# MARKOV CHAIN ANALYSIS FOR HYPERTENSION AMONG SCHOOL CHILDREN'S

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***Abstract:*** Hypertension has emerged as an important public health concern in India. Several studies across globe and in India demonstrated a high prevalence and rising trends of hypertension, overweight and obesity in school children. And the conditions were also found to be associated increasing the tremendous burden on the children putting them at risk of its detrimental effects. In this paper, we have analyzed the association of hypertension and obesity with various risk factors through Markov Chain Analysis.

***Keywords: TPM, Markov Chain, Steady State, Hypertension.***

## 1. Introduction

Stochastic models are used in several fields of medical research. Some of the models like traffic flow models, queuing models and reliability models are used in basic sciences. Biostatistics is a field of science that uses quantitative methods to study life sciences related problems that arise in a broad array of fields. Several studies across globe and in India demonstrated a high prevalence and rising trends of hypertension, overweight and obesity among school children. Both the conditions were also found to be associated increasing the tremendous burden on the children putting them at risk of its detrimental effects. Several lifestyle factors like diet and physical activities were attributed for this rising burden. Subramanyam et al., [12] have reported that overweight was seen in 9.7 % and obesity in 6.2% of the girls. A study in 2002 showed that the prevalence was seen in 17.8 % in boys and 15.8 % in girls was increased due to changes in lifestyle factors. De Onis et al.,[2] have studied the worldwide trends and prevalence of overweight and obesity among preschool children on the basis the WHO standards. Genc [3] has developed stochastic algorithm for physiological model of the cardiovascular system. Buch et al., [1] have identified obesity, family history of diabetes mellitus, ischemic heart disease were found to be significant association for childhood hypertension. Wasan et al., [15] have discussed the impact of data mining techniques on medical diagnostics with neural network. Tayem et al., [14] have identified the high prevalence of elevated BP and excess weight gain among students at Al-Quds University. Rao et al.,[10] have highlighted that BP measurements needs to be a routine part of physical examination in school children, and the use of cut-offs anchored to metabolic risks may be essential for assessment of obesity. Kinra et al., [6] have examined association between socio-economic position and cardiovascular risk factors, to investigate whether childhood socio-economic position is a risk factor. It showed evidence that mean BMI was 16.7 kg/m$^2$ for boys and 17.8 kg/m$^2$ for girls and Socio-economic position was positively associated with fat mass index (0.15 kg/m$^2$; 95% CI: 0.05-0.25). Mishra et al.[7] have conducted a cross-sectional study among

1913 children (58.1% males) aged 6-16 years, from schools around Bangalore in 2015 shows that 15.1% were overweight/obese and 21.7% had high waist circumference. These obesity indicators were associated with risk of high blood pressure in urban Indian schoolchildren. Ranjani et al., [9] have reviewed overweight and obesity rates in children and adolescents. Kar et al.,[4] have conducted a cross sectional study on 979 school children, in 2010 in Gangtok, Sikkim shows 2.04%, 14.5% and 5.62% prevalence of obesity, overweight, and hypertension respectively. The average fast food intake, screen time and limited outdoor activities were significantly associated with obesity and related hypertension. Mistry et al.,[8] showed significant association between overweight and obesity and various risk factors.

## 2. Materials and Methods

A family of random variables {X (t), t ∈T} is called stochastic processes for each t∈T, where T is the index set of the process, X (t) is a random variable. An element of T is usually referred as a time parameter. The state space of the process is the set of these values that random variables X (t) can assume. Each of these values is called that state of the process.In stochastic processes the current state of the system depends on all of its previous states. But in Markov process, the current states of the process depend only on immediate preceding state. The Markov process is a system that can be in one of several numbered states, and as from one state to another for each time step according to fixed probabilities [5, 11].

