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Association of Fertility with Anthropometric Measures

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Introduction

Fertility is regarded as the most important variable in the study of population dynamics. Fertility is the ability of an individual or couple to reproduce. A complex set of genetic, social, political, legal and psychological factors influences reproductive behaviour of individuals and hence the level of fertility. Researchers from different disciplines have, therefore, tried to establish calibrated theories of fertility which are applicable to their disciplinary approaches. Such theories are classified into three broad categories: 1) biological theories; 2) social or cultural theories; and 3) economic theories. The biological theories claim that the law which regulates fertility in human beings is the same as the law which regulates the growth of plants and other animals (Sadler, 1830; Doubleday, 1847; Spencer, 1880; Gini, 1943; De Castro, 1952). On the other hand, social and cultural theories tend to portray fertility in the context of the psychological mind-set of the individual which is determined by the prevailing culture (Dumont, 1890; Ogburn, 1922; Davis, 1963). The economic theories, by contrast, stress the importance of economic factors in the social change process, which drives the fertility behaviour of individuals (Liebenstein, 1957; Becker, 1960; Esterlin, 1975; Caldwell, 1976). Among the different biological, social, cultural and economic factors, Davis and Blake (1956) have identified 11 factors that are called intermediate variables that directly influence the human reproduction mechanism. Bongaarts (1978), subsequently, modified Davis and Blake framework and identified a smaller set of seven variables and named them proximate determinants of fertility. Among them, four determinants are considered to be the most important in terms of explaining variation in fertility across countries (Bongaarts, 1982).

The above theories suggest that reproductive behaviour of an individual is determined by many biological, behavioural, ecological, cultural and socioeconomic factors. Besides these factors, some studies suggest that physical composition of an individual may also has a bearing on the reproductive behaviour. The physical composition of an individual is commonly measured in terms of anthropometric measurements, particularly, the weight and the height and reflects the nutritional status of the individual. Other anthropometric measures such as arm, waist, hip, head and calf circumference, waist to hip ratio (WHR), elbow amplitude, knee-heel length, etc. are also used but the use of weight and height is the most common (Sánchez-García et al, 2007). There are studies that have attempted to analyse the relationship between the physical composition and the level of fertility. In 1923, Davenport (1923) observed on the basis of 506 American families that stockier couples had larger families as compared to their thinner counterparts. Similar observations were made by Frassetto (1934) on the basis of the data collected from 1450 Italian families. These findings have also been supported by Clark and Sphuler (1959) and Bajema (1973). On the contrary, Damon and Thomas (1967) have found no correlation between the level of fertility and the height or weight or the ponderal index on the basis of longitudinal data from 1880 to 1912 obtained from 2616 college men but concluded that lean fathers were more fertile than the fat ones. Mitton (1975) applied multivariate procedures to the data of Clark and Spuhler (1959) and Damon and Thomas (1967) and observed significant difference in fertility in males of different height. He concluded that men who were closer to mean height and weight (in some cases) had relatively higher fertility than others. Vetta (1975) used the data of Damon and Thomas (1967) and, after making corrections for apparent tabular errors, observed significant relationship between fertility of an individual and his or her height, weight and ponderal index.

In the developed societies, Bernard (1952) and Bressler (1962) found evidence of association of maternal size with higher fetal survival. In these studies, factors associated with high stature such as enriched nutritional status and improved health care facilities have been shown to result in more successful pregnancies. Furusho (1964) found that there were more live births to short stature couples than the tall ones in Japan, but there was no difference in the number of surviving children between tall and short couples. Frisancho et al (1973) found that short-stature mothers had a higher proportion of survivors per couple than tall mothers of similar age among Peruvian urban poor couples. Lasker and Thomas (1976) observed that females having high fertility had a low variance of limb length from a sample of 480 Mexican families. In 1978, Lasker and Thomas had noted higher reproductive ability among dolichocephalic persons in their Mexican sample. In India, the relationship between physical composition and fertility has been studied by Tiwari (1974), Chatterjee and Datta (1982), Kalla and Sadhu (1983) and Malik (1992).

