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Multiple regression analysis of the relationship between some predictors of socioeconomic status and developmental instability

Barış Özener[1*] and Berna Ertuğrul[2]

[1]*Department of Anthropology, Cumhuriyet University, Sivas, Turkey*
[2]*Anthropologist, Sivas, Turkey*

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Abstract

Fluctuating asymmetry (FA) is thought to be the outcome of developmental instability, the impressive expression of design due to perturbations during development. Early interest in FA has been centered on its potential as an indicator of environmental stress. The aim of this study is to determine the effect of socioeconomic status on the level of FA in Turkish young males. The study examined 350 young males (mean age = 8.65±0.58) who live under different socioeconomic conditions in Ankara. Family size, mother's education, father's education, mother's job, father's job, number of siblings and number of rooms were assessed. The hand length, hand width, elbow width, wrist width, knee width, ankle width, foot length, foot width, ear height and ear width of the subjects were measured with a Vernier digital caliper of 0.01 mm sensitivity. According to multiple regression analysis, relationship between composite fluctuating asymmetry and family size, mother's education, father's education, mother's job, father's job, number of siblings, number of rooms were statistically significant ($R^2 = 0.41$, $F = 17.95$, $P < 0.001$). Standardized coefficients-β values showed that the mother's and father's educations had higher correlations even when the effects of other predictors were controlled. We conclude that fluctuating asymmetry was found to increase with the improving living standards. However, when the effects of the SES variables were considered separately, mother's education and then father's job were found to have greater effects on developmental stability.

Keywords: *Developmental instability, fluctuating asymmetry, socioeconomic predictors, multiple regression analysis*

1. Introduction

Foremost research demonstrates that the human phenotype is extremely plastic and the physical growth is particularly sensitive to the quality of its social and economic environments (e.g. Tanner, 1986; Bogin, 1999). It was long taken for granted that people of lower socioeconomic status (SES) have worse health than people of higher

* Corresponding author: Department of Anthropology, Faculty of Arts and Sciences, Cumhuriyet University, Kampüs 58140, Sivas, Turkey (**e-mail:** barisozener@yahoo.com)

SES. Individuals lower in SES experience higher rates of morbidity and mortality compared to individuals higher in SES, across many different health outcomes, and across numerous countries, both with and without universal health care (for review see Adler et al., 1993, 1994). Understanding these relationships early in life is critical both for maximizing children's health and for early prevention efforts to improve health across the lifespan. Children lower in SES also suffer from poorer physical and mental health outcomes compared to children higher in SES (e.g. Duncan and Brooks-Gunn, 1997; Chen et al., 2006).

Although it is known that there are significant differences between physical growth quality of individuals living under different socioeconomic conditions the number of studies that are directly focused on the relationship between socioeconomic conditions and fluctuating asymmetry (FA) is rather limited. FA refers to small random deviations from perfect symmetry in bilaterally paired structures and it is thought to reflect an organism's ability to cope with genetic and environmental stress during development. FA has been used as an indicator of individual quality and developmental stability in studies of natural and sexual selection (e.g. Van Valen, 1962; Zakharov, 1992; Palmer and Strobeck, 2003a). Developmental stability is defined as the ability of an organism to buffer its development against genetic or environmental disturbances encountered during development to produce the genetically predetermined phenotype (Waddington, 1942; Zakharov, 1992; Nijhout and Davidowitz, 2003). As for both directional asymmetry and antisymmetry the bilateral variation may have an unknown genetic basis, and thus may not solely reflect pure developmental noise. These two types of asymmetry are generally not used as indicators for developmental instability (Palmer and Strobeck, 1986; 1992; however see for DA, Graham et al., 1993; Møller, 1994).

Although several studies suggest that environmental pressures increase FA level via anthropometric measurements (Waynforth, 1998; Gray and Marlowe, 2002), others do not confirm this trend (e.g. Flinn et al., 1999; Little et al., 2002). But it can be said that these studies did not focus directly on the effect of socioeconomic conditions on FA. Therefore, it would be wrong to assess the correlation between socioeconomic conditions and FA on the basis of these studies.

This study seeks to observe FA degrees of young males coming from different socioeconomic environments in Ankara. Socioeconomic status can be ascertained at the individual level by assessment through questionnaire items that directly quantify personal or family income, items that delineate markers of social status such as education and occupation (which are also surrogates of economic status), or survey measures that estimate wealth or financial assets. SES can also be measured at an area level, that is, the status of the surrounding neighborhood or community. In the study, seven socioeconomic parameters (family size, mother's education, father's education, mother's job, father's job, number of siblings and the number of rooms) were obtained directly from 350 young males who live under different socioeconomic conditions in Ankara. The relation between each factor and FA was independently analyzed using multiple regression analysis, taking the effects of other factors under control.