### 2.1 Markov Chain

The stochastic process X={$X^n$ : n $\Xi$ N} is called a Markov chain provided that P[$X^{n+1}$ =j /$X^0$,…., $X^n$ ] =P[$x^{n+1}$ =j|$X^n$ ] for all **j** ∈S where S is the countable state space and n∈N. A Markov Chain is a sequence of random variables such that for any n, the next state $X^{n+1}$ , of the process is independent of the past states $\boldsymbol{X_0}, \boldsymbol{X_1}, \ldots, \boldsymbol{X_{n-1}}$ provided that the present state $X^n$ be known. A Markov chain X is said to be time- homogenous if the conditional probability P[$X^{n+1}$ =j| $X^n$ i] =$P^{I\,j}$ , i, j∈S is independent of n and s is the countable state space. The probabilities $P^{ij}$ are then called the transition probabilities for the Markov chain X. It is customary to arrange the $P^{ij}$ or P (ij) =$P^{ij}$ into a square array and to be called the resulting matrix P= ($\boldsymbol{P_{ij}}$) the transition matrix of the Markov chain X; for any i, j∈S, $P^{ij} \geq 0$. and for each $i \in \sum_{j\text{E}} pij = 1$ for any M∈N. $p[X^{n+m} = j / X^{n=i}]pijm^{th}$ Power of $pij$

## 3. Results and Discussions

A study was conducted among school children's between the ages of 10 to 14 years at various government schools in Tamilnadu. Prevalence rate estimated according to the various categories like age, sex, socio-economic status etc.

Sample size estimated for hypertension prevalence study based on the below formula

$$n = \frac{z^2 P(1-P)}{d^2} \quad \ldots (1)$$

Where n= sample size, Z= z statistics for a level of confidence, p= Expected prevalence or proportion and d= precision. Sample size was calculated by using N master software and approximately 6% the prevalence of hypertension as reported by various studies across India. [13, 1]. Considering prevalence of 6%, level of confidence 95% with precision of 0.02 the estimated sample size was 542. It was observed that the majority, 187 (34.4%) of the students belonged to the age group of 11 years, followed by 162, (29.8%) students in the age group of 12 years. The mean age of the participants was 11.81±0.95 years. Out of the total 544 students, 343 (63.1%) were males and 201 (36.9%) were females.

**Table 1: Baseline anthropometric parameters of school children's**

| Parameters | Height | | Weight | | Waist | | Hip | | Waist-Hip ratio | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sex | Male | Female | Male | Female | Male | Female | Male | Female | Male | Female |
| Mean | 146.95 | 147.90 | 40.64 | 41.10 | 68.94 | 99.14 | 78.17 | 77.42 | 0.88 | 1.35 |
| SD | 9.28 | 8.59 | 9.97 | 10.13 | 9.97 | 30.65 | 10.09 | 10.75 | 0.050 | 6.53 |
| Minimum | 120 | 122 | 21 | 21 | 48 | 42 | 52 | 50 | 0.73 | 0.77 |
| Maximum | 175 | 168 | 75 | 80 | 97 | 73 | 106 | 118 | 1.05 | 93.53 |

Table 1 describes the baseline anthropometric parameters of the male students. The mean height of the boys was 146.95 ± 9.284 cm, the mean weight was 40.64 ± 9.973, and the mean waist-hip ratio was 0.8813 ±. 05064. The mean height of the girls was 147.90 ± 8.595 cm, the mean weight was 41.10 ± 10.135, and the mean waist-hip ratio was 1.3502 ±. 6.534. It was observed that a majority, 484 (89.0%) of the students lived in urban areas followed by 60 students (11.0%) in rural areas.

**Table 2: Body mass index of the participant according to age**

| Age In years | BMI Category | | | | | |
|---|---|---|---|---|---|---|
| | Normal | Thinness | Severe Thinness | Overweight | Obesity | Total |
| 10 | 32 (80.0%) | 1 (2.5%) | 1 (2.5%) | 6 (15.0%) | 0 (0.0%) | 40 (100) |
| 11 | 149 (79.7%) | 7 (3.7%) | 9 (4.8%) | 21 (11.2%) | 1 (0.5%) | 187 (100) |
| 12 | 129 (79.6%) | 12 (7.4%) | 6 (3.7%) | 12 (7.4%) | 3 (1.9%) | 162 (100) |
| 13 | 126 (84.6%) | 8 (5.4%) | 5 (3.4%) | 10 (6.7%) | 0 (0.0%) | 149 (100) |
| 14 | 4 (66.7%) | 1 (16.7%) | 0 (0.0%) | 0 (0.0%) | 1 (16.7%) | 6 (100) |
| Total | 440 (80.9%) | 29 (5.3%) | 21 (3.9%) | 49 (9.0%) | 5 (0.9%) | 544 (100) |

