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Somatotype of the individuals with lower extremity amputation and its association with cardiovascular risk

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With 7 tables

Summary: Anthropometric somatotyping is one of the methods to describe the shape of the human body, which shows some associations with an individual's health and disease condition, especially with cardiovascular diseases (CVD). Individuals with lower extremity amputation (LEA) are known to be more vulnerable to the cardiovascular risk. The objectives of the present study are to report the somatotype of the individuals having lower extremity amputation, to study the possible variation in somatotype between two groups of amputated individuals, and to study the association between cardiovascular disease risk factor and somatotype components among individuals with locomotor disability. 102 adult male individuals with unilateral lower-extremity amputation residing in Calcutta and adjoining areas were investigated. The anthropometric data for somatotyping and data on cardiovascular risk traits (such as body mass index, blood pressure measurements, blood lipids) have been collected. The somatotyping technique of Carter & Heath (1990) has been followed. The result shows high mean values of endomorphy and mesomorphy components and a low mean value of the ectomorphy component among the amputated individuals having cardiovascular risks. The results of both discriminant analysis and logistic regression analysis show a significant relationship between somatotype components and CVD risk among the individuals with LEA. The findings of the present study support the findings of similar studies conducted on the normal population. Diagnosis of CVD risk condition through somatotyping can be utilized in prevention/treatment management for the individuals with LEA.

Key words: Somatotypes, cardiovascular risk factors, lower extremity amputation.

Introduction

Somatotyping is a method of describing human physique; the credit for the development of somatotype method goes to Sheldon (1940), though various scientists like Viola, Kretschmer, Sheldon and Parnell also contributed in their own way to develop the method for assessing the shape of the human body (Harrison et al. 1988). Somatotype is a 3-numeral rating system, in which the shape of the human body (not the size) is expressed. The method of Sheldon, subsequently modified by others like Hammond (1957), Tanner (1951), Hooton (1959) and Parnell (1958) in order to make the method more useful, can effectively describe an individual's physical constitution. Ultimately, Heath & Carter (1967) proposed a somatotype technique using anthropometric measurements with universal rating scales, applicable to both sexes and all ages, which is followed even today. The Heath-Carter (1967) method

has been further modified including the conversion of somatotype rating in a continuous scale, the use of height adjustment for endomorphy and the use of equations instead of rating form to calculate the component ratings (Carter et al. 1983, Carter & Heath 1990). There are 3 components of somatotype – *endomorphy* (describes relative fatness), *mesomorphy* (describes relative musculoskeletal development) and *ectomorphy* (describes relative linearity) –, which jointly express the physical constitution of an individual in an easily comprehensible form compared to an array of anthropometric measurements presented as such.

Anthropometric somatotyping has been employed extensively in evaluating the relationship between physique and physical performance of athletes at various competitive levels in a variety of sports (Carter 1970, Parizkova 1970, 1972, de Garay 1974, Ross et al. 1977, Withers 1987). Studies of somatotyping also have been used for various purposes, including demonstration of similarities/differences between and within different groups (Prakash & Malik 1989), the influence of different factors on somatotype such as age (Zuk 1958, Heath & Carter 1971, Walker 1978, Bailey et al. 1982, Hebbelinck et al. 1995, Ji et al. 1996, Gaur & Singh 1997, Carter et al. 1997, Buffa et al. 2005), sex (Bailey et al. 1982, Carter et al. 1997, Buffa et al. 2005, Tanner 1962, Parizkova & Carter 1976, Carter & Parizkova 1978), smoking factors (Prakash & Malik 1988), physical environment (Docherty et al. 1986, Hayward et al. 1986, Malik et al. 1986a, Singh et al. 1986, Pandey & Malik 1990), genetic effects (Song et al. 1993), nutritional status and body composition (Malik et al. 1986b, Slaughter & Lohman 1976, Rosique et al. 1994, Bolonchuk et al. 1989, Bolonchuk et al. 2000), psychological condition (Bulbena et al. 1996). Roy (1990, 2002) studied the relationship of somatotype with work performance/productivity among the tea garden and agricultural labourers.

The epidemiological studies for determining the association between somatotype and different diseases (especially cardiovascular diseases) as well as metabolic fitness (Katzmarzyk et al. 1998) is presently getting momentum. The association between somatotype and cardiac heart diseases received attention several decades ago (Spain et al. 1955, 1963, Paul et al. 1963, Gartler et al. 1967, Damon et al. 1962), but extensive studies have not been done. Later on, several large scale studies have also been done based on both hospital and population based data (Bailey 1985, Gordon et al. 1987, Newell-Morris et al. 1989, Malina et al. 1997, Willams et al. 2000, Bell et al. 2005). The majority of these studies indicated that most of the cardiac patients have a high score of mesomorphic component and some also have high scores of endomorphic component.

