.361 *.746*	629 *.432*	.474 *.414*	.337 *.316*	.283* *.144**	.678 *.404*	.549 *.342*	.549 *.381*	.338 *.216**
Trunk length	5					1.00	.229* *.434*	.038* *.397*	.196* *.356*	.224* *.135**	.283* *.414*	.260* *.289*	.166* *.452*	.151* *.258**
Lenght of the upper limb	6						1.00	.729 *.856*	.478 *.656*	.382 *.508*	.696 *.800*	.573 *.690*	.625 *.638*	.233* *.314*
Upper arm lenght	7							1.00	−.014* *.407*	.101* *.277*	.561 *.730*	.440 *.664*	.523 *.554*	.189* *.208**
Forearm lenght	8								1.00	.004* −.091*	.372 *.599*	.284* *.495*	.368 *.508*	.135* *.330*
Hand length	9									1.00	.272* *.290*	.241* *.228**	.199* *.261**	.127* *.079**
Lenght of the lower limb	10										1.00	.824 *.886*	.725 *.749*	.264* *.341*
Thigh lenght	11											1.00	.278* *.402*	.217* *.186**
Leg length	12												1.00	.060* *.163**
Ankle height	13													1.00

2. *Total Correlations of the Proportional Body Measurements*

In the group the women athletes among the correlations of the proportional body measurements with each other the author found close relationship only between the length of lower limb and thigh length (Table V and Figure 3). It is notable that the trunk length yields such low correlations with the remaining proportional body measurements that its correlation with the proportions of the limbs is not significant at ·001 level.

