Research Note（Non-Peer Reviewed Paper）（研究ノート）

Comparisons of anthropometric obesity indicators for predicting hypertension among male factory workers in Rajasthan, India

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Abstract:

Background: It is still largely unknown which anthropometric indicators of obesity are the best predictors of hypertension (HTN) in developing countries. **Objective:** This study compared four common anthropometric obesity indicators; body mass index (BMI), waist-to-height ratio (WHtR), waist-to-hip ratio (WHpR), and waist circumference (WC), to evaluate as predictors of HTN among male factory workers in Rajasthan, India. **Methods:** Cross-sectional surveys, including questionnaires and health checkups, were conducted for 379 male participants at two dairy factories; one in a rural and another in an urban area between March 2018 and December 2019. **Results:** Participants with BMI cutoff points of ≥ 24 kg/m^2 and ≥ 23 kg/m^2 were 1.77 and 2.41 times more likely to have HTN than those with BMI < 24 kg/m^2 and < 23 kg/m^2. Similarly, participants with WHtR cutoff points of ≥ 0.53 and ≥ 0.51 were 1.88 and 2.12 times more likely to have HTN than those with WHtR < 0.53 and < 0.51, respectively. Participants with WC ≥ 85 cm and ≥ 83 cm were 1.78 and 2.44 times more likely to have HTN than those with WC < 85 cm and < 83 cm, respectively. **Conclusions:** The study findings suggest that BMI, WHtR, and WC are better than WHpR for predicting HTN in male factory workers in India.

Keywords: Anthropometric indicators, hypertension, health checkups, factory workers, India

Introduction

Hypertension (HTN), or elevated blood pressure, is a major risk factor for heart, brain, kidney, and other cardiovascular diseases[1-3]. The World Health Organization (WHO) reported that an estimated 1.13 billion people worldwide have HTN, and two-thirds of whom live in low- and middle-in-

come countries [1]. A meta-analysis of various studies conducted in different areas of India showed that the overall prevalence of HTN in India is 29.8% [2]. HTN prevalence is higher in urban areas (33.8%) than in rural areas (27.6%) in India, partially due to lifestyle changes (dietary practices, consumption of tobacco, and sedentary habits) [2,4]. Existing studies also reported that overweight and obesity are increasing risk factors for HTN, hypercholesterol, and type 2 diabetes [5-7].

Several anthropometric obesity indicators have been used as risk factors for HTN and other cardiovascular diseases [8-15]. The most widely recognized is body mass index (BMI) for measuring total body fat in general obesity. Waist-to-hip ratio (WHpR), waist-to-height ratio (WHtR), and waist circumference (WC) were other commonly used indicators of abdominal central obesity for predicting HTN [8,10,14]. Recent meta-analyses and other studies on the associations of anthropometric measurements with HTN suggest that WHtR is a better predictor of HTN than BMI and WC [10,12,13,14], while other studies concluded that there were no significant differences among the four anthropometric measures for predicting the risk of HTN [8,9,11,15]. Due to these conflicting results, it is still unclear which anthropometric indicators are most appropriate for predicting HTN in developing countries [15].

In India and in many developing countries, a large number of people, including factory employees, do not have access to regular health checkups services [16]. A telemedicine and mobile health check-up system called "portable health clinic" (PHC) was developed by Kyushu University in Japan and Grameen Communications in Bangladesh in 2010 [17-19]. PHC is an e-health service delivery system that includes a set of medical sensor devices in a briefcase to allow mobile health checkups and doctor's counseling and e-prescription using Skype [17-19]. This PHC service has been implemented and it has covered more than 40,000 patients in Bangladesh and India since 2010 [20]. This study utilized the real-world patient data which

systematically collected from PHC surveys in India and investigated the strength of associations among WHtR, WHpR, WC, and BMI with HTN.