In this paper, we have made an attempt to analyse the association of the interval between marriage and first birth or the first birth interval with the height and the body mass index (BMI) of the women of Madhya Pradesh. The BMI is defined as the ratio of the weight in the kilogram divided by the square of the height in the centimetres. The BMI is now universally used to measure the nutritional status of an individual aged at least 15 years. An individual is characterised as underweight if $BMI<18.5$; normal weight if $18.5 \leq BMI<25.0$; and overweight if $BMI \geq 25.0$. Although, the construction of BMI involves height but BMI is not correlated with the height but is highly correlated with the weight of the individual and, therefore, reflects the thinness or the fatness of the body (Divers Populations Collaborative Group, 2005).

Data

The data used in the present analysis is available through the National Family Health Survey (NFHS) 2015-16 which was conducted by the International Institute for Population Sciences for the Government of India. The survey covered all the districts of the country. It was designed to collect information on a range of health and family welfare related indicators along with indicators related to the standard of living. The survey covered 601509 households from 640 districts of the country as they existed at the time of the survey. In these households, 699686 females aged 15-49 years; 112122 males aged 15-54 years; and 259627 children aged 0-5 years were identified. In Madhya Pradesh, 62803 females aged 15-49 years, 10268 males aged 15-54 years; and 24611 children aged 0-5 years from 52042 households were covered under the survey. Details about sample selection, survey methodology, etc. are given elsewhere (IIPS, 2017). The survey provided district level estimates of key health and family welfare related indicators for the 50 districts of Madhya Pradesh as they existed at the time of the survey.

Methodology

The reproductive behaviour of the couple is measured in the present study in terms of the first birth interval or the interval between the marriage and the first birth. The relationship between age at marriage and fertility dynamics, specifically the initiation of childbearing and total fertility, is well established and with the increase in the age at marriage, there is shortening of the first birth interval (MacQuarrie, 2016). Marriage and the initiation of childbearing or the timing of the first birth are two significant milestones that mark a transition from childhood or adolescence to adulthood. On the other hand, two anthropometric indicators have been selected to measure the physical composition of the woman: 1) height of the woman; and 2) the body mass index of the woman. It may be pointed out that, although height is used for the calculation of the body mass index (BMI), yet, the two are not correlated

The analysis is limited to women aged 15-49 years who were residing in Madhya Pradesh at the time of the National Family Health Survey 2015-16; who were married for not more than 10 years; and who had at least one child ever born at the time of the survey. Total number of these women in Madhya Pradesh who were covered under the National Family Health Survey 2015-16 was 13383. However the interval between the marriage and the first birth was found to be less than 9 months in 383 women and, therefore, these women were excluded from the present analysis and the analysis is based on 13000 women aged 15-49 years in Madhya Pradesh who were married for not more than 10 years and who had at least one child ever born at the time of the survey.

At the first stage of the analysis, all women covered in the present analysis were first classified into three categories on the basis of their height and body mass index (BMI). The height classification was based on the average height of women (152.4 cm) and the associated standard deviation (5.8 cm). Using the average height and the standard deviation of the distribution, women were classified into the following three categories:

Category I	Height < (Mean - Standard deviation) or height<146.6 cms.
Category II	(Mean - Standard deviation) ≤ height <(Mean + Standard deviation) or 146.6 ≤ height < 158.3 cms.
Category III	Height ≥ (Mean + Standard deviation) or height ≥ 158.3 cms.

On the other hand, all women were also classified into three categories on the basis of their BMI following the criterion adopted in the National Family Health Survey:

Underweight	BMI<18.5
Normal	18.5 ≤ BMI < 25.0
Over weight	BMI ≥ 25.0

The null hypothesis for the analysis is that there is no difference between the mean scores of fertility parameters among women in different height and BMI categories of women. Since, a comparison of means for more than two groups on a metric variable has to be done, the analysis of variance (ANOVA) is the most appropriate statistical technique. However, application of ANOVA requires the homogeneity assumption which states that the population variance is equal in all the groups. This assumption may, however, be ignored, if the sample size of different groups is nearly the same. In order to test the homogeneity of the variance across different categories of women, the Levene's test was first carried out (Levene, 1960). The analysis of variance can be performed only when the Levene's statistic is found to be statistically insignificant. Otherwise it is suggested that non parametric tests such as Kruskal-Wallis test should be applied (Gastwirth et al, 2009).

