GROWTH AND MATURATION IN HUMAN BIOLOGY AND SPORTS

FESTSCHRIFT HONORING ROBERT M. MALINA BY FELLOWS AND COLLEAGUES

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PHYSIQUE, ADIPOSITY AND RISK FOR CHRONIC DISEASE

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INTRODUCTION

Professor Robert Malina has shown a lifelong interest in the study of physique and has made significant contributions to our understanding of the relationship between body type and disease risk. His approach has been grounded in the concept that "the whole is greater than the sum of the parts". Placed within the context of "human constitution", the development and consequences of physique have been central themes in the first and second editions of the seminal textbook *Growth, Maturation and Physical Activity* (Malina and Bouchard 1991; Malina et al. 2004). Dr. Malina has encouraged students and colleagues to consider holistic approaches to the study of human constitution and health. The latter notion is complex, and necessitates appropriate measures of physique, such as in somatotype assessment, and adequate statistical techniques like principal components analysis or canonical correlation. The rationale for studying the relationship between physique and disease risk is that individuals with specific body types are potentially at elevated risk for common diseases.

The notion that body habitus has a role to play in determining health risks has a long history in medicine and human biology. Early physicians understood that physique was an important consideration in assessing a patient's overall health status. However, variation in physique is difficult to measure, cannot be captured in a single measurement and does not lend itself to being represented by a simple number. Hundreds of years ago, Hippocrates suggested a simple generalized classification of habitus phthisicus (linear) versus habitus apoplecticus (lateral) (Malina et al. 2004). Numerous classification systems for human physique have emerged over the years, and the concept of the somatotype evolved particularly during the first half of the 20th century. Davenport was among the first to recognize the need for a quantitative assessment of physique (Davenport 1923). Subsequently Sheldon and colleagues used a series of reference photographs plus height and weight (a so-called anthroposcopic method) to somatotype individuals along three dimensions labeled ectomorphy, mesomorphy and endomorphy (Sheldon et al. 1954; Sheldon et al. 1940). The adoption of a system based on standardized and representative pictures combined with anthropometry allowed for the quantification of the somatotype in terms of three dimensions (ectomorphy, mesomorphy and endomorphy), which offered an objective, measurable index of physique. At about the same time, Parnell developed another typing system based on anthropometric indicators and referred to the components as fatness, muscularity and linearity (Parnell 1958). A modification of the anthropometric approach was reported by Heath and Carter in 1967. The Heath and Carter anthropometric somatotyping method has been the most commonly used over the last 40 years or so. Even though the latter approach rates the somatotype along the same three dimensions as the Sheldonian method, ectomorphy, mesomorphy and ectomorphy, they are not quantitatively fully identical.

Over the years, the endomorphic component of physique (body fatness) has dominated the discussion regarding health risks, and interest in overall physique has declined. More recent investigations have focused on determining the best way to measure total and regional adiposity as markers of disease risk. A critical question that remains to be answered is whether the association between health risks and some body types is stronger and more specific than what is captured in current indices of adiposity, body composition and fat distribution.

FAMILIAL RESEMBLANCE FOR PHYSIQUE

In order to better understand the extent to which physique is a modifiable characteristic, it is important to determine the degree to which it is influenced by genetic and environmental factors. Dr. Malina and colleagues have studied this issue using data from French-Canadian families from Montreal (Bouchard et al. 1980), the Québec Family Study (Song et al. 1993; Song et al. 1994) as well as in a sample from Northern Ontario, Canada (Katzmarzyk et al. 2000). Based on sibling correlations, the broad heritability estimates were 50%, 42% and 54% for endomorphy, mesomorphy and ectomorphy, respectively among 239 families from Montreal (Bouchard et al. 1980). Using data from 243 nuclear families enrolled in the Québec Family Study, the pattern of familial correlations suggested a significant familial resemblance for physique. The spouse correlations for the somatotype components were low and not significant, whereas the parent-child and sibling correlations ranged from 0.18 to 0.48 for endomorphy, 0.23 to 0.59 for mesomorphy, and from 0.14 to 0.47 for ectomorphy (Song et al. 1993). In a subsequent study, twin resemblance was considered as a strategy to further define the presence of genetic variation in physique. Data from 28 male and 34 female monozygotic (MZ) and 19 male and 21 female dizygotic (DZ) twin pairs indicated greater resemblance within MZ twin pairs than within DZ twin pairs, suggesting that genetic factors are playing a role in explaining variation in human physique (Song et al. 1994). In the family study we conducted in Northern Ontario, we computed maximal heritability estimates for somatotype from a familial correlation model. The maximal heritabilities for the somatotype components were 56%, 68% and 56% for endomorphy, mesomorphy and ectomorphy, respectively. Further, the maximal heritability for a composite somatotype score derived from principal components analysis was 64%, indicating a significant familial resemblance for physique (Katzmarzyk et al. 2000). Taken together, the results of the research conducted by Dr. Malina and his colleagues indicate a significant familial resemblance in physique, which has been corroborated by more recent studies (Jelenkovic et al. 2011; Peeters et al. 2007).

