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Ankita Henry Date

Hypertension in Rural and Indigenous Populations in Odisha, India

By

Ankita Henry
Degree to be awarded: MPH

Hubert Department of Global Health

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Shivani A. Patel
Committee Chair

Hypertension in Rural and Indigenous Populations in Odisha, India

By

Ankita Henry

B.S.
Denison University
2015

Thesis Committee Chair: Shivani A. Patel, MPH, PhD

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Abstract

Hypertension in Rural and Indigenous Populations in Odisha, India
By Ankita Henry

Introduction: Indigenous communities around the world tend to reside in rural and remote areas and experience social and economic exclusions that have rendered them vulnerable to malnutrition and infectious diseases. Odisha is one of the poorest states of India, with a large indigenous and rural population. As chronic diseases expand their reach to rural settings globally, the prevalence of conditions such as hypertension are rising in indigenous communities. However, there is limited knowledge of the distribution of chronic diseases and their risk factors in indigenous and remote populations. **Methods:** In this analysis, we investigate the prevalence of hypertension and its correlates among participants of a health screening camp targeting remote villages in rural Odisha. Linear and logistic regression models were used to measure the associations of age, body mass index, gender, and social group (Scheduled Tribe or Scheduled Caste) with elevated systolic and diastolic blood pressure, and hypertension (systolic/diastolic blood pressure of 140/90 mmHg or higher). **Results:** Most screening participants identified as Scheduled Tribe (81.2%). Participants were 63.3% female, were an average age of 39.5 years, and had an average BMI of 19.2 kg/m^2. The prevalence of hypertension was 14.9%, with 10.2% in women and 22.7% in men. The strongest correlates of high blood pressure were age (coefficient=0.3 mmHg, 95% CI:0.2, 0.3 for systolic blood pressure; coefficient=0.2 mmHg, 95% CI: 0.1, 0.2 for diastolic blood pressure) and BMI (coefficient=0.8 kg/m^2, 95% CI:0.3, 1.3 for systolic blood pressure; coefficient=0.6 kg/m^2, 95% CI: 0.3, 0.9 for diastolic blood pressure). Age (odds ratio=1.0, 95% CI: 1.0, 1.1) and gender (odds ratio: 2.4, 95% CI: 1.4, 3.9 ref= women) were the strongest correlates of hypertension. The mean BMI among those with hypertension was 20.1 (18.3 in women, 21.5 in men), well within the normal range and much lower than BMI observed among adults with hypertension elsewhere. **Conclusions:** One in ten women and one in five men screened positive for hypertension among participants at a screening camp serving rural populations in Odisha, indicating a prevalence of hypertension on par with the national average. The findings indicate that individuals with BMI in the normal range must still be included in screening efforts.

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INTRODUCTION

Indigenous communities around the world tend to reside in rural and remote areas and experience social and economic exclusions that have rendered them vulnerable to malnutrition and infectious diseases. Odisha is one of the poorest states of India, with a large indigenous and rural population. As chronic diseases increasingly expand their reach to rural settings globally, the prevalence of conditions such as hypertension are rising in indigenous communities. However, there is limited knowledge of the distribution of chronic diseases and their risk factors in indigenous and remote populations. Cardiovascular disease is one of the most common chronic diseases in India. Yet there is limited understanding of its risk factors and disease patterns, especially among indigenous populations. In this analysis, we investigate the prevalence of hypertension and its correlates among participants of a health screening camp targeting remote villages in rural Odisha. To provide context for this analysis, we briefly introduce the Scheduled tribes and Scheduled castes, site trends of hypertension in low- and middle- income countries within global trends of chronic disease, review the epidemiology of hypertension in India, and outline some of the major correlated factors of hypertension.

Background

Scheduled Tribes of India

Scheduled tribe (ST) is the term used by the Indian government to recognize and protect the original inhabitants of an area (*Scheduled Tribes in India*, 2019). Also known as Adivasis, the ST population has historically been the most underprivileged segment of Indian society and remain geographically and socially isolated from the mainstream. At the time of colonialization, the British regarded them "backward" and sought to either control and conquer them or to get rid of them entirely (Corry, 2013). They are distinct from scheduled castes (SC), or Dalits, who are also socially excluded, but included in the caste system as the lowest tier (M. B. Das, Hall, Kapoor, & Nikitin, 2014) . The terms first appeared in the Constitution of India under Articles 341 and 346 and thereafter used for governmental protectionary policies (*Scheduled Castes and Scheduled Tribes*, 2019). Historically, the government of India set aside 8% from the Planning Commission of the Five-Year plans for the development of STs and 16% for SCs (*Scheduled Castes and Scheduled Tribes*, 2019). Policies such as the Panchayats Extension to the Scheduled Areas Act (PESA), the Forest Rights Act, the Tribal Rights Act, and the Tribal sub-plan were enacted to protect the indigenous lifestyle and address disparate access to resources.

According to the 2001 census of India, scheduled tribes made up 8.2% and scheduled castes made up 16.2% of the national population (Government of India, 2019). In the state of Odisha scheduled tribes make up 22.1% of the state population and scheduled castes make up 16.5%. There are 62 scheduled tribes, of which the largest is the Kondh tribe. They make up 17.1% of the tribal population, and reside primarily in the districts of Kandhamal, Nayagarh, Baudh, and Rayagada (Government of India, 2001). 47.7% have less than primary level education and 85.9% work as either cultivators or agricultural laborers (39.1% and 46.8% respectively).

The Kondh tribals in the Kalahandi area of Odisha have been continuously subjected to colonialist forces, social stratification by higher castes, and profit making schemes on land use (Pati, 2016). The resource rich state was much sought after by the East India Company in the nineteenth century. Through the manipulation of the local religious hierarchy of kings and priests, the construction of a transport and communication system, and the introduction of such profit-making schemes as a tax system, the British slowly spread their control and religion. Salt along the coast, iron ore in the hills, and rice being exported all served to further incentivize foreigners to encroach on tribal land (Pati, 2016). A relatively recent example of this invasion of indigenous lands was the attempt by Vedanta Alumina in 2004 to take over the Niyamgiri hills, the sacred home of the Kondhs, for bauxite mining. In a rare and remarkable success, the twelve Kondh villages that were consulted won the legal case in 2009 against Vedanta to keep the hills in their original condition (Jena, 2013; Sahu, 2008). Prior to and throughout the colonial era, the prominence of Puri as a pilgrimage city attracted higher castes to the state, who took over tribal land as their agricultural space. The strict hierarchical structure of chiefs and officials meant that the higher castes dictated every level of society and were in control of land use and trade (Pati, 2016).

Epidemiological transition

The distribution of communicable and non-communicable diseases has shifted dramatically in India over the past few decades. The epidemiological transition level (ETL) is the ratio of communicable diseases to non-communicable diseases that signifies which of the two contributes a larger proportion to the overall burden of disease (Dandona et al., 2017). A smaller ratio indicates a higher ETL where the majority of the disease burden can be attributed to non-communicable diseases. This is where developed countries like the United States lie. Age standardized tracking of disease burden over time shows that the crude prevalence of non-communicable diseases has stayed constant while communicable diseases have declined as we have developed better methods of controlling and treating infectious diseases. Therefore, tracking ETL over time generally shows ratios getting progressively smaller as non-communicable diseases take precedence.

The national ETL ratio for India would not provide a meaningful picture of local circumstances due to the variation in health and social context across states. The Global Burden of Disease study in 2017 therefore grouped states into 4 different levels of transition and compared all data from 1996 and 2016 to show shifts over time (Dandona et al., 2017). This shift was evident by the fact that the top five causes of death in 1996 were all communicable diseases while three of the five top causes in 2016 were non-communicable.

The state of Odisha, as one of the nine low ETL states, had a ratio of 2.00 in 1996 and 0.58 in 2016. With a primarily rural and indigenous population, this shift indicates the relevance of non-communicable diseases even in non-urban settings. Learning from other states and regions of the world, Odisha presents an opportunity for early interventions to mitigate the effects of chronic diseases and their risk factors. In order for that to occur, the current prevalence of risk factors like hypertension need to be understood among the indigenous populations living in Odisha.

Hypertension in India

High blood pressure, or hypertension, is one of the main risk factors for cardiovascular disease. While chronic diseases were previously the predominant type of morbidity in high income countries only, they have become increasingly common in low and middle income countries in the past decade (Prabhakaran et al., 2018). Globally, there were 422.7 million cases of cardiovascular disease recorded in 2017, with 17.92 million deaths attributed to the disease (Roth et al., 2017). In India alone, in 2016, 28.1% of all deaths and 14.1% of all disability adjusted life years (DALYs) were attributed to cardiovascular diseases (Prabhakaran et al., 2018). High systolic blood pressure accounted for 54.6% of total DALYs for cardiovascular disease (Prabhakaran et al., 2018). A recent study using the nationally representative National Family Health Survey that omitted adults older than 54 years found the prevalence of hypertension to be 14.4%, with a 14.3% prevalence among ST (Corsi & Subramanian, 2019). In India, the effect of this increasing burden of chronic diseases is felt more sharply on individuals dealing with the diseases due to the continued prevalence of communicable diseases, also called the double burden of disease (Boutayeb, 2006).

