Five-Year Blood Pressure Trends and Regression-to-the-mean in An Industrial Population

R Tongia*, R Gupta**, Malvika Agarwal**, VP Gupta***

Abstract
Objective: To determine trends in blood pressure (BP) and assess the statistical phenomenon of regression to the mean we performed sequential examinations in an industrial population.

Methods: All the employees in an industrial plant were examined. Height, weight, body mass index (BMI) and blood pressure were measured using standardised techniques successively for 5 years as part of annual medical check-up of these employees. All the male employees (n=145) were targeted in the first year of which 122 (84.1%) were examined. These numbers declined to 121, 99, 90 and 87 in subsequent years respectively due to employee attrition. Trends in levels of systolic and diastolic BP and hypertension prevalence were examined using standard regression analysis, least-squares regression and graphic analyses using a commercially available statistical programme.

Results: The mean age 31.3 ± 5.9 years (range 23-41). The mean height was 1.68 ± 0.06 m, weight 60.0 ± 9.1 kg and BMI 21.2 ± 3.1 kg/m². 18 subjects (14.8%) were overweight. From the first to the fifth year, respectively, BMI increased from 21.2 ± 3.1 kg/m² to 21.3 ± 3.0, 21.9 ± 3.0, 22.3 ± 3.0 and 22.6 ± 2.9 kg/m² (r= 0.93, p= 0.011), systolic BP declined from 127.1 ± 13.5 to 125.7 ± 15.4, 125.5 ± 12.9, 125.0 ± 12.6 and 124.9 ± 14.0 mm Hg (r= -0.60, p= 0.034) while diastolic BP remained unchanged (r= 0.15). Prevalence of hypertension (> 140/> 90) declined from 34.4% at baseline to 28.9, 28.3, 24.4 and 24.1% respectively (r= -0.948, p= 0.021).

Conclusions: A high prevalence of hypertension in observed in this young industrial cohort. Without treatment, the hypertension prevalence as well as mean systolic BP decline over time demonstrating the statistical phenomenon of regression to the mean. ©

INTRODUCTION

Industrial populations provide a stable source of tracking of cardiovascular risk factors. Studies in many developed and developing countries worldwide have used subjects in industrial populations to track changes in coronary risk factors and to determine incidence of cardiovascular end points successfully.1 Examples include the Railroad Workers Prospective study, Chicago Firemen Study, and others in USA, Whitehall Study in UK, Norwegian and Finnish studies, many international cohorts in WHO-MONICA (MONItoring trends of CArdiovascular risk factors) study, the Chinese workplace study in Joint USA-People’s Republic of China cardiovascular (USA-PRC) risk factor study, Japanese and Korean studies.1 In India some cross-sectional studies have evaluated cardiovascular risk factors in industrial cohorts. Blood pressure has been examined among tea-workers in Assam, alcohol-making units in Maharashtra, Railway workers from all over India, and industrial workers in Punjab.2 There is an ongoing Indian Council of Medical Research (ICMR) multicentre study of worksite evaluation of multiple cardiovascular risk factors and one cohort of the Prospective Urban-Rural Epidemiology (PURE) study is evaluating aeronautical employees and families in Bangalore.

Epidemiological study that measure normally distributed numerical variables such as weight, blood pressure or blood glucose levels over a period of time are fraught with statistical problem of regression-to-mean.3 Francis Galton in 1886 initially described this statistical phenomenon when he noted that height of children of tall father tended to follow the mean height of the population and not the father.4 Subsequently many observational and interventional epidemiological studies have noted that initial pathological blood pressure or blood glucose level in the second or third phase of examination tended to yield closer to normal subsequent measurements.5,6 There are no studies in India that have examined long term trends in obesity

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determined by body-mass index (BMI) and blood pressure (BP). We performed a pilot study to determine five year trends in BMI and BP levels in a single industry to study feasibility of performing a long-term prospective trial in an industrial population. This study also examined the statistical phenomenon of regression-to-mean in systolic and diastolic BP as data from multiple observations over a prolonged period were available.

METHODS

Medical check-up of all the employees of a non-government industry was planned with a view to collect data on obesity and hypertension. Permissions were obtained from the factory owners and employees. This being a new industry, the average age of the employees was less than 35 years. Annual medical check up all the employees working in the factory (n=150) was planned at baseline and repeated yearly thereafter for 5 years.

The medical examination included measurement of height and weight, and blood pressure levels. Height was measured by a stadiometer and weight using calibrated spring balance at the worksite. BP was measured using a standardised mercury sphygmomanometer according to the guidelines of WHO. Phase I of Korotkoff’s sound was considered for systolic BP and phase V for diastolic BP. At least two readings were taken 5 minutes apart and averaged. If a high BP >140/≥ 90 was noted, the examination was repeated after 30 minutes and lower of the two readings were averaged. BMI was calculated by diving weight in Kg by squared height in metres. A low prevalence of obesity was noted and only 18 subjects were either obese or overweight. Hypertension was observed in 42 subjects (34.4%) of which stage I hypertension (BP >140-159/≥ 90-99 mm Hg) was in 35 and stage II hypertension (≥ 160/≥ 100) in 7 subjects.

