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[AP3-E2-3-01] Comparisons of Anthropometric Indices for Predicting Type 2 Diabetes Among Participants in Telemedicine and Health Checkups in Bangladesh

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Keywords: Anthropometric Indices, Type 2 Diabetes, Mobile Health Check-ups, Telemedicine, Bangladesh

This study compares three common anthropometric measures; body mass index (BMI), waist-to-height ratio (WHtR), and waist circumference (WC) in predicting type 2 diabetes among 8 different sub-population stratified by age, sex, and site locations in Bangladesh. Community based surveys including health checkups, questionnaires, and telemedicine services were conducted for more than 16,000 individuals in 16 nationwide service sites in Bangladesh during 2012 and 2014. Participants were randomly selected factory and office workers in Dhaka and suburban of Dhaka and also voluntary recruited community residents in 6 different rural areas. These data were stratified into 8 different sub-population groups by sites (rural vs. urban), sex (male vs. female), and age (<40 years old vs. ≧40 years old). Participants who were BMI≧25 ≧24 or ≧23 were significantly more likely than others to be type 2 diabetes in 5 sub-population groups out of 8 total sub-groups. The ORs for BMI with type 2 diabetes were between 1.585 (95%CI: 1.12-2.25) in rural women (≧40 yrs) and 5.325 (95%CI: 2.19-12.95) in rural men (<40). Participants who were WHtR≧0.50 and ≧0.53 were significantly more likely than others to report type 2 diabetes in all sub-groups except for the urban women (≧40 yrs) group which has the smallest sample size (n=202). The ORs for WHtR vary between 1.975 (95%CI: 1.06-3.70) in urban men (<40 yrs) and 7.959 (1.90-33.43) in urban men (≧40 yrs). Similarly, the association of WC≧90 and ≧80 with type 2 diabetes were significant in all sub-groups, except for the urban women(≧40 yrs) group. The study suggests WHtR and WC are better indicators than BMI for prediction of type 2 diabetes in Bangladesh.

Comparisons of Anthropometric Indices for Predicting Type 2 Diabetes Among Participants in Telemedicine and Health Checkups in Bangladesh

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Abstract

It is still largely unknown which anthropometric measure of obesity is the best predictor for type 2 diabetes (T2D) in developing countries. This study compares four common anthropometric indices, namely body mass index (BMI), waist-to-height ratio (WHtR), waist circumference (WC), and waist-to-hip ratio (WHR) for predicting T2D among eight different sub-populations stratified by age, sex, and site locations in Bangladesh. Nationwide cross-sectional surveys, including health checkups, questionnaires, and telemedicine services, were conducted for more than 16,000 individuals in 14 nationwide service sites in Bangladesh between 2012 and 2014. The participants included were randomly selected factory and office workers in Dhaka and suburban Dhaka and voluntarily recruited community residents in six different rural areas. These individual data were stratified into eight different sub-population groups with respect to sites (rural vs. urban), sex (male vs. female), and age (<40 y vs. ≥ 40 y). Participants with WHR ≥0.90 for men and ≥0.85 for women were significantly more likely to be T2D in seven out of eight total sub-groups. Odds rations (ORs) for WHR with T2D were the highest among all four indices in four sub-groups. Participants with WHtR ≥ 0.50 were significantly more likely to have T2D in seven sub-groups. ORs for WHtR were the highest in two sub-groups. Participants with WC ≥ 90 for men and ≥80 for women were significantly more likely to have T2D in seven sub-groups. ORs for WC were the highest in urban young female sub-groups. Participants with BMI ≥ 23 were significantly more likely to have T2D in only 4 sub-population groups and ORs for BMI were the lowest among all four indices in four sub-groups. The study findings suggest that abdominal obesity indices, particularly WHR and WHtR, are better than BMI for predicting T2D in all sub-groups in Bangladesh.