Cardiovascular diseases (CVD) are the leading cause of mortality in humans (WHO 2002). Clinicians and the researchers have identified several risk factors of CVD to screen out the persons at risk of attaining the CVD (Kannel 1961), which is useful for the proper management of the disease. The term 'risk factor' generally denotes a factor, which has a positive association of developing a particular disease (Beaglehole et al. 1993). The Framingham Heart Study (Wilson 1998) introduced the concept of cardiovascular risk factors, to make primary prevention of CVD more effective, which enables a categorization of patients for selection of appropriate interventions, through an assessment of cardiovascular risk. Subsequent researches classified the cardiovascular risk factors into 1. Major independent risk factors (includes smoking, advance age, elevated blood pressure, elevated serum total cho-

lesterol, elevated blood glucose, etc.), 2. Predisposing risk factors (includes obesity, abdominal obesity, physical inactivity, family history, etc.), and 3. Conditional risk factors (includes elevated serum triglycerides, VLDL, etc.) (Grundy et al. 1999).

Grundy et al. (1999) emphasized physical inactivity as one of the leading factors of CVD. This was supported by Oldridge & Stump (2004) and Pollitt et al. (2005). They proved that a low physical activity level has a fatal effect, which often leads to an enhanced risk of developing CVD in the general population. Physically disabled individuals are particularly vulnerable to this problem, especially the locomotor disabled persons, who generally have a very low physical activity level due to their impairedness. Therefore, the risk of developing CVD is higher among locomotor disabled persons (Reshnick et al. 2004).

Various follow-up studies on prognosis of the lower extremity amputation (LEA) show that most of the individuals with LEA suffer from peripheral vascular or cardiovascular diseases (Weiss et al. 1990, Condie et al. 1996). Cross-sectional studies also reveal higher prevalence of CVD risk factors among individuals with LEA (Reshnick et al. 2004, Madan et al. 1998). Again, Resnick et al. (2004) reported that the risk of developing CVD is higher among individuals with amputation due to peripheral vascular disease, but the individuals with traumatic amputation also show high mortality due to CVD (Madan et al. 1998). In a follow-up study among traumatic amputees, Hrubec & Ryder (1980) showed that the differential mortality rate due to CVD varies, depending on the site of amputation and the mortality rate due to CVD is higher in the individuals with proximal limb amputation than the individuals with distal limb amputation.

It is intuitively understandable and the literature review also stated that disabled individuals especially with locomotor disability are more likely to develop CVD. Furthermore, CVD has been found to be associated with specific somatotype. Therefore, somatotype rating of the individuals with locomotor disability can be utilized for the management of CVD risk. However, hardly any study attempted to report the somatotype of the individuals with locomotor disability.

In view of the above, the objectives of the present study are: (1) to report the somatotype of the individuals having lower extremity amputation living in and around Calcutta city, (2) to study the possible variation in somatotype between two types of locomotor disabled groups, and (3) to study the association between cardiovascular disease risk factor and somatotype components among individuals with locomotor disability. It would have also been more interesting to see the CVD risk of non-amputated persons, having similar somatotype components as that of amputated persons, but due to hugeness of data, it was not possible to include the data and analysis with the present article.

Methods

Population and area

The data used in the present study have been collected as a part of a larger biomedical program involving individuals with lower extremity amputation living in Calcutta and its adjoining areas. Two national level rehabilitation centres, the National Institute for the Orthopedically Handicapped and the Mahavir Seva Sadan,

have been contacted for a list of addresses of amputated individuals. A statement of purpose of the present research and a consent form seeking their participation in the study, have been mailed to about 1000 individuals with unilateral lower extremity amputation. Respondents, with written consent, have been included in the study. The study has been performed in accordance with the responsible committee on human experimentation (Scientific Ethical Committee for Protection of Research Risks to Humans, Indian Statistical Institute). Data have been collected from a total of 102 adult males (voluntarily participated), who had unilateral lower extremity amputation. 32 individuals of them have above knee amputation (AKA) and 70 individuals have below knee amputation (BKA). These are the common terms used in literature of the amputees as above knee (transfemoral amputation) and below knee (transtibial amputation) amputation.

The mean age of the subjects was 43.54 ± 15.37 years. A large proportion (82.6 %) of the individuals had traumatic amputation, only 11.0 % had amputation due to gangrene and the remaining 6.4 % had a reported history of cancer. All subjects have prosthesis and all of them had been amputated at least two years prior to the study. All data have been collected by a single investigator (AM) through multiple home visits.