It may also be pointed out that converting scale variables into categorical variables normally results in substantial loss of variability in the data which may bias the results of the analysis. Since all the variables used in the present analysis are scale or quantitative variables, we have also carried out the correlation analysis to examine the relationship between the fertility parameters and the anthropometric measures. Finally, the classification or segmentation analysis has also been carried out to group women into mutually exclusive groups on the basis of their height and BMI in such a way that the average fertility parameters in different groups of women are essentially different.

Results and Discussion

The mean duration of the first birth interval - the interval between the marriage and the first birth - is found to be 25.7 months with a standard deviation of 15.3 in the women covered under the present study. The median first birth interval, however, is found to be 22 months which suggests that the distribution of women in terms of the first birth interval was positively skewed with a skewness coefficient of 1.780 which is statistically significant. At the same time, although, the standard deviation is found to be very large, yet, the inter-quartile range is found to be small and the excess kurtosis is very high and statistically significant. This means that there are only a small proportion of outlier values in the distribution of first birth interval in the women studied and in most of the women, the first birth interval was close to the mean value.

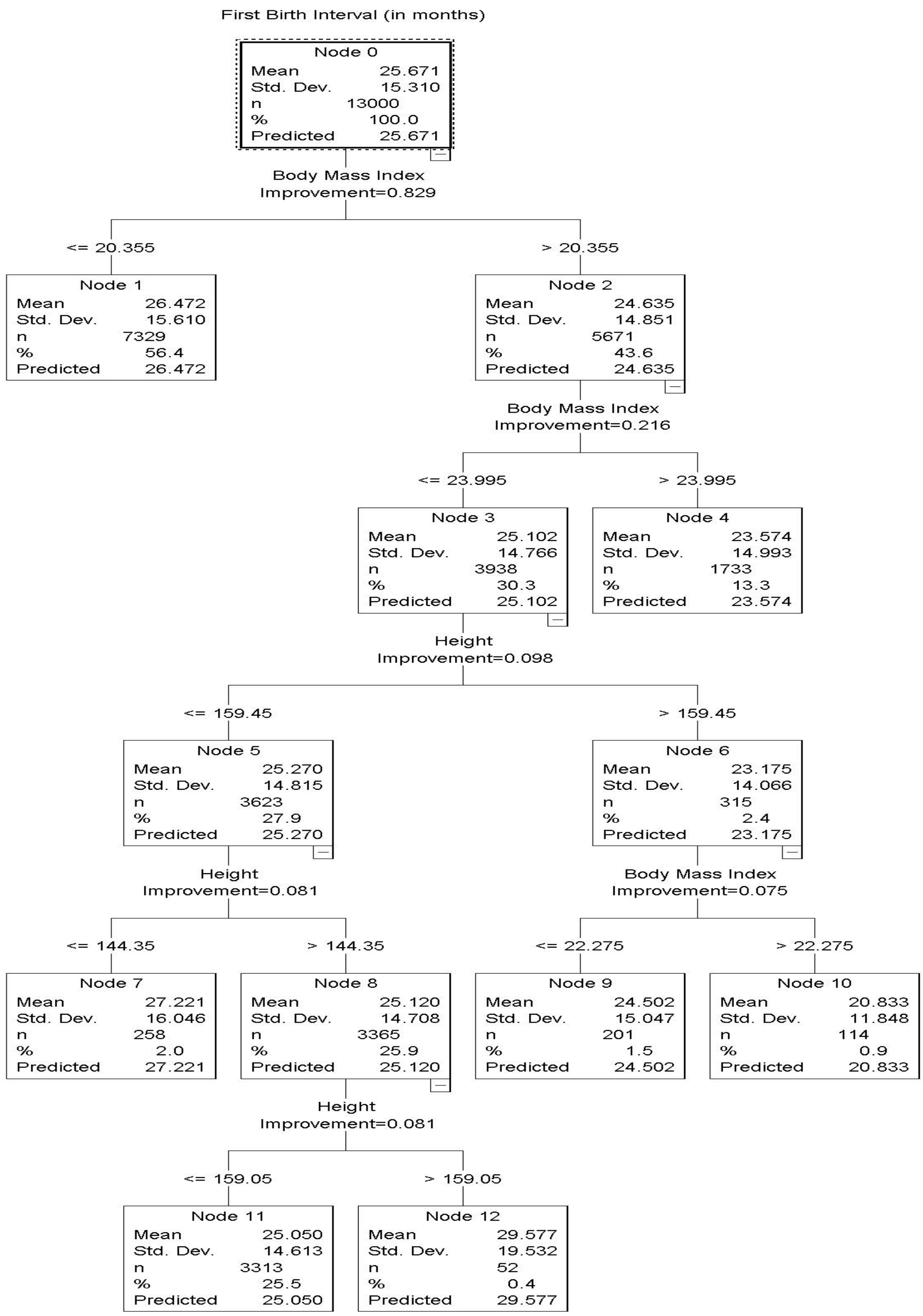
On the other hand, the average height of the women covered in the analysis was 152.4 cms with a standard deviation of 5.8 while the median height was 152.3 cms which suggests the height of the women was almost normally distributed. The distribution of the women by the body mass index (BMI) is however skewed. The average BMI is estimated to be 20.5 with a standard deviation of 3.5 but the median BMI is 19.9 and the skewness is 1.718. However, the excess kurtosis of the distribution of BMI is very high which means that the distribution is essentially leptokurtic. In other words, the distribution of three variables used in the analysis is essentially different.