Keywords:

Anthropometric Indices, Type 2 Diabetes, Mobile Health Check-ups, Telemedicine, Bangladesh

Introduction

In the past three decades, the prevalence of type 2 diabetes (T2D) has increased dramatically in countries of all income levels [1]. Approximately 422 million people worldwide had diabetes in 2014, with the majority living in low-and middle-income countries, and 1.6 million deaths are directly attributed to diabetes each year [1]. There is a globally agreed target to halt the increase in diabetes and obesity by 2025 [1]. Several anthropometric obesity indices have been used as predictors and risk factors of T2D [2-4]. The most widely recognized is the body mass index (BMI) for measuring total body fat in general obesity. Waist-to-hip ratio (WHR), waist-to-height ratio (WHtR), and waist circumference (WC) were other commonly used indices of abdominal central obesity for predicting T2D [1-2]. The recent meta-analyses on the associations of anthropometric indices with T2D suggest that WHR, WHtR, and WC are better predictors for T2D than BMI [1-3], while other existing studies concluded that there were no significant differences among the four anthropometric measures for predicting the risk of T2D [15-16]. These previous meta-analyses consist of data predominantly derived from developed or middle-income countries and lack data from developing countries, particularly South Asia. A few studies on association between anthropometric indices and T2D conducted in Bangladesh focus only on urban populations such as male factory workers in the capital Dhaka city or one sub-urban area near Dhaka [4-6]. More nationwide large-scale data are needed to consider age, gender, and geographical differences in body shape and risk of T2D [4-5]. Very few studies have investigated the different anthropometric indices such as WHR, WHtR, WC, and BMI with T2D using a nationwide large number of sub-groups [7]. Thus, it is still largely unknown which anthropometric indicators are more appropriate to predict T2D in rural vs. urban, women vs, men, and young vs. elderly individuals in developing countries.

In Bangladesh, non-communicable diseases (NCDs), including T2D, account for over 60% of all deaths [8]. However, a large number of Bangladeshi do not have access to regular health checkups and telemedicine services [9-11]. A telemedicine and mobile health check-up system called "portable health clinic" (PHC) was developed by Kyushu University and Grameen Communications in Bangladesh in 2010 [9]. PHC is an e-health service delivery system that includes a set of medical sensor devices in a briefcase to allow mobile health check-up and doctor's counseling and e-prescription using Skype [10-11] (Figure 1). This PHC service has been implemented and it has reached more than 40,000 patients in Bangladesh and India [9-11] since 2010.

This study utilizes this real-world health check-up data systematically collected from nationwide community-based surveys in Bangladesh and investigates the strength of associations among WHR, WHtR, WC, and BMI with T2D in eight different sub-population groups stratified by age, sex, and study locations.

Figure 1- Portable health clinic (PHC) box and telemedicine

Methods

Data Source and Data Collection Procedures

Data were collected from community based surveys including health checkups, questionnaires, and telemedicine services using PHC (Figure 1). Cross-sectional surveys were conducted for more than 16,000 individuals in 14 nationwide service sites in Bangladesh between 2012 and 2014 (Table 1).

Table 1- Study locations, target populations, data collection periods, and sample size

#	Site Type	Site (city/district)	Populations	Date Collection Periods	Sample Size
1	Rural	Shariatpur	Community Residents	2012, Sep 19-24, Oct 2-4	1954
2		Chandpur		2012, Dec 11-30	911
3		Thakurgaon		2013, Jun 5-10	1002
4		Rajshahi		2013, Jun 17-23	1328
5		Chittagong 1		2013, Jun 30-July 7	962
6		Chittagong 2		2013, July 1-8	898
7	Sub-Urban	Gazipur	Garment factory/office workers	2012, Nov 12-19	1747
8				2012, Nov 20-29	2304
9				2013, Jan 22-24	794
10	Urban	Dhaka	Office workers	2012, Sep 3-5	190
11				2012, Oct 14-18	644
12			Garment factory/office workers	2013, Jan 8-14	1982
13				2013, Jan 15-17	708
14				2013, Jan 19-20	625
Nine participants did not complete blood gulcose and/or urine tests. Thus, total sample size is 16040.					

The ethics committee of the Kyushu University Institutional Review Board approved the study (#24-048) in 2012. Study participants in urban and suburban sites were factory and office workers who were randomly selected from the employee lists. In contrast, participants in rural sites were voluntarily recruited community residents (Table 1). Both rural and urban participants' eligibility criteria were those who were aged 16 years or older, who provided written consent forms, and were healthy enough to participate. Prior to the implementation of PHC services, awareness events and prior notification was provided to all potential participants in those areas. These PHC services were scheduled and arranged by local research staff and Grameen communications staff. Randomly selected participants were identified and booked by local research coordinators for PHC service camps at the local service sites. The field research team consists of field research coordinators, field supervisors, healthcare workers, survey interviewers, IT data managers, registration staff, and remote medical doctors who were locally recruited and trained.

