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Original Article

Gender Differences in Association Between Measures of Central Obesity and Falls in Community-Dwelling Middle-Aged and Older Adults in Malaysia

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ABSTRACT

Background/Purpose: Conflicting findings of the previous studies on association of obesity and fall may be attributed to the potential limitations associated with utilizing body mass index (BMI) to define obesity. Therefore, we aim to evaluate the relationship between central obesity measures waist circumference (WC) and waist-hip ratio (WHR) with falls in individuals recruited to the Malaysian Elders Longitudinal Research (MELoR) study.

Methods: A cross-sectional analysis was conducted using first-wave MELoR data. Sociodemographic, medical history, lifestyle factors, self-reported falls, measures of central obesity (WC & WHR), and physical performance were obtained. Individuals were considered in the high fall risk group if they either had a history of falls in the past 12 months or had a timed-up and go (TUG) score of ≥13.5s.

Results: Data on WC and WHR were available for 1,335 participants, 574 (43.0%) men. No difference in self-reported falls or falls risk across WC quartiles among men but women in the third quartile (87cm <WC <97cm) were significantly more likely to have self-reported falls than those in the lowest quartile (reference group), odds ratio (OR)=2.05, 95% confidence interval (CI)=1.17-3.60.

Conclusion: A 'J' shaped relationship was apparent among men between WHR and probability of being considered at high risk of falls. Among women, those with WC in the third quartile and WHR in the highest quartile were significantly more likely to have fallen in the past 12 months.

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1. INTRODUCTION

Falls are considered major public health issues in elderly people and has been identified as the second leading cause of unintentional deaths after motor vehicle accidents.[1] Falling increases the rate of hospitalization, disability, morbidity and mortality in older individuals. Despite addressing the established risk factors for falls such as environmental hazards, gait and balance problems, polypharmacy, neurological conditions including cognitive impairment, musculoskeletal conditions, impaired vision, and psychological issues,[2] identification of new risk factors have potential to reduce this global emerging burden across ageing populations.

The prevalence of obesity is growing rapidly, particularly in developing countries. A handful of studies have shown obesity as a risk factor for falls[3-5] while the findings of other studies have been equivocal.[6,7] The conflicting findings of the previous studies published to date on obesity may be attributed to the potential limitations associated with utilizing BMI to define obesity, particularly in elderly people.[8] Furthermore, BMI alone does not fully identify obesity-related health issues as it is less likely to reflect the accumulation of visceral fat compared to WC or WHR.[9, 10]

Measuring obesity with BMI may exclude older adults who are not obese by BMI but are centrally obese based on WC or waist WHR from fall prevention programmes, when they might be the most susceptible population to fall. Considering the limitations of BMI to define obesity in elders and the limited studies that have considered the relationship between WC or WHR and falling in elderly people, it may now be more appropriate to evaluate relationship between central obesity rather than just obesity with falls in elderly people. This study, therefore, evaluated the relationship between WC and WHR with falling men and women in aged 55 and over recruited to the Malaysian Elders Longitudinal Research (MELoR) study.

2. METHODS

2.1. Study Design and Setting

A cross-sectional analysis was conducted from the data obtained from the first-wave of the MELoR. A detailed description of the study procedure has been published previously.[11] In brief, the MELoR study was a longitudinal study of ageing involving individuals in aged 55 years and above in the Klang Valley. Participants were selected through stratified, simple random sampling from the electoral rolls of three Parliamentary constituencies of Lembah Pantai, Petaling Jaya North and Petaling Jaya South. A total of 8,769 participants were notified and recruited through phone calls and postal invitation, of whom 5,815 participants were contactable. After exclusion of individuals who did not fulfil recruitment criteria or had incomplete data, the final number of participants included in the analysis were 1,335.

2.2. Data Collection

Computer-assisted interviews were conducted at participants' homes. Information collected during the first visit included participant demographics, previous medical history and lifestyle factors. Participants were then invited to attend the hospital for a detailed health check which included anthropometric measurements: weight, height, waist and hip circumference. Additionally, physical performance in the participants were evaluated during the hospital-based health checks.

2.3. Measures

2.3.1. Body mass index

Height and body weight were measured using a height stadiometer (SECA™ 220, Hamburg, Germany) and calibrated weighing scale (SECA™ 769, Hamburg , Germany) respectively. BMI was calculated using the formula: weight [kg] / height [m^2].