Since the homogeneity of the variance plays an important role in determining the appropriate test for analysing the difference between different groups, the Levene's test was applied and the results are presented in table 2. For height categories, the p-value is found to be greater than the significance level of 0.05 which means that the null hypothesis of the homogeneity of the variance is accepted. Similarly, the null hypothesis is also accepted in case of BMI categories as the p-value is found to be greater than the significance level of 0.05. This indicates that the groups of women formed on the basis of BMI also have equal variance as far as the interval between marriage and the first birth is concerned and, therefore, the analysis of variance can be applied.

Table 3 presents the mean interval between marriage and first birth or the mean first birth interval for women of different categories of height while table 4 gives the mean birth interval for BMI categories. It may be inferred from the table that the first birth interval decreases with the increase in the height of the woman as well as with the increase in BMI. More specifically, the first birth interval is relatively shorter in short stature women compared to tall women. Similarly, the mean first birth interval is shorter in under weight women relative to over weight women. It is also obvious from the table that the difference in the first birth interval by height categories and by BMI categories is statistically significant. The table thus suggests that both the height of the woman and her BMI influence the interval between marriage and first birth.

The very fact that the first birth interval is influenced by both the height of the woman and her BMI, we have applied the classification modelling approach or segmentation analysis (Han, Kamber, Pei, 2012; Tan, Steinbach, Kumar, 2006) to classify women in terms of both height and BMI in the context of the first birth interval. Classification modelling involves classifying women on the basis of their height and BMI and then analysing the distribution of the first birth interval in different groups of women. The classification and regression tree (CRT) technique (Brieman et al, 1984) has been used for the purpose. CRT is a nonparametric recursive technique that divides women into different mutually exclusive groups in such a manner that within group homogeneity with respect to the dependent variable - first birth-interval - is the maximum. The technique sorts women into mutually exclusive groups based on the independent variable that causes the most effective split. The process is repeated till either the perfect similarity is achieved or the stopping criterion is met (Ambalavanan et al, 2006; Lemon et al, 2003). A group in which all women have the same value of the classification variable is termed as "pure." If a group is not "pure," then the impurity within the group can be

Figure 1
The classification tree



measured. If the dependent variable is a categorical one, then the method provides the distribution of the dependent variable across women in each group. If the dependent variable is continuous, then the method gives estimates of the arithmetic mean and standard deviation of the dependent variable in each group of women.

Results of the classification modelling exercise are presented in table 5 and figure 1. The classification modelling exercise suggests that 13000 women included in the present analysis can be grouped into seven mutually exclusive groups and the distribution of the first birth interval across women in different groups is essentially different. The mean first birth interval is the shortest in women in group 10. There are 315 women in this group. The height of women in this group is more than 159.45 cms and the BMI is more than 20.275 but less than or equal to 23.995. The mean first birth interval is also relatively very short in women belonging to group 4. There are 1733 women in this group and the BMI in these women is more than 23.995 which means that majority of the women in this group are over weight. By contrast, the mean first birth interval is the longest in women belonging to group 12. There are only 52 women in this group and the height of these women is more than 159.05 cms but less than or equal to 159.45 cms whereas the BMI is more than 20.355 but less than or equal to 23.995 which means that these women are neither under weight or over weight. The table also suggests that the mean first birth interval in under weight women (BMI≤20.355) is longer than the mean first birth interval in over weight women (BMI>23.995). The classification analysis also confirms that the first birth interval varies by both height of the woman and her physical composition and nutritional status as measured by the body mass index.