Methods

Data Source and Data Collection Procedures

Data were collected through cross-sectional surveys, including questionnaires and health checkups using PHC. The surveys were conducted for 379 male factory workers in Jaipur, India between March 2018 and December 2019. The ethical committee of the Biyani Group of Colleges Institutional Review Board approved the study in 2018. Study participants were dairy factory and office workers who were randomly selected from the employee lists at Saras Dairy (urban site) and Lotus Dairy (rural site) factories in Jaipur, India. Participants' eligibility criteria were those who were aged 18 years or older, who provided written consent forms, and were healthy enough to participate. Prior to the implementation of the PHC services, awareness events and prior notification were provided to all potential participants in these factories. These PHC services were scheduled and arranged by local research staff from the Biyani Group of Colleges, which is a collaborative research partner in India. Randomly selected participants were identified and booked by local research coordinators for PHC service camps at these two dairy factory sites. The field research team consisted of field research coordinators, field supervisors, healthcare workers, survey interviewers, IT data managers, registration staff, and medical doctors who were locally recruited and trained.

The PHC services and survey questionnaires were implemented in the local language "Hindi" to all participants. The interviewers explained the purpose of the survey and its confidentiality, in accordance with the principles of the Declaration of Helsinki. At each survey, participants' basic sociodemographic, behavioral and health related information were collected us-

ing a standardized questionnaire. In addition, the following anthropometric and clinical data were measured or tested with free of charge; 1) height, 2) weight, 3) hip circumference, 4) WC, 5) body temperature, 6) systolic blood pressure, 7) diastolic blood pressure, 8) blood glucose, 9) blood hemoglobin, 10) urinary glucose, 11) urinary protein, 12) pulse rate, and 13) blood cholesterol. The results of each health checkup were ranked into one of four different color-coded risk levels as follows: green (healthy), yellow (caution), orange (affected), and red (emergent). Only those in the orange or red code received telemedicine services to obtain e-prescription, clinical advices and health education by a connected remote doctor using Skype. More detailed methodologies, including color-coded logic, privacy, and security of collecting patient's personal health data have been described elsewhere [21-23].

Dependent and Independent Variables and Measurements

The dependent variable, HTN was defined as a systolic blood pressure greater than or equal to 140 mmHg or a diastolic blood pressure greater than or equal to 90 mmHg. Blood pressure was measured using the OMRON HEM 7130 (OMRON Corporation, Kyoto, Japan).

The independent variables were BMI, WHtR, WHpR, and WC. BMI was calculated as weight (kg)/height $(m)^2$ and was categorized into two groups; normal weight: <25 kg/m^2 or overweight/obese: ≥25 kg/m^2. BMI was also categorized as normal: <24 (<23 kg/m^2) or overweight/obese: ≥24 (≥23 kg/m^2) based on the previous studies [9,13,15,25]. WHtR was calculated as waist circumference (cm)/height (cm) and categorized into two groups using the three cutoff values; normal: <0.55 (<0.53 and <0.51) vs. obese: ≥0.55 (≥0.53 and ≥0.51) based on previous studies [13,14,15,25]. WHpR was calculated as waist circumference (cm)/hip circumference (cm) and categorized into two groups using three different cutoff values; normal: <0.90, <0.93 and <0.95 vs. obese: ≥0.90, ≥0.93, and ≥0.95, based on the previous studies [8, 10, 11, 25]. WC was measured in cm and was categorized into three

groups using two different cutoff values; normal: <90 cm, <85 cm, and <83 cm vs. obese: ≥90 cm, ≥85 cm, and ≥83 cm, based on the previous research [9, 13, 15, 25]. Different cutoffs for different ethnic groups to predict HTN and other cardiovascular diseases have been proposed by WHO and other previous studies, because of different body shape and composition among ethnic groups [24, 25]. For the Asian-pacific population, BMI≥23 kg/m^2 for overweight and BMI ≥25 kg/m^2 for obesity are recommended [25]. WC ≥83-90 cm for men, WHtR ≥0.50-0.55, and WHpT ≥0.90-0.95 are recommended as optimal cutoff for the prevention of cardiovascular diseases for Asian populations [8-15, 24, 25].

Age, sampling location, participants' history of HTN, and participants' current use of anti-HTN drugs were included in logistic regression models as control variables because these variables are known to be confounding factors that are related to both obesity and HTN.