Data type and data collection

Anthropometric measurements have been collected following standard techniques as recommended by the International Biological Program (IBP) (Weiner & Lourie 1981). The anthropometric somatotypes of Carter & Heath (1990) has been used for obtaining somatotype rating. The following measurements have been taken from subjects wearing light apparel:

1. Stature (cm)
2. Body weight (kg)
3. Biepicondylar breadth of humerus (cm)
4. Bicondylar breadth of femur (cm)
5. Upper arm circumference (cm)
6. Calf circumference (cm)
7. Skinfold thickness, triceps (mm)
8. Skinfold thickness, subscapular (mm)
9. Skinfold thickness, supraspinale (mm)
10. Skinfold thickness, calf (mm)

All the subjects of the present study have some physical disability (unilateral lower extremity amputation), the anthropometric measurements of the subjects have been collected with prior precautions. The subjects were requested to wear prosthesis before taking stature and body weight measurements (if required supported against a wall and with adequate precautions to guard against bending of the trunk and knees). The weight of the prosthesis was taken alone and subtracted from the previous weight with prosthesis, to get the actual weight (post-amputation) of the body. As there is no standard method for measuring stature of the amputated individuals, the stature measurement of an amputee was cross-checked for consistency by calculating body proportions (sitting height/stature) (Drillis & Contini 1986) and compared with normal individuals. It was therefore necessary to recalculate the body weight of the individuals with LEA in order to obtain more reliable data for body mass.

The body weight of the individuals with LEA has been calculated by using the method described by Mozumdar & Roy (2004), i.e. by using the weight proportions of the different limb segments of the body with the help of following equations:

$$W_E = W_O / (1 - \Delta W / W_E),$$
$$\Delta W / W_E = 1.5 + 4.4\,(1 - L_{Stp} / L_{Kn}) \text{ (for individuals with BKA)},$$
$$\Delta W / W_E = 1.5 + 4.4 + 10.1\,(1 - L_{Stp} / L_{BtK}) \text{ (for individuals with AKA)},$$

where W_O is the observed body weight, W_E is the body weight to be estimated, $\Delta W = (W_E - W_O)$, L_{Stp} is the length of the stump (remaining portion of the limb from its nearest distal

bone-joint). L_{Kn} is the knee height and L_{BtK} is the buttock knee length.

However, some additional anthropometric measurements have been taken for this purpose, i.e. length of the stump and knee height (for individuals with BKA) or buttock knee length (for individuals with AKA). 'Stump' here denotes the remaining portion of the amputated limb from its nearest distal bone-joint (knee joint in case of individuals with BKA and hip joint in case of individuals with AKA). The length of the stump has been measured from the distal most tip of the stump to tibiale (for individuals with BKA) or rear most point of the buttock (for individuals with AKA), followed by standard techniques of measurement in case of the other two measurements (i.e. knee height and buttock knee length), which have been included in the IBP list of standard measurements (Weiner & Laurie 1981). The measurements have been utilised in many studies on locomotor disabled individuals including amputees (Goswami et al. 1987, Jarosz 1994, Das & Kozey 1994). It is worth noting that measurements like knee height and buttock knee length have been taken from the limb, which lies intact (not amputated) assuming bilateral symmetry.

Somatotype rating

In the present study the anthropometric somatotyping techniques following Carter & Health (1990) have been used.

Endomorphy has been determined by using the following formula: $0.0000014\ (X^3) + 0.00068\ (X^2) + 0.1451\ (X) - 0.7182$, where X is the sum of the triceps, subscapular and supraspinale skinfold thickness adjusted for stature i.e. X = sum of the skinfold thickness × (170.18/ stature).

Mesomorphy has been determined by using the following formula: [(0.858 × biepicondylar diameter of humerus) + (0.601 × bicondylar diameter of femur) + {0.188 × (upper arm circumference – triceps skinfold)} + {0.161 × (calf circumference – calf skinfold)}] – (stature × 0.131) + 4.50. As a note of caution both triceps and calf skinfold thickness have been measured in millimeter scale and at the time of subtraction this unit have been converted into centimeter scale in order to equalize the unit of measurement.

Ectomorphy has been obtained by using the formula HWR (Height Weight Ratio) × 0.732 – 28.58. Where, HWR = Stature / $\text{Weight}^{1/3}$. If HWR is less than 40.75 but greater than 38.25, ectomorphy has been determined by using HWR x 0.463 – 17.63. If HWR is equals to or less than 38.25, a rating of 0.1 has been assigned to the ectomorphy rating.

The X and Y coordinates have been calculated using the following formulae:

$$X = \text{Ectomorphy} - \text{Endomorphy},\ Y = 2 \times \text{Mesomorphy} - (\text{Ectomorphy} + \text{Endomorphy}).$$

A number of cardiovascular disease (CVD) risk factor measurements have also been taken from the same individuals and their respective cut-off points have been used for determining the association between CVD risk factors and somatotype components (Table 1).

The Body Mass Index (BMI) has been calculated from the anthropometric measurements using the formula body weight in kg/stature in m^2. BMI has been calculated after estimating the total body weight of the individuals with amputation using the method of Mozumdar & Roy (2004). The waist circumference measurement has been taken at the iliac crest level.