Established risk factors of hypertension include age, sex, and body mass index (BMI). Older adults are at an increased risk for developing hypertension as blood pressure increases with age (Chaudhry, Krumholz, & Foody, 2004) (Anderson, 1999; Franklin, 1999). Men tend to have higher blood pressures than women (Wiinber et al., 1995) (Reckelhoff, 2001). Body mass index, a measure of weight for height used to classify weight status, is also positively associated with blood pressure such that heavier individuals are more likely to have an increased blood pressure (Rajeev Gupta, Agrawal, Misra, Guptha, & Vikram, 2012). Often these correlations are controlled for because they are not the effect of interest in the study. Other factors that may increase the risk of hypertension include lifestyle, cultural context, urban or rural settings, and ethnicity.

Lifestyle and Sociocultural Context

Lifestyle and the sociocultural context of indigenous groups shape their risk towards hypertension and chronic diseases. For example, the introduction of trade and the redistribution of resources may have changed the availability of foods that they were used to. The Kondh diet includes mostly carbohydrates with some meat and fruits from the forest (Mandal & Das, 1994). However, under the below the poverty line schemes, they are provided with certain foods from the government at a subsidized cost, such as wheat, rice, and sugar (Kshatriya & Acharya, 2016). Their beliefs are also shaped by outsiders, especially regarding the origin of diseases. Ethnographic studies among Odisha Adivasis find that explanations for diseases such as small pox and cholera include elements of European characters and ideas of sexuality and cleanliness similar to Hinduism (A. Mishra & Sarma, 2011). An example of this is illustrated by Pati, who recounts stories of Gods that were created in the image of European officials or guards they believed had brought the new and unfamiliar diseases (Pati, 1998).

Urban and rural differences

Hypertension has long been observed as a public health concern in cities and urban areas (Ali et al., 2016). However, rural areas are not far behind in the burden of this risk factor. A study on the Bhil tribal group compared a community that had migrated to an urban area with a community living in the original rural area (D. Mishra, Naorem, & Saraswathy, 2018). Within a span of two generations, the group living in the urban setting had more individuals with higher measures for cardiometabolic risk factors such as BMI, blood pressure, and cholesterol (D. Mishra et al., 2018). A comparison of Bangladeshi, Pakistani, and Indian adults in urban and rural settings found that the greater prevalence of hypertension in urban areas was explained by higher education, greater wealth, and lower social capital index in these settings (R. Gupta et al., 2017). This is in contrast to trends observed in other countries in the region as well as high income countries, but no explanation is provided by the researchers. What is more in line with previous research is that rural areas and people with lower education levels and less wealth have lower levels of awareness, treatment and control of hypertension.

Disparities between urban and rural areas also vary by region. A review by Anchala et al, divided studies based on geographical region and compared urban and rural prevalence of hypertension in each region. Overall, the prevalence of hypertension was 27.6% in rural areas and 33.8% in urban areas (Anchala et al., 2014). Of note, for this study, the prevalence in rural areas in eastern India, where Odisha is situated, was similar to what was observed in the urban areas in all four parts of the country. Even amongst the other three regions, the prevalence of hypertension in rural areas was not that low. A similar study using 54 rural villages in Andhra Pradesh also found a high prevalence of hypertension coupled with low rates of awareness and control (Praveen et al., 2018). These findings suggest that while most research is done in urban areas, there could be an increased need in rural areas that is not being addressed. Indeed, a study on 120 tribal villages in nine states of India found a 27.1% prevalence of hypertension in men and 26.4% prevalence in women (Laxmaiah et al., 2015).

South Asian populations

South Asians are particularly predisposed to cardiovascular disease and experience earlier onset of related factors such as diabetes, and the detrimental effects of obesity (Anoop Misra & Shrivastava, 2013; A. Misra et al., 2017). As reviewed by Kalra et al, numerous studies show both native South Asians as well as immigrant South Asian populations in Western countries having an increased risk of chronic diseases such as diabetes and cardiovascular disease as compared to whites (Kalra, Eapen, Merchant, Arora, & Khan, 2009). However, trends of diseases and risk factors have not been observed uniformly in all South Asian groups. A study on Bangladeshi, Pakistani, and Indian adults and children in the United Kingdom found varying blood pressure and BMI trends within the three groups (Battu, Bhopal, & Agyemang, 2018). While South Asian adults had lower blood pressures and BMI than their white counterparts, their children showed trends of having a BMI similar to their counterparts but with higher blood pressures. South Asians develop cardiometabolic diseases at a lower BMI than Western populations, prompting a debate on the use of ethnicity specific BMI cutoffs specific for this population. Compared to other ethnicities, South Asians can have more visceral fat distribution at lower BMIs, contributing to early onset of disease at low BMIs.

Other differences by ethnic group are related to lifestyle factors and biochemical differences. A comparison of 18 countries from different regions of the world showed that South Asians consumed the lowest amount of fruits, vegetables, and legumes, far below the daily recommendation (Miller et al., 2017). Additionally, the majority of vegetables are eaten cooked instead of raw, which changes and may decrease their nutrient content. On a molecular scale, several single-nucleotide polymorphisms associated with cardiovascular disease have been identified in South Asians (A. Das et al., 2017). Diastolic blood pressure was also found to be associated with brain matter changes that signified aging and cerebrovascular disease in South Asians but not Europeans (Sudre et al., 2018).

Problem statement

The increasing prevalence of chronic diseases in India may be particularly devastating given that its health system is not adequately resourced to handle the disease burden due to both communicable and non-communicable diseases. Additionally, the heterogeneity of economic, socio-cultural, and political circumstances across India adds levels of complexity to how the issue of chronic diseases is addressed. The ubiquitous prevalence of hypertension in India necessitates an equitable solution that includes even the most marginalized populations.

There is not much known about chronic diseases and their risk factors, such as hypertension, in indigenous populations, even though recent studies suggest that there is a high prevalence. This analysis will provide a more comprehensive understanding of hypertension and its associated factors in a sample from a rural and primarily indigenous population. It will also contribute to knowledge on how to improve the screening of risk factors for chronic disease.

Purpose statement and significance

This thesis will investigate blood pressure and its correlates among indigenous and rural people in Odisha, India. Data comes from participants of a health screening and education camp organized by Christian Hospital Bissamcuttack. We report the prevalence of hypertension and its correlates among participants in a health education and screening camp. Specifically, we examine the demographic factors of age, gender, and social group (ST, SC, other) and the behavioral factor of BMI, in relation to blood pressure and hypertension. The results of this analysis will describe the burden of hypertension in a vulnerable population in India and provide early data on chronic diseases in a setting that we know little about- the ST groups in India.

LITERATURE REVIEW

There is a considerable amount of evidence supporting the rising burden of chronic diseases in India, particularly in urban areas. There is limited research, however, on indigenous populations and how they are affected by chronic diseases. Although risk factors are well established in other populations, they should be verified in these indigenous populations as well to see if they adhere to the same disease patterns. The following is a review of the research on hypertension as a risk factor of cardiovascular disease in India, with special focus on rural and indigenous populations. The most common type of study were cross-sectional studies with relatively small sample sizes. Additionally, there was one systematic review, several general reviews, and one survival analysis.

Few studies have looked at hypertension nationally in India. Geldsetzer et al used national household surveys that were representative at the district level to calculate the national prevalence of hypertension to be 23.6% (23.3, 23.8) for women and 27.4% (27.0, 27.7) for men, with the highest prevalence in the states of Punjab, Himachal Pradesh, Kerala, Sikkim, and Nagaland (Geldsetzer et al., 2018). When they compared by sociodemographic characteristics, they found that although being in a higher household wealth quintile increased one's risk for hypertension, the difference was not very large between the richest and poorest quintiles in both urban and rural areas.

A systematic review on 142 studies from different geographical regions found an overall prevalence of 29.2% (25.7, 35.6), with 27.6% (23.2, 32.0) in rural areas and 33.8% (29.7, 37.8) in urban areas (Anchala et al., 2014). While the urban prevalence was fairly stable, rural prevalence varied from 20 to 59%. To indicate the changing disease patterns in India, Indrayan et al grouped states by the primary cause of years of life lost. Although they only included 13 states in their analysis, five of these had more than half of the years of life lost caused by chronic diseases (Indrayan;, Wysocki;, Kumar;, Chawla;, & Singh, 2002).

Socio-economic factors can also play a role in how risk factors like high blood pressure are distributed in the population. The Centre for Cardiometabolic Risk Reduction in South Asia (CARRS) study showed that among the urban population, tobacco use decreases and BMI increases with increasing years of education (Ali et al., 2016). In the same sample, the most common combination of multimorbidities was hypertension and diabetes at 11%, the prevalence of which was less in people with a college or higher degree as well as manual laborers (Singh et al., 2018). A district and community level analysis of the state of Maharashtra found that prevalence of hypertension varied by religious group, social group, and marital status (Bhise & Patra, 2018).