Data Analysis

Chi-square tests and t-tests were performed to investigate the associations of HTN with participants' demographic, anthropometric, behavioral, and clinical characteristics. Multivariable logistic regression analysis was performed separately for each anthropometric variable to determine the adjusted associations between the independent and dependent variables after controlling for age, location, participants' history of HTN, and participants' current use of anti-HTN drugs. All statistical analyses were performed using SPSS Version 21 (IBM Corp., Armonk, NY, USA). P <0.05 was considered statistical significant.

Results

Overall, 379 samples were analyzed. Table 1 and Table 2 show the participants' demographic, anthropometric, behavioral, and clinical characteris-

tics by their HTN status. Table 1 shows a significant association between HTN and age groups (P=0.001) and also Table 2 shows that the mean age of participants who had HTN was significantly higher than those who did not have HTN (42.2 years vs. 35.8 years; P=0.000). An association between HTN and BMI categories in both tertiles and quartiles was also significant (P=0.000; Table 1). In addition, BMI categories with cutoff of ≥25, ≥24, and ≥23 were significantly associated with HTN (P=0.005, P=0.001, and P=0.000, respectively; Table 1). The mean BMI of participants with no HTN was sig-

Table 1: Demographic, anthropometric, and behavioral characteristics of participants by their hypertension status

Items	Total (N=379)		No hypertension (N=265)		Hypertension (N=114)		χ^2
	n	%	n	%	n	%	P
Age groups							0.001
15–29 years	145	38.3	113	42.6	32	28.1	
30–39 years	89	23.5	67	25.3	22	19.3	
40–49 years	48	12.7	31	11.7	17	14.9	
50+ years	97	25.6	54	20.4	43	37.7	
Location							0.026
Rural	179	47.2	116	43.8	63	55.3	
Urban	200	52.8	149	56.2	51	44.7	
BMI (kg/m^2)							0.000
1st tertile (15.5-22.5)	126	33.2	105	39.6	21	18.4	
2nd tertile (22.5-25.3)	126	33.2	84	31.7	42	36.8	
3rd tertile (25.3-38.7)	127	33.5	76	28.7	51	44.7	
BMI (kg/m^2)							0.000
1st quartile (15.5-21.5)	94	24.8	82	30.9	12	10.5	
2nd quartile (21.5-23.8)	95	25.1	67	25.3	28	24.6	
3rd quartile (23.8-26.3)	95	25.1	58	21.9	37	32.5	
4th quartile (26.3-38.7)	95	25.1	58	21.9	37	32.5	
Waist-to-Height Ratio							0.000
1st tertile (0-0.51)	126	33.2	106	40.0	20	17.5	
2nd tertile (0.51-0.56)	126	33.2	81	30.6	45	39.5	
3rd tertile (0.56-0.79)	127	33.5	78	29.4	49	43.0	
Waist-to-Height Ratio							0.000
1st quartile (0-0.49)	94	24.8	82	30.9	12	10.5	
2nd quartile (0.49-0.54)	94	24.8	64	24.2	30	26.3	
3rd quartile (0.54-0.58)	96	25.3	64	24.2	32	28.1	
4th quartile (0.58-0.79)	95	25.1	55	20.8	40	35.1	
Waist-to-Hip Ratio							0.003
1st tertile (0.76-0.91)	126	33.2	101	38.1	25	21.9	
2nd tertile (0.91-0.96)	127	33.5	88	33.2	39	34.2	
3rd tertile (0.96-1.21)	126	33.2	76	28.7	50	43.9	
Waist-to-Hip Ratio							0.002
1st quartile (0.76-0.89)	93	24.5	77	29.1	16	14.0	
2nd quartile (0.89-0.94)	95	25.1	64	24.2	31	27.2	
3rd quartile (0.94-0.97)	96	25.3	69	26.0	27	23.7	
4th quartile (0.97-1.21)	95	25.1	55	20.8	40	35.1	
Waist Circumference (cm)							0.016
1st tertile (59.0-86.0)	130	34.3	103	38.9	27	23.7	
2nd tertile (86.0-95.0)	130	34.3	86	32.5	44	38,.6	
3rd tertile (95.0-130.0)	119	31.4	76	28.7	43	37.7	
Waist Circumference (cm)							0.001
1st quartile (59.0-83.0)	96	25.3	82	30.9	14	12.3	
2nd quartile (83.0-90.0)	91	24.0	58	21.9	33	28,9	
3rd quartile (90.0-96.6)	94	24.8	64	24.2	30	26.3	
4th quartile (96.6-130.0)	98	25.9	61	23.0	37	32.5	