Blood pressure measurements i.e. systolic blood pressure (SBP) and diastolic blood pressure (DBP) have been taken after 15 minutes' rest period, in a sitting position on the left hand by the auscultatory method using a mercury blood pressure instrument (Sphygmomanometer) and a stethoscope.

The blood samples have been collected by finger pricking following standard techniques and collecting the blood on different strips meant for different blood analysis. All the blood parameters have been analysed immediately after taking the blood samples from the subjects on the spot, i.e. in the field itself with a dry autoanalyser (Accutrend-GCT manufactured by Boehringer, Mannheim, 1999). The blood samples were placed in different strips into the auto-analyser and the respective results were recorded. The presence of at least three or more

CVD risk factors (overweight, central obesity, hypertension either for SBP or DBP, hyperglycemia, hyperlipidemia, hypertriglyceridemia) has been considered as a case of CVD risk.

The subjects have been classified according to the presence or absence of knee joint as the functional outcome varies between the groups and the groups are Above Knee Amputees (AKA) and Below Knee Amputees (BKA).

Data analysis

The Somatotype Dispersion Distance (SDD) for the individual somatotypes has been calculated to measure the distance from the mean somatotype separately for the individuals with AKA and BKA, using the following formula:

$$SDD_i = \sqrt{[3\ (X_i - \overline{X})^2 + (Y_i - \overline{Y})^2]},$$

where SDD = Somatotype Dispersion Distance; X_i, Y_i represent the somatoplot of a given individual in 2 dimension; $\overline{X}$ and $\overline{Y}$ are the mean values of X and Y coordinate scores of the individuals of a group.

The Somatotype Attitudinal Distance (SAD) for the individual somatotypes has been calculated to measure the distance from the mean somatotype separately for the individuals with AKA and BKA, using the following formula:

$$SAD_i = \sqrt{[(EN_i - \overline{EN})^2 + (ME_i - \overline{ME})^2 + (EC_i - \overline{EC})^2]},$$

where SAD = Somatotype Attitudinal Distance; EN_i, ME_i, EC_i represent the endomorphic, mesomorphic and ectomorphic components of the somatotype of a given individual; $\overline{EN}$, $\overline{ME}$ and $\overline{EC}$ are the mean values of somatotype components of the individuals of a group.

Table 1. Cardiovascular disease risk factor measurements and their respective cut-off points.

Risk factors	Name of measurements	Cut-off points	References
Overweight	Body Mass Index (BMI)	≥ 25 kg/m^2	WHO (2002)
Central adiposity	Waist Circumference (WC)	> 90 cm	Tan et al. (2004)*
Hypertension	Systolic Blood Pressure (SBP)	≥ 140 mm Hg	Wilson et al. (1998)
	Diastolic Blood Pressure (DBP)	≥ 90 mm Hg	Wilson et al. (1998)
Hyperglycemia	Random Blood Glucose	> 126 mg/ dL	ADA (2004)
Hyperlipidemia	Total Cholesterol in Blood	> 200 mg/ dL	NCEP (2001)
Hypertriglyceridemia	Total Triglycerides in Blood	> 150 mg/ dL	NCEP (2001)

* In classic studies the standard cut-off value ≥ 94 cm of WC had been considered as a CVD risk. However, Lear et al. (2002, 2003) studied the relationship of anthropometric measurements and risk factors (mostly metabolic) across different ethnic groups (Europeans and South Asians). One of the major findings of them is that men and women of South Asian descent show more adverse risk profile than those of European descent at the same BMI and/or WC. Therefore, the inappropriateness of the recommended cut-off value of WC for diagnosis of CVD risk in Asian population, due to their smaller stature was noted. In a study to determine appropriate cut off value of WC for metabolic syndrome among Asian population, Tan et al. (2004) had found that cut-off value of WC higher than 90 cm among male is more appropriate for the said purpose than the conventional 94 cm cut-off value for WC. Therefore In the present paper, the cut-off value of > 90 cm WC has been considered as one of the CVD risk condition.

The Somatotype Intensity (INT) for the individual somatotypes has been calculated to measure the magnitude of the vector from the origin of the two or three-component scales (hypothetical 0,0 score of X–Y coordinates or 0-0-0 somatotype) to the somatoplots separately for the individuals with AKA and BKA, using the following formula:

$$INT_i = X_{O \cdot i},$$

where X = SDD or SAD; the intensity of somatotype (INT) of an individual (i) is equal to the magnitude of the SDD or SAD from the origin (O).

The difference between mean somatotypes of two groups (i.e. individuals with AKA and BKA) has been tested both in terms of SDD and of SAD separately by calculating somatotype t-test using following formula:

$$t = X_{\bar{S}_1 \bar{S}_2} / \sqrt{[(\sum X_1^2 + \sum X_2^2) * (1/n_1 + 1/n_2) / (n_1 + n_2 - 2)]},$$

where X = SDD or SAD; $\bar{S}$ = mean somatotype.