Table 2 shows the Body Mass Index of the school students. It has been observed that of the 544 students, 440 students had normal BMI values followed by overweight (49 students) (9.0 %), whereas only few 5 students (0.9 %) were obese. A total of 29 students (5.33) had BMI values in thin category and 21 students belonged to severely thin category, as per their BMI.The body mass index of the students according to their age out of the 544 students, 440 had a BMI in the normal range. A total 49 (9%) students were overweight, among them maximum ie. 21students were belonging to the age group of 11 years, followed by 12 students in the age group of 12 years. Maximum no of obese individuals (3 students) was seen in 12 years age group, and 1 obese student each in 11 and 14 years age group. For analysis purposes, we clubbed the values of thin and normal in one category and overweight and obesity into another and applied the chi square test to find out the association between age and obesity. Since P= 0.41, there is no statistically significant association observed between the BMI values and student's age. The mean days of sport activities of students per week were comparatively higher in non-obese students (3.302 ± 3.0814) than in those who are obese (2.83 ± 2.8266) and this difference was statistically significant (P=0.025).

**Table 3: Age wise hypertension status of students**

| Age in years | Normal | Pre- hypertension | Stage 1 HTN | Stage 2 HTN | Total |
|---|---|---|---|---|---|
| 10 | 24 (60.0%) | 4(10.0%) | 9(22.5%) | 3(7.5%) | 40(100%) |
| 11 | 136 (72.7%) | 19 (10.2%) | 27 (14.4%) | 5 (2.7%) | 187(100%) |
| 12 | 112 (69.1%) | 18 (11.1%) | 27 (16.7%) | 5 (3.1%) | 162(100%) |
| 13 | 120 (80.5%) | 18 (12.1%) | 9 (6.0%) | 2 (1.3%) | 149(100%) |
| 14 | 3 (50.0%) | 1 (16.7%) | 2 (33.3%) | 0 (0.0%) | 6(100%) |
| Total | 395 (72.6%) | 60 (11.0%) | 74 (13.6%) | 15 (2.8%) | 544(100%) |

Table 3 shows the age distribution and the hypertension status of the study group. It was seen that out of the 544 students, 395 students were normotensive, 60 were pre hypertensive, 74 had stage 1 HTN and 15 were in stage 2 HTN. Maximum number of students exhibiting pre-hypertension were in the 11 years age group (19 students). Maximum numbers of students in Stage 1 Hypertension were in 11 and 12 years age group (27 students each). Maximum numbers of students exhibiting hypertension stage 2 were in 11 and 12 years age group (5 each). And applied the chi square test to find out association between age and hypertension. Since P= 0.025 there is a statistically significant association observed between the hypertension and student's age.

**Table 4: Association between hypertension and obesity**

| Variables | | HTN Category | | | | |
|---|---|---|---|---|---|---|
| | | Normal | Pre-hypertension | Stage 1 HTN | Stage 2 HTN | Total |
| BMI | Thin and normal | 369 (75.3%) | 49 (10.0%) | 62 (12.7%) | 10 (2.0%) | 490 (100% ) |
| | Overweight and Obesity | 26 (48.1%) | 11 (20.4%) | 12 (22.2%) | 5 (9.3%) | 54 (100%) |
| | Total | 395 (72.6%) | 60 (11.0%) | 74 (13.6%) | 15 (2.8%) | 544 (100%) |

Table 4 shows that out of total 54 students who were overweight and obese 11 students were pre-hypertensive, 12 students were in stage 1 hypertension and 5 students were in stage 2 hypertension. There is a strong association between hypertension and obesity as p= 0.000.

**Table no 5: Transition Count Matrix for hypertension**

| Variable | Normal | Prehypertension | Stage 1 HTN | Stage 2 HTN | Total |
|---|---|---|---|---|---|
| Normal | 323 | 46 | 61 | 10 | 440 |
| Prehypertension | 26 | 1 | 1 | 1 | 29 |
| Stage 1 HTN | 17 | 2 | 1 | 1 | 21 |
| Stage 2 HTN | 26 | 11 | 12 | 5 | 54 |
| Total | 395 | 60 | 74 | 15 | 544 |

**Table no 6: TPM for hypertension**

| State | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.734 | 0.105 | 0.139 | 0.023 |
| 2 | 0.897 | 0.034 | 0.034 | 0.034 |
| 3 | 0.304 | 0.036 | 0.196 | 0.464 |
| 4 | 0.031 | 0.034 | 0.014 | 0.920 |

In the above matrix all the entries are non-zero hence it confirms that the underline Markov chain is ergodic. The above estimated transition probability matrix reveals that probability of student staying in same state 1, sate 2 is higher compared to transitioning to another state.(Staying in State 1 (P) = 73 %; and in State 4 (P) = 92%). A negligible percent of students transition from State 1 to State 4 (P) = (0.023%) and 0.034 % transition from State 2 to State 3 and State 4 (P) was observed.