The PHC services and survey questionnaires were implemented in the local language "Bengali" 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, participant's basic socio-demographic and health related information were collected using a standardized questionnaires. In addition, the following anthropometric and clinical data were measured or tested free of charges; 1) height, 2) weight, 3) hip circumference, 4) waist circumference, 5) body temperature, 6) systolic blood pressure, 7) diastolic blood pressure, 8) blood glucose, 9) blood hemoglobin, 10) urinary glucose, 11) urinary protein, 12) urinary urobilinogen, 13) urinary pH, 14) pulse rate, and 15) blood cholesterol. The result of each health check-up was ranked into one of four different color-coded risk levels as follow: green (healthy), yellow (caution), orange (affected), and red (emergent). Only those in the orange or red code received telemedicine services using skype to obtain e-prescription, clinical advices and health education by a connected remote doctor. More detailed methodologies, including color-coded logic, privacy, and security of collecting patient's personal health data have been described elsewhere [11].

Dependent and Independent Variables and Measurements

The dependent variable, T2D was measured using OMRON HGM-112 Glucometer (OMRON Corporation, Kyoto, Japan) during the health check-ups by trained healthcare workers. T2D was defined as a fasting blood glucose level of 126 mg/dL and 200 gm/dl for non-fasting participants. Blood glucose was measure using a drop of blood taken from each participant's middle fingertip.

The independent variables were BMI, WHtR, WHR, 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) respectively. WHtR was calculated as waist circumference (cm)/height (cm) and categorized into two groups using the cut-off value; normal: <0.50 vs. obese: ≥0.50 for both sexes. WHR was calculated as waist circumference (cm)/hip circumference (cm) and categorized into two groups using two different cut-off values; normal: <0.90 (male) or <0.85 (female) vs. obese: ≥0.90 (male) or ≥0.85 (female). WC was measured in cm and was categorized into two groups using two different cut-off values; normal: <90 cm (male) or <80 cm (female) vs. obese: ≥90 cm (male) or ≥80 cm (female) respectively. Different cut-offs for different ethnic groups to predict type 2 diabetes and other cardiovascular diseases has been proposed by WHO, because of different body shape and composition among ethnic groups. For the Asian-pacific population, BMI≥23 kg/m2 for overweight and BMI ≥25 kg/m2 for obesity are recommended [5]. WC ≥90 cm for men and ≥80 cm for women, WHtR ≥0.50 for both sexes, and WHT ≥0.90 for men and ≥0.85 for women are recommended as optimal cutoff for the prevention of cardiovascular diseases by the WHO and other previous studies for Asian populations [5], [7].

Age, hypertension, and proteinuria were included in logistic regression models as control variables because these variables are known to be related with both obesity and T2D.

Data Analysis

Data were stratified into eight different sub-populations by sites (rural vs. urban), sex (male vs. female), and age (<40 y vs. ≥40 y) for analysis. These eight distinct sub-populations are (1) rural young females (RYF), (2) rural elder females (REF), (3) rural young males (RYM), (4) rural elder males (REM), (5) urban young females (UYF), (6) urban elder females (UEF), (7) urban young males (UYM), and (8) urban elder males

(UEM). Descriptive analysis was performed to demonstrate the participant's anthropometric and clinical characteristics and the relationship with T2D separately in eight sub-populations. Multivariable logistic regression analysis was performed separately in eight sub-population groups to determine the adjusted associations between the independent and dependent variables. All statistical analyses were performed using SPSS version 21 (IBM Corp., Armonk, NY, USA). P <0.05 was considered statistical significant.

Results

Overall, 16,040 samples were analyzed (Table 1). Table 2 shows that percentages of T2D were higher among elderly groups (6.0% in REF, 6.2% in REM, 5.4% in UEF, and 5.9% in UEM) than young groups (2.6% in RYF, 2.8% in RYM, 1.1% in UYF, and 0.9% in UYM). Similar trends were found in pre T2D and hypertension, but not in proteinuria.