Cressie et al. (1986) claimed that the procedure of Carter et al. (1983) prematurely collapse the three component somatotype vectors into a scalar SAD value, leading to inappropriate degrees of freedom. They suggested increasing the degrees of freedom to include those for the three separate components, thus increasing the likelihood of type I errors when compared to the method of Carter et al. (1983). However, Carter (1996) rejected the idea by saying that the procedure suggested by Cressie et al. (1986) fails to analyse the whole somatotype. On the other hand, it prematurely separates the somatotype into three components and therefore denies the integrity of the whole somatotype and erroneously increases the degree of freedom. The SAD should be treated as any other derived variable and not be assigned as degree of freedom based on the variables from which it is calculated. The degrees of freedom for a given variable are not normally based on the number of variables which contribute to them (like body mass index or height weight ratio, etc.) and such a notion violates the basic biological premise of the somatotype as a whole. Therefore, in the present study, the somatotype analysis described in Carter et al. (1983) has been followed.

Descriptive statistics of the somatotype components have been done separately between the individuals 'having' and 'not having' CVD risk. Since there are three components or variables in the somatotype rating of individual, a multivariate approach is more powerful in order to examine the difference in somatotype rating between two groups (Carter 1996).

Discriminant function analysis (DFA) has been used to determine, which continuous variables (somatotype components) discriminate between two or more naturally occurring groups (having and not having CVD risk). DFA is a multivariate analysis of variance (MANOVA) reversed. In MANOVA, the independent variables are the groups and the dependent variables are the predictors. In DFA, the independent variables are the predictors and the dependent variables are the groups. It answers the question: Can a combination of variables be used to predict group membership? Usually, several variables are included in a study to see which ones contribute to the discrimination between groups.

Discriminant function analysis is broken into a 2-step process: (1) testing significance of a set of discriminant functions, and (2) classification. The first step is computationally identical to MANOVA. There is a matrix of total variances and covariances; likewise, there is a matrix of pooled within-group variances and covariances. The two matrices are compared via multivariate F-tests in order to determine whether or not there are any significant differences (with regard to all variables) between groups. The multivariate test is performed first, and, if statistically significant, it is proceeded to see, which of the variables have significantly different means across the groups.

Once group means are found to be statistically significant, classification of variables is undertaken. DFA automatically determines some optimal combination of variables so that the first function provides the most overall discrimination between groups, the second provides second most, and so on. Moreover, the functions will be independent or orthogonal, i.e., their contributions to the discrimination between groups will not overlap. The first function picks

up the most variation; the second function picks up the greatest part of the unexplained variation, etc.

Discriminant functions are interpreted by means of standardised coefficients and the structure matrix. Standardised beta coefficients are given for each variable in each discriminant (canonical) function, and the larger the standardised coefficient, the greater is the contribution of the respective variable to the discrimination between groups. The nature of the discrimination for each discriminant function can be identified, by looking at the means for the functions across groups. Group means are centroids. Differences in location of centroids show dimensions along which groups differ. Therefore, how the two functions discriminate between groups can be visualised by plotting the individual scores for the two discriminant functions.

Another way to determine, which variables define a particular discriminant function is to look at the factor structure. The factor structure coefficients are the correlation between the variables in the model and the discriminant functions. The discriminant function coefficients denote the unique contribution of each variable to the discriminant function, while the structure coefficients denote the simple correlations between the variables and the functions. For the present purpose multivariate DFA has been done in order to determine, which of the somatotype components is associated with the discriminant function (here having or not having CVD risk) among the individuals with LEA.

Furthermore, a stepwise discriminant analysis was performed, in order to identify which subset of somatotype components is best for discrimination of the individuals having or not having CVD risk.

Table 2. Descriptive statistics of anthropometric measurements for the somatotype rating and cardiovascular risk factor measurements in the individuals with LEA.

Anthropometric measurements for somatotype rating	Above knee amputees N = 32		Below knee amputees N = 70		t-value (df = 100)
	Mean	SD	Mean	SD	
Stature (cm)	164.42	6.83	160.85	7.15	2.373*
Body weight (kg)	59.97	12.41	54.49	11.36	2.196*
Biepicondylar breadth of humerus (cm)	6.93	0.73	6.49	0.42	3.837**
Bicondylar breadth of femur (cm)	9.31	0.79	8.99	0.56	2.355*
Upper arm circumference (cm)	29.14	3.24	26.40	3.37	3.858**
Calf circumference (cm)	35.56	3.36	32.20	4.83	3.56**
Skinfold thickness, triceps (mm)	12.91	4.63	10.63	4.43	2.377*
Skinfold thickness, subscapular (mm)	24.38	10.09	17.70	9.12	3.32**
Skinfold thickness, supraspinale (mm)	15.42	7.01	12.37	5.40	2.397*
Skinfold thickness, calf (mm)	12.33	4.34	9.99	5.24	2.197*
Cardio vascular risk factor measurements					
Body mass index (kg/m^2) (estimated)	24.34	3.82	21.78	3.68	3.222**
Waist circumference (cm)	89.71	11.15	82.14	13.22	2.812*
Systolic blood pressure (mm Hg)	139.50	29.63	130.79	17.00	1.880
Diastolic blood pressure (mm Hg)	89.44	14.73	85.06	11.33	1.644
Random blood glucose (mg/dL)	140.44	78.56	123.77	59.17	1.187
Total cholesterol (mg/dL)	182.81	31.42	171.80	22.99	1.992*
Total triglycerides (mg/dL)	171.31	99.77	158.29	77.92	0.715