The annual trends in weight, BMI, systolic and diastolic BP and prevalence of hypertension are reported in Table 1. There is a significantly increasing trend in weight (r= 0.995, 95% confidence intervals (CI) 0.992 to 0.995, p<0.01) and BMI (r= 0.93, CI 0.87 to 0.98, p= 0.011). The BMI increased from 21.2 ± 3.1 kg/m2 to 21.3 ± 3.9, 21.9 ± 3.0, 22.3 ± 3.0 and 22.6 ± 2.9 kg/m2. Simple regression analysis reveals a significant positive trend in BMI. The linear regression equation for BMI is y = 20.8 + 0.38*x (p = 0.0009).

The mean systolic BP declined significantly from 127.1 ± 13.5 mm Hg at baseline to 125.7 ± 15.4, 125.5 ± 12.9, 125.0 ± 12.6 and 124.9 ± 14.0 mm Hg at successive examinations (r= -0.60, CI -0.53 to -0.66, p= 0.034) (Fig. 1). The regression equation for systolic BP is y = 126.6-

### Table 1: Baseline characteristics of the study population

<table>
<thead>
<tr>
<th>N=122</th>
<th>Age (years, mean ± SD, range) 31.3±5.9, 23-41</th>
<th>Gender (men) 122 (100.0)</th>
<th>Height (metres) 1.68 ± 0.06</th>
<th>Weight (kg) 59.9±9.2</th>
<th>Obesity prevalence Normal BMI &lt;25 kg/m² 104 (85.3)</th>
<th>Overweight, 25.0-29.9 17 (13.9)</th>
<th>Obese, ≥ 30 kg/m² 1 (0.8)</th>
<th>Hypertension prevalence Stage I (BP 140-159/90-99) 35 (28.7)</th>
<th>Stage II (BP ≥ 160/≥ 100) 7 (5.7)</th>
</tr>
</thead>
</table>

### Table 2: Five-year trends in BMI, mean BP and hypertension prevalence

<table>
<thead>
<tr>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
<th>Trend analysis (r value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=122</td>
<td>N=121</td>
<td>N=99</td>
<td>N=90</td>
<td>N=87</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.6±9.1</td>
<td>60.5±9.5</td>
<td>61.6±8.8</td>
<td>62.4±8.6</td>
<td>62.9±8.7</td>
</tr>
<tr>
<td>Body-mass index</td>
<td>21.2±3.1</td>
<td>21.3±3.9</td>
<td>21.9±3.0</td>
<td>22.3±3.0</td>
<td>22.6±2.9</td>
</tr>
<tr>
<td>Systolic BP mm Hg</td>
<td>127.1±13.5</td>
<td>125.7±15.4</td>
<td>125.5±12.9</td>
<td>125.0±12.6</td>
<td>124.9±14.0</td>
</tr>
<tr>
<td>Diastolic BP mm Hg</td>
<td>80.1±7.4</td>
<td>80.7±7.6</td>
<td>80.1±8.7</td>
<td>79.4±8.4</td>
<td>80±8.9</td>
</tr>
<tr>
<td>Hypertension prevalence (%)</td>
<td>42 (34.4)</td>
<td>35 (28.9)</td>
<td>28 (28.3)</td>
<td>22 (24.4)</td>
<td>21 (24.1)</td>
</tr>
</tbody>
</table>

BP - blood pressure, BMI - body mass index, * p<0.05

RESULTS

Of the total employee strength of 145 men we could examine 122 subjects in the first year (84.1%), 121 in second, 99 in third, 90 in fourth and 87 in the fifth year. This high rate of attrition in employee status over a period of time has been noted in many industries that employ young personnel. The baseline anthropometric data are reported in Table 1. This was a young cohort with mean age 31.3 ± 5.9 years (range 23-41). The mean height was 1.68 ± 0.06 m, weight 60.0 ± 9.1 kg and BMI of 21.2 ± 3.1 kg/m². A low prevalence of obesity was noted and only 18 subjects were either obese or overweight. Hypertension was observed in 42 subjects (34.4%) of which stage I hypertension (BP >140-159/≥ 90-99 mm Hg) was in 35 and stage II hypertension (≥ 160/≥ 100) in 7 subjects.