BMI category							0.005
< 25	238	62.8	178	67.2	60	52.6	
≥ 25	141	37.2	87	32.8	54	47.4	
BMI category							0.001
< 24	199	52.5	154	58.1	45	39.5	
≥ 24	180	47.5	111	41.9	69	60.5	
BMI category							0.000
< 23	145	38.3	120	45.3	25	21.9	
≥ 23	234	61.7	145	54.7	89	78.1	
Waist for Height Ratio							0.003
< 0.55	229	60.4	173	65.3	56	49.1	
≥ 0.55	150	39.6	92	24.7	58	50.9	
Waist for Height Ratio							0.000
< 0.53	169	44.6	135	50.9	34	29.8	
≥ 0.53	210	55.4	130	49.1	80	70.2	
Waist for Height Ratio							0.000
< 0.51	119	31.4	99	37.4	20	17.5	
≥ 0.51	260	68.6	166	62.6	94	82.5	
Waist for Hip Ratio							0.002
< 0.90	102	26.9	83	31.3	19	16.7	
≥ 0.90	277	73.1	182	68.7	95	83.3	
Waist for Hip Ratio							0.008
< 0.93	172	45.4	132	49.8	40	35.1	
≥ 0.93	207	54.6	133	50.2	74	64.9	
Waist for Hip Ratio							0.008
< 0.95	228	60.2	171	64.5	57	50.0	
≥ 0.95	151	39.8	94	35.5	57	50.0	
Waist Circumference (cm)							0.025
< 90cm	187	49.3	140	52.8	47	41.2	
≥ 90cm	192	50.7	125	47.2	67	58.8	
Waist Circumference (cm)							0.001
< 85cm	121	31.9	98	37.0	23	20.2	
≥ 85cm	258	68.1	167	63.0	91	79.8	
Waist Circumference (cm)							0.000
< 83cm	96	25.3	82	30.9	14	12.3	
≥ 83cm	283	74.7	183	69.1	100	87.7	
Ever been diagnosed with hypertension?							0.182
No	357	94.2	252	95.1	105	92.1	
Yes	22	5.8	13	4.9	9	7.9	
Currently taking any drugs for hypertension?							0.056
No	361	95.3	256	96.6	105	92.1	
Yes	18	4.7	9	3.4	9	7.9	
Hypertension							
No	265	69.9					
Yes	114	30.1					

BMI=Body Mass Index

nificantly lower than that of participants with HTN (23.5 kg/m^2 vs. 24.9 kg/m^2; P=0.000; Table 2). WHtR in both tertiles and quartiles were significantly associated with the participant's HTN status (P=0.000; Table 1). WHtR categories with cutoff points of ≥0.55, ≥0.53, and ≥0.51 were significantly associated with HTN (P=0.003, P=0.000, P=0.000, respectively; Table 1). The mean WHtR of those with no HTN was significantly lower than that of participants with HTN (0.53 vs. 0.55; P=0.001; Table 2). WHpR in both tertiles and quartiles had significant association with the participant's HTN status (P=0.003 and P=0.002, respectively; Table 1). WHpR categories with cutoff

points of ≥0.91, ≥0.93, and ≥0.95 were significantly associated with HTN (P=0.002, P=0.008, P=0.008, respectively; Table 1). The mean WHpR among participants with no HTN was significantly lower than that of participants with HTN (0.93 vs. 0.95; P=0.009; Table 2). WC in both tertiles and quartiles had significant association with the participant's HTN status (P=0.016 and P=0.001, respectively; Table 1). WC categories with cutoff points of ≥90 cm, ≥85 cm, and ≥83 cm were also significantly associated with HTN (P=0.025, P=0.001, P=0.000, respectively; Table 1). The mean WC among those with no HTN was significantly lower than that of participants with HTN (89.4 cm vs. 92.1 cm; P=0.019; Table 2). The mean level of systolic and diastolic blood pressure among participants with no HTN was significantly lower than those with HTN (123.3 and 75.0 mmHg vs.148.0 and 90.0 mmHg; Table 2).