Table 2- Percentages of T2D, pre diabetes, hypertension, and proteinuria among participants in eight sub-populations

	Rural (n=7,053)								Urban & Sub-Urban (n=8,987)							
	Female (n=4,347)				Male (n=2,706)				Female (n=2,982)				Male (n=6,005)			
	<40 yrs (n=1,941)		>40 yrs** (n=2,406		<40 yrs (n=980)		=>40 yrs (n=1,726)		<40 yrs (n=2,780)		=>40 yrs (n=202)		<40 yrs (n=5,242)		=>40 yrs (n=763)	
	1. RYF*		2. REF*		3. RYM*		4. REM*		5. UYF*		6. UEF*		7. UYM*		8. UEM*	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Blood Glucose (BG) mean±SD (Range)	93.3±39.8 (44-600)		106.1±59.5 (36-600)		95.6±40.3 (40-482)		108.0±56.7 (37-600)		98.5±25.5 (55-519)		114.4±50.8 (69-436)		99.4±25.4 (50-524)		117.3±46.8 (65-484)	
Diabetes (BG =>200mg/dl)																
No	1890	97.4	2262	94.0	953	97.2	1619	93.8	2750	98.9	191	94.6	5196	99.1	718	94.1
Yes	51	2.6	144	6.0	27	2.8	107	6.2	30	1.1	11	5.4	46	0.9	45	5.9
Pre Diabetes (BG=>126mg/dl)																
No	1814	93.5	2085	86.7	903	92.1	1437	83.3	2584	92.9	166	82.2	4844	92.4	583	76.4
Yes	127	6.5	321	13.3	77	7.9	289	16.7	196	7.1	36	17.8	398	7.6	180	23.6
Systolic BP mean±SD (Range)	114.0±15.7 (70-290)		126.7±23.2 (61-235)		118.4±13.8 (65-171)		126.4±23.3 (65-233)		110.1±13.8 (70-190)		121.8±18.2 (80-189)		118.2±13.2 (73-182)		127.0±17.5 (80-195)	
Diastolic BP mean±SD (Range)	77.7±10.8 (42-155)		81.3±12.4 (37-143)		76.7±10.9 (44-120)		78.9±12.8 (46-150)		75.0±9.9 (40-114)		79.0±11.4 (55-110)		75.5±10.5 (40-130)		80.7±11.1 (49-120)	
Hypertension																
No	1692	87.2	1616	67.2	859	87.7	1220	70.7	2555	91.9	151	74.8	4670	89.1	523	68.5
Yes	249	12.8	790	32.8	121	12.3	506	29.3	225	8.1	51	25.2	572	10.9	240	31.5
Proteinuria (=>30mg/dl)																
No	1716	88.4	2086	86.7	911	93.0	1470	85.2	2441	87.8	182	90.1	4993	95.2	718	94.1
Yes	225	11.6	320	13.3	69	7.0	256	14.8	339	12.2	20	9.9	249	4.8	45	5.9

Table 3 shows that higher percentages of those with BMI ≥23 were primarily found in urban elderly groups such as UEM (58.5%) and UEF (53.0%), while lower percentages were found among urban young groups such as UYM (32.2%) and UYF (32.3%). This trend was the same when BMI cut off value was ≥24 and ≥25. Similarly, higher percentages of those who were WHtR ≥0.50 were primarily found in elderly groups such as UEF (78.2%), followed by REF (71.3%), and UEM (54.0%) and lower percentages were found among both urban and rural young groups such as UYM (21.3%) and RYM (21.9%). For WC, the percentages of female and male participants who have ≥80 cm and ≥90 cm respectively were also higher among both urban and rural elderly groups including UEF (63.4%), followed by REF (51.8%) and UEM (37.1%), while lower percentages were found in urban and rural young groups; UYM (10.4%) and RYM (13.1%). Finally, the percentages of female and male participants who have WHR≥0.85 and ≥0.90, respectively were higher among urban elderly groups including UEM (81.7%), followed by REF (80.2%), and lower percentages were found among young male groups; UYM (45.9%) and RYM (49.2%).

