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Occupational Health Hazards in Stone Quarry Workers: A Multivariate Approach

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ABSTRACT The relationships of cardiorespiratory functions, physical fitness and body measurements with duration of stone dust exposure has been investigated in Malis working in stone quarries of Alwar district of Rajasthan. The exposed group comprised 125 adult males and 125 adult females working actively in different stone quarries in Alwar district. For the control group samples were drawn from pastoral Malis, totalling 250 individuals (125 adult males and 125 adult females). The results of the study delineate that cardiorespiratory functions, physical fitness and some of the body measurements are affected by stone dust exposure. Principal component and discriminant analysis reveal that cardio-respiratory functions and physical fitness are crucial variables in separating the control from the exposed.

INTRODUCTION

Safety, comfort and efficiency are the three crucial factors in any industrial set-up. One of the important aims of occupational health is to provide a safe occupational environment to safeguard the health of the workers. Occupational exposure to dust reduces lung functions and increases respiratory disorders (Kilburn et al., 1985; Amandus and Piacitelli, 1987; Amandus et al., 1989; Zohu et al., 1989). Dust control measures and regular medical examination are still almost invariably absent in remotely situated stone quarries in India. One of the numerous difficulties that prevent early intervention is the lack of proper data on stone quarry workers. Thus the present study is designed with the aim to study relationship of cardiorespiratiory functions, physical fitness and body measurement with duration of stone dust exposure in Malis working in stone quarries of Rajasthan.

MATERIAL AND METHODS

This study is a part of a larger investigation conducted in Alwar district of Rajasthan. The district falls in Thar desert and has a dry climate. The temperature in the area ranges from 8^0 C to 45^0 C with a mean annual temperature around 26^0 C. Data were collected on the endogamous group of Malis. The exposed group comprised 125 adult males and 125 adult females working actively in different stone quarries in Alwar district. For the control group, samples were drawn from pastoral Malis totalling 250 individuals (125 adult males and 125 adult females). The two groups are similiar in age, smoking habits and share common cultural and environmental factors except those created by their respective occupation.

The difference in mean age between control (males 30.32 and females 34.46) and exposed (males 30.62 and females 34.85) are non-significant at 5% probability level (F values: Males 10.18; Females 9.83)

In the present study, all the females were non-smokers but some of the males were smokers. The male subjects were divided into three groups based on the smoking history. *(1) Non-smoker :* included those who had never smoked any brand of tobacco regularly. *(2) Smokers:* included those who were currently smoking regularly *(3) Ex-smokers :* included those who had formally smoked cigarettes regularly but were no longer smoking at the time of the test. The number of smokers and non-smokers was similar in control and exposed group, *i.e.* 75 smokers and 50 non-smokers. In both the control and exposed males, none of the subjects was classed as ex-smoker. For the analysis, three indices of cigarette smoking were used. First, whether or not the subject smoked, second, the number of cigarettes per day, and third, the product of the average number of cigarettes smoked per day and the duration of smoking (Cigarette years)

A set of 16 anthropometric measurements, *viz.* stature, sitting height, lower extremity length, transverse chest diameter, antero-posterior chest diameter, bicondylar humerus, bicondylar femur, biacromial diameter, calf circumference, upper arm circumference, chest circumference, weight, skinfolds at - triceps, subscapula, suprailiac and calf were taken following standard techniques (Tanner et al., 1969). Chest circumference in males was taken at nipple level and in females at infra-mammae level.

Forced vital capacity (FVC), forced expiratory volume 1st second (FEV 1.0) and peak expiratory flow rate (PEF) were measured in sitting position with Morgan's portable spirometer following standard techinque (Consolazio et al., 1963; Cotes, 1975; Weiner and Lourie, 1969). Subjects were asked to exhale air forcefully after a full maximum inspiration. The best of three attempts was taken for further analysis.

Indirect ausculatory method was used for taking blood pressure in sitting position. Pulse rate and blood pressure were taken as per the recommendation of International Biological Program (Weiner and Lourie, 1969).

The measurement of right and left hands grip strength were taken with a dynamometer and recorded in kilograms (Weiner and Lourie, 1969). Subjects were encouraged to press the maximum, keeping the active arm in hanging position, close to the body but not touching it.