*$p < 0.05$, **$p < 0.01$

Logistic regression answers the same questions as discriminant analysis. It is often preferred to discriminate analysis as it is more flexible in its assumptions and types of data that can be analysed. Logistic regression can handle both categorical and continuous variables, and the predictors do not have to be normally distributed, linearly related, or of equal variance within each group (Tabachnick & Fidell 1996). In the present study, logistic regression analysis has also been done to determine the degree of association of the somatotype components of the individuals with LEA having or not having the CVD risk.

Results

Table 2 shows the descriptive statistics of anthropometric variables for the somatotype rating and cardiovascular disease risk factor measurements in the individuals with LEA. Comparisons between the individuals with AKA and BKA show that all anthropometric variables show significantly high mean values in individuals with AKA. The mean values of all CVD risk factor measurements are also higher in individuals with AKA than those in individuals with BKA and the differences in body mass index, waist circumference and total cholesterol are significant between the two groups.

Table 3 shows the descriptive statistics of the somatotype of individuals with AKA and BKA. Somatotype components like endomorphy and mesomorphy are

Table 3. Descriptive statistics of somatotype components in the individuals with LEA.

Somatotype components	Above knee amputees N = 32		Below knee amputees N = 70		t-value (df = 100)
	Mean	SD	Mean	SD	
Endomorphy	5.240	1.518	4.234	1.540	3.074**
Mesomorphy	5.264	1.244	4.186	1.492	3.558**
Ectomorphy	1.600	1.103	2.426	1.649	2.580*
X	–3.640	2.367	–1.808	2.983	3.058**
Y	3.687	2.753	1.710	3.700	2.697**

*p < 0.05, **p < 0.01

Table 4. Descriptive statistics of somatotype distances in the individuals with LEA.

Somatotype distances	Above knee amputees N = 32		Below knee amputees N = 70		t-value (df = 100)
	Mean	SD	Mean	SD	
Somatotype dispersion distance (SDD)	4.423	2.049	5.430	3.236	2.943** [a]
Somatotype attitudinal distance (SAD)	2.037	0.886	2.349	1.310	3.078** [a]
Somatotype intensity (INT) (SDD)	8.822	4.289	7.038	3.906	2.074**
Somatotype intensity (INT) (SAD)	7.789	1.425	6.879	1.115	3.496**

*p < 0.05, **p < 0.01

[a] Somatotype t-ratio (Carter & Heath 1990).

Table 5. Descriptive statistics of somatotype components in the individuals with LEA having or not having CVD risk.

Somatotype components	Above knee amputees					Below knee amputees				
	No CVD risk N = 14		CVD risk N = 18		t-value	No CVD risk N = 47		CVD risk N = 23		t-value
	Mean	SD	Mean	SD	(df = 30)	Mean	SD	Mean	SD	(df = 68)
Endomorphy	4.287	1.465	5.981	1.109	3.727**	3.682	1.345	5.362	1.295	4.969**
Mesomorphy	4.591	0.874	5.786	1.255	3.031**	3.762	1.258	5.051	1.584	3.693**
Ectomorphy	2.110	1.086	1.204	0.969	2.489*	2.953	1.620	1.349	1.110	4.276**

*p < 0.05, **p < 0.01

Table 6. Discriminant function analyses of the somatotype components for the presence of CVD risk factors among the individuals with LEA.

	Above knee amputees (N = 32)			Below knee amputees (N = 70)		
	Univariate F-tests	Standardised canonical discriminant function coefficients	Structure matrix	Univariate F-tests	Standardised canonical discriminant function coefficients	Structure matrix
Endomorphy	13.893**	0.784	0.874	24.684**	0.881	0.907
Mesomorphy	9.190**	0.565	0.710	13.134**	0.561	0.674
Ectomorphy	6.196*	0.148	–0.583	18.285**	0.227	–0.780
% of correct prediction		71.9			75.7	
Stepwise analysis	F to enter	Tolerance	Structure matrix	F to enter	Tolerance	Structure matrix
Endomorphy	13.893#	1.000	1.000	24.694#	1.000	1.000
Mesomorphy	2.709	0.914	0.294	3.581	0.898	0.319
Ectomorphy	0.282	0.732	–0.518	1.136	0.545	–0.674
% of correct prediction		71.9	CC = 0.563		68.6	CC = 0.516