The annual trends in weight, BMI, systolic and diastolic BP and prevalence of hypertension are reported in Table 2. There is a significantly increasing trend in weight (r= 0.995, 95% confidence intervals (CI) 0.992 to 0.995, p<0.01) and BMI (r= 0.93, CI 0.87 to 0.98, p= 0.011). The BMI increased from 21.2 ± 3.1 kg/m² to 21.3 ± 3.9, 21.9 ± 3.0, 22.3 ± 3.0 and 22.6 ± 2.9 kg/m². Simple regression analysis reveals a significant positive trend in BMI. The linear regression equation for BMI is y = 20.8 + 0.38*x (p = 0.0009).

The mean systolic BP declined significantly from 127.1 ± 13.5 mm Hg at baseline to 125.7 ± 15.4, 125.5 ± 12.9, 125.0 ± 12.6 and 124.9 ± 14.0 mm Hg at successive examinations (r= -0.60, CI -0.53 to -0.66, p= 0.034) (Fig. 1). The regression equation for systolic BP is y =126.6-
0.33\times (p= 0.0499). The diastolic BP did not show any significant change (r= 0.15, CI -0.14 to 0.29). Prevalence of hypertension was 34.4% in the first examination and declined serially to 28.9%, 28.3%, 24.4% and 24.1% respectively (least squares regression r= 0.95, p= 0.021) (Fig. 2).

**DISCUSSION**

This study shows that over a short period of five years, multiple blood pressure examinations reveal a trend towards lower systolic as well as diastolic BP over the five year time period in this population. The prevalence of hypertension also decreases. This is despite an increase in mean body-mass index.

Stewart collected data on forty young men with established hypertension over a period of 6 years. In twelve of these subjects with an average age of thirty five years the diastolic BP fell gradually without treatment from an average established level of 115 mm Hg to 88 mm Hg over the next six years. Pickering considered this fall as extinction of the defence reflex or normalisation of white-coat hypertension. Current evidence favours this to represent regression towards the mean. It has been shown that regression to the mean occurs whenever we select an extreme group based on one variable and then measure another variable for that group. In clinical practice there are many measurements such as weight, serum cholesterol concentration or BP, for which particularly high or low values are signs of underlying disease or risk factors for disease. Even if the subjects are not treated the mean BP would go down, owing to the regression to the mean. The first and second measurement will have correlation r<1 because of the inevitable measurement error and biological variation. The difference between the second mean for the subgroup and the population mean will be approximately r times the difference between the first mean and population mean. In the present study the mean systolic BP in this group of young men is 127.1 ± 13.5 mm Hg at the first examination and decreases to 125.7 ± 15.4 at the second year and to 124.9 ± 14.0 by the fifth examination. We previously reported population mean BP in urban and rural subjects in Rajasthan. Among urban men the mean systolic BP was 119 ± 12 in age-group 20-29 years and 123 ± 13 in those aged 30-39 years. In the present study the initially high systolic BP has tracked to levels closer to mean of age-group 30-39 years. This finding has important practical implications in day to day practice when we rely on a single time or single day BP measurement to diagnose high BP. This is also important in cautious interpretation of results in hypertension intervention studies that do not have a randomised control group.

A high prevalence of hypertension in this young group is a need for concern. A gradual decline in its prevalence over the next five years without treatment in many of the subjects would be an example of regression to the mean. On the other hand it could also be a manifestation of increasing hypertension among the Indian population. Joseph et al reported hypertension in 31.0% men of 76 subjects after multiple examinations in Thiruvananthapuram, Kerala while Anand et al performed multiple examination in middle-aged Mumbai executives and reported hypertension in 34.1% of 1521 subjects. The present study in younger subjects also reports an initial high prevalence of hypertension. However there is a decline in its prevalence to 25.0% by the fifth year of examination. This may represent an attrition of study subjects as the number of available men declined in five-year period, or it may reflect the true prevalence of hypertension in young urban subjects in India. The prevalence of hypertension in India in recent years has varied from 14.0% to 44.9% among urban men and a recent study in India reported hypertension prevalence of 36.4% among urban men. Among industrial workers, earlier studies that defined hypertension by BP ≥ 160/≥ 95 reported prevalence of 9.2% in Railway employees in 1971 and 14.1% in Ludhiana (Punjab) in 1985. Our study is not comparable as criteria used are different. Reddy et al reported hypertension among New Delhi industrial workers and in men (n=2186) the prevalence was 30.6%, similar to the present study.
In conclusion, this study highlights the high prevalence of hypertension among young urban male industry workers. Importance of the statistical phenomenon of regression-to-the-mean is emphasised as a major confounding event in non-randomised hypertension treatment studies.

REFERENCES


Announcement

Railway Chapter of Association of Physicians of India

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Railway Chapter of Association of Physicians of India (RAPI) is organizing its 12th Annual Conference – RAPICON 2005 on 25-26th November 2005 at Divisional Railway Hospital, Vishakhapatnam.

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