Table 3- Anthropometric characteristics of the study participants in eight sub-populations

	Rural (n=7,053)								Urban & Sub-Urban (n=8,987)							
	Female (n=4,347)				Male (n=2,706)				Female (n=2,982)				Male (n=6,005)			
	<40 yrs (n=1,941)		=>40 yrs** (n=2,406		<40 yrs (n=980)		=>40 yrs (n=1,726)		<40 yrs (n=2,780)		=>40 yrs (n=202)		<40 yrs (n=5,242)		=>40 yrs (n=763)	
	1. RYF		2. REF		3. RYM		4. REM		5. UYF		6. UEF		7. UYM		8. UEM	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
BMI																
<18.5	325	16.7	429	17.8	173	17.7	359	20.8	473	17.0	20	9.9	799	15.2	55	7.2
18.5-25	1098	56.6	1339	55.7	621	63.4	1007	58.3	1805	64.9	113	55.9	3650	69.6	425	55.7
25-30	430	22.2	535	22.2	166	16.9	315	18.3	462	16.6	53	26.2	742	14.2	253	33.2
=>30	88	4.5	103	4.3	20	2.0	45	2.6	40	1.4	16	7.9	51	1.0	30	3.9
BMI																
<25g/m^2	1423	73.3	1768	73.5	794	81.0	1366	79.1	2278	81.9	133	65.8	4449	84.9	480	62.9
=>25 kg/m^2	518	26.7	638	26.5	186	19.0	360	20.9	502	18.1	69	34.2	793	15.1	283	37.1
BMI																
<24g/m^2	1278	65.8	1569	65.2	726	74.1	1235	71.6	2085	75.0	117	57.9	4043	77.1	401	52.6
=>24 kg/m^2	663	34.2	837	34.8	254	25.9	491	28.4	695	25.0	85	42.1	1199	22.9	362	47.4
BMI																
<23 kg/m^2	1122	57.8	1358	56.4	643	65.6	1093	63.3	1881	67.7	95	47.0	3552	67.8	317	41.5
=>23 kg/m^2	819	42.2	1048	43.6	337	34.4	633	36.7	899	32.3	107	53.0	1690	32.2	446	58.5
WHtR for both sexes																
<0.50	1122	57.8	1016	42.2	765	78.1	1121	64.9	1877	67.5	75	37.1	4127	78.7	351	46.0
=>0.50	819	42.2	1390	57.8	215	21.9	605	35.1	903	32.5	127	62.9	1115	21.3	412	54.0
WC for male																
<90 cm	1683	86.7	1910	79.4	852	86.9	1353	78.4	2563	92.2	142	70.3	4695	89.6	480	62.9
=>90 cm	258	13.3	496	20.6	128	13.1	373	21.6	217	7.8	60	29.7	547	10.4	283	37.1
WC for female																
<80 cm	1161	59.8	1160	48.2	583	59.5	855	49.5	1935	69.6	74	36.6	2989	57.0	187	24.5
=>80 cm	780	40.2	1246	51.8	397	40.5	871	50.5	845	30.4	128	63.4	2253	43.0	576	75.5
WHR for male																
<0.90	1290	66.5	1151	47.8	530	54.1	523	30.3	2103	75.6	91	45.0	2665	50.8	140	18.3
=>0.90	651	33.5	1255	52.2	450	45.9	1203	69.7	677	24.4	111	55.0	2577	49.2	623	81.7
WHR for female																
<0.85	708	36.5	514	21.4	233	23.8	156	9.0	1094	39.4	40	19.8	803	15.3	33	4.3
=>0.85	1233	63.5	1892	78.6	747	76.2	1570	91.0	1686	60.6	162	80.2	4439	84.7	730	95.7

Table 4 presents the unadjusted association of BMI, WHtR, WC, and WHR with T2D. Significant associations of BMI ≥25, ≥24, and ≥23 with T2D were founds in six, seven, and the entire eight sub-groups, respectively. Participants with WHtR ≥0.50 had significantly higher percentage of T2D in all the eight groups. In WC ≥90cm for male and WC ≥80cm for female, all

groups also showed significant association with T2D. Finally, in WHR ≥90cm for male and WC ≥80cm for female, only UEF did not show significant association with T2D but all others did.