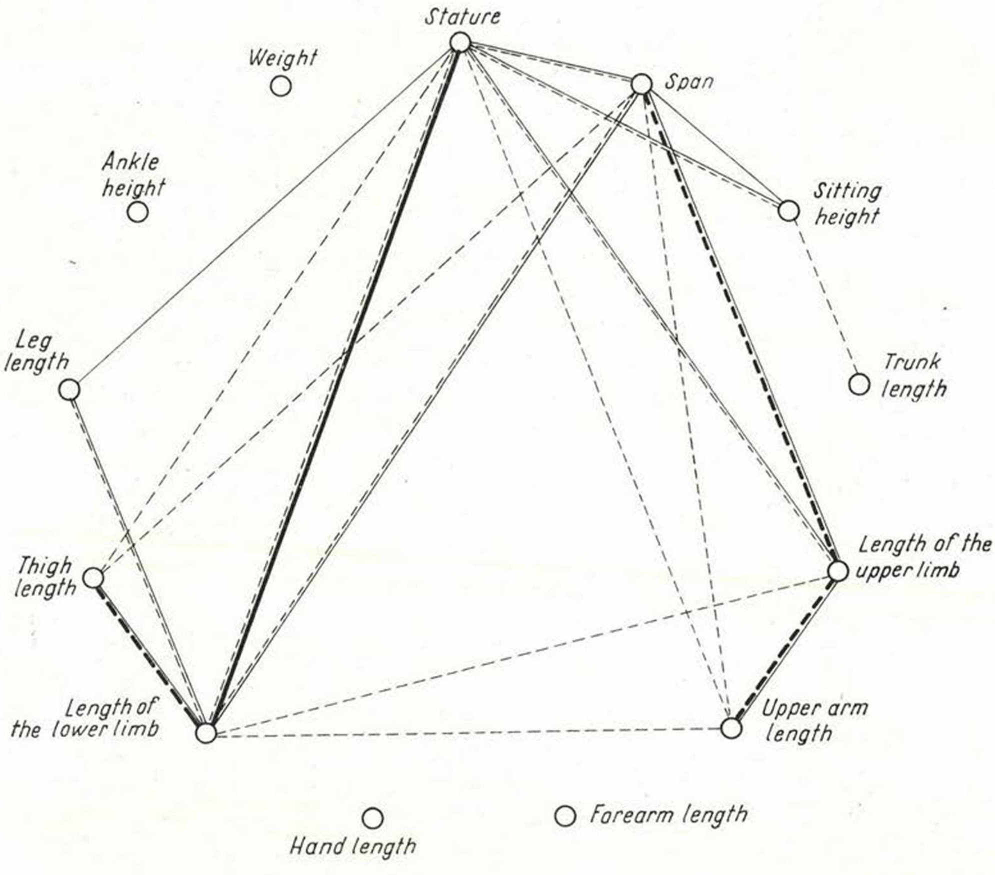

Fig. 3. A schematic representation of some important total correlations of the proportional body measurements with themselves

Among the proportional body measurements and the width measurements of the trunk for women athletes there also occur noticeably low correlations (of 72 correlation coefficients 47 do not reach the level of significance at ·001). Length of the trunk is no exception in this respect. Only the length of the lower limb and thigh length show relatively high ($r = \cdot 4 - \cdot 5$) correlations with the dimensions of widths of the trunk (Table VI).

Table VI.

Total correlations of the proportional body measurements with the breadth measurements of the trunk

Measurements	Biacromial breadth	Bideltoid breadth	Chest breadth	Chest depth	Waist breadth	Bispinal breadth	Bitrochanteric breadth	Breadth of the back
Trunk length	.240* .277	.286* .271	.290 .184*	.227* .424	.257* .087*	.197* .172*	.363 .361	.259* .225*
Length of the upper limb	.316 .450	.322 .453	.393 .429	.280* .365	.357 .409	.261* .322	.442 .558	.240* .377
Upper arm length	.216* .465	.220* .475	.277* .410	.240* .412	.152* .375	.108* .267*	.302 .557	.144* .373
Forearm length	.146* .295	.297 .222*	.281* .268*	.156* .178*	.295 .290	.259* .203*	.293 .321	.136* .225*
Hand length	.240* .145*	.143* .193*	.164* .167*	.002* .158*	.174* .106*	.158* .141*	.155* .194*	.156* .152*
Length of the lower limb	.410 .394	.360 .382	.419 .354	.356 .390	.476 .401	.272* .243*	.543 .478	.257* .329
Thigh length	.405 .404	.354 .372	.419 .307	.401 .359	.487 .395	.247* .212*	.515 .434	.364 .308
Leg length	.250* .225*	.215* .243*	.256* .269*	.144* .281	.256* .206*	.209* .226*	.365 .337	.063* .209*
Ankle height	.043* .136*	.047* .106*	.090* .120*	−.046* .110*	.105* .201*	.034* .015*	.031* .216*	−.004* .199*

There are also low correlational values for the women athletes among the proportional body measurements and the measurements of girth (Table VII). More than half of the correlation coefficients (69 of 120) do not reach the ·001 level of significance. The correlation coefficients of the upper arm length, the hand length, the leg length and the ankle height are all beneath the ·001 level of significance. Of the relatively high values of the correlation coefficient for the length of the upper and lower limbs the highest ones refer to the circumference of the trochanter.

Table VII.

Total correlations of the proportional body measurements with the girth measurements of the trunk and limbs