The Andhra Pradesh Children and Parents' Study (APCAPS), using 20 rural villages in the state of Andhra Pradesh, attempted to further map the distribution of socio-economic risk factors in rural and peri-urban areas. They categorized 14 risk factors by education, occupation, and standard of living index (SLI), stratified by sex and adjusted for age. While a different combination of risk factors was associated with each socio-economic factor, the clustering of three or more risk factors was noted in men with no education, unskilled occupation, and low standard of living index (V. Gupta et al., 2015). In addition to multiple risk factors, having multiple chronic diseases, also known as metabolic syndrome, can also factor into disease patterns. A cross-sectional study with 7500 Jenu Kuruba tribal people in Mysore showed that 33.6% of those living with diabetes and 36.7% of pre-diabetics had metabolic syndrome (Hathur, Basavegowda, Kulkarni, & Ashok, 2015). Blood pressure was significantly higher in the group that had metabolic syndrome while other measurements like BMI, waist circumference, hip circumference, and body weight were not significantly different.

There is also a difference between rural and tribal groups, as demonstrated by the comparison done by Bhardwaj et al in their community-based cross-sectional study with 900 people from the Himalayan region of the state of Himachal Pradesh. Even though rural areas had a higher BMI, tribal areas had a greater prevalence of obesity (using the South Asian cutoffs) as well as higher total cholesterol and low-density lipoproteins (Bhardwaj et al., 2013). Another study in Odisha compared tribal, rural, and urban individuals in three districts. Similar to the previous study, BMI increased from tribal to rural to urban, as did the prevalence of hypertension (Kusuma & Das, 2008). However, with 24.8% of tribal men and 13.4% of tribal women being hypertensive, this study conducted roughly five years before the previous one shows that differences due to environmental setting may not be as large as previously assumed.

Another way of seeing how environmental setting may impact hypertension is by studying changes in migrating groups, a direct result of the increasing urbanization in India. A risk factor profile was created for 275 individuals in an urban slum migrating from tribal areas to Hyderabad. 18.4% of men and 16.8% of women were hypertensive, 14.3% of men and 24.3% of women were obese, 52.2% of men had a body fat percentage greater than 25 and 23.0% of women had a body fat percentage greater than 30 (Geddam et al., 2015). Comparing these values with those of people living in rural settings suggests that tribal people moving to urban areas have an increased risk for chronic diseases. Although this was the first study done on tribal migrant populations, they used the 2005-6 version of the National Family Health Survey as their comparison, which is now more than a decade old.

A systematic review of 53 tribal subgroups in India found the pooled prevalence of hypertension to be 16.1% (13.5, 19.2), increasing drastically from the 1990 decade to the 2000 decade (Rizwan; et al., 2014). Further, tribes that were considered more acculturated had higher prevalence, even though this classification was not objectively made. They also found no significant association with age or sex, which is contradictory to the common finding of older adults and males having increased risk for hypertension than younger people and females (Rizwan; et al., 2014).

While larger studies use household surveys, smaller studies that focus on specific tribal groups or regions have more data at the individual level. One study that drew from nine major tribal groups in three states looked at the growing rate of the triple burden of undernutrition, overweight, and hypertension. Along with a varied distribution of the three risk factors, it was noted that women were more prone to undernutrition, demonstrated by a low BMI and low body fat percentage, while men were more prone to being overweight (Kshatriya & Acharya, 2016). The authors propose that the development of urban centers in rural areas and the subsidization of foods with the below poverty line schemes caused an increased dependence on an outside market and foreign foods, hence contributing to the increase in cardiovascular disease risk factors.

Another cross-sectional study with 120 tribal villages from nine states measured prevalence of hypertension as well as the knowledge and behaviors related to chronic diseases. Across all participants, 27.1% of men and 26.4% of women were found to be hypertensive, with inter-state variances resulting in the highest prevalence in Odisha and the lowest in Gujarat. Of these, only 5% of men and 9% of women were aware of their blood pressure being high, and roughly two thirds of those who knew of their status received treatment for hypertension

(Laxmaiah et al., 2015). In a sample that is entirely tribal, this points to the very high levels of unawareness that could be addressed by screening and outreach efforts.

In another primarily rural state, Assam, authors Misra, Mini, and Thankappan created a risk factor profile for chronic diseases using a sample of 332 people from the Mishing tribe. 88% of the population had ever used tobacco and 87.3% had ever used alcohol. 15.7% were overweight and 11.4% were obese at the abdomen, but none of the participants reported low levels of physical activity. 25.6% of the sample was found to have hypertension, of which 76.5% were newly detected at the time of the study and 16.5% were taking blood pressure medication (P. J. Misra, Mini, & Thankappan, 2014). While this study did not complete all three of the WHO STEPS components, it sufficiently pointed to the low awareness of high blood pressure among a tribal group.

Another small cross-sectional study among the Katkari tribe in the state of Maharashtra showed a prevalence of systolic hypertension as 16% in women and 17.8% in men (Deo, Pawar, Kanetkar, & Kakade, 2017). Additionally, half of the women and a third of the men were underweight while 1% of women and 2% of women were obese. While their definition of hypertension only includes systolic blood pressure, the authors noted the similarity between their trends and national survey data. The regional difference between different tribes, as seen in the difference between this study and the previous one in Assam is also addressed by the authors as possibly due to the tribes of India being from three different races. Whereas the tribe in this study are descendants of the Proto-Australoid race, northeastern tribes are descendants of the Mongoloid race, which could cause biochemical differences that result in differences in chronic disease risk (Deo et al., 2017). This study was expanded to include three other tribal groups in the area, but besides seeing the same trends of anthropometric measurements and low awareness, they were not able to identify a tribe-specific trend (Deo, Pawar, Kanetkar, & Kakade, 2018). A unique aspect of their community-based study was a discussion with the leaders of the villages as well as with each individual household to collect socio-demographic, dietary, and lifestyle information, which revealed that the majority are meat eaters but subsisted on a vegetarian diet low in green leafy vegetables.

Recently, there are has been an increase in research on particular tribes, as demonstrated by this review. There is still a gap in the large studies that include several tribes from different regions, as well as systematic reviews of the research on tribal groups. However, given the wide variety of unique tribal and indigenous populations across the country, research results cannot be generalized to wider groups of people. In general, the studies support the trends of increasing prevalence of hypertension in tribal groups despite the low BMI. However, the mixed results presented here coupled with the different combination of risk factors that are measured and included exhibit a continued uncertainty in the understanding of the causes of hypertension in indigenous populations.

METHODS

Study Setting

Christian Hospital Bissamcuttack (CHB) is a private non-profit mission hospital located in Bissamcuttack, in the district of Rayagada in southern Odisha. Founded in 1954 by a Danish missionary doctor, the hospital has since been a hub of primary and secondary medical services as well as education for nurses and students (CHB, 2014). Since its founding, there has been a significant emphasis on community health and outreach through programs to build self-sufficiency and encourage development, formally known as the MITRA (Madsen Institute for Tribal and Rural Advancement) program. Through these activities, the hospital has strong engagement and good rapport with the surrounding community, comprised primarily of the Kondh tribe. The health education and screening camp was held in the village of Hazaridanga which is 6.8 miles (11km) from Bissamcuttack.

Study population

The study population consisted of adults who attended the health education and screening camp conducted by CHB. In 2018, due to an apparent increase in hypertension in the community, the local government requested that CHB conduct a community-based health education and screening camp for hypertension. The head of the local government informed each village of the camp details ahead of time and invited all villagers to attend. The screening camp took place in a government school building in Hazaridanga village on May 8th and 9th, 2018. A total of 627 participants were recorded in the paper roster. Sixteen participants with missing blood pressure data were excluded from the analysis.

Data collection procedures

All adults from the surrounding area were invited and eligible to participate. The educational component preceded the screening component and consisted of the Hypertension Education Exhibition. The exhibition included multiple stations with posters on display and a nurse or nursing student who would explain the material verbally. Topics included “What is Hypertension”, “Why does it happen”, “Prevention strategies including lifestyle options”, and “Treatment and possible complications”.

Screening was conducted by trained nurses from CHB. All participants with clinically high blood pressure were counseled and advised to seek further treatment, either at the government hospital or at CHB. Participants were first asked to attend the exhibition and complete the educational component. Following this, they were asked to sit quietly for a few minutes. Trained nurses employed by CHB conducted the screening, recording participants’ age, gender, and village of residence on a paper roster. Next, nurses assessed participants’ height, weight, and blood pressure. Height and weight were measured with an inch tape fixed to a wall and weighing scale. Blood pressure was measured using digital machines (Omrom HEM 720). If blood pressure was 140/90 mmHg or higher, participants were asked to sit for several more minutes after which a second reading was taken. For the second reading, either a single reading was taken, or one from each arm. This procedure was repeated for some participants whose blood pressure was high at screening. The paper roster contained three columns for blood pressure readings. If single readings were taken at each time interval, the respective columns were filled with only one reading. If a measurement was taken at each arm, both readings were recorded on a single column.

Study measures

The primary study outcomes were continuously measured systolic and diastolic blood pressure and hypertension (systolic or diastolic blood pressure of more than 140/90mmHg (Hiremath, Katekhaye, Chamle, Jain, & Bhargava, 2016)). When more than one reading was taken, the last possible measurement was used for analysis. If the last measurement was a reading from each arm, the average of these was used for analysis.