## 4. CONCLUSION

Hypertension among school going students overweight/obese suggested an early clinical detection of prehypertension and life style modification mainly weight management. The body mass index is closely associated with both systolic and diastolic blood pressure among the school going students. BP is also associated with rising age independently. The risk of hypertension was higher among school going students who were overweight or obese. There is a strong association between hypertension and obesity indicating its importance as a target group for immediate intervention to prevent further morbidity and mortality.

hypertension of school going students for the probability 34% of chance for normal, 5.9 % of chance for prehypertension, 7% of chance for Stage 1 HTN and 53 % of chance for Stage 2 HTN. The steady state transition is reached from after 50 months. Although traditional populations around the world were often believed to have low blood pressure, gradually with changing socioeconomic environment, marked increase in blood pressure and overweight or obesity level has been noted as was evident from the present study among the School going students.

**References**

[1] Buch N, Jagdish P. Goyal, Nagendra Kumar, Indira Parmar, Vijay B. Shah, and Charan J.(2011). Prevalence of hypertension Inschool going children of Surat city, Western India. J Cardiovasc Dis Res: 2(4): 228–232.

[2] De Onis M, Blössner M, Borghi E. (2010). Global prevalence and trends of overweight and obesity among preschool children. Am JClinNutr: (92)5:1257-1264.

[3] Genc. S, (2011). "Prediction of mean arterial blood pressure with linear stochastic models," Annual International Conference of the IEEE Engineering in Medicine and Biology Society: 712-715.

[4] Kar S, Khandelwal B., (2015). Fast foods and physical inactivity are risk factors for obesity and hypertension among adolescent schoolchildren in east district of Sikkim, India, J Nat SciBiol Med: 6(2):356-9.

[5] Karlin S and Taylor E. A First Course in Stochastic Processes (Second Edition), Academic Press, New York. ISBN: 978-0-08-057041-9

[6] Kinra S, Johnson M, Kulkarni B, RameshwarSarma KV, Ben-Shlomo Y, Smith GD. (2014). Socio-economic position and cardiovascular risk in rural Indian adolescents evidence from the Andhra Pradesh children and parents study (APCAPS). Public Health: 128(9):852-9.

[7] Mishra PE, Shastri L, Thomas T, Duggan C, Bosch R, McDonald CM, Kurpad AV, Kuriyan R.. (2015). Waist-to-Height Ratio as an Indicator of High Blood Pressure in Urban Indian School Children. Indian Pediatr: 52(9):773-778.

[8] Mistry SK, Puthussery S. (2015). Risk factors of overweight and obesity in childhood and adolescence in South Asian countries: a systematic review of the evidence. Public Health: 129(3):200-209.

[9] Ranjani H, Mehreen TS, Pradeepa R, Anjana RM, Garg R, Anand K, Mohan V. (2016). Epidemiology of childhood overweight & obesity in India: A systematic review. Indian J Med Res: 143(2): 160–174.

[10] Rao S, Kanade A, Kelkar R. (2007). Blood pressure among overweight adolescents from urban school children in Pune, India. Eur J ClinNutr: 61(5):633-41.

[11] Robert G. Gallager (2013). Stochastic Processes Theory for Applications Hardcover, first edition, Cambridge University press.

[12] Subramanyam V, Jayashree R, Rafi M. (2003) Prevalence of overweight and obesity in affluent adolescent girls in Chennai in1981 and 1998. Indian Pediatr: 40(8):775-9. 13.

[13] Taksande A, Chaturvedi, P., Vilhekar, K., and Jain M., (2008). Distribution of blood pressure in school going children in rural area of Wardha district, Maharashatra, India. Ann PediatrCardiol: 1(2): 101–106.

[14] Tayem YI, Yaseen NA, Khader WT, Abu Rajab LO, Ramahi AB, Saleh MH. Prevalence and risk factors of obesity and hypertension among students at a central university in the West Bank. The Libyan Journal of Medicine, 2012(7).

[15] Wasan, K.S., Bhatnagar, V., and H. Kaur, (2006). The Impact of Data Mining Techniques on Medical Diagnostics, *Data Science Journal*: 5(19):119-126.