Measurements	Head circum-ference	Neck circum-ference	Chest circum-ference	Waist circum-ference	Abdomen circum-ference	Trochan-ter circum-ference	Upper arm circum-ference	Forearm circum-ference	Wrist circum-ference	Thigh circum-ference	Leg circum-ference	Ankle circum-ference
Trunk length	.306 *.264**	.208* *.162**	.338 *.306*	.256* *.174**	.287* *.223**	.325 *.329*	.328 *.165**	.385 *.308*	.258* *.254**	.270* *.319*	.325 *.288*	.316 *.273*
Lenght of the upper limb	.394 *.351*	.397 *.229**	.385 *.427*	.311 *.495*	.269* *.449*	.396 *.525*	.202* *.289*	.405 *.440*	.333 *.373*	.295 *.433*	.248* *.322*	.340 *.311*
Upper arm lenght	.262* *.305*	.274* *.278*	.228* *.430*	.121* *.484*	.073* *.439*	.223* *.501*	.072* *.342*	.209* *.438*	.104* *.401*	.186* *.460*	.103* *.355*	.162* *.291*
Forearm length	.236* *.263**	.297 *.088**	.276* *.234**	.318 *.246**	.261* *.257**	.324 *.306*	.172* *.052**	.325 *.155**	.243* *.094**	.226* *.173**	.241* *.248**	.289* *.209**
Hand length	.252* *.129**	.092* *.101**	.116* *.175**	.096* *.234**	.159* *.190**	.143* *.224**	.216* *.163**	.164* *.275*	.216* *.213**	.066* *.210**	.097* *−.049**	.166* *.071**
Length of the lower limb	.345 *.272*	.351 *.240**	.408 *.383*	.361 *.449*	.390 *.464*	.457 *.504*	.284* *.229**	.390 *.324*	.278* *.229**	.362 *.349*	.331 *.258**	.398 *.251**
Thigh length	.279* *.279*	.282* *.313*	.384 *.336*	.402 *.399*	.438 *.429*	.455 *.467*	.303 *.219**	.408 *.321*	.326 *.268**	.371 *.356*	.315 *.255**	.395 *.248**
Leg length	.274* *.132**	.293 *.052**	.279* *.256**	.169* *.295*	.158* *.308*	.282* *.331*	.132* *.101**	.212* *.157**	.094* *.053**	.201* *.159**	.198* *.090**	.230* *.092**
Ankle height	.228* *.161**	.162* *.025**	.009* *.178**	.018* *.180**	.053* *.076**	.086* *.213**	.101* *.130**	.131* *.202**	.175* *.220**	.122* *.232**	.120* *.372*	.150* *.281*
Total head height	.446 *.294*	.293 *.169**	.351 *.211**	.337 *.194**	.322 *.186**	.320 *.037**	.342 *.151**	.363 *.220**	.273* *.107**	.319 *.192**	.268* *.185**	.322 *.147**

3. Total Correlations of Breadth Measurements of the Trunk

The breadth measurements of the women athletes yield moderately high correlations with each other. Values higher than $r = \cdot 7$ refer to the upper half of the trunk; the chest breadth shows the lowest correlations (Table VIII, Figure 4).

Table VIII.

Total correlations of the breadth measurements of the trunk with themselves

Measurements		1	2	3	4	5	6	7	8
Biacromial breadth	1	1.00	.667 *.687*	.585 *.555*	.394 *.200**	.506 *.382*	.310 *.266**	.589 *.408*	.518 *.471*
Bideltoid breadth	2		1.00	.789 *.766*	.512 *.388*	.610 *.540*	.410 *.264**	.697 *.521*	.745 *.760*
Chest breadth	3			1.00	.579 *.304*	.717 *.603*	.360 *.207**	.707 *.465*	.740 *.705*
Chest depth	4				1.00	.521 *.349*	.254* *.062**	.535 *.427*	.552 *.300*
Waist breadth	5					1.00	.330 *.288*	.677 *.573*	.637 *.557*
Bispinal breadth	6						1.00	.566 *.490*	.277* *.167**
Bitrochanteric breadth	7							1.00	.607 *.451*
Breadth of the back	8								1.00

Among the breadths and girths of the trunk the highest correlations also refer mostly to the upper half of the trunk. The breadth and girth measurements of the chest, and the bitrochanter breadth and bitrochanter circumference give high correlations, too (Table IX, Figure 5).