Physical fitness was evaluated using the famous Harward step test, described in detail by Hockev (1973). The test is most suitable for measuring cardiovascular endurance of subjects under field conditions. The test is based on the premise that for a given submaximal work, a person with higher physical fitness will have a smaller increase in heart rate and a faster recovery rate. Rapid fitness index was calculated as under :

$$RFI = \frac{\text{Duration of exercise (in seconds)} * 100}{5.5 * \text{Pulse count} \quad 1 \quad 1 \text{ \& } ½ \text{ min after exercise}}$$

As the human body is not made up of mutually exclusive parts, but is a complex integrated system. Therefore, a multivariate approach was considered proper. Multiple discriminant analysis was done using SAS package programme. This method transforms original variables into a set of multivariate vectors which are a linear combination of independent variables. In this process of transformation correlations between variables are taken into consideration, and the ratio of among-group variance to the total variance is maximized (Tatsnoka, 1971). Pattern of group difference was determined by calculating the generalized distance (D^2) after Mahalanobis. The results of the univariate analysis have been discussed and published already (Malik and Swami, 1991).

RESULTS AND DISCUSSION

Population samples of Malis used in the study were divided by sex and exposure. In our earlier publications, it was observed that the exposed groups, both males and females, had significantly lower forced vital capacity (FVC), forced expiratory volume 1 second (FEV 1.0), peak expiratory flow (PEF), bone breadths, circumferences, skinfolds and physical fitness and significantly higher blood pressure and pulse rate (Swami and Mālik, 1990; Malik and Swami, 1991). Care was taken to select control population so that it resembled with the exposed population in terms of ethnic background, age, smoking habits and other sociocultural concomitants, except those which were occupation specific. But during indepth analysis, it was realised that it might not have been possible to control all the confounding factors. For example, there might have been differences between two groups in amount and component of nutritional intake, as pastoral Malis (control group) have easier access to milk and its products, which might be a crucial supplement in diet in this group. As such it was found appropriate to examine the correlations in the exposed group between the biological variables and the years of exposure, so that the effect of exposure, if any, could be revealed. The results of correlation analysis are set out in table 1. All the biological variables show negative correlations with duration of exposure in males and females except blood pressure, pulse rate showing positive correleation. Here it is important to mention that only the significant correlation values are relevant (and the sign, either plus or minus, may be due to chance fluctuation, if non-significant). Importantly enough, the differences are significant at 5% probability level, in respiratory functions, cardiovascular measurements, bicondylar femur, bicondylar humerus, skinfold at calf and RFI with the duration of exposure in both males and females. The consistent results of having significant association between the aforementioned biological variables in both males and females further affirm their relation. The analysis confirms that with the increase in duration of exposure there is a noticeable decrease in respiratory functions, bone breadths and physical fitness and an increase in blood pressure and pulse rate.

Out of 25 variables introduced for the stepwise discriminant analysis, 14 were found to have significant contribution to group differentiation. In decreasing order of

Table 1 : Correlation values between period of exposure and morpho-physiological variables

Biological Variables	*Males*	*Females*
Forced vital capacity	-0.4708*	-0.4819*
Forced expiratory volume in one second	-0.3612*	-0.4604*
Peak expiratory flow rate	-0.2950*	-0.3246*
Pulse rate	0.2013*	0.4609*
Systolic blood pressure	0.2603*	0.4906*
Diastolic blood pressure	0.3160*	0.4784*
Stature	-0.1007	-0.1011
Sitting height	-0.1247	-0.1104
Lower extremity length	-0.1608	-0.1204
Transverse chest diameter	-0.0975	-0.1234
Antero-posterior chest diameter	-0.0803	-0.1429
Biocondylar humerus	-0.3679*	-0.4689*
Bicondylar femur	-0.4298*	-0.4935*
Biacromial diameter	-0.0714	-0.1154
Calf circumference	-0.3130*	-0.0813
Upper arm circumference	-0.0236	-0.1298
Chest circumference (Normal)	-0.1219	-0.2262*
Body weight	-0.0213	-0.1283
Triceps skinfold	-0.1277	-0.1084
Subscapular skinfold	-0.0609	-0.0819
Suprailiac skinfold	-0.1189	-0.1173
Skinfold at calf	0.1693*	-0.1788*
Right hand grip strength	-0.0288	-0.0294
Left hand grip strength	-0.0201	-0.0236
Rapid fitness index	-0.5289*	-0.5675*

*Significant at 5% probability level

Table 2 : Stepwise selection of variables contributing significantly in group discrimination

Biological Variables	*F-value*	*Degree of freedom*
Forced expiratory volume 1st Second	592.263	3.4960
Transverse chest diameter	86.021	6.9900
Left hand grip strength	59.881	9.1202
Rapid fitness index	26.342	12.1304
Systolic blood pressure	21.795	15.1358
Forced vital capacity	21.311	18.1389
Chest circumference	20.552	21.1407
Calf skinfold	15.898	24.1418
Pulse rate	10.623	27.1425
Diastolic blood pressure	9.020	30.1430
Bicondylar humerus	5.176	33.1432
Peak expiratory flow rate	4.260	36.1433
Subscapular skinfold	4.459	39.1434
Upper arm circumference	4.250	42.1433