2. Material and methods

2.1. Study population

The study examined 350 young males who live under different socioeconomic conditions in Ankara. The individuals of low-middle socioeconomic status (N = 208) were selected from the senior students of three high schools located in Yenimahalle, a poor district of Ankara, while the young males of high socioeconomic status (N = 142) from three private high schools in Çankaya district where mostly the students from high income families are educated. Before the start of data collection, the subjects were told that the purpose of the study. The measurement procedure was also explained in detail to them. After they fully understood the purpose and the procedure of the study, they could decide whether or not to take part in the survey. Subjects agreeing to take part in the study were asked to fill a questionnaire form defining socioeconomic properties. The ages of the individuals are recorded as day/month/year and later calculated by the decimal system (Tanner et al., 1969). The mean age of the group is 18.65 ± 0.58 years. The individuals who engaged/engage in work requiring heavy physical activity and who regularly participate in a sport were excluded in that they could have an effect on the body symmetry. Therefore, the individuals in the two groups examined could be considered sedentary. The hand length, hand width, elbow width, wrist width, knee width, ankle width, foot length, foot width, ear height and ear width of the subjects were measured with a Vernier digital caliper of 0.01 mm sensitivity.

2.2. Socioeconomic predictors

Many variables can be examined to determine socioeconomic status of the individual. In the study, seven parameters (family size, mother's education, father's education, mother's job, father's job, number of siblings and the number of rooms) were examined. Parental education level was determined considering the total education time as 0-23 years. In the study, parental job was classified between 1 and 10, from unemployed=1 to holding owner, senior bureaucrat, etc. = 10. Therefore, the variables were numerically expressed.

2.3. Data analysis

In the study hand length, hand width, elbow width, wrist width, knee width, ankle width, foot length, foot width, ear height and ear width of the subjects were measured with a Vernier digital caliper of 0.01 mm sensitivity in accordance with the techniques proposed by the International Biological Programme (Weiner and Lourie, 1981). Bilateral data was obtained using blind measurement technique (Palmer and Strobeck, 2003a) and all measurements were taken by the first author. At first right side of the body was measured in this exact order. The data on the left side of these traits were then collected. This procedure was repeated for the second measurements without reference to the prior data. There was about a 15 minute lag between the two measurements. Edinburgh Handedness Inventory was also applied to determine the handedness of the individuals (Oldfield, 1971).

In the study, 80 individuals were measured twice in order to determine the measurement error. A mixed model ANOVA (individuals [*random*] X sides [*fixed*]) was used for estimating repeatability of the asymmetry (see in Palmer and Strobeck, 2003a). The side-by-individual interaction term was significant ($P < 0.001$) by demonstrating that this asymmetry variance was significantly greater than measurement error variance (σ^2_m / (σ^2_i), (Hand: $F_{[1,79]} = 11.09$, $P < 0.0001$; elbow: $F_{[1,79]} = 7.01$, $P < 0.0001$; wrist: $F_{[1,79]} = 7.67$, $P < 0.0001$; knee: $F_{[1,79]} = 4.52$, $P < 0.0001$; ankle: $F_{[1,79]} = 6.37$, $P < 0.0001$; foot: $F_{[1,79]} = 7.49$, $P < 0.0001$; ear height: $F_{[1,79]} = 4.39$, $P < 0.0001$; ear width: $F_{[1,79]} = 3.51$, $P < 0.0001$).

2.4. Analysis of directional asymmetry, and departures from normality

"Ideal" fluctuating asymmetry requires that signed R − L values (i.e. signed asymmetry) of individual traits be normally distributed about a population mean of zero (Palmer and Strobeck, 1992). In the study group hand length are positive skewed ($P < 0.05$), and the leptokurtosis of ear width is significant ($P < 0.01$), ankle width are positive skewed ($P < 0.05$), and knee width ($P < 0.05$) and ear width ($P < 0.01$) measures have a leptokurtic distribution. A log-transformation has done of all of the measurements and then re-tested for departures from normality and outliers on the distribution of log(R) − log(L). Possible outliers were identified visually after log-transformation from scatter plots and than this measures were tested and removed according to Grubbs' test (Grubbs, 1969; Palmer and Strobeck 2003b). Normal distribution was attained once 10 measures were excluded from the sample. In order to detect the existence of directional asymmetry within the groups, one-sample t-test was used as recommended by Swaddle et al. (1994). The null hypothesis for this test is mean signed asymmetry equals zero. Hand length and hand width significantly demonstrated DA. For this, two traits were not used in the FA analysis. It can be concluded that from this stage neither of the measures have skewness, leptokurtosis, antisymmetry and directional asymmetry that would hinder the fluctuating asymmetry analysis.