*p < 0.05, **p < 0.01

Variable entered in analysis, minimum partial F to enter is 3.84, maximum partial F to remove is 2.71

CC = canonical correlation in discriminant functions in stepwise analysis

dominant over ectomorphy in both locomotor disability groups (i.e. individuals with AKA and BKA). The mean value of somatotype components for the individuals with AKA is 5.2–5.3–1.6 and that for the individuals with BKA is 4.2–4.2–2.4. The mean values of all three somatotype components show a highly significant difference ($p < 0.01$) between the two groups of individuals with LEA. The differences in the mean values of X and Y coordinates of somatotypes between two groups of individuals with locomotor disability are also highly significant.

Table 4 shows the descriptive statistics of somatotype dispersion distance (SDD), somatotype attitudinal distance (SAD) and somatotype intensity (INT) of indivi-

duals with AKA and BKA. The difference between somatotypes of individuals with AKA and BKA has been tested by calculating somatotype t-test (following Carter & Heath 1990) for SDD and SAD. Somatotype t-test for both SDD and SAD show a highly significant difference ($p < 0.01$) between individuals with AKA and BKA. Highly significant difference also has been found in case of somatotype intensity between two groups as shown by the t-value.

Table 5 shows the descriptive statistics of the somatotype components of the individuals with LEA having or not having CVD risk. In both groups (i.e. individuals with AKA and BKA) the individuals having CVD risk show significantly higher endomorphy and mesomorphy scores than the individuals not having CVD risk. However, ectomorphy scores are also significantly higher in the individuals not having CVD risk than the individuals having CVD risk.

Table 6 shows the discriminant function analyses of the somatotype components for the presence of CVD risk factors among the individuals with LEA. The results of the univariate F-ratios show endomorphy consistently yields the largest value for pairwise comparison. The canonical discriminant function coefficient identifies the somatotype components according to their relative importance in discriminating between groups. Endomorphy is again identified as most important discriminant function followed by mesomorphy and ectomorphy. The structure matrix, which is pooled within-groups correlations between discriminating variables and standardized canonical discriminant functions also show endomorphy as best discriminant function. However, the mesomorphy among the individuals with AKA and ectomorphy among the individuals with BKA have been found to have some importance next to endomorphy.

Forward stepwise discriminant analysis of somatotype components has been used to determine which subsets of somatotype components is best for discriminating the

Table 7. Logistic regression analysis and odds ratio (and 95 % CI) of the somatotypic components for the presence of cardiovascular risk factors among the individuals with LEA.

	Above knee amputees N = 32			Below knee amputees N = 70		
	B	OR	95 % of CI	B	OR	95 % of CI
Model 1						
Constant	−4.9627			−5.2026		
Endomorphy	1.0013**	2.7218	1.3185, 5.6186	1.0013**	2.6770	1.5908, 4.5050
Constant	−5.5914			−4.0296		
Mesomorphy	1.1462*	3.1461	1.2361, 8.0077	0.7480**	2.1128	1.3249, 3.3692
Constant	1.6612			1.1907		
Ectomorphy	−0.8613*	0.4226	0.1960, 0.9111	−0.9344**	0.3928	0.2347, 0.6576
Model 2						
Constant	−9.3612			−6.2979		
Endomorphy	0.8895*	2.4340	1.0173, 5.8238	0.8429*	2.3231	1.1642, 4.6357
Mesomorphy	0.8954	2.4483	0.8062, 7.4351	0.4183	1.5193	0.7338, 3.1456
Ectomorphy	0.2291	1.2575	0.3931, 4.0228	−0.0782	0.9248	0.3404, 2.5121

*$p < 0.05$, **$p < 0.01$

individuals having or not having CVD risk among the individuals with AKA and BKA. The smallest limit of F-to-enter value has been chosen for this analysis is 3.84, because a variable is entered into the model if the significance level of its F value is less than the entry value, and is removed if the significance level is greater than the removal value. The entry must be less than removal and both values must be positive. The result shows endomorphy is clearly dominant since it is entered first in each case with largest F-to-enter value. No other components have been selected for their contribution in discriminant function. The tolerance value of mesomorphy is greater than ectomorphy with respect to endomorphy, which determines how much the independent variables are linearly related to one another (multicollinear), indicating relatively smaller contribution of ectomorphy than mesomorphy in the model. However, unlike the univariate analysis the structure matrix shows greatest value of endomorphy followed by ectomorphy in both groups.

Table 7 shows the results of logistic regression analysis of the somatotype components for predicting the CVD risk among the individuals with LEA. In model 1, the logistic regression analysis has been done separately for each somatotype components for predicting the CVD risk. In model 2, multiple logistic regression analysis has been done combining all the three somatotype components as predictor for predicting the CVD risk among the individuals with LEA. The result shows that all three somatotype components have a significant predicting capacity for detecting the CVD risk. Odds ratios of somatotype components suggest that both endomorphy and mesomorphy have a positive relation with CVD risk, however, ectomorphy shows a negative relation. Model 2 shows that endomorphy is the only significant predictor for both groups of individuals with AKA and BKA.