Table 3 presents the adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for factors associated with HTN among participants. In both BMI and WHtR, participants in in the 2nd and 3rd tertiles were significantly more likely to have HTN than those in the 1st tertile (OR=2.20, P=0.011; OR=2.67, P=0.002 in BMI, OR=2.43, P=0.005, OR=2.42, P=0.007 in WHtR, respectively). Similarly, participants in 2nd, 3rd, and 4th quartiles of BMI and WHtR had significantly higher ORs with HTN than those in the 1st quartile (P=0.018,

Table 2: Differences in mean of clinical indicators between urban (N=179) and rural participants (N=161)

Item	Total (N=379)			No Hypertension (N=265)			Hypertension (N=114)			T test
	Mean	Median	SD (Range)	Mean	Median	SD (Range)	Mean	Median	SD (Range)	P for diff
Age	37.7	33.0	13.9 (18-79)	35.8	31.0	13.2 (18-66)	42.2	41.0	14.5 (19-79)	0.000
BMI	23.9	23.9	3.61 (15.5-38.7)	23.5	23.4	3.7 (15.5-38.3)	24.9	24.9	3.1 (18.1-38.7)	0.000
Waist-to-Height Ratio	0.54	0.54	0.06 (0.36-0.79)	0.53	0.53	0.07 (0.36-0.79)	0.55	0.55	0.05 (0.40-0.73)	0.001
Waist-to-Hip Ratio	0.94	0.94	0.06 (0.76-1.21)	0.93	0.93	0.06 (0.76-1.21)	0.95	0.95	0.05 (0.79-1.06)	0.009
Waist Circumferences	90.2	91.0	10.6 (59.0-130.0)	89.4	89.0	11.1 (59.0-130.0)	92.1	93.0	9.08 (63.0-127.0)	0.019
Systolic Blood Pressure	130.7	130.0	15.7 (95.0-201.0)	123.3	123.0	10.0 (95.0-139.0)	148.0	145.0	12.6 (127.0-201.0)	0.000
Diastolic Blood Pressure	79.5	79.0	10.9 (47.0-113.0)	75.0	75.0	8.2 (47.0-89.0)	90.0	90.0	9.2 (57.0-113.0)	0.000
Blood Glucose (mg/dl)	116.6	109.0	39.5 (67.0-396.0)	113.3	107.0	33.8 (68.0-396.0)	124.2	116.5	49.8 (67.0-378.0)	0.014

SD=Standard Division; BMI=Body Mass Index

P=0.001, P=0.002 in BMI, P=0.009, P=0.015, P=0.001 in WHtR). Only participants in the 4th quartile of WHpR were 2.22 times more likely to have HTN than those in the 1st quartile (P=0.040, 95%CI=1.04-4.74), but not in the other quartiles and tertile groups. Participants in the 2nd, 3rd, and 4th quartiles of WC were significantly more likely to have HTN than those in the 1st quartile (OR=2.70, P=0.008, OR=2.17, P=0.041, OR=2.46, P=0.019, respectively).

Participants with BMI cutoff points of ≥24 and ≥23 were 1.77 and 2.41 times more likely to have HTN than those with BMI<24 and <23, respectively (P=0.017 and P=0.001, respectively). Similarly, participants with WHtR cutoff points ≥0.53 and ≥0.51 were 1.88 and 2.12 times more likely to have HTN than those with WHtR <0.53 and <0.51 (P=0.014 and P=0.011, respectively). Participants with WC≥ 85 cm and ≥83 cm were 1.78 and 2.44 times

Table 3: Adjusted ORs and 95% CIs for the factors associated with hypertension among participants (N=379)