2.3.2. Waist Circumference (WC) and Waist-Hip Ratio (WHR)

The waist and hip circumferences were measured in centimetres with participants standing position using a tape measure. The WC was obtained with the tape measure where placed at approximately midpoint between the lower margin of the last palpable rib and the superior border of iliac crest. The hip circumference was measured at the widest part of the buttocks.[9] WHR was calculated by dividing the waist measurement by the hip measurement.

2.3.3. Physical performance

Physical performance was assessed with the following three tests: timed-up and go (TUG), functional reach and handgrip strength.

2.3.3.1. Timed-up and go

The TUG test was a composite measurement of lower limb strength, gait and balance. This was performed on a three-metre walking path clearly marked with a yellow tape from the front legs of a standard chair with arms. Participants were asked to walk at their normal walking speed using their normal footwear and usual walking aids if required, and to stand up from the chair, walk towards the tape, turn around at the tape and return to their chair. The timer was started when the participant left the chair and stopped as soon as the participant sat back on the chair. The time-taken to complete the cycle was recorded in seconds.[12] A TUG time of 13.5 seconds or greater was considered the cut-off for increased risk of falls.[13]

2.3.3.2. Functional reach

The functional reach test was used to assess stability by measuring the maximum distance an individual can reach forward while standing in a fixed position next to the wall with a metre rule fixed horizontally at shoulder height. The maximum distance was measured by subtracting the initial measurement, which participants kept their feet shoulder width apart while holding their arms outstretched forward at 90 degrees parallel to the wall from the final measurement, which participants kept their feet shoulder width apart, while reaching out as far as they could with the arm held forward at the level of the metre rule. The maximum distance was measured in centimetres (cm).[14]

2.3.3.3. Handgrip strength

The handgrip strength test was performed using a calibrated handgrip dynamometer (Jamar Plus+, Sammons Preston, Illinois, USA) to test the maximum isometric strength of the hand. Participants were required to hold the dynamometer with elbow flexed at 90 degrees held by the side of the body, while seated. Three measurements were obtained from the dominant hand. The average grip strength measured in kilograms was considered in subsequent analyses.

2.3.4. Fall history

Falls in this study was defined as unintentionally coming to rest on the ground or lower level. All participants were asked during their home-based computer assisted interview, "Have you fallen in the past 12 months?".

2.3.5. High fall risk group

Individuals who had either a history of falls in the preceding 12 months or a TUG score of 13.5 seconds or greater were considered to be in the high fall risk group.[15]

2.3.6. Statistical analysis

Data analysis was conducted using SPSS 24.0 statistical software (SPSS Inc, Chicago, IL). All descriptive and analytical statistics were performed separately for men and women. Both WC and WHR were categorized into quartiles. Q1 represented the smallest WC and WHR while Q4 represented the largest WC and WHR. Univariate and multivariable comparisons were made first between those who reported at least one fall in the previous year with those without any falls in the previous year (fallers vs. non-fallers), as well those with and without high falls risk (history of at least one fall or TUG score of 13.5 seconds or greater) across quartiles. The χ^2-test (for categorical variables) and independent *t*-test (for continuous variables) were used in univariate analyses. Multivariate analyses were performed using logistic regression with dummy variables with Q1 as reference category. Age, ethnicity, marital status, education level, medical history, number of medications, BMI and handgrip strength were added as potential covariates of WC and WHR with falls and high falls risk. A *p*-value <0.05 was considered statistically significant. Graphpad software was used to plot the trend of fall rates and high fall risk group across quartiles of WC and WHR. The cut-off points for WC and WHR for both men and women for falls and high risk of falls were also determined through areas under receiver operating characteristic (ROC).

2.3.7. Ethical consideration

Written informed consent was obtained from all participants and individuals who were unable to provide consent were excluded. The MELoR study was approved by the University of Malaya Medical Ethics Committee (MED Ref No: 925.4).