Table 3: Distribution of subjects in various groups (Jackknifed's Classification)

Groups	Per cent correct	Number of cases classified into groups			
		Control males	Exposed males	Control females	Exposed females
Control males	87.2	109	10	6	0
Exposed males	88.8	10	111	4	0
Control females	92.8	1	3	116	5
Exposed females	93.6	0	0	8	117
Total	90.6	120	124	134	122

discriminant values the variables are forced expiratory volume 1st second, transverse chest diameter, left hand grip strength, rapid fitness index, systolic blood pressure, forced vital capacity, chest circumference, skinfold at calf, pulse rate, diastolic blood pressure, bicondylar humerus, peak expiratory flow rate, subscapular skinfold and upper arm circumference (Table 2).

Approximately 90% of the subjects could be classified in their correct group when Jackknifed classification was used (Table 3). This clearly demonstrates that though sex differences were marked, the effect of exposure was of no less significance. However, it seems that the exposure has larger effect in females than in males. Higher percentage of subjects classified correctly delineates greater distinction of the groups. From the Jackknifed classification the following point emerged. Firstly, the variables introduced had a large classificatory power, when the data were divided by exposure and sex; the exposure had larger effect on females than on males, secondly there were clear cut differences in two sexes and between control and exposed group. And finally, the variables introduced had large classificatory power when the sample was divided by exposure and sex.

Principal component analysis was used to reduce the numbers of correlated variables into a small number of uncorrealted components. These component are to be considered as a new set of data. Now the effect of exposure may be examined on the extracted components. A total of six components were retained with eigen value greater that 0.8 (Table 4). Together, these four principal components accounted 74.30% of the total variance.

Table 4: Eigen values and percentage of variance explained by different principal components

Principal component	Eigen values	Percentage of variance explained
1	8.96269	35.9
2	4.36528	17.5
3	2.19243	8.8
4	1.26988	5.1
5	0.90079	3.6
6	0.84543	3.4

The first component explained 35.9% of the total varaince and showed high loading (higher than 0.4) for all the variables except blood pressure, pulse rate and skinfolds. The component appeared to separate samples on the basis of two criteria. The first was based on the lung functions and the second one on body measurements and grip strength. The lung functions included forced vital capacity, forced expiratory volume one second, peak expiratory flow rate and body measurements included stature, sitting height, lower extremity length, weight, circumferences (upper arm, chest, and calf), transverse chest diameter, antero-posterior chest diameter, bicondylar humerus, bicondylar femur, biacromial diameter, hand grip strengths of right and left hand and rapid fitness index (Table 5).

The second component explained 17.5% the total variance. This component had high

Table 5: Principal component scroes

Biological Variables	*I*	*II*	*III*	*IV*
Stature	0.8286	-0.28062	0.19166	-0.15792
Left hand grip strength	0.82133	-0.32688	0.06496	-0.02769
Right hand grip strength	0.81760	-0.30399	0.09638	-0.02133
Chest circumference	0.81127	0.05368	0.16218	-0.18007
Sitting height	0.78610	-0.19712	-0.12449	-0.11789
Forced vital capacity	0.75632	-0.32435	-0.32405	0.33902
Weight	0.75233	0.38570	0.30832	-0.13539
Transverse chest diameter	0.74997	0.22888	-0.10796	-0.25568
Foirced expiratory volume 1st second	0.74538	-0.32799	-0.31714	0.35406
Antero-posterior chest diameter	0.68690	0.35804	0.10001	-0.18197
Lower extremity length	0.67280	0.25486	0.17696	-0.09932
Biocondylar femur	0.66990	0.27401	-0.41110	-0.07097
Biacromial diameter	0.66228	-0.01549	-0.00474	-0.15945
Peak expiratory flow rate	0.63211	-0.33110	-0.28729	0.35027
Biocondylar humerus	0.63117	0.29466	-0.41123	0.00356
Calf circumference	0.56569	0.27789	0.24542	0.05319
Skin fold at triceps	0.16762	0.80013	0.11381	0.23155
Skin fold at subscapular	0.01572	0.74496	0.10334	0.41149
Skin fold at suprailac	0.01748	0.74366	0.07872	0.27750
Skin fold at calf	0.25703	0.73641	0.18279	0.08813
Upper arm circumference	0.40190	0.65967	0.08630	-0.03014
Diastolic blood pressure	0.12935	-0.34512	0.60148	0.34446
Systolic blood pressure	0.12496	-0.40897	0.57695	0.34086
Rapid fitness index	0.42489	-0.04779	-0.45355	0.31334
Pulse rate	-0.03647	-0.27531	0.54317	0.18109

loading for the group which was represented by skinfolds and upper arm circumference. Thus this component had a separation based on the fat component (Table 5). The third component accounted for 8.8% of total variance. This component had a high loading for blood pressure, pulse rate and RFI. This component factor was represented by cardio-respiratory functions and physical fitness (Table 5). The fourth component possessed an eigen value of 1.270 and explained 5% of the total variance.