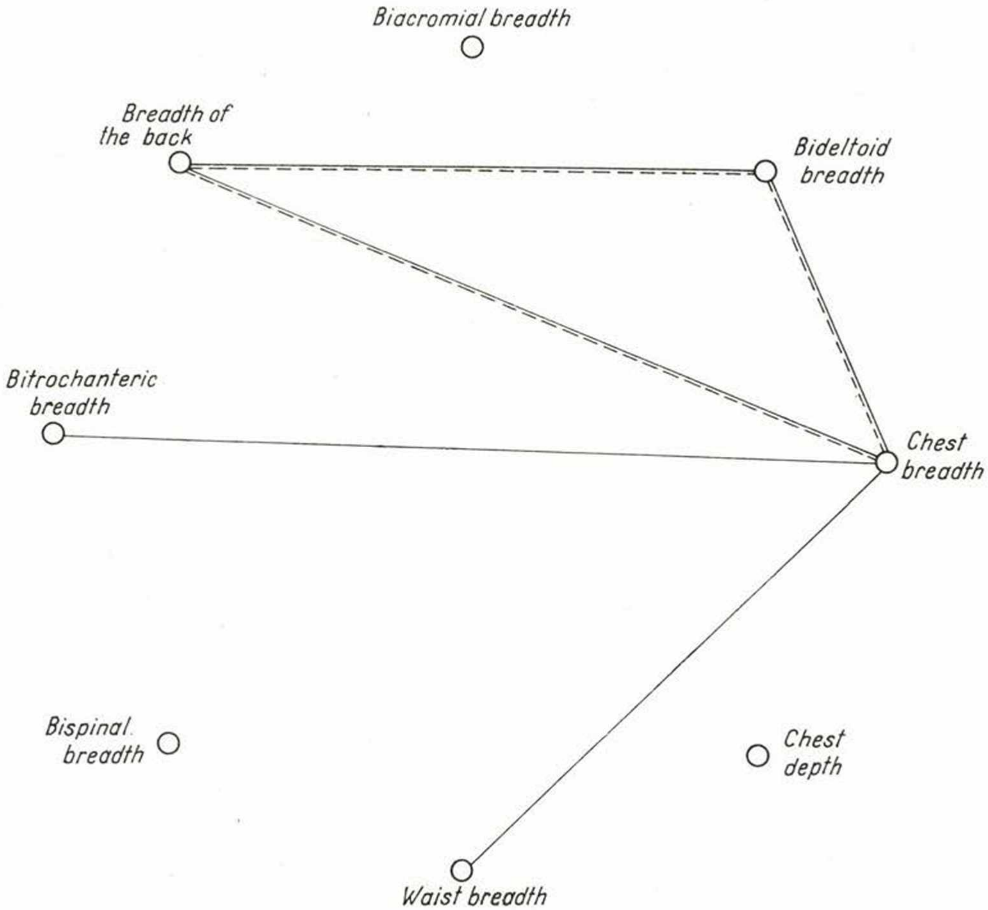

Fig. 4. A schematic representation of some important total correlations of the breadth measurements with themselves

Table IX.

Total correlations of the breadth measurements of the trunk with the girth measurements of the trunk and limbs