Table 4- Un-adjusted association of participant's anthropometric characteristics with T2D in eight sub-populations

	Type 2 Diabetes (Yes)																					
	Rural (n=7,053)												Urban & Sub-Urban (n=8,987)									
	Female (n=4,347)						Male (n=2,706)						Female (n=2,982)						Male (n=6,005)			
	<40 yrs (n=1,941)			=>40 yrs (n=2,406)			<40 yrs (n=980)			=>40 yrs (n=1,726)			<40 yrs (n=2,780)			=>40 yrs (n=202)			<40 yrs (n=5,242)			=>40 yrs (n=763)		
	1. RYF			2. REF			3. RYM			4. REM			5. UYF			6. UEF			7. UYM			8. UEF		
	n/N	%	P	n/N	%	P	n/N	%	P	n/N	%	P	n/N	%	P	n/N	%	P	n/N	%	P	n/N	%	P
BMI																								
<25g/m^2	28/1423	2.0	0.003	91/1768	5.1	0.003	15/794	1.9	0.002	75/1366	5.5	0.014	14/2278	0.6	0.000	5/133	3.8	0.128	27/4449	0.6	0.000	30/480	6.3	0.357
=>25 kg/m2	23/518	4.4		53/638	8.3		12/186	6.5		32/360	8.9		16/502	3.2		6/69	8.7		19/793	2.4		15/283	5.3	
BMI																								
<24g/m^2	25/1278	2.0	0.009	78/1569	5.0	0.003	10/726	1.4	0.000	63/1235	5.1	0.002	12/2085	0.6	0.000	3/117	2.6	0.036	24/4043	0.6	0.000	23/401	5.7	0.481
=>24 kg/m2	26/663	3.9		66/837	7.9		17/254	6.7		44/491	9.0		18/695	2.6		8/85	9.4		22/1199	1.8		22/362	6.1	
BMI																								
<23 kg/m^2	20/1122	1.8	0.005	61/1358	4.5	0.000	7/643	1.1	0.000	49/1093	4.5	0.000	10/1881	0.5	0.000	2/95	2.1	0.045	23/3552	0.6	0.009	12/317	3.8	0.025
=>23 kg/m2	31/819	3.8		83/1048	7.9		20/337	5.9		58/633	9.2		20/899	2.2		9/107	8.4		23/1690	1.4		33/446	7.4	
WHtR for both sexes																								
<0.50	13/1122	1.2	0.000	32/1016	3.1	0.000	11/765	1.4	0.000	46/1121	4.1	0.000	6/1877	0.3	0.000	1/75	1.3	0.041	25/4127	0.6	0.000	12/351	3.4	0.005
=>0.50	38/819	4.6		112/1390	8.1		16/215	7.4		61/605	10.1		24/903	2.7		10/127	7.9		21/1115	1.9		33/412	8.0	
WC for male																								
<90 cm	10/856	1.2	0.000	15/691	2.2	0.000	5/634	0.8	0.000	28/854	3.3	0.000	4/1432	0.3	0.000	0/44	0	0.062	14/3224	0.4	0.000	2/210	1.0	0.000
=>90 cm	41/1085	3.8		129/1715	7.5		22/346	6.4		79/872	9.1		26/1348	1.9		1/158	7.0		32/2018	1.6		43/553	7.8	
WC for female																								
<80 cm	15/1161	1.3	0.000	40/1160	3.4	0.000	4/583	0.7	0.000	35/855	4.1	0.000	7/1935	0.4	0.000	1/74	1.4	0.044	14/2989	0.5	0.000	1/187	0.5	0.000
=>80 cm	36/780	4.6		104/1246	8.3		23/397	5.8		72/871	8.3		23/845	2.7		10/128	7.8		32/2253	1.4		44/576	7.6	
WHR for male																								
<0.90	16/1290	1.2	0.000	49/1151	4.3	0.000	6/530	1.1	0.001	10/523	1.9	0.000	24/2555	0.9	0.030	3/91	3.3	0.183	9/2665	0.3	0.000	1/140	0.7	0.001
=>0.90	35/651	5.4		95/1255	7.6		21/450	4.7		97/1203	8.1		6/225	2.7		8/111	7.2		37/2577	1.4		44/623	7.1	
WHR for female																								
<0.85	6/708	0.8	0.000	12/514	2.3	0.000	2/233	0.9	0.027	4/156	2.6	0.027	13/2103	0.6	0.000	1/40	2.5	0.321	2/803	0.2	0.020	1/33	3.0	0.407
=>0.85	45/1233	3.6		132/1892	7.0		25/747	3.3		103/1570	6.6		17/677	2.5		10/162	6.2		44/4439	1.0		44/730	6.0	