Mahalonobis D^2 matrix revealed that the control and exposed groups could be seperated from each other (Table 6). The values of Mahalanobis D^2 signalling the distance between pairs of four groups *viz.* control and exposed males and females, showed greater distance in females than in males between control and exposed.

Table 6 : Mahalanobis D^2 matrix based on anthropometric and cardiorespiratory functions in exposed and control males and females

Groups	*Control males*	*Exposed males*	*Control females*	*Exposed females*
Control males	—	—	—	—
Exposed males	2.6426	—	—	—
Control females	4.3556	—	—	—
Exposed females	6.9677	5.6181	3.5550	—

The values of canonical correlations revealed that the discrimination on the first two variates was highly significant. The first canonical variate explained 82% of the total variability. Forced vital capacity and forced expiratory volume in one second were the important discriminating variables on this axis. The second canonical variate, in combination with first canonical variate explained as high as 98% of the total variablity. In canonical variate II, bicondylar femur and rapid fitness index were the important variables. This showed that respiratory functions, bone breadth and physical fitness were the principal variables explaining the variation in these four groups. Contributions of other variables were rather low in differentiating the groups.

Canonial variate I emerged as a better sex discriminator whereas canonical variate II was important in deciphering stone dust exposure effect. The group centroids of the four groups are given in fig. 1. In females, both the canonical variates were equally important in separating the control group from the exposed group.

This indicated that respiratory functions, physical fitness and bone mass were important in discriminating the exposed females from the control females. In males, differentiation between exposed and control males was much more explained by the canonical variate II, *i.e.* bicondylar femur and rapid fitness index and slightly less by canonical variate I, represented by respiratory functions.

Sex difference was much lower in canonical variate I in the control group than the exposed group suggesting that the exposure increased the existing sex differences in respiratory functions. The sex difference in the control and the exposed group were similar for canonical variate II indicating that the exposure did not elevate sex differences in rapid fitness index and bone breadths to that extent.

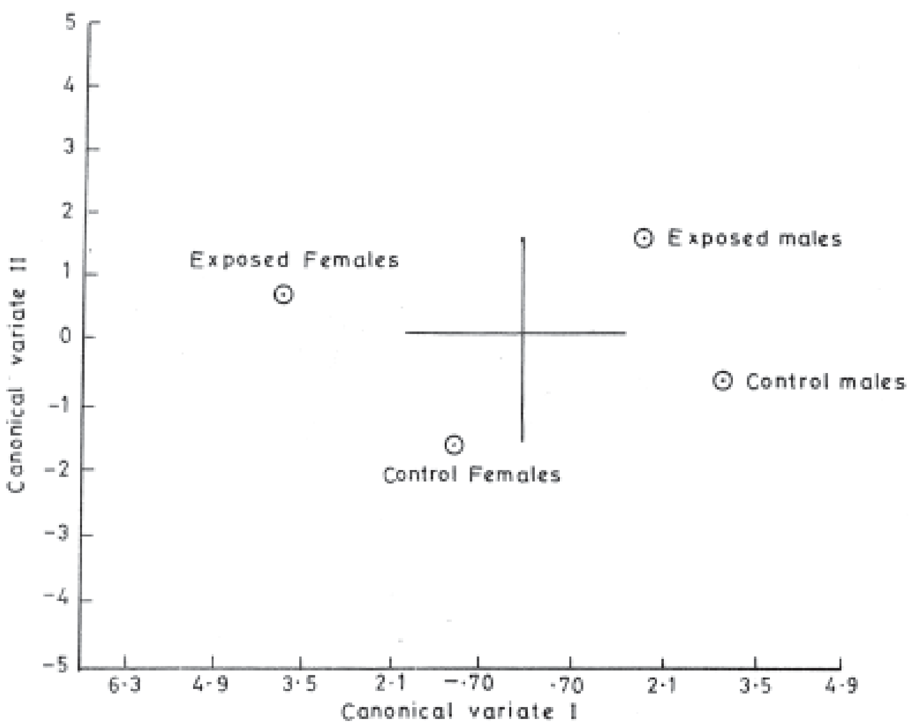

Fig. 1. The distribution of group centroids of control and exposed, males and females

From the results and discussion it may be concluded that exposure has effect on cardio-respiratory functions, physical fitness and some of the body measurements. Principal component and discriminant analysis revealed that cardio-respiratory functions and physical fitness contributed a lot in separating the control from the exposed.

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