Measurements	Head circum-ference	Neck circum-ference	Chest circum-ference	Waist circum-ference	Abdomen circum-ference	Trochanter circum-ference	Upper arm circum-ference	Forearm circum-ference	Wrist circum-ference	Thigh circum-ference	Leg circum-ference	Ankle circum-ference
Biacromial breadth	.425 *.332*	.346 *.371*	.551 *.467*	.505 *.494*	.563 *.480*	.553 *.424*	.492 *.359*	.522 *.458*	.365 *.439*	.451 *.419*	.435 *.316*	.506 *.343*
Bideltoid breadth	.533 *.311*	.394 *.481*	.736 *.688*	.663 *.702*	.642 *.589*	.680 *.557*	.666 *.703*	.748 *.674*	.459 *.590*	.677 *.645*	.587 *.387*	.611 *.375*
Chest breadth	.586 *.353*	.364 *.418*	.806 *.753*	.733 *.677*	.671 *.562*	.729 *.515*	.681 *.601*	.733 *.568*	.471 *.484*	.700 *.588*	.514 *.362*	.607 *.366*
Chest depth	.326 *.237**	.333 *.495*	.645 *.556*	.534 *.519*	.565 *.439*	.574 *.516*	.490 *.467*	.535 *.473*	.310 *.451*	.493 *.533*	.466 *.320*	.510 *.300*
Waist breadth	.419 *.222**	.351 *.457*	.679 *.549*	.674 *.795*	.692 *.647*	.646 *.560*	.545 *.566*	.634 *.517*	.383 *.450*	.594 *.554*	.494 *.344*	.530 *.441*
Bispinal breadth	.187* *.184**	.230* *.118**	.366 *.148**	.345 *.341*	.342 *.299*	.358 *.363*	.234* *.182**	.297 *.258**	.214* *.170**	.296 *.189**	.293 *.172**	.263* *.341*
Bitrochanteric breadth	.463 *.232**	.417 *.321*	.685 *.494*	.680 *.660*	.656 *.543*	.748 *.710*	.583 *.535*	.656 *.526*	.479 *.508*	.637 *.636*	.567 *.443*	.565 *.502*
Breadth of the back	.463 *.305*	.284* *.373*	.683 *.644*	.644 *.623*	.615 *.461*	.645 *.465*	.642 *.622*	.676 *.577*	.353 *.493*	.617 *.588*	.528 *.419*	.502 *.390*

It is notable in the relationship of the trunk and the girth measurements of the limbs that the distal girth measurements of the upper limbs but the proximal girth measurements of the lower limbs show higher correlation with the width dimensions of the trunk.

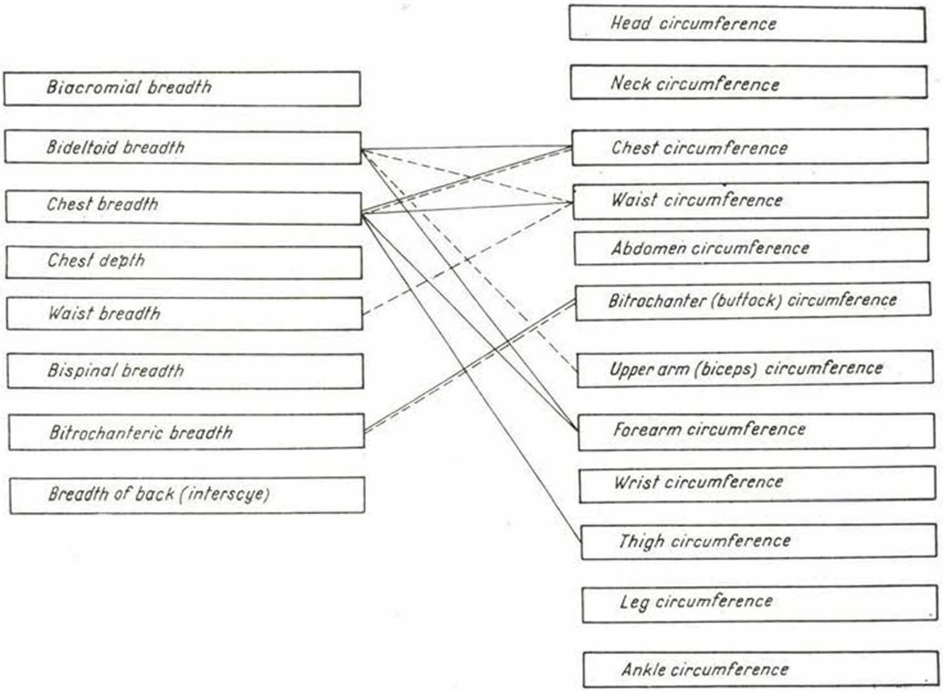

Fig. 5. A schematic representation of some important total correlations of the breadth measurements with the girth measurements

4. Total Correlations of the Girth Measurements of the Trunk and Limbs

The author found satisfactory correlations with each other for the girth measurements of the women athletes; there are numerous values above $r = \cdot 7$. In this respect the trunk forms a strongly homogeneous block. The above mentioned phenomenon recurs in connection with the limbs: the values of the correlation coefficients are greater for the forearm and the thigh than for the upper arm and leg (Table X, Figure 6).