Covariates included age, gender, BMI, social group, BMI categories, and location. BMI was calculated from height and weight measurements and rounded to the nearest whole number for analysis. Age and gender were recorded at the time of screening. A hospital staff member noted whether the participant was a member of the scheduled caste or scheduled tribe group based on his/her last name. We created a new variable, location, to indicate where each participant was from; the first group was where the screening camp was done, the second group included all villages within 3 km of the camp, and the third group included all of the remaining participants. We also created two sets of BMI categories, one that follows the international recommendation while the other follows the modified recommendation for South Asian populations (WHO, 2004).

Statistical analysis

Data cleaning and analysis was completed using SAS 9.4 statistical software (Cary, NC). Data cleaning consisted of checking for implausible or mistyped values. Blood pressure and BMI values that were five or more standard deviations from the mean were considered implausible. According to this criteria, one measurement of BMI (BMI=60 kg/m^2) was identified and removed from the analysis. Cooke's D was also calculated to identify outliers that may influence the regression line; this calculation resulted in no additional outliers. However, observations that had some but not all the covariates were still included in the analysis. Descriptive analysis included computing the mean, standard deviation, range, and a test for normality and collinearity for each variable. Assumptions were checked for regression and all were met.

We analyzed blood pressure, hypertension, and their demographic correlates among all participants attending the health education and screening camp. Two different regression models were developed separately for diastolic and systolic blood pressure. The linear regression model included the variables age, gender, social group, body mass index, and location, using blood pressure as a continuous variable. The logistic regression modeled hypertension as a binary outcome and included the same independent variables as the linear regression.

As a supplementary analysis, we compared BMI categories using the global cutoffs and South Asian cutoffs for BMI. Previous research has shown that certain populations, such as South Asians, experience obesity related diseases at a lower BMI, encouraging the adoption of lower cut off points than the ones used for Western countries. With the globally recognized BMI categories, a BMI of 18.5 kg/m^2 and lower is underweight, 18.5 to 24.9 kg/m^2 is normal, 25 to 29.9 kg/m^2 is overweight, and 30 kg/m^2 and above is obese. The suggested categories for South Asians is 18.5 kg/m^2 and below as underweight, 18.5 to 22.9 kg/m^2 is normal, 23 to 27.4 kg/m^2 is overweight and 27.5 kg/m^2 and above is obese (WHO, 2004). Proportions of the sample in each category of weight classification were compared. The different categories were also used in a logistic regression model to see if there were large shifts in the odds ratios describing the association between weight status and hypertension. Previous research has shown that certain populations, such as South Asians, experience obesity related diseases at a lower BMI, encouraging the adoption of lower cut off points than the ones used for Western countries (WHO, 2004)

Additional supplemental analyses were conducted to examine the robustness of our selection of blood pressure measures. We repeated the primary analysis with the following alternative outcome specifications for participants with more than one blood pressure reading: (1) the mean blood pressure across the first and second readings; (2) the first blood pressure reading.

This analysis was deemed non-human subjects research by the Rollins School of Public Health Institutional Review Board because it is a secondary analysis of de-identified data. The data was obtained from Christian Hospital Bissamcuttack with written consent.

RESULTS

Primary Results

Data from a total of 627 participants were analyzed (Table 1). There were 396 (63%) women and 230 (36.7%) men. The majority of the sample (500 people, 81.2%) were members of a scheduled tribe. A remaining 70 people (11.4%) were scheduled caste and 46 people (7.5%) were classified as neither. Over a third of the sample (247 people, 39.5%) was from the two neighboring villages where the screening camp was conducted. The average age (95% CI) of the sample was 39.5 (38.2, 40.7) years and the average body mass index was 19.2 (18.9, 19.5) kg/m^2. The average systolic blood pressure was 119.8 (118.4, 121.1) mmHg and the average diastolic blood pressure was 77.3 (76.4, 78.2) mmHg.

The prevalence of hypertension in this sample was 14.9% (10.2% in women, 22.7% in men) (Table 2). 78.7% of those in the hypertensive group were members of a scheduled tribe. Of all ST in the sample, 14.3% had hypertension. The average age of the hypertensive group was 48.7 years, which was similar for men and women. The average BMI of this group was 20.1 kg/m^2, 18.3 kg/m^2 in women and 21.4 kg/m^2 in men. This was in comparison to the non-hypertensive group, which had an average age of 38 years and BMI of 19.1 km/m^2. The hypertensive group had a systolic blood pressure of 147.4 mmHg and diastolic blood pressure of 93.9 mmHg while the non-hypertensive group had a systolic blood pressure of 114.8 mmHg and diastolic blood pressure of 74.2 mmHg. Using the international cutoffs for BMI categories, both the hypertensive and non-hypertensive groups had very few overweight and obese individuals (0.2% of non-hypertensive and 1.1% of hypertensive were obese). The majority of the hypertensive group were in the underweight BMI category, while the majority of the non-hypertensive group were in the normal BMI category.

Results from the linear regression model are shown in Tables 3a and 3b. For both systolic and diastolic blood pressure, age was significantly associated with higher blood pressure. With every one year increase in age, average systolic blood pressure was 0.3 (0.2, 0.3) mmHg higher while diastolic was 0.2 (0.1, 0.2) mmHg higher. Likewise, each unit of BMI corresponded with a 0.8 (0.3, 1.3) mmHg higher systolic blood pressure and 0.6 (0.3, 0.9) mmHg higher diastolic blood pressure. Relative to women, men had higher levels of blood pressure, with a positive association in systolic blood pressure (8.7 for systolic and 2.3 for diastolic). Compared to ST, belonging to SC was not significantly associated with blood pressure levels, although the general class that was neither ST or SC did have a significant association. Distance to the screening camp did not seem to have any significant association with increased diastolic blood pressure but was inversely associated with systolic blood pressure (coefficient=-3.9, 95% CI: -7.1, -0.8 for participants furthest away from the screening camp; ref=closest). However, this variable was created to account for the effect of proximity to screening camp and is limited by its non-uniformity. The associations that were statistically significant in the crude model remained significant in the fully adjusted model, with the exception of the group that lived four or more kilometers from screening camp for diastolic blood pressure, which was attenuated in the adjusted model.

Results of the logistic regression analysis of hypertension is shown in Table 4. The odds of hypertension were greater with each additional year by 1.0 (95% CI: 1.0, 1.1) and for men compared to women by 2.4 (95% CI: 1.4, 3.9). A higher BMI did not change the odds of hypertension. Compared to belonging to Scheduled Tribe, being a member of a Scheduled Caste or neither social group did not significantly change the odds of being hypertensive in either direction. The odds ratios against the references are pictorially presented in Figure 1.

Sensitivity Analysis

A supplementary analysis was done to compare the association of weight status and categories using the different cut off points. When comparing proportions of people in each category, the number of people in the underweight category did not change as the cutoff for both is 18.5. However, there were 2.6% fewer individuals in the normal category when using the Asian cutoff, with a corresponding increase in the overweight and obese categories (Supplementary Table 1). Among the hypertensive group, the percentage of obesity increased from 1.1% to 7.8% when using the South Asian definition (Supplementary Table 2). Compared to the normal range, both the obese and overweight category using the South Asian cutoffs were significantly associated with high blood pressure and hypertension, while only the overweight category using the global cutoffs was significant (Supplementary Tables 3a, 3b, 3c).

A sensitivity analysis was conducted to see if the method of the choice of first or second or mean blood pressure reading impacted the proportion of hypertensive individuals in the sample. Taking only the first reading for every participant, the prevalence of hypertension increased from 14.9% to 16.0%. As there were no large differences, it provides support for the primary method.

The adjusted associations for age and body mass index remained the same for systolic and diastolic blood pressure (Table 6a, 6b). Using only the first reading, men had an increased association with high blood pressure and the general class individuals had a decreased association with high systolic blood pressure (Table 6a). These same trends were noted in the odds of hypertension (Table 7). Of note is the change in significance in the odds of diastolic blood pressure greater than 90 mmHg which was not significant when using the first readings but was significant when using the adjusted method of choosing a reading.

DISCUSSION

In this primarily indigenous population in one of India's poorest states, the prevalence of hypertension was 14.9%. This is similar to national studies among populations of reproductive age (Corsi & Subramanian, 2019). However, it is lower than previous studies conducted in other rural regions and those among other indigenous communities of India (Deo et al., 2017; Laxmaiah et al., 2015; P. J. Misra et al., 2014), suggesting the varying pace of the epidemiologic transition across rural areas and across other countries. The Kondh tribe in particular is known in the region and internationally for being especially resistant to urbanization and acculturation attempts (Thekaekara, 2010). Their social and economic isolation may ironically be protective against hypertension.

Age, sex and body mass index were the strongest associated risk factors to hypertension, with some variation, which aligns closely with previous studies (Deo et al., 2017). This is consistent with prior literature that observes a higher prevalence of hypertension in men, older adults and overweight or obese individuals. While this study was small in scale, the consistency of associations of these three factors in this populations point to their importance and further inclusion in chronic disease screening and management efforts. What was not fully expected, but supported by previous literature, was the low body mass index of 18.3 kg/m^2 in the women of the hypertensive group. While hypertension is substantially more prevalent in overweight and obese individuals, it was shown here that even individuals, particularly women, who are underweight are at a risk of being hypertensive. In this light, while higher body mass index is associated with higher risk of hypertension, hypertension may also occur among the underweight population. Perhaps more than body mass index, other anthropometric measurements such as waist-to-stature ratio and waist-circumference may be better predictors of hypertension (Maken & Varte, 2013).