PHYSIQUE, CHRONIC DISEASE AND RISK FACTORS

Early studies identified an association between physique and risk of chronic diseases, particularly heart disease and hypertension (Gertler and White 1954; Robinson and Brucer 1940; Spain et al. 1963). These relationships between physique and chronic disease risk factors in adulthood were replicated in more recent times (Malina et al. 1997; Williams et al. 1997). For example, we examined the association between somatotype and cardiovascular disease (CVD) risk factors among 642 adults from the Québec Family Study. Correlations between individual somatotype components and risk factors were modest; however, stronger associations were more apparent at the extremes of the risk factor distributions (Malina et al. 1997). Those with a poorer risk factor profile tended to be more endomorphic and mesomorphic, and less ectomorphic than those with a better profile.

To our knowledge, the association between somatotype and risk of CVD death has not been investigated using a prospective design. We undertook an analysis of 1700 men 40-69 y of age who were participants in the 1981 Canada Fitness Survey. These men were followed for 13 y and their data were linked with the Canadian Mortality Database at Statistics Canada, yielding 21,349 person-years of follow-up. At baseline, somatotype components (endomorphy, mesomorphy, ectomorphy) were calculated by the Heath-Carter anthropometric method and principal components analysis was used to derive an underlying physique score (PC1). A total of 71% of the variance in the somatotype components was explained by PC1, which was characterized by positive loadings for endomorphy and mesomorphy and a negative loading for ectomorphy. A total of 41 deaths from CVD occurred during the follow-up period. There was elevated CVD mortality risk in the upper quintiles of PC1 (Q4 HR = 2.75; 95% CI 0.96-7.82 and Q5 HR = 3.18; 95% CI 1.14-8.85), compared to the lower quintile. Further, the pattern of hazard ratios for PC1 followed a j-shaped curve (see Figure 1). Overall the results indicate that there is an elevated risk of CVD mortality among men who have a physique characterized by high levels of endomorphy and mesomorphy and low levels of ectomorphy.

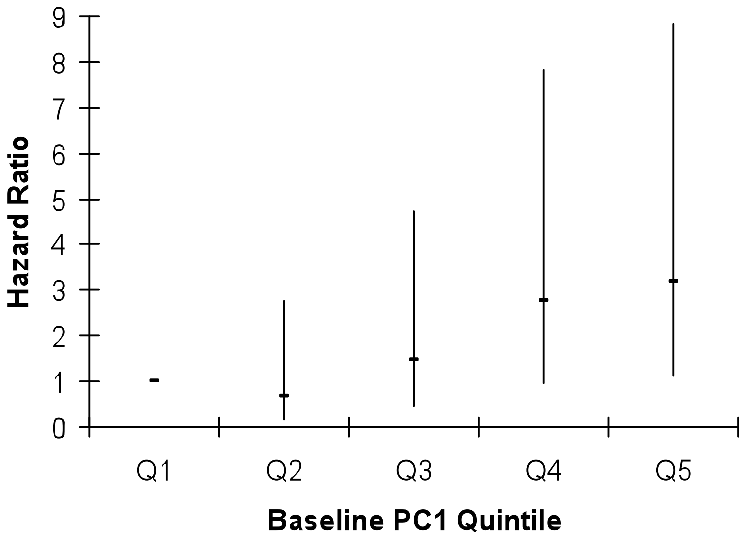

Figure 1. Hazard ratios for CVD mortality across baseline quintiles of the first principal component score of the three somatotype components in 1700 men from the 1981 Canada Fitness Survey. The model includes the effects of age, smoking and alcohol consumption. All men who died in the first two years of follow-up have been eliminated from the analysis. Bars indicate 95% confidence intervals.

PHYSIQUE IN CHILDHOOD AND ADULTHOOD

The degree to which the relationships between physique and chronic disease risk factors are established in childhood and how they translate or track into elevated risk as an adult has been one focus of Dr. Malina's interest (Malina et al. 2004). We examined the relationship between physique and chronic disease risk factors in children and youth 9-18 years of age from the Québec Family Study (Katzmarzyk et al. 1998). Canonical correlation analysis was used to quantify the relationship between the Heath-Carter somatotype and risk factor variables. The results suggest that a physique characterized by high endomorphy and mesomorphy, and low ectomorphy is associated with higher levels of triglycerides, LDL-cholesterol, and plasma glucose, and lower levels of HDL-cholesterol.