Asymmetry of an individual trait may vary as the size of their trait varies (Leung, 1998; Palmer and Strobeck, 2003a). Sperman's rank correlation coefficient was used to quantify the relations between unsigned asymmetry and mean trait size for all traits by groups. There is no indication of size dependency for any of these traits (all $P > 0.05$).

2.5. *Asymmetry analysis*

In the study fluctuating ($\sqrt{(R-L)^2/n}$) and composite fluctuating asymmetry (CFA; $\Sigma(\sqrt{(R-L)^2/n})$ values were determined. For the subsequent statistical analyses, only the composite fluctuating asymmetry index was used because composite scores often show stronger associations with fitness parameters than single trait asymmetry measures (see Leung and Forbes, 1997; Gangestad and Thornhill, 1999; Leung et al., 2000). Multiple regression analysis was used to test the correlation between CFA and socioeconomic parameters. In all tests effect of handedness was controlled. The Statistical Package for Social Sciences (SPSS of version 15.0) was used for all statistical calculations and processes.

3. Results

According to multiple regression analysis, relationship between CFA and family size, mother's education, father's education, mother's job, father's job, number of siblings, number of rooms were statically significant (R^2=0.41, F=17.95, $P < 0.001$) (Table 1). The seven variables explained 40% of the variation in CFA. Zero-order coefficient values, where socioeconomic variables were analyzed separately (Table 2), showed the high

Table 1: Model summary of multiple regression analysis (Dependent variable = composite fluctuating asymmetry, CFA)

Model	R	R^2	Adjusted R^2	SE[b]	F	P	Change statistics				
							R^2 Change	F Change	df1	Df2	Sig F Change
1	0.677[a]	0.413	0.391	0.43783	17.950	0.000	0.393	17.950	9	192	0.000

a = Predictors: (Constant), Family size, mother's education, father's education, mother's job, father's job, number of siblings, number of rooms.
b = Standard error of the estimate

correlation between the variable and CFA. Standardized coefficients-β values showed that the predictors of the mother's and father's educations had higher correlations even when the effects of other predictors were controlled (Table 2, Figs. 1-2).

Table 2: Coefficients of multiple regression analysis results

	Zero-order correlation	Standardized coefficients (β)	95% Confidence interval for β	
Family size	0.246***	0.092	-0.086	0.019
Mother's education	-0.411***	-0.353***	-0.326	0.119
Father's education	-0.352***	-0.198	-0.138	0.086
Mother's job	-0.259***	-0.047	-0.096	0.056
Father's job	-0.406***	-0.311**	-0.318	0.109
Number of siblings	0.281***	0.002	-0.058	0.057
Number of rooms	-0.285***	-0.042	-0.115	0.061

** $P<0.01$, *** $P<0.001$

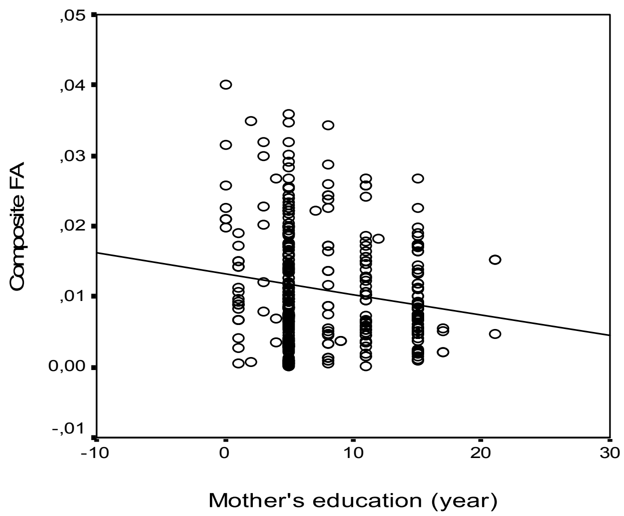

Fig. 1: Scatterplot of the association between composite fluctuating asymmetry (CFA) and mother's education (year).