*

Table X.

Total correlations of the girth measurements of the trunk and limbs with themselves

Measurements		1	2	3	4	5	6	7	8	9	10	11	12
Head circumference	1	1.00	.380 *.309*	.485 *.397*	.460 *.320*	.401 *.284*	.523 *.303*	.558 *.259**	.589 *.321*	.305 *.335*	.550 *.288*	.440 *.269**	.427 *.270*
Neck circumference	2		1.00	.435 *.500*	.419 *.545*	.425 *.495*	.484 *.468*	.379 *.503*	.467 *.511*	.334 *.552*	.428 *.500*	.363 *.260**	.394 *.464*
Chest circumference	3			1.00	.743 *.749*	.745 *.586*	.779 *.611*	.665 *.686*	.782 *.657*	.466 *.585*	.706 *.702*	.607 *.415*	.641 *.429*
Waist circumference	4				1.00	.749 *.770*	.777 *.741*	.707 *.744*	.766 *.685*	.505 *.557*	.686 *.714*	.562 *.391*	.606 *.483*
Abdomen circumference	5					1.00	.715 *.752*	.677 *.532*	.710 *.515*	.531 *457*	.631 *.583*	.593 *.263**	.671 *.407*
Trochanter circumference	6						1.00	.704 *.592*	.782 *.587*	.573 *.560*	.760 *.725*	.688 *.368*	.652 *.451*
Upper arm circumference	7							1.00	.765 *.749*	.583 *.635*	.706 *.747*	.592 *.439*	.595 *.454*
Forearm circumference	8								1.00	.605 *.723*	.788 *.683*	.695 *.434*	.768 *.524*
Wrist circumference	9									1.00	.488 *.613*	.491 *.473*	.560 *.600*
Thigh circumference	10										1.00	.706 *.552*	.644 *.537*
Leg circumference	11											1.00	.695 *.565*
Ankle circumference	12												1.00

In most cases the *female students* of the Physical Education College (their data are given in all Tables in the lower rows in italics) show similarly high correlations with those of the women athletes. Their correlation coefficients generally give some lower values than those of the women athletes. The reverse case occurs too ,but rarely. All the more important connections are graphically shown in Figures 1 – 6.