	OR	P	95% CI
BMI (kg/m^2)			
T1	1		
T2	2.20	0.011	1.20-4.04
T3	2.67	0.002	1.45-4.91
BMI (kg/m^2)			
Q1	1		
Q2	2.51	0.018	1.17-5.39
Q3	3.64	0.001	1.72-7.68
Q4	3.35	0.002	1.57-7.13
Waist-to-Height Ratio			
T1			
T2	2.43	0.005	1.31-4.53
T3	2.42	0.007	1.27-4.61
Waist-to-Height Ratio			
Q1			
Q2	2.75	0.009	1.29-5.89
Q3	2.62	0.015	1.20-5.70
Q4	3.60	0.001	1.65-7.89
Waist-to-Hip Ratio			
T1			
T2	1.41	0.272	0.76-2.62
T3	1.78	0.084	0.93-3.40
Waist-to-Hip Ratio			
Q1			
Q2	1.91	0.076	0.94-3.89
Q3	1.36	0.427	0.64-2.89
Q4	2.22	0.040	1.04-4.74
Waist Circumference (cm)			
T1			
T2	1.60	0.113	0.89-2.87
T3	1.52	0.181	0.82-2.80
Waist Circumference (cm)			
Q1			
Q2	2.70	0.008	1.30-5.63
Q3	2.17	0.041	1.03-4.57
Q4	2.46	0.019	1.16-5.22

BMI category (kg/m^2)			
< 25			
≥ 25	1.54	0.071	0.96-2.45
BMI category (kg/m^2)			
< 24			
≥ 24	1.77	0.017	1.11-2.82
BMI category (kg/m^2)			
< 23			
≥ 23	2.41	0.001	1.43-4.08
Waist-to-Height Ratio			
< 0.55			
≥ 0.55	1.48	0.110	0.91-2.40
Waist-to-Height Ratio			
< 0.53			
≥ 0.53	1.88	0.014	1.14-3.12
Waist-to-Height Ratio			
< 0.51			
≥ 0.55	2.12	0.011	1.19-3.79
Waist-to-Hip Ratio			
< 0.90			
≥ 0.90	1.59	0.142	0.86-2.96
Waist-to-Hip Ratio			
< 0.93			
≥ 0.93	1.33	0.264	0.81-2.20
Waist-to-Hip Ratio			
< 0.95			
≥ 0.95	1.33	0.257	0.81-2.17
Waist Circumference (cm)			
< 90cm			
≥ 90cm	1.25	0.357	0.78-2.00
Waist Circumference (cm)			
< 85cm			
≥ 85cm	1.78	0.044	1.02-3.10
Waist Circumference (cm)			
< 83cm			
≥ 83cm	2.44	0.008	1.27-4.69

Note: Each anthropometric variable was entered in the logistic regression model separately and adjusted for (1) age, (2) site locations (rural vs. urban), (3) participants'history of hypertension, and (4) participants'current use of antihypertension drugs.

more likely to have HTN than those with WC<85 cm and <83 cm, respectively (P=0.044 and P=0.008, respectively).

Conclusion

The study findings suggest that WC, weight, and/or height-related obesity indicators such as WHtR, BMI, and WC are better indicators for predicting HTN than the hip-related obesity indicator (WHpR) among male factory workers in India, regardless of their age and location. In particular, WHtR and BMI should be measured and used for HTN prevention, early diagnosis, and education interventions targeting male workers in resource-limited developing countries such as India.

Acknowledgement

This research was supported by the Future Earth and QR Projects at Kyushu University, Fukuoka, Japan. The authors would like to thank Prof. Tetsukazu Yahara, Prof. Kaoru Izumi, and all team members at the Institute of Decision Science for a Sustainable Society, Kyushu University, Fukuoka, Japan. Special thanks to Mr. Anil Shama at the Saras Dairy Company and Mr. Modi at the Lotus Dairy Company at Jaipur, India, for supporting and participating in the project. Particular thanks are owed to Dr. Rajeev Biyani, Sanjay Biyani, Dr. Neha, Dr. Sunita Rao, and Dr. Satish Gupta at Biyani Group of Colleges (Jaipur, India) who provided valuable comments and assistance.

Compliance with Ethical Standards

There is no disclosure of potential conflicts of interest.

Data collection from each participant was performed in accordance with the Declaration of Helsinki. The ethics committee of the Kyushu University Institutional Review Board (Fukuoka, Japan) approved the study (#24-048) in 2012. Written informed consent was obtained from all participants who received a detailed explanation of the study purposes by the field research assistants.

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