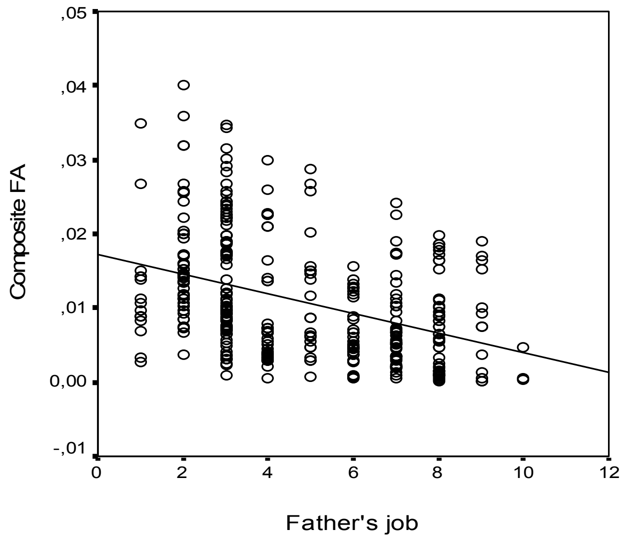

Fig. 2: Scatterplot of the association between composite fluctuating asymmetry (CFA) and father's job.

4. Discussion

According to results, effect of SES on body FA was important. It is seen that there is a significant increase in fluctuating asymmetry parallel to the increase in life standards. In other words, young males who live in optimal conditions show more symmetric body structure. In humans, it is known that individuals in poor living conditions suffer from malnutrition and have limited access to health services, which makes them more prone to infectious diseases (see for review Adler et al., 1994; Chen et al., 2002). Information about the effect of SES on physical development is quite considerable. However, the effect of SES on FA is a rather neglected subject. The impact of environmental conditions and stress on human anatomical structures has been reported in previous studies, including the cranium and post-cranium (e.g. Albert and Greene, 1999; Schaefer et al., 2006; DeLeon, 2007; Kujanová et al., 2008). There are a few studies on groups with different development and nutritional status, in other words, with different socioeconomic status. Little et al. (2002) conducted research on children with chronic malnutrition in South Mexico. At odds with the expectations, the researchers found that body asymmetry was higher among the well-nutritioned children. A similar observation could be found in another study in the villages on the East coast of The Dominican Republic. Flinn et al. (1999) which compared the growth patterns of step children and children raised by biological parents in the same family. This study revealed that for all age groups between 0-20, biological children had better weight and height development. The results show that fluctuating asymmetry coefficient for both sexes is lower among step children (Flinn, 1999). Hume and Montgomerie (2001) measured asymmetry of 22 traits (including facial, bodily and fingerprint traits) in addition to other anthropometric (i.e. body-mass-index) and health measures in a sample of males and females. It was found that the composite measure of FA accounted for a significant percentage of variation in facial attractiveness in both sexes, whilst socioeconomic status (SES) was not associated with facial symmetry. Also Schaefer et al. (2006) found that FA in dental arches of individuals from an inbred Adriatic island population was higher than those of individuals from an outbreed island group. These authors argued that the differences were caused by environmental as well as a genetic influence on dental arch asymmetry. As this research illustrates, the literature lacks studies establishing a direct link between socioeconomic parameters and body bilateral asymmetry. Differences between studies may arise as a result of: (*a*) differences between characters; (*b*) differences in statistical power; (*c*) differences between methods (i.e. measurement error analysis) or indexes used; (*d*) differences in genetic structures among the populations; (*e*) impact of unmeasured and undocumented environmental stress that differ among the populations being compared. One or more of the factors listed above could be helpful in explaining the unanticipated results of these studies. In this study in order to investigate the effect of socioeconomic status on FA, the groups with highly diverse life standards were examined using the necessary methods and statistics for the FA analysis (see Palmer and Strobeck, 2003a,b).

In the study, when the effects of the seven parameters on CFA were considered separately, it was seen that all the parameters had independently significant effects on FA. However, partial correlation analysis, where the effects of other parameters were controlled, showed that mother's education and then father's education had the greatest effect on level of CFA. These two parameters had even greater effects on FA, which was not surprising. These parameters had decisive effects on other five variables. Among the potential indicators of developmental quality of the children and young adults, the mother's education has been the focus of economists. More educated mothers may have healthier children because they have better knowledge about health care and nutrition, have healthier behavior, and provide more sanitary and safer environments for their children (e.g. Behrman and Deolalikar, 1988; Currie and Moretti, 2003). On the other hand, educated women would more possibly prefer an educated husband, which improved the socioeconomic level of the family (McGrary and Royer, 2005). In addition to mother's education, father's education was also decisive for level of FA. For both western and non-western societies, main income source of the family was father's earnings (e.g. Strazdins et al., 2007). The studies reported that father earned more money than mother for both low and high socioeconomic groups. Mean income level is the most important factor determining the levels of housing, nutrition and sanitary services available to family. Therefore, it has as many effects as mother's education on individual's development level. In summary, according to the findings of the study body symmetry was found to increase with the improving living standards. However, when the effects of the SES variables were considered separately, mother's education and then father's job were found to have greater effects on developmental stability.

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