3. RESULTS

3.1. Basic Characteristics

Data on WC, WHR, falls history and physical performance measures were available for 1,335 participants. The mean age of participants was 69.6 (*SD*, 7.06) for men and 67.4 (*SD*, 7.07) for women. Women made up 761 (56.0%) of the total sample. Sample characteristics were presented separately for men and women according to WC quartiles in Table 1 and WHR quartiles in Table 2. The WC quartile cut-offs for men were <87cm, ≤93cm and ≤101cm, and <81 cm, ≤87cm and ≤97cm for women. Quartile cut-offs for WHR were 0.91, 0.94 and 0.98 for men, and 0.83, 0.87 and 0.93 for women, respectively. In men, significant different was only found in age for WHR quartile, and in marital status and education level for WHR quartile only while ethnicity, BMI, hypercholesteremia, diabetes, hypertension, number of medication and physical performance appears to be difference with both WC and WHR quartiles. On the other hand, in women, there were significant differences in age and history of cancer for WC quartiles and in ethnicity, education level, BMI, hypercholesteremia, diabetes, hypertension, number of medication and physical performance in both WC and WHR quartiles (Tables 1 and 2).

3.2. Waist Circumference, Waist-Hip Ratio, falls and fall risk

Three hundred (22.5%) participants, 106 (35.3%) men and 194 (64.7%) women experienced at least one fall in the past 12 months while 559 (41.9 %) participants,

Table 1. Baseline characteristics by Waist Circumference quartiles

Variable	Men (n=574)					Women (n=761)				
	Q1 (WC <87cm)	Q2 (87cm ≤WC ≤93cm)	Q3 (93cm <WC <101cm)	Q4 (WC ≥101cm)	*P*-value	Q1 (WC <81cm)	Q2 (81cm ≤WC ≤87cm)	Q3 (87cm <WC <97cm)	Q4 (W ≥97cm)	*P*-value
Age(Years), mean (*SD*)	69.51 (6.75)	70.65 (7.45)	69.15 (6.97)	69.62 (7.06)	0.22	68.23 (6.79)	67.96 (7.08)	67.48 (7.14)	67.45 (7.07)	0.01*
Age Group (%)					0.74					0.03*
55-65 years old	40 (26.7)	34 (23.3)	44 (28.9)	33 (26.2)		68 (32.5)	66 (38.6)	79 (39.3)	85 (47.8)	
≥65 years old	110 (73.3)	112 (76.7)	108 (71.1)	93 (73.8)		141 (67.5)	105 (61.4)	122 (60.7)	93 (52.2)	
Ethnicity (%)					<0.01*					<0.01*
Malay	42 (28.0)	49 (33.6)	55 (36.2)	45 (36.0)		31 (14.9)	37 (21.5)	65 (32.3)	93 (52.0)	
Chinese	72 (48.0)	52 (35.6)	41 (27.0)	19 (15.2)		139 (66.8)	86 (50.0)	60 (29.9)	16 (8.9)	