Table 5 shows adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for BMI, WHtR, WC, and WHR associated with T2D in eight sub-populations in Bangladesh. Participants with BMI ≥23 was significantly more likely to have T2D in four sub-groups: REF (P<0.01), RYM (P<0.001), REM (P<0.001), UYF (P<0.01). Among all four indices, ORs for BMI ≥23 was the lowest in REF (OR=1.823, 95% CI: 1.29-2.60) and the second lowest in REM (OR=2.171, 95% CI: 1.44-3.27), and UYF (OR=3.603; 95% CI: 1.64-7.93). Similar trends of significance and ORs were found for BMI ≥24 and ≥25. Participants with WHtR ≥0.50 were significantly more likely to have T2D in seven sub-groups: RYF (P<0.01), REF (P<0.001), RYM (P<0.001), REM (P<0.001), UYF (P<0.01), UYM (P<0.01), and UEM (P<0.01). Among all four indices, ORs for WHtR ≥0.50 were highest in REF (OR=3.549, 95% CI: 2.06-6.12) and RYM (OR=7.624, 95% CI: 2.82-20.61). Participants with WC ≥90 cm for men and WC ≥80 cm for women were significantly more likely to have T2D in seven sub-groups: RYF (P<0.001), REF (P<0.001), RYM (P<0.001), REM (P<0.01), UYF (P<0.001), UYM (P<0.01), and UEM (P<0.05). Among all the four indices, ORs for WC ≥80 cm for women was the highest in UYF (OR=6.828, 95% CI: 2.84-16.39). Participants with WHR ≥0.90 for men and WHR ≥0.85 for women were significantly more likely to have T2D in seven sub-groups: RYF (P<0.01), REF (P<0.001), RYM (P<0.01), REM (P<0.001), UYF (P<0.05), UYM (P<0.01), and UEM (P<0.05). Among all four indices, ORs for WHR ≥0.90 for men and WHR ≥0.85 for women were the highest in four sub-groups: RYF (OR=3.692, 95% CI: 1.55-8.77), REM (OR=4.383, 95% CI: 2.26-8.49), UYM (OR=2.930, 95% CI: 1.37-6.26) and UEM (OR=8.987, 95% CI: 1.22-66.18).

Table 5- Adjusted odds ratios (ORs) and 95% confidence intervals (CIs) for BMI, WHtR, WC, and WHR associated with T2D

	Type 2 Diabetes (Yes)															
	Rural (n=7,053)								Urban & Sub-Urban (n=8,987)							
	Female (n=4,347)				Male (n=2,706)				Female (n=2,982)				Male (n=6,005)			
	<40 yrs (n=1,941)		=>40 yrs (n=2,406)		<40 yrs (n=980)		=>40 yrs (n=1,726)		<40 yrs (n=2,780)		=>40 yrs (n=202)		<40 yrs (n=5,242)		=>40 yrs (n=763)	
	1. RYF		2. REF		3. RYM		4. REM		5. UYF		6. UEF		7. UYM		8. UEM	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
BMI																
<25g/m^2	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>25 kg/m2	1.845*	(1.03-3.30)	1.668**	(1.16-2.40)	3.279**	(1.47-7.33)	1.672*	(1.07-2.61)	4.483***	(2.10-9.57)	2.164	(0.57-8.20)	2.796**	(1.50-5.22)	0.716	(0.37-1.38)
BMI																
<24g/m^2	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>24 kg/m2	1.638	(0.92-2.92)	1.631**	(1.15-2.32)	4.703***	(2.09-10.61)	1.808**	(1.19-2.74)	3.874**	(1.80-8.35)	4.040	(0.94-17.43)	2.139*	(1.16-3.95)	0.879	(0.47-1.65)
BMI																
<23 kg/m^2	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>23 kg/m2	1.769	(0.99-3.18)	1.828**	(1.29-2.60)	5.325***	(2.19-12.95)	2.171***	(1.44-3.27)	3.603**	(1.64-7.93)	4.763	(0.90-25.31)	1.417	(0.77-2.61)	1.708	(0.85-3.43)
WHtR for both sexes																
<0.50	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>0.50	2.697**	(1.33-5.49)	3.549***	(2.06-6.12)	7.624***	(2.82-20.61)	2.874***	(1.84-4.50)	6.128**	(2.10-17.88)	N/A	N/A	2.429**	(1.24-4.75)	7.645**	(1.82-32.13)
WC for male																
<90 cm	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>90 cm	2.715**	(1.46-5.03)	2.338***	(1.63-3.36)	4.981***	(2.22-11.19)	1.910**	(1.25-2.93)	4.073**	(1.72-9.62)	3.724	(0.94-14.77)	2.648**	(1.37-5.13)	1.917*	(1.03-3.58)
WC for female																
<80 cm	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>80 cm	3.077***	(1.65-5.73)	2.530***	(1.73-3.69)	7.959***	(2.69-23.55)	2.042**	(1.34-3.12)	6.828***	(2.84-16.39)	7.917	0.79-78.91)	1.979*	(1.02-3.86)	12.80*	(1.73-94.40)
WHR for male																
<0.90	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>0.90	3.897***	(2.12-7.15)	1.773**	(1.24-2.54)	3.572**	(1.40-9.11)	4.383***	(2.26-8.49)	3.660**	(1.74-7.68)	2.175	(0.51-9.31)	2.930**	(1.37-6.26)	8.987*	(1.22-66.18)
WHR for female																
<0.85	Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.		Ref.	
=>0.85	3.692**	(1.55-8.77)	3.034***	(1.66-5.54)	3.278	(0.76-14.14)	2.559	(0.93-7.06)	2.978*	(1.13-7.85)	2.275	0.26-19.68	2.630	(0.63-11.03)	1.578	(0.21-11.99)