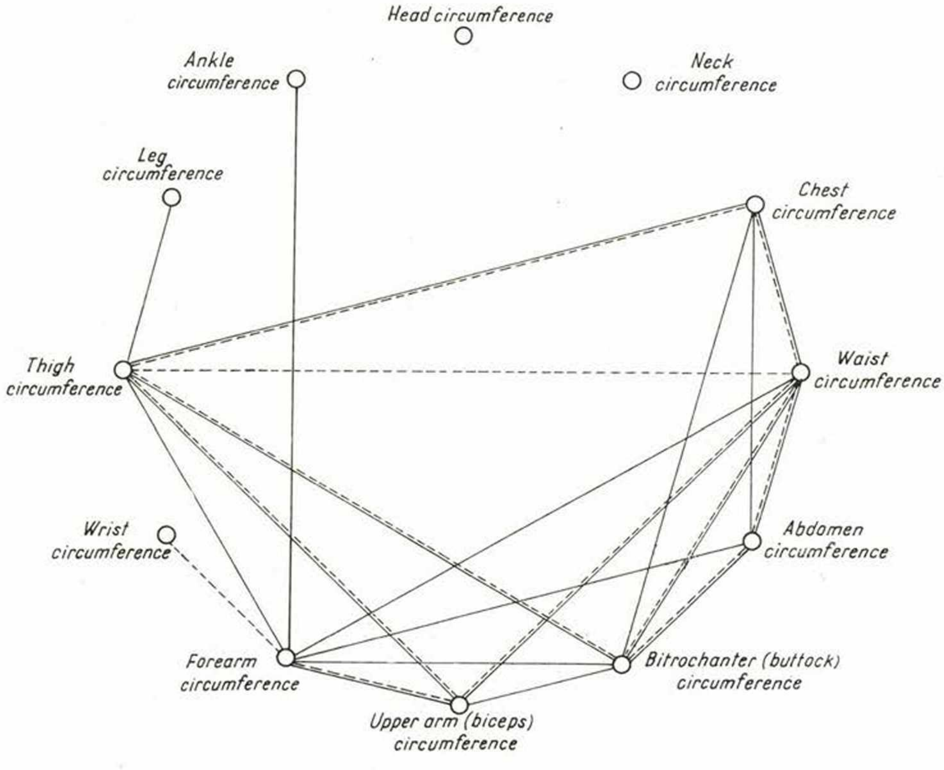

Fig. 6. A schematic representation of some important total correlations of the girth measurements with themselves

The Teachers College girls' body measurement correlations show similar order to the two former groups, but here we can find more of the lower r values than in the first two groups (Table XI). (It must be mentioned that during this research because of some technical difficulties only a part of the total correlations could be computed.)

Table XI.

Some total correlation coefficients with the female students of the Teachers College

Measurements	Weight	Stature	Biacromial breadth	Bideltoid breadth	Bitrochanteric breadth	Chest circumference
Weight	1.00	.560	.552	.819	.822	.803
Sitting height	.521	.755				
Span		.811				
Stature	.560	1.00	.619	.492	.482	.385
Suprasternale height		.960				
Acromiale height		.966				
Radiale height		.791				
Stylion height		.831				
Dactylion height		.737				
Spina iliaca height	.425	.842				
Tibiale height		.792				
Ankle height		.315				
Biacromial breadth	.552	.619	1.00	.723	.443	.478
Bideltoid breadth	.819	.492	.723	1.00	.691	
Chest breadth	.646	.359	.497	.721	.528	.711
Chest depth	.547	.320	.225*	.419	.539	.531
Bispinal breadth	.539	.544	.439	.490	.526	.390
Bitrochanteric breadth	.822	.482	.443	.691	1.00	.640
Breadth of the back	.708	.353	.607	.770	.569	.732
Chest cricumference	.803	.385	.478		.640	1.00
Abdomen circumference		.317	.342	.637	.669	.686
Trochanter circumference	.891	.456	.413	.728	.869	.750
Upper arm circumference		.264				
Forearm circumference		.352				
Wrist circumference		.172*				
Thigh circumference		.312				
Leg circumference		.152*				
Ankle circumference		.428				

B) Partial Correlations

In addition to the total correlational connections discussed above we have to refer to the partial correlations. Here first of all those connections must be considered in which the value of p.c.c. is higher than $r = \cdot 6$. These connections can be seen in the first column of Table XII. For an easier comparison besides the p.c.c-s the t.c.c-s are also given (in column 2).

The *length measurements* give high partial correlations partly with some length measurements, partly (and more often) with some proportion measurements, but their partial correlation values always remain under $r = \cdot 6$ with the widths of the trunk and the girths of the trunk and the limbs.

The *proportions* of the body give a higher p.c.c. than $r = \cdot 6$ with the length measurements only.

Table XII.