Indian	36 (24.0)	45 (30.8)	54 (35.5)	61 (48.8)		36 (17.3)	48 (27.9)	75 (37.3)	69 (38.5)	
Others	0 (0.0)	0 (0.0)	2 (1.3)	0 (0.0)		2 (1.0)	1 (0.6)	1 (0.5)	1 (0.6)	
Marital Status, n (%)					0.71					0.45
Single/Never Married/ Divorced/Widow	16 (10.7)	16 (11.0)	14 (9.2)	9 (7.2)		78 (37.5)	59 (34.3)	65 (32.3)	71 (39.7)	
Married	133 (89.3)	130 (89.0)	138 (90.8)	116 (92.8)		130 (62.5)	113 (65.7)	136 (67.7)	108 (60.3)	
Education Level n (%)					0.19					<0.01*
No Formal Education/ Primary	31 (20.7)	22 (15.3)	33 (21.7)	37 (29.6)		36 (17.2)	43 (25.0)	66 (32.8)	82 (45.8)	
Secondary	58 (38.7)	60 (41.7)	54 (35.5)	43 (34.4)		113 (54.1)	84 (48.8)	83 (41.3)	69 (38.5)	
Tertiary	61 (40.7)	62 (43.1)	65 (42.8)	45 (36.0)		60 (54.1)	84 (48.8)	83 (41.3)	69 (38.5)	
Body Mass Index	21.35 (2.41)	23.88 (1.86)	26.09 (1.92)	29.94 (4.25)	<0.01*	21.00 (2.70)	23.84 (2.93)	26.30 (2.87)	31.52 (4.67)	<0.01*
Physical Comorbidities and Symptoms, n (%)										
High Cholesterol	62 (41.3)	85 (58.2)	88 (57.9)	73 (58.4)	<0.01*	99 (47.6)	96 (55.8)	118 (59.0)	119 (66.5)	<0.01*
High Blood Pressure	60 (40.0)	78 (53.4)	95 (62.5)	86 (68.8)	<0.01*	73 (35.1)	97 (56.4)	107 (53.5)	114 (63.7)	<0.01*
Diabetes	31 (20.7)	43 (29.5)	51 (33.6)	57 (45.6)	<0.01*	31 (14.9)	35 (20.3)	56 (28.0)	84 (46.9)	<0.01*
Cancer	6 (4.0)	8 (5.5)	8 (5.3)	5 (4.0)	0.90	23 (11.1)	10 (5.8)	16 (8.0)	6 (3.4)	0.03*
Osteoarthritis	16 (10.7)	16 (11.0)	17 (11.2)	19 (15.2)	0.63	28 (13.5)	34 (19.8)	44 (22.0)	48 (26.8)	0.01*
≥5 number of medications, n (%)	49 (36.3)	55 (39.6)	74 (51.7)	74 (62.7)	<0.01*	51 (28.7)	66 (41.5)	82 (43.6)	93 (53.4)	<0.01*
Physical Performance Tests, mean (*SD*)										
Timed-Up and Go (seconds)	11.77 (3.31)	11.93 (2.94)	13.09 (6.31)	13.46 (3.87)	<0.01*	11.65 (3.20)	11.98 (3.50)	12.16 (3.63)	14.12 (5.04)	<0.01*
Functional Reach (cm)	27.50 (7.56)	26.81 (7.48)	27.97 (7.43)	25.84 (7.73)	0.110	25.15 (7.15)	24.20 (6.92)	23.84 (6.69)	21.80 (6.78)	<0.01*
Dominant Handgrip Strength (kg)	28.12 (7.62)	28.48 (8.00)	28.17 (8.09)	28.34 (7.88)	0.951	19.54 (4.80)	18.82 (4.81)	19.18 (5.66)	17.98 (5.20)	0.02*
History of Fall, n (%)	28 (18.7)	19 (13.0)	31 (20.4)	28 (22.2)	0.22	40 (19.1)	40 (23.3)	66 (32.8)	48 (26.8)	0.01*
High Fall Risk, n (%)⁺	50 (33.3)	46 (31.5)	71 (46.7)	58 (46.0)	<0.01*	73 (34.9)	62 (36.0)	98 (48.8)	101 (56.4)	<0.01*