Most of the previous literature on this topic has used the body mass index categories specific to the South Asian population, while noting the applicability of the global cutoff (Bhardwaj et al., 2013). In this analysis as well, the two cutoffs were used to identify if there was a change in proportions of categories. As expected, with the South Asian categories, there were generally more overweight and obese individuals. Among the hypertensive group, there were two fewer individual in the overweight category and six more in the obese category when using the South Asian cutoffs as compared to the global cutoffs. When the regression coefficients were compared, the overweight category was significant for high blood pressure for both types of cutoffs while the obesity category was only significant for the South Asian cutoffs. This is an indication of how BMI cutoffs specific to a population can reflect the morbidity and mortality due to particular diseases better than very generalized definitions.

The choice of BMI categories is important especially in populations such as these that tend to be on the low BMI side, so as to not let high risk individuals go unidentified. Population specific categories are more accurate in capturing the mortality risk and the health status of individuals, not just with cardiovascular diseases but with other diseases as well (Lim et al., 2017). Often, guidance is based on science conducted in high-income or “Western” context under the assumption that all populations follow the same trend (Simonds & Christopher, 2013). In addition to the context specific studies that have been done on tribal groups in India, the use of the South Asian cutoff is particularly useful in understanding and potentially preventing chronic disease.

The sensitivity analysis did not show any large deviations from the original analysis due to the method of choosing a reading, with a slight increase in hypertension prevalence from 14.9% to 16.0% due to a shift in status for seven individuals. This was further supported by no change in the linear associations of age and BMI. The increased risk for men with high systolic and diastolic blood pressure could have been because of the small sample size.

The study had several limitations. Given that this analysis was based on a screening sample, there is a possibility that the time of day the camp took place could have selected for certain characteristics in the population, such as women and those staying at home during the day. There is also the concern of over selecting for participants that are more concerned about their health, which may have contributed to the discrepancy between the numbers of men and women attending. As a cross-sectional study, these results are only valid for the time frame in which it was conducted, and no causal effect can be ascertained. We caution that the results cannot be interpreted as the prevalence of hypertension in the general population or to the rest of the community that this sample was obtained from. There is possibility of measurement error with the use of the apparatus and inconsistencies in the person taking the measurements. The method of taking readings could have also been more standardized, with all participants having three readings or only one reading. This would have left less unaccounted for error in the calculation of an average blood pressure reading during analysis. BMI was also calculated after measuring height and weight, which introduces more error. Although contingent on the availability of resources, the use of a handheld device to measure BMI would have given a more accurate measurement.

However, this method was an effective way of gathering a large number of people together in a short amount of time. It also served the dual purpose of identifying hypertensive individuals and raising awareness within the community. There is additional value in a community-based study as it organically gathered individuals more effectively than a clinical trial and exhibits the importance of leveraging rapport built within communities.

IMPLICATIONS

In this analysis, the prevalence of hypertension among participants of a health education and screening camp was found to be 14.9%. While this coincided with the national average for hypertension, the average BMI of those with hypertension was 20.1 kg/m^2, which falls in the normal range according to international BMI categories. These results could inform further screening efforts conducted in this area. Given that each tribal group in India has its own lifestyle, biochemical, socio-contextual and environmental factors, the findings from this analysis can only be used with reference from the Kondh tribal group who are the main inhabitants in the area where this screening camp was conducted. Future outreach and prevention efforts can be informed by the finding of low BMI in the hypertensive group, focusing on the importance of all individuals, regardless of their BMI, periodically checking their blood pressure, being mindful of the symptoms of high blood pressure, and incorporating lifestyle habits that can delay the onset of hypertension and cardiovascular disease. The strong associations of increasing age and BMI exemplified here and supported by literature further encourage gearing outreach efforts towards older adults to help identify the onset of hypertension earlier as well as get this population connected with treatment to control it.

REFERENCES

Ali, M. K., Bhaskarapillai, B., Shivashankar, R., Mohan, D., Fatmi, Z. A., Pradeepa, R., . . . Prabhakaran, D. (2016). Socioeconomic status and cardiovascular risk in urban South Asia: The CARRS Study. *Eur J Prev Cardiol, 23*(4), 408-419. doi:10.1177/2047487315580891

Anchala, R., Kannuri, N. K., Pant, H., Khan, H., Franco, O. H., Di Angelantonio, E., & Prabhakaran, D. (2014). Hypertension in India: a systematic review and meta-analysis of prevalence, awareness, and control of hypertension. *J Hypertens, 32*(6), 1170-1177. doi:10.1097/hjh.0000000000000146

Anderson, G. H. (1999). Effect of Age on Hypertension: Analysis of Over 4,800 Referred Hypertensive Patients. *Saudi Journal of Kidney DIseases and Transplantation, 10*(3), 286-297.

Battu, H. S., Bhopal, R., & Agyemang, C. (2018). Heterogeneity in blood pressure in UK Bangladeshi, Indian and Pakistani, compared to White, populations: divergence of adults and children. *J Hum Hypertens, 32*(11), 725-744. doi:10.1038/s41371-018-0095-5

Bhardwaj, A. K., Kumar, D., Raina, S. K., Bansal, P., Bhushan, S., & Chander, V. (2013). Community Based Assessment of Biochemical Risk Factors for Cardiovascular Diseases in Rural and Tribal Area of Himalayan Region, India. *Biochemistry Research International*, 1-6. doi:10.1155/2013/696845

Bhise, M. D., & Patra, S. (2018). Prevalence and correlates of hypertension in Maharashtra, India: A multilevel analysis. *Plos One, 13*(2), e0191948. doi:10.1371/journal.pone.0191948

Boutayeb, A. (2006). The double burden of communicable and non-communicable diseases in developing countries. *Trans R Soc Trop Med Hyg, 100*(3), 191-199. doi:10.1016/j.trstmh.2005.07.021

Chaudhry, S. I., Krumholz, H. M., & Foody, J. M. (2004). Systolic hypertension in older persons. *Jama, 292*(9), 1074-1080. doi:10.1001/jama.292.9.1074

CHB. (2014). Christian Hospital, Bissamcuttack: About. Retrieved from http://chbmck.org/about.html

Corry, S. (2013). Like Mother, Like Daughters? Campaigns for Tribal Peoples' Rights in the Commonwealth. *Round Table, 102*(4), 343-353. doi:10.1080/00358533.2013.795011

Corsi, D. J., & Subramanian, S. V. (2019). Socioeconomic Gradients and Distribution of Diabetes, Hypertension, and Obesity in IndiaSocioeconomic Distribution of Diabetes, Hypertension, and Obesity in IndiaSocioeconomic Distribution of Diabetes, Hypertension, and Obesity in India. *JAMA Network Open, 2*(4), e190411-e190411. doi:10.1001/jamanetworkopen.2019.0411

Dandona, L., Dandona, R., Kumar, G. A., Shukla, D. K., Paul, V. K., Balakrishnan, K., . . . Swaminathan, S. (2017). Nations within a nation: variations in epidemiological transition across the states of India, 1990-2016 in the Global Burden of Disease Study. *The Lancet, 390*(10111), 2437-2460. doi:10.1016/S0140-6736(17)32804-0

Das, A., Ambale-Venkatesh, B., Lima, J. A. C., Freedman, J. E., Spahillari, A., Das, R., . . . Murthy, V. L. (2017). Cardiometabolic disease in South Asians: A global health concern in an expanding population. *Nutrition, Metabolism and Cardiovascular Diseases, 27*(1), 32-40. doi:https://doi.org/10.1016/j.numecd.2016.08.001

Das, M. B., Hall, G., Kapoor, S., & Nikitin, D. (2014). India: The Scheduled Tribes *Indigenous Peoples, Poverty, and Development*: Cambridge University.

Deo, M. G., Pawar, P. V., Kanetkar, S. R., & Kakade, S. V. (2017). Prevalence and risk factors of hypertension and diabetes in the Katkari tribe of coastal Maharashtra. *Journal of Postgraduate Medicine, 63*(2), 106-113. doi:10.4103/0022-3859.194204

Deo, M. G., Pawar, P. V., Kanetkar, S. R., & Kakade, S. V. (2018). Multicentric study on prevalence and risk factors for hypertension and diabetes in tribal communities in Western and Northern Maharashtra. *Journal of Postgraduate Medicine, 64*(1), 23-34. doi:10.4103/jpgm.JPGM_245_17

Franklin, S. S. (1999). Ageing and hypertension: the assessment of blood pressure indices in predicting coronary heart disease. *J Hypertens Suppl, 17*(5), S29-36.

Geddam, J. B., Kokku, S. B., Nagalla, B., D, A., Vijaya, R. K. K., & Parttipati, A. K. (2015). Diet, nutrition and cardiac risk factor profile of tribal migrant population in an urban slum in India. *Indian Journal of Community Health, 27*(1), 77-85.