Conclusions

It is well known that the physical composition of an individual influences his or her reproductive behaviour. In the present study, it is found that both height of the woman and her body mass index, which is an indicator of both physical composition and nutritional status of the individual has an impact on the first birth interval or the interval between marriage and first birth. The body mass index of a woman is also affected by several factors such as food habit, chronic under nutrition, haemoglobin level, wealth index, etc. (Mueller, 1979; Bailey and Garn, 1979). Generally under nourished females belong to the households having low wealth index and where nutritional supplements are generally not available. The chronic under nutrition is responsible for various health problems in females. Hence these females fail to conceive earlier than normal females. At the same time, households having low wealth index get their girls married at an early age and these girls have to wait for a longer period than other girls to be physically fit for conceiving a child. In the same manner, it is also found that height of a woman affects the first birth interval. Usually, women having height less than the standard average height are considered nutritionally deficient for a long time. There may be a possibility that the children of these women suffer due to their poor nutritional status. Death of an infant/child also motivates a couple to go for another child as early as possible, a phenomenon which is known as the child replacement hypothesis. Despite the fact that individual fertility is influenced by a range of social, cultural, economic and other variables and despite the fact that the physical composition of an individual is also influenced by a number of nutrition and health related factors, the present analysis shows a statistically significant association between the first birth interval and anthropometric measures of women. It can, therefore, be concluded that physique and nutritional status of women play an important role in determining their reproductive behaviour their fertility is associated with anthropometric measures for women. Since the physique of a woman is ultimately responsible for a successful termination of the gestation period, the anthropometric measures should also be considered as factors of reproductive behaviour of individuals.

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Table 1
Summary statistics of the variables used in the analysis

Summary statistics	First birth interval	BMI	Height
Mean	25.671	20.491	152.4
Median	22	19.88	152.3
Variance	234.391	12.15	30.563
Standard deviation	15.31	3.496	5.793
Skewness	1.78	1.718	-0.346
Kurtosis	4.398	7.487	6.298

Source: Authors' calculations

Table 2
Test of homogeneity of variances (among different groups of women)

Fertility Parameters	Levene's Statistic	p-value
For height-classified groups		
First birth interval	0.024	0.976
For BMI-classified groups		
First birth interval	2.281	0.102

Source: Authors' calculations

Table 3
Descriptive statistics and analysis of variance for first birth interval.

Height	Mean first birth interval	Standard deviation for first birth interval	Standard error for first birth interval	95% confidence interval for mean first birth interval	
				Lower bound	Upper bound
Height ≤ 146.6 cm	25.24	15.199	0.348	24.56	25.92
Height 146.7-158.2 cm	25.10	15.464	0.158	24.79	25.41
Height ≥ 158.3 cm	24.90	15.765	0.361	24.19	25.61
ANOVA	$F_{cal} = 0.229$		p-value = 0.796		

Source: Authors' calculations

Table 4
Descriptive statistics and analysis of variance for first birth interval

BMI	Mean first birth interval	Standard deviation for first birth interval	Standard error for first birth interval	95% confidence interval for mean first birth interval	
				Lower bound	Upper bound
< 18.50	25.88	15.715	0.248	25.39	26.36
18.50-24.99	25.00	15.350	0.171	24.66	25.33
≥ 25.00	23.22	15.270	0.426	22.38	24.06
ANOVA	F_{cal} = 14.780		p-value = 0.000*		

* significant at α = 0.05 level of significance
Source: Authors' calculations

Table 5
Results of the classification modelling exercise

Group number	Defining characteristics		First birth interval		N
	BMI	Height	Mean	SD	
All			25.671	15.31	13000
1	≤20.355		26.472	15.61	7329
4	>23.995		23.574	14.993	1733
7	>20.355 ≤23.995	≤144.35	27.221	16.046	258
11	>20.355 ≤23.995	>144.35 ≤159.05	25.05	14.613	3313
12	>20.355 ≤23.995	>159.05 ≤159.45	29.577	19.532	52
9	>20.355 ≤22.275	>159.45	24.502	15.047	201
10	>22.275 ≤23.995	>159.45	23.175	14.066	315

Source: Authors' calculations