Partial correlations with women athletes and female students of the Physical Education College

Variates	$r_{partial}$	r_{total}
Suprasternale height – Symphysis height	.999 *.714*	.834 *.853*
Suprasternale height – Trunk length	.999 *.774*	.423 *.718*
Symphysis height – Trunk length	*.890*	*.289*
Acromiale height – Radiale height	.849	.926
Acromiale height – Length of the upper limb	*.612*	*.822*
Acromiale height – Upper arm length	.975 *.809*	.638 *.761*
Radiale height – Stylion height	*.725*	*.921*
Radiale height – Upper arm length	.867	.302
Radiale height – Forearm length	*.874*	*.573*
Stylion height – Forearm length	–.915 *.813*	.247* *.209**
Dactylion height – Hand length	.638 *.834*	.133* *–.021**
Spina iliaca height – Thigh length	.998 *.834*	.834 *.884*
Tibiale height – Ankle height	.905 *.647*	.282* *.430*
Tibiale height – Thigh length	*.702*	*.406*
Tibiale height – Leg length	.903 *.680*	.975 *.956*
Ankle height – Leg length	.999 *.943*	.060* *.163**
Dideltoid breadth – Forearm length	.664	.748
Stature – Kaup index	.615 *–.490*	.191* *.016**
Stature – Body surface	.643 *.721*	.820 *.835*
Weight – Kaup index	.612 *.542*	.870 *.773*
Weight – Body surface	.696 *.819*	.964 *.954*

From the *breadth measurements* of the trunk only the bideltoid breadth can be found once in Table XII; among the girth measurements discussed here there is no p.c.c. which is higher than $r = \cdot 6$.

It must be mentioned, however, that very high ($r = \cdot 8 - \cdot 9$) p.c.c. values are given between the two circumferences of the chest (maximal inspiration and maximal exspiration), furthermore between these two chest circumferences and the difference of these ones, and between the extended and flexed upper arm circumferences.

We have to mention the Kaup-index and the body surface here. These two indices were calculated from the stature and the weight (by a nomogram). They generally show very high correlations with these two body measurements. Therefore is the very low, non-significant total correlation between the stature and Kaup-index so remarkable (Table XII, second part).

Conclusions

In the research of the feminine physique by total correlation analysis it can be stated that the length measurements of the body are highly correlated among themselves. The length measurements show a high correlational connection with that proportion with which they are connected directly, e. g. tibiale (knee) height and leg length. The length of the upper and the lower limb give a high correlation coefficient value with nearly all length measurements. Among the proportion length measurements of the limbs in the case of the upper limb the proximal part (i.e. upper arm length) and in the case of the lower limb the distal part (i.e. leg length) show relatively higher correlation with the length measurements. But the correlation is always higher between the total length of the limbs and the length of their proximal parts ($r = \cdot 7 - \cdot 8$), than between the total length of the limb and its distal part ($r = \cdot 5 - \cdot 7$). Weight gives a high correlation with the widths of the trunk and with all the circumferences.

The low correlations which can be found among the proportions and the width measurements of the trunk, as well as among the former ones and all the circumferences have been already mentioned. The width measurements of the trunk — within each region of the trunk — are in high correlation with each other and the circumferences. The circumferences of the trunk give relatively high correlation not only with each other, but with the girths of the limbs, too.

Most of these connections are well known in the literature of physique. Connections which appear to be new have properly been discussed.

Sometimes the *partial correlations* simply strengthen i.e. verify the already known correlations with the nearly equal values of correlation coefficients. It happens in other cases that — though the t.c.c. is not significant at the $\cdot 001$ level — the value of the p.c.c. is high (a number of examples can be found like this in Table XII). One must not come to a very decisive conclusion from this fact, because in our sample the case of multicollinearity is present. We speak about multicollinearity in the regression analysis and in the correlation analysis based on this (first of all in the multiple linear regression analysis) if among the independent variates there are (one or more) linear function relationships. In our case there is a high linear correlation among the partly independent variates (i.e. body measurements) of the linear regression. That means that each body measurement is not only explained by that other one with which we have brought it into a partial correlation, but by all the other ones together, too. In this case the normal equations can be solved, but the adequate partial regression coefficients can be estimated with a high error.

Therefore we have to be satisfied with those connections which were shown by the t.c.c-s, and which are summarized here. The further analysis of this sample is made by generalized coordinates (E i b e n 1969 b).

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