Geldsetzer, P., Manne-Goehler, J., Theilmann, M., Davies, J. I., Awasthi, A., Vollmer, S., . . . Atun, R. (2018). Diabetes and Hypertension in India: A Nationally Representative Study of 1.3 Million Adults. *JAMA Intern Med, 178*(3), 363-372. doi:10.1001/jamainternmed.2017.8094

Government of India. (2001). *Orissa: Data Highlights- The Scheduled Tribes. Census of India 2001*. Retrieved from http://censusindia.gov.in/Tables_Published/SCST/dh_st_orissa.pdf.

Government of India. (2019). *T 00-005: Total Population, Population of Scheduled Castes and Scheduled Tribes and their proportions to the total population*. Delhi, India Retrieved from http://censusindia.gov.in/Tables_Published/A-Series/A-Series_links/t_00_005.aspx.

Gupta, R., Agrawal, A., Misra, A., Guptha, S., & Vikram, N. K. (2012). Metabolic cardiovascular risk factors worsen continuously across the spectrum of body mass index in Asian Indians. *Indian Heart J, 64*(3), 236-244. doi:https://doi.org/10.1016/S0019-4832(12)60079-0

Gupta, R., Kaur, M., Islam, S., Mohan, V., Mony, P., Kumar, R., . . . Yusuf, S. (2017). Association of Household Wealth Index, Educational Status, and Social Capital with Hypertension Awareness, Treatment, and Control in South Asia. *Am J Hypertens, 30*(4), 373-381. doi:10.1093/ajh/hpw169

Gupta, V., Millett, C., Walia, G. K., Kinra, S., Aggarwal, A., Prabhakaran, P., . . . Ebrahim, S. (2015). Socio-economic patterning of cardiometabolic risk factors in rural and peri-urban India: Andhra Pradesh children and parents study (APCAPS). *Z Gesundh Wiss, 23*(3), 129-136. doi:10.1007/s10389-015-0662-y

Hathur, B., Basavegowda, M., Kulkarni, P., & Ashok, N. C. (2015). Metabolic syndrome among diabetics and pre-diabetics of Jenu Kuruba tribe in Mysore district (JKDHS-2)--An evidence of metabolic abnormalities leading to increase in CVD's among Jenu Kuruba tribal population. *Diabetes Metab Syndr, 9*(4), 205-209. doi:10.1016/j.dsx.2015.08.004

Hiremath, J. S., Katekhaye, V. M., Chamle, V. S., Jain, R. M., & Bhargava, A. I. (2016). Current Practice of Hypertension in India: Focus on Blood Pressure Goals. *Journal of clinical and diagnostic research : JCDR, 10*(12), OC25-OC28. doi:10.7860/JCDR/2016/21783.8999

Indrayan;, A., Wysocki;, M. J., Kumar;, R., Chawla;, A., & Singh, N. (2002). Estimates of the years-of-life-lost due to the top nine causes of death in rural areas of major states in India in 1995. *The National Medical Journal of India, 15*(1), 7-13.

Jena, M. (2013). Voices from Niyamgiri. *Economic and Political Weekly, 48*(36), 14-16.

Kalra, G., Eapen, D., Merchant, N., Arora, A., & Khan, B. V. (2009). Metabolic syndrome and cardiovascular disease in South Asians. *Vascular Health and Risk Management, 2009*(5), 731-743. doi:doi:10.2147/VHRM.S5172

Kshatriya, G. K., & Acharya, S. K. (2016). Triple Burden of Obesity, Undernutrition, and Cardiovascular Disease Risk among Indian Tribes. *Plos One, 11*(1), e0147934. doi:10.1371/journal.pone.0147934

Kusuma, Y. S., & Das, P. K. (2008). Hypertension in Orissa, India: a cross-sectional study among some tribal, rural and urban populations. *Public Health (Elsevier), 122*(10), 1120-1123. doi:10.1016/j.puhe.2007.10.007

Laxmaiah, A., Meshram, II, Arlappa, N., Balakrishna, N., Rao, K. M., Reddy, C. G., . . . Brahmam, G. N. V. (2015). Socio-economic & demographic determinants of hypertension & knowledge, practices & risk behaviour of tribals in India. *The Indian Journal of Medical Research, 141*(5), 697-708. doi:10.4103/0971-5916.159592

Lim, J. U., Lee, J. H., Kim, J. S., Hwang, Y. I., Kim, T. H., Lim, S. Y., . . . Rhee, C. K. (2017). Comparison of World Health Organization and Asia-Pacific body mass index classifications in COPD patients. *Int J Chron Obstruct Pulmon Dis, 12*, 2465-2475. doi:10.2147/copd.s141295

Maken, T., & Varte, L. R. (2013). ANTHROPOMETRIC INDICATORS AS PREDICTORS OF HIGH BLOOD PRESSURE AMONG THE AO TRIBE OF NORTH-EAST INDIA. *Asian Journal of Medical Sciences, 4*(3), 15-22.

Mandal, S., & Das, S. (1994). Effects of ethnic origin, dietary and life-style habits on plasma lipid profiles--a study of. *Journal of Nutritional Medicine, 4*(2), 141. doi:10.3109/13590849409034549

Miller, V., Mente, A., Dehghan, M., Rangarajan, S., Zhang, X., Swaminathan, S., . . . Yusuf, S. (2017). Fruit, vegetable, and legume intake, and cardiovascular disease and deaths in 18 countries (PURE): a prospective cohort study. *Lancet, 390*(10107), 2037-2049. doi:10.1016/s0140-6736(17)32253-5

Mishra, A., & Sarma, S. (2011). Understanding Health and Illness among tribal communities in Orissa. *Indian Anthropologist, 41*(1), 1-16.

Mishra, D., Naorem, K., & Saraswathy, K. N. (2018). Angiotensin-Converting Enzyme Gene Insertion/Deletion Polymorphism and Cardiometabolic Risk Factors: A Study Among Bhil Tribal Population from Two Environmental Settings. *Biochem Genet, 56*(4), 295-314. doi:10.1007/s10528-018-9845-x

Misra, A., & Shrivastava, U. (2013). Obesity and dyslipidemia in South Asians. *Nutrients, 5*(7), 2708-2733. doi:10.3390/nu5072708

Misra, A., Tandon, N., Ebrahim, S., Sattar, N., Alam, D., Shrivastava, U., . . . Jafar, T. H. (2017). Diabetes, cardiovascular disease, and chronic kidney disease in South Asia: current status and future directions. *BMJ, 357*, j1420. doi:10.1136/bmj.j1420

Misra, P. J., Mini, G. K., & Thankappan, K. R. (2014). Risk factor profile for non-communicable diseases among Mishing tribes in Assam, India: Results from a WHO STEPs survey. *Indian Journal of Medical Research, 140*(3), 370-378.

Pati, B. (1998). Siting the Body: Perspectives on Health and Medicine in Colonial Orissa. *Social Scientist, 26*(11/12), 24.

Pati, B. (2016). The Rhythms of Change and Devastation: Colonial Capitalism and the World of the Socially Excluded in Orissa. *Social Scientist, 44*(7/8), 27-51.

Prabhakaran, D., Jeemon, P., Sharma, M., Roth, G. A., Johnson, C., Harikrishnan, S., . . . Dandona, L. (2018). The changing patterns of cardiovascular diseases and their risk factors in the states of India: the Global Burden of Disease Study 1990-2016. *The Lancet Global Health, 6*(12), e1339-e1351. doi:10.1016/S2214-109X(18)30407-8

Praveen, D., Peiris, D., MacMahon, S., Mogulluru, K., Raghu, A., Rodgers, A., . . . Patel, A. (2018). Cardiovascular disease risk and comparison of different strategies for blood pressure management in rural India. *Bmc Public Health, 18*(1), 1264. doi:10.1186/s12889-018-6142-x

Reckelhoff, J. F. (2001). Gender differences in the regulation of blood pressure. *Hypertension, 37*(5), 1199-1208.

Rizwan;, S. A., Kumar;, R., Singh;, A. K., Kusuma;, Y. S., Yadav;, K., & Pandav, C. S. (2014). Prevalence of Hypertension in Indian Tribes: A Systematic Review and Meta-Analysis of Observational Studies. *Plos One, 9*(5).

Roth, G. A., Johnson, C., Abajobir, A., Abd-Allah, F., Abera, S. F., Abyu, G., . . . Murray, C. (2017). Global, Regional, and National Burden of Cardiovascular Diseases for 10 Causes, 1990 to 2015. *J Am Coll Cardiol, 70*(1), 1-25. doi:10.1016/j.jacc.2017.04.052

Sahu, G. (2008). Mining in the Niyamgiri Hills and Tribal Rights. *Economic and Political Weekly, 43*(15), 19-21.

Scheduled Castes and Scheduled Tribes. (2019). Retrieved from http://in.one.un.org/task-teams/scheduled-castes-and-scheduled-tribes/.

Scheduled Tribes in India. (2019). Center for Development of Advanced Computing Retrieved from http://vikaspedia.in/social-welfare/scheduled-tribes-welfare/ministry-of-tribal-welfare.