**P*-value <0.05; ***P*-value <0.01 ⁺Falls in the past 12 months or TUG ≥13.5 seconds

225 (40.3 %) men and 334 (59.7 %) women, fulfilled the criteria for high falls risk (≥1 fall or TUG ≥13.5s). In men, a J-shaped relationship was seen between WC and high fall risk group, WHR and fall in past 12 months, WHR and increased TUG and WHR and high fall risk group while only association between WC and increased TUG revealed a J-shape relationship in women (Figure 1). With the J-shaped relationship, individuals within the lowest quartile for WC and WHR were more likely have fallen, increased TUG or high fall risk compared to those who belonged to the second quartile, while the risk then increases with being in the third and fourth quartiles.

3.3. Univariate Analyses

3.3.1. Waist Circumference

The unadjusted analysis using logistic regression summarized in Table 3. There were no statistically significant associations between fall occurrence in the previous 12 months and WC in men, while women with WC in the Q3 were statistically significantly more likely to report falls in the previous 12 months compared to those in Q1. Both men and women in Q3 and Q4 were more likely to be in the high fall risk group than those in Q1.

3.3.2. Waist-Hip Ratio

There was no significant difference in self-reported

Table 2. Baseline Characteristics by Waist-Hip quartiles

Variable	Men (n=574)					Women (n=761)				
	Q1 (WHR <0.92)	Q2 (0.92 ≤WHR ≤0.94)	Q3 (0.94 <WHR <0.99)	Q4 (WHR ≥0.99)	*P*-value	Q1 (WHR <0.84)	Q2 (0.84 ≤WHR ≤0.87)	Q3 (0.87 <WHR <0.94)	Q4 (WHR ≥0.94)	*P*-value
Age (Years), Mean (*SD*)	69.39 (7.19)	69.24 (6.71)	68.65 (7.04)	71.11 (7.00)	0.02*	67.27 (6.85)	67.26 (6.63)	67.26 (6.93)	68.00 (7.80)	0.67
Age Group (%)					0.03*					0.93
55-65 Years Old	51 (29.0)	29 (28.2)	46 (31.3)	25 (16.9)		79 (37.4)	64 (40.5)	79 (39.7)	76 (39.8)	
≥65 Years Old	125 (71.0)	74 (71.8)	101 (68.7)	123 (83.1)		132 (62.6)	94 (59.5)	120 (60.3)	115 (60.2)	
Ethnicity (%)					< 0.01*					<0.01*
Malay	64 (36.4)	32 (31.1)	50 (34.0)	45 (30.6)		40 (19.0)	35 (22.0)	64 (32.3)	87 (45.5)	
Chinese	78 (44.3)	39 (37.9)	40 (27.2)	27 (18.4)		123 (58.3)	83 (52.2)	65 (32.7)	30 (15.7)	
Indian	33 (18.8)	31 (30.1)	57 (38.8)	75 (51.0)		47 (22.3)	40 (25.2)	69 (24.7)	72 (37.7)	
Others	1 (0.6)	1 (1.0)	0 (0.0)	0 (0.0)		1 (0.5)	1 (0.6)	1 (0.5)	2 (1.0)	
Marital Status, n (%)					0.04*					0.66
Single/Never Married/ Divorced/Widow	17 (9.7)	5 (4.9)	22 (15.0)	11 (7.5)		70 (33.2)	55 (34.6)	77 (38.7)	71 (37.2)	
Married	158 (90.3)	98 (95.1)	125 (85.0)	136 (92.5)		141 (65.8)	104 (65.4)	122 (61.3)	120 (62.8)	
Education Level, n (%)					<0.01*					<0.01*
No Formal Education/ Primary	34 (19.4)	11 (10.8)	31 (21.1)	47 (32.0)		40 (18.9)	46 (28.9)	59 (29.6)	82 (42.9)	
Secondary	62 (35.4)	42 (41.2)	63 (42.9)	48 (32.7)		108 (50.9)	77 (48.4)	82 (41.2)	82 (42.9)	
Tertiary	79 (45.1)	49 (48.0)	53 (36.1)	52 (35.4)		64 (30.2)	36 (22.6)	58 (29.1)	27 (14.1)	
Body Mass Index	23.00 (3.39)	24.76 (3.12)	25.93 (3.35)	27.14 (4.95)	< 0.01*	23.35 (4.43)	25.50 (5.31)	25.90 (4.76)	27.51 (5.12)	<0.01*
Physical Comorbidities and Symptoms, n (%)										
High Cholesterol	76 (43.2)	53 (51.5)	86 (58.5)	93 (63.3)	< 0.01*	104 (49.3)	87 (54.7)	126 (63.3)	115 (60.5)	0.02*
High Blood Pressure	71 (40.3)	56 (54.4)	92 (62.6)	100 (68.0)	< 0.01*	75 (35.5)	88 (55.3)	109 (54.8)	119 (62.6)	<0.01*
Diabetes	34 (19.3)	23 (22.3)	51 (34.7)	74 (50.3)	< 0.01*	26 (12.3)	31 (19.5)	68 (34.2)	81 (42.6)	<0.01*
Cancer	7 (4.0)	6 (5.8)	7 (4.8)	7 (4.8)	0.92	19 (9.0)	11 (6.9)	19 (9.5)	6 (3.2)	0.06
Osteoarthritis	20 (11.4)	9 (8.7)	16 (10.9)	23 (15.6)	0.37	29 (13.7)	37 (23.3)	42 (21.2)	46 (24.2)	0.04*
≥5 Number of Medications, n (%)	50 (30.9)	48 (50.5)	70 (50.7)	84 (60.0)	< 0.01*	58 (30.9)	56 (39.4)	80 (43.0)	98 (53.6)	<0.01*
Physical Performance Tests, Mean (*SD*)										
Timed-Up and Go (seconds)	11.79 (2.99)	11.25 (2.40)	12.50 (3.45)	14.38 (6.64)	<0.01*	11.49 (2.78)	11.83 (3.62)	12.50 (4.16)	13.92 (4.73)	<0.01*
Functional reach (cm)	28.44 (7.29)	28.73 (7.91)	27.30 (7.40)	27.08 (7.57)	<0.01*	25.42 (6.72)	24.44 (7.01)	23.51 (7.35)	21.78 (6.34)	<0.01*
Dominant Handgrip Strength (kg)	29.32 (7.91)	28.78 (8.10)	28.63 (7.69)	26.56 (7.63)	0.01*	19.90 (4.71)	19.78 (5.24)	18.96 (5.06)	17.03 (5.20)	<0.01*
History of fall, n (%)	30 (17.0)	15 (14.6)	27 (18.4)	34 (23.0)	0.35	45 (21.2)	38 (23.9)	47 (23.6)	64 (33.5)	0.03*
High Fall Risk, n (%)[+]	57 (25.3)	24 (10.7)	62 (27.6)	82 (36.4)	<0.01*	74 (22.2)	62 (18.6)	89 (26.6)	109 (32.6)	<0.01*