Discussion

The present paper aims to report the somatotype of individuals with lower extremity amputation, and the variation of somatotype among the groups of individuals with two types of LEA, and secondly, to study the association of somatotype with CVD risk in the two groups of individuals with LEA. Data have been collected using standard techniques, however, some modified anthropometric methods suitable for the individuals with LEA have also been utilised. Somatotype rating and subsequent data analyses have been done using the method described by Carter & Heath (1990).

Anthropometric traits (Table 2) depict a larger body size of the individuals with AKA than that of individuals with BKA as the locomotion of above knee amputees are more restricted than below knee amputees. The mean values of all CVD risk factor measurements for the individuals with AKA are also high. Somatotype rating of individuals with LEA show high mean values of endomorphy and mesomorphy components. The individuals with AKA show higher scores of endomorphy and mesomorphy components than those of individuals with BKA. However, the ectomorphy component show lower scores among the individuals with LEA.

The mean values of X – Y coordinates show lower values than that of standard deviation in case of individuals with BKA, which suggest a wider range of variation in somatotype ratings among the individuals with BKA than that of the individuals

with AKA. This finding also supports the greater value of SDD and SAD among the individuals with BKA than those of individuals with AKA.

The results of somatotype t-test show significant differences between the two disability groups both in 2 dimensional and 3 dimension scores. The smaller mean value of INT among the individuals with BKA in comparison to those with AKA show the greater prevalence of the 'central' somatotype (as they are more scattered around the base of X and Y axis).

The comparison of the somatotype components between the individuals with or without CVD risk shows significant differences in all the three components. Among the three components, endomorphy and mesomorphy scores are higher among the individuals both having the CVD risk in both disability groups (i.e. individuals with AKA and BKA). However, the scores of endomorphy and mesomorphy are relatively less dominant over ectomorphy among all (with LEA) the individuals not having CVD risk and least among the individuals with BKA not having CVD risk.

The results of both discriminant analysis and logistic regression analysis show a significant relationship between somatotype components and CVD risk among the individuals with LEA. About 70 % of the cases having CVD risk can be properly predicted by somatotype components. Considering the components independently, endomorphy and mesomorphy have a significantly positive contribution and ectomorphy has a significantly negative contribution in identifying the CVD risk. The result of logistic regression analysis also supports the findings of DFA. Considering all three components together, only endomorphy has been found to have a significant positive relationship to the CVD risk.

The result of the present study does not completely corroborate with the studies of Gartler (1967) and Spain et al. (1955, 1963), who suggested that mesomorphy was the most significant somatotype component associated with coronary artery disease (CAD), which is the most common form of CVD. However, these studies examined the somatotype not as a gesalt (whole), but focused on the dominant component. But the result of the present study corroborates with the studies of Spain et al. (1953) and Paul et al. (1963), who stated that endo-mesomorphic individuals had the highest prevalence rate for CAD, suggesting that body fatness was the characteristic risk. The findings of the present study contrasts the study of Smit et al. (1979), who used the Heath-Carter technique and reported a mean somatotype of 4.5.–5–1 for a group of cardiac patients. The findings of Williams et al. (2000) suggest a mean somatotype of 5.7–5.6–1.2 for the CAD patients in Wales, which corroborates with the present study (individuals having CVD risk with AKA is 6.0–5.8–1.2 and with BKA is 5.4–5.1–1.3).

The present study also corroborates with the study of Malina et al. (1997), who used upper and lower tertiles of CVD risk traits to identify individuals with CVD risk and reported that individuals having CVD risk show high scores of endomorphic and mesomorphic component and low scores of ectomorphic component. The findings of DFA and logistic regression of present study also corroborates with the studies of Malina et al. (1997) and Willams et al. (2000).

The findings of the present study have been compared with studies conducted on normal individuals; the ideal comparison would have been with the studies on individuals with locomotor disability. To our knowledge, studies on the relationship of somatotype and CVD risk among locomotor disabled are not presently available.

It has been mentioned earlier that locomotor disabled are more vulnerable to vascular diseases because of their low mobility status. This could be one of the reasons for developing more adiposity, which leads to higher scores of the endomorphic component among individuals with LEA. The effort of the present study is to examine whether the somatotyping method is applicable for the assessment of CVD risk of individuals with LEA. Early diagnosis of CVD risk through somatotyping can be utilised in prevention/treatment management for individuals with LEA. The present article is an outcome on a small sample of individuals with LEA but the findings of the present study is very consistent with other studies. However, a final conclusion cannot be drawn without conducting a similar study on a large sample of disabled individuals.

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