Simonds, V. W., & Christopher, S. (2013). Adapting Western research methods to indigenous ways of knowing. *American journal of public health, 103*(12), 2185-2192. doi:10.2105/AJPH.2012.301157

Singh, K., Patel, S. A., Biswas, S., Shivashankar, R., Kondal, D., Ajay, V. S., . . . Prabhakaran, D. (2018). Multimorbidity in South Asian adults: prevalence, risk factors and mortality. *Journal of Public Health*, 1-10. doi:10.1093/pubmed/fdy017

Sudre, C. H., Smith, L., Atkinson, D., Chaturvedi, N., Ourselin, S., Barkhof, F., . . . Cardoso, M. J. (2018). Cardiovascular Risk Factors and White Matter Hyperintensities: Difference in Susceptibility in South Asians Compared With Europeans. *J Am Heart Assoc, 7*(21), e010533. doi:10.1161/jaha.118.010533

Thekaekara, M. M. (2010). Vedanta undermined! *New Internationalist*(437), 56-56.

WHO. (2004). Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet, 363*(9403), 157-163. doi:10.1016/s0140-6736(03)15268-3

Wiinber, N., Hoegholm, A., Christensen, H., Bang, L., Mikkelsen, K., Nielsen, P., . . . Bentzon, M. (1995). 24-h Ambulatory blood pressure in 352 normal Danish subjects, related to age and gender. *Am J Hypertens, 8*, 978-986.

TABLES AND FIGURES

Table 1: Characteristics of sample screened at Hazaridang village

Variable	Mean (CI) / n (%)*	Range (min – max)
Age (years), mean	39.5 (38.2, 40.7)	9 - 80
Sex, n		
Female	396 (63.3)	-
Male	230 (36.7)	-
Group, n		
Scheduled Tribe	500 (81.2)	-
Scheduled Caste	70 (11.4)	-
Other	46 (7.5)	-
Distance from screening camp, n**		
0-1 km	247 (39.5)	-
1-3 km	172 (27.5)	-
4+ km	207 (33.1)	-
Body Mass Index (kg/m^2), mean	19.1 (18.9, 19.4)	12 - 32
Body Mass Index categories, n***		
Underweight	290 (46.4)	-
Normal	301 (48.2)	-
Overweight	32 (5.1)	-
Obese	2 (0.3)	-
Blood Pressure (mmHg), mean****		
Systolic	119.8 (118.4, 121.1)	82 - 204
Diastolic	77.3 (76.4, 78.2)	39 - 201

* % indicates column percentages
** Villages are grouped by distance from screening camp, where villages within 0-1km are Hazaridang and Lelibadi; within 1-3 km are Ankul Padar, Bada Kiribiri, Sano Kiribiri, Budhuni, and Degalbuduni; and 4+ km are Rambu, Patharguda, Kakar Maska, Gospadi, and Bordaguda, Pichiliguda, Bissamcuttack, Kandam Padar, Dakulguda, Ghantikhal, Andhra Pradesh, Gujarat, and Vellore.
***Categories for body mass index are based on global categories, where BMI less than 18.5 kg/m^2 is underweight, 18.5 to 25 kg/m^2 is normal, 25 to 30 kg/m^2 is overweight, and greater than 30 kg/m^2 is obese.
****11 of the readings were a second measurement, 4 were a third measurement, and 14 were an average of two second measurements done on each arm several minutes after the first single measurement.

Table 2: Characteristics of sample by hypertension status

Predictors	non-Hypertensive	Hypertensive*
N	519 (85.1)	91 (14.9)
Age (years), mean	38.4 (37.1, 39.8)	48.7 (45.7, 51.7)
Sex, n		
Women	342 (65.9)	39 (42.9)
Men	177 (34.1)	52 (57.1)
Group, n		
ST	421 (82.4)	70 (78.7)
SC	58 (11.4)	5 (5.6)
Other	32 (6.3)	14 (15.7)
Distance from screening camp, n		
0-1km	192 (37.1)	50 (55.0)
1-3km	142 (27.4)	19 (20.9)
4+km	184 (35.5)	22 (24.2)
BMI (kg/m^2), mean	19.1 (18.8, 19.3)	20.1 (19.3, 20.9)
BMI Categories, n (%)		
Underweight	235 (45.3)	42 (46.7)
Normal	266 (51.3)	32 (35.6)
Overweight	17 (3.3)	15 (16.7)
Obese	1 (0.2)	1 (1.1)
BP (mmHg), mean		
Systolic	114.8 (113.8, 115.7)	147.4 (143.7, 151.1)
Diastolic	74.2 (73.6, 74.8)	93.9 (91.9, 95.9)

Values for N are row percentages, all others are column percentages.
*Hypertension was defined as having either high systolic or diastolic blood pressure at or above 140/90 mmHg.
ST=Scheduled Tribe, SC= Scheduled Caste

Table 3a: Crude and adjusted β values for predictors of systolic blood pressure

Predictor	Crude β	Adjusted β
Age (years)	**0.3 (0.2, 0.4)**	**0.3 (0.2, 0.3)**
Sex		
Women	ref	ref
Men	**10.4 (7.8, 13.1)**	**8.7 (6.0, 11.3)**
Caste/Tribe		
ST	ref	ref
SC	-4.1 (-8.5, 0.3)	-1.9 (-6.2, 2.3)
Other	**10.3 (5.3, 15.3)**	**5.4 (0.6, 10.2)**
Location		
0-1 km	ref	ref
1-3 km	-1.6 (-4.7, 1.4)	-2.5 (-5.6, 0.6)
4+ km	**-4.5 (-7.3, -1.7)**	**-3.9 (-7.1, -0.8)**
BMI (kg/m^2)	**1.2 (0.7, 1.6)**	**0.8 (0.3, 1.3)**

Note: Results are from a linear regression of systolic blood pressure. The adjusted beta reflects the coefficients from a model that includes all variables shown in the table.

Table 3b: Crude and adjusted β values for predictors of diastolic blood pressure

Predictor	Crude β	Adjusted β
Age (years)	**0.2 (0.1, 0.2)**	**0.2 (0.1, 0.2)**
Sex		
Women	ref	ref
Men	**3.8 (2.1, 5.5)**	**2.3 (0.7, 4.0)**
Caste/Tribe		
ST	ref	ref
SC	-2.2 (-4.9, 0.5)	-1.4 (-4.1, 1.3)
Other	**6.5 (3.4, 9.6)**	**3.4 (0.4, 6.5)**
Location		
0-1 km	ref	ref
1-3 km	-0.8 (-2.6, 1.1)	-0.2 (-2.2, 1.7)
4+ km	**-2.1 (-3.8, -0.3)**	-1.1 (-3.1, 0.8)
BMI (kg/m^2)	**0.7 (0.4, 1.0)**	**0.6 (0.3, 0.9)**

Note: Results are from a linear regression of diastolic blood pressure. The adjusted beta reflects the coefficients from a model that includes all variables shown in the table.

All numbers as β (95% CI)

Bold numbers indicate $p<0.05$

Table 4: Demographic and metabolic correlates of hypertension (SBP ≥ 140 or DBP ≥ 90)

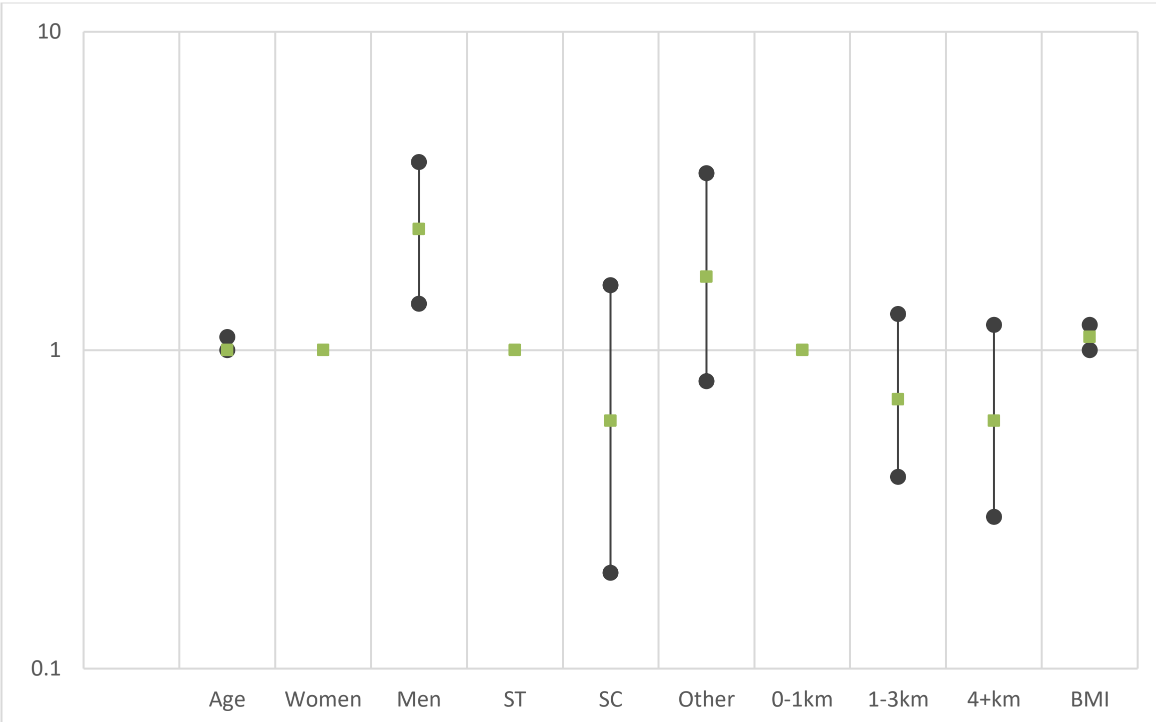
Predictor	Crude OR	Adjusted OR
Age (years)	**1.0 (1.0, 1.1)**	**1.0 (1.0, 1.1)**
Sex		
Women	ref	ref
Men	**2.6 (1.6, 4.1)**	**2.4 (1.4, 3.9)**
Caste/Tribe		
ST	ref	ref
SC	0.5 (0.2, 1.3)	0.6 (0.2, 1.6)
Other	**2.6 (1.3, 5.2)**	1.7 (0.8, 3.6)
Location		
0-1 km	ref	ref
1-3 km	**0.5 (0.3, 0.9)**	0.7 (0.4, 1.3)
4+ km	**0.5 (0.3, 0.8)**	0.6 (0.3, 1.2)
BMI (kg/m^2)	**1.1 (1.0, 1.2)**	1.1 (1.0, 1.2)