Each anthropometric variable was separately entered in the multivariate logistic regression models which include (1) age [16-29, 30-39, 40-49, 50+], (2) hypertension [no vs. yes], (3) proteinuria [no vs. yes])

Discussion

To the best of our knowledge, this is the first study to compare the strength of associations of four anthropometric indices with T2D in sub-populations disaggregated by age, sex, and study sites in a developing country. The key finding was that all the three abdominal obesity indices, namely; WHR, WHtR, and WC, were significantly associated with T2D in all sub-populations except for UEF which had the smallest sample size. In contrast, for BMI, significant associations with T2D were found only in four sub-groups: REF, RYM, REM, and UYF. In addition, ORs for BMI were lower than those for WHR, WHtR and WC in almost all sub-groups. These findings were inconsistent with existing evidence from Western and non-Asian countries which had suggested that none of the four anthropometric measures are superior in predicting the risk of T2D [15-16]. These findings suggest that central abdominal obesity indicators are better predictors of T2D than general obesity as measured by BMI in South Asia [4-6]. BMI is widely considered to be a crude measurement of total body fat obesity and does not provide details on body composition and body fat distribution, while WHtR, WHR, and WC are considered as indicators for abdominal fat obesity [5], [12]. This finding is explained by the previous studies suggesting that South Asian populations are more prone to so called "thin–fat" body composition, comprising higher abdominal adiposity with increased insulin resistance and lower muscle mass, compared with Western populations [14]. Thus, body weight parameter alone might provide very little value in identifying obesity in Bangladeshi population.

This finding provides important implication that individual with normal BMI could be at a high risk of T2D when their WHR, WHtR, or WC are higher than normal values. Considering limited resources in Bangladesh, WHR and WHtR can be simpler and more effective as early warning measurements for T2D [2], [13] particularly in rural Bangladesh. It is easy to identify those at risks of T2D in the absence of a weight scale. For WHtR, the concept of "keeping your waist to less than half your height" (WHtR <0.50) would be an easy public health message understandable irrespective of age, gender, and geographical locations in Bangladesh [13].

This study had some limitations. First, a possible selection bias, such that our subjects who voluntarily and willingly participated in health checkups were unlikely to be representative of residents, factory/office workers in Bangladesh. Second, our regression models did not include potential confounding factors, such as a family history of T2D and behavioral information including physical activity, smoking, diet/drinking habits, and current medication status. Finally, this was a cross-sectional survey that does not permit conclusions to be drawn regarding causal links between anthropometric indices and T2D risk. The major strength of the present study was the large sample size covering both rural and urban areas which enabled sub-population analysis by sex and age groups in Bangladesh.

Conclusion

The study findings suggest that abdominal obesity indices such as WHR, WHtR, and WC are better indicators for predicting T2D than total body fat obesity indices (BMI) in all sub-groups, regardless of age, sex, and locations in Bangladesh. Particularly, WHtR and WHR should be measured and used for T2D prevention, early diagnosis, and education program in resource limited developing countries like Bangladesh.

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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 approved the study (#24-048) in 2012. Written informed consent was obtained from all participants who received detailed explanation about the study purposes by the field research assistants.

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