The stability or tracking of a person's physique over time is a subject of interest. Although a person may change an individual characteristic such as their body weight through changes in their lifestyle behaviors, the degree to which overall physique changes throughout the lifespan is not well understood. Several studies using longitudinal research designs have investigated the stability of physique over time in the same group of people (Malina et al. 2004) . The most common way of expressing stability or tracking of physique is by inter-age correlations. Given that the somatotype is a three-component index, it is best not to study one component in isolation, but to consider one component after statistically adjusting for the other two components.

Data from the Leuven Longitudinal Study revealed inter-age correlations of 0.79, 0.73 and 0.82 for boys between the ages of 13-18 years for endomorphy, mesomorphy and ectomorphy, respectively (Claessens et al. 1986). Further, Hebbelinck et al. (1995) reported inter-age tracking correlations of 0.29, 0.50, and 0.55 for males and 0.60, 0.36 and 0.73 for females for endomorphy, mesomorphy and ectomorphy, respectively between the ages of 12-17 years in Belgian youth, after statistically controlling for the other two components. Among younger South African girls 4 years of age, 2-year inter-age correlations ranged from 0.75 for endomorphy, 0.52 for mesomorphy, and 0.35 for ectomorphy, after statistically controlling for the other two components, while the corresponding correlations for girls 8 years of age were 0.75 for endomorphy, 0.46 for mesomorphy, and 0.50 for ectomorphy (Monyeki et al. 2002). Overall, the results of these and other studies indicate that somatotype is a relatively stable characteristic throughout the growing years and into adulthood.

PHYSIQUE, ADIPOSITY AND RISK FACTORS

Given the dramatic increases in obesity observed in recent years, there has been great interest in determining the health concerns associated with excess adipose tissue. At the same time, there has been diminished interest in overall physique as an independent risk factor. The most common method of assessing physique is the Heath-Carter somatotype, which requires the measurement of several body dimensions, elaborate computations, and sophisticated statistical analyses. Thus, the degree to which knowing the somatotype improves the prediction of disease risk beyond simpler anthropometric indicators of adiposity is of interest.

We undertook a study in the Québec Family Study to determine the independent roles that indicators of body adiposity (sum of skinfolds, trunk-to-extremity skinfold ratio) and somatotype might play in relation to CVD risk factors (blood pressure, lipids, glucose) in children and young adults (Katzmarzyk et al. 1999). A modest amount of the variation (up to 16%) in CVD risk factors was explained by the indicators of adiposity and the somatotype components. Indicators of adiposity and the somatotype components entered the stepwise regression models as predictors a similar number of times, explaining a similar proportion of the variance. Overall, the results of this single study do no appear to suggest that computing somatotype components adds value to the prediction of risk factors beyond measures of adiposity, but further research is required to better determine the independent nature of these associations.

In a recent report on somatotype and blood pressure in 980 boys and 922 girls, 6 to 13 years of age, from Ellisras, South Africa, systolic blood pressure was found to be weakly and negatively associated to ectomorphy (Makgae et al. 2007). No relations were observed between systolic or diastolic blood pressure with endomorphy and mesomorphy, even though the prevalence of hypertension reached 6% in boys and 11% in girls.

SUMMARY

Studies of the relationship between physique and health have a long tradition in human biology and medicine. Overall physique, often operationalized as the three-component somatotype, demonstrates a significant amount of familial resemblance, suggesting that there is a substantial genetic effect on human variation in ectomorphy, mesomorphy and endomorphy. A body of data supports the concept that a physique characterized by high levels of endomorphy and mesomorphy and low levels of ectomorphy, is associated with an increased risk of CVD and mortality. The somatotype and its relationship with chronic disease risk factors appears to begin in childhood, and evidence from several longitudinal studies has demonstrated that a person's physique is a relatively stable trait through childhood into adulthood. The degree to which the somatotype adds to the predictive ability of more common indicators of body composition, overall adiposity and adipose tissue distribution remains to be determined. Studies comparing ectomorphy, mesomorphy and endomorphy against direct measures of lean mass, fat mass, abdominal fat depot, visceral fat level, and hepatic and intramyocellular fat deposition would be helpful in evaluating a potential role for global measures of physique and body type, particularly as risk factors for common chronic diseases and premature mortality.

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