Note: Results are from a logistic regression of hypertension. The adjusted OR reflects the odds ratios from a model that includes all variables shown in the table.

All numbers as OR (95% CI)

Bold numbers indicate p<0.05

Figure 1: Odds ratios for Hypertension (Systolic/ Diastolic ≥ 140/90)



Endpoints indicate 95% confidence interval, squares indicate adjusted odds ratio.

References groups are indicated by square markers without endpoints, namely Women, ST, and 0-1km.

Table 5: Sample characteristics by BMI categories

BMI Category	N	BMI (kg/m^2)	Age (years)	Systolic BP (mmHg)	Diastolic BP (mmHg)
Underweight	277	16.8 (16.7, 17.0)	42.0 (40.0, 47.8)	118.7 (116.6, 120.8)	76.5 (75.3, 77.7)
Normal	298	20.6 (20.4, 20.1)	37.7 (36.0, 39.4)	118.9 (117.2, 120.6)	76.5 (75.4, 77.7)
Overweight	32	26.2 (25.7, 26.6)	42.4 (37.1, 47.8)	133.3 (126.7, 139.9)	87.4 (83.8, 91.0)
Obese	2	31.0 (18.3, 43.7)	42.0 (-85.1, 169.1)	135.5 (-10.6, 281.6)	83.0 (-44.1, 210.1)

All values are mean (95% CI)

BMI Categories are defined using international cutoffs

Table 6a: β values for 1st reading and mean readings* of systolic blood pressure		
Predictor	1st reading β	Mean reading β
Age (years)	**0.3 (0.2, 0.4)**	**0.3 (0.2, 0.3)**
Sex		
Women	ref	ref
Men	**9.3 (6.5, 12.1)**	**8.7 (6.0, 11.3)**
Caste/Tribe		
ST	ref	ref
SC	-2.1 (-6.6, 2.3)	-1.9 (-6.2, 2.3)
Other	**5.1 (0.1, 10.1)**	**5.4 (0.6, 10.2)**
Location		
0-1 km	ref	ref
1-3 km	-2.1 (-5.4, 1.2)	-2.5 (-5.6, 0.6)
4+ km	**-3.7 (-6.9, -0.4)**	**-3.9 (-7.1, -0.8)**
BMI (kg/m^2)	**0.7 (0.2, 1.1)**	**0.8 (0.3, 1.3)**

Table 6b: β values for 1st reading and mean readings* of diastolic blood pressure		
Predictor	1st reading β	Mean reading β
Age (years)	**0.2 (0.1, 0.2)**	**0.2 (0.1, 0.2)**
Sex		
Women	ref	ref
Men	**2.9 (1.2, 4.7)**	**2.3 (0.7, 4.0)**
Caste/Tribe		
ST	ref	ref
SC	-1.3 (-4.1, 1.5)	-1.4 (-4.1, 1.3)
Other	**3.2 (0.1, 6.4)**	**3.4 (0.4, 6.5)**
Location		
0-1 km	ref	ref
1-3 km	-0.1 (-2.2, 1.9)	-0.2 (-2.2, 1.7)
4+ km	-1.2 (-3.3, 0.8)	-1.1 (-3.1, 0.8)
BMI (kg/m^2)	**0.5 (0.2, 0.8)**	**0.6 (0.3, 0.9)**

All numbers as β (95% CI)

Bold numbers indicate $p<0.05$

*1st reading indicates using only the first measurement for blood pressure, mean reading indicates the adjusted method of taking the mean blood pressure reading.

Table 7a: Odds ratios for 1st reading and mean readings* of hypertension (SBP≥140 or DBP≥90)

Predictor	Original OR	Adjusted OR
Age (years)	**1.0 (1.0, 1.1)**	**1.1 (1.0, 1.1)**
Sex		
Women	ref	ref
Men	**2.6 (1.6, 4.3)**	**3.2 (1.7, 5.8)**
Caste/Tribe		
ST	ref	ref
SC	0.7 (0.3, 1.7)	1.2 (0.4, 3.4)
Other	1.5 (0.7, 3.2)	2.1 (0.9, 5.0)
Location		
0-1 km	ref	ref
1-3 km	0.7 (0.4, 1.3)	0.6 (0.3, 1.2)
4+ km	0.6 (0.3, 1.1)	**0.4 (0.2, 0.9)**
BMI (kg/m^2)	1.1 (1.0, 1.1)	1.1 (1.0, 1.2)

All numbers as OR (95% CI)

Bold numbers indicate $p<0.05$

*1st reading indicates using only the first measurement for blood pressure, mean reading indicates the adjusted method of taking the mean blood pressure reading.

Supplementary Table 1: Comparison of Global and Asian Specific Body Mass Index Categories

Category	Global* cutoff (n (%))	South Asian cutoff** (n, (%))
Underweight	277 (45.5)	277 (46.5)
Normal	298 (48.9)	282 (46.3)
Overweight	32 (5.1)	41 (6.7)
Obese	2 (0.3)	9 (1.5)

*Global categories are defined by a BMI of 18.5 kg/m^2 and lower as underweight, 18.5 to 24.9 kg/m^2 is normal, 25 to 29.9 kg/m^2 as overweight, and 30 kg/m^2 and above as obese.

**South Asian categories care defined by a BMI of 18.5 kg/m^2 and below as underweight, 18.5 to 22.9 kg/m^2 is normal, 23 to 27.4 kg/m^2 as overweight and 27.5 kg/m^2 and above as obese.

Supplementary Table 2: Hypertensive and non-hypertensive participants by Global and Asian Body Mass Index categories

Category	Global* cutoff (n (%))		South Asian** cutoff (n, (%))	
	Non-HTN	HTN	Non-HTN	HTN
Underweight	235 (45.3)	42 (46.7)	235 (45.3)	42 (46.7)
Normal	266 (51.3)	32 (35.6)	254 (48.9)	28 (31.1)
Overweight	17 (3.3)	15 (16.7)	28 (5.3)	13 (14.4)
Obese	1 (0.2)	1 (1.1)	2 (0.4)	7 (7.8)

*Global categories are defined by a BMI of 18.5 kg/m^2 and lower as underweight, 18.5 to 24.9 kg/m^2 is normal, 25 to 29.9 kg/m^2 as overweight, and 30 kg/m^2 and above as obese.

**South Asian categories care defined by a BMI of 18.5 kg/m^2 and below as underweight, 18.5 to 22.9 kg/m^2 is normal, 23 to 27.4 kg/m^2 as overweight and 27.5 kg/m^2 and above as obese.

Supplementary Table 3a β values for BMI and high systolic blood pressure (≥140 mmHg) by global and South Asian BMI category

Level	Global	South Asian
Underweight	0.8 (-1.8, 3.4)	1.1 (-1.5, 3.8)
Normal	ref	ref
Overweight	**9.7 (3.4, 16.0)**	**7.4 (2.0, 12.8)**
Obese	9.3 (-12.0, 30.7)	**15.1 (4.7, 25.5)**

Supplementary Table 3b β values for BMI and high diastolic blood pressure (≥90 mmHg) by global and South Asian BMI category

Level	Global	South Asian
Underweight	-0.2 (-1.9, 1.4)	0.0 (-1.6, 1.7)
Normal	ref	ref
Overweight	**9.0 (5.1, 13.0)**	**7.3 (3.9, 10.7)**
Obese	3.1 (-10.3, 16.6)	**11.8 (5.3, 18.4)**

Supplementary Table 3c Odds ratios for BMI and hypertension by global and South Asian BMI category

Level	Global	South Asian
Underweight	1.5 (0.9, 2.6)	1.6 (0.9, 2.8)
Normal	ref	ref
Overweight	**5.0 (1.9, 12.9)**	**3.7 (1.5, 9.0)**
Obese	5.3 (0.3, 108.8)	**14.4 (2.5, 82.8)**

All values are β (95% CI) and OR (95% CI)

Bold numbers indicate $p<0.05$