**P*-value <0.05; ***P*-value <0.01 [+]Falls in the past 12 months or TUG ≥13.5 seconds

falls when comparing WHR Q2, Q3 and Q4 against Q1 in men. In women, however, individuals in WHR Q4, were more likely to have self-reported falls in the past 12 months. Men in WHR Q4 were more likely to be at high risk of falls compared to those in Q1, while women in both Q3 and Q4 were more likely to be at high risk of falls compared to women in Q1.

3.4. Multivariate Analysis

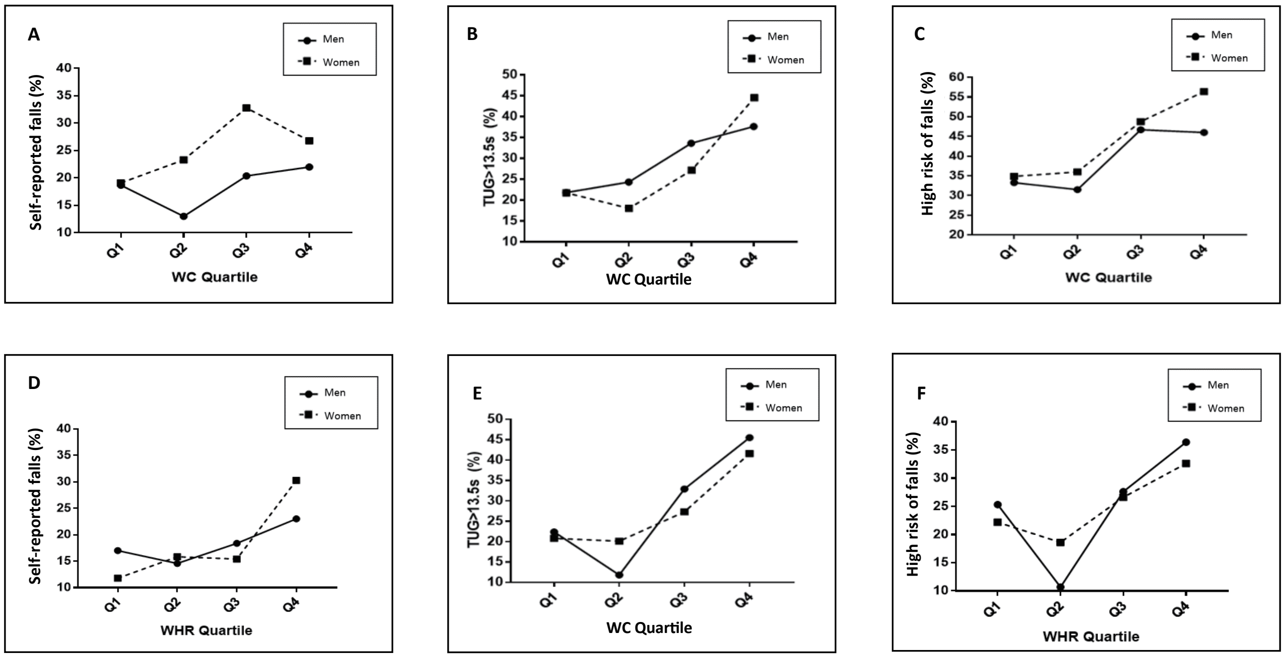
3.4.1. Waist Circumference in men

The statistically significant relationship between waist circumference and high falls risk in WC Q4 men compared to Q1 men was no longer significant following adjustment for age, ethnicity, marital status and educational level, OR=1.39; 95% CI=0.82 to 2.38 (Table 3). As for high fall risk group, the differences between Q3 men and Q1 men was also no longer statistically significant, OR=1.46; 95% CI=0.81 to 2.64 after adjustment for BMI.

3.4.2. Waist Circumference in women

Women in Q3 remained more likely to fall in the last 12 months compared to those in Q1 following adjustments for all potential confounders and mediators, OR=2.05; 95% CI=1.17 to 3.60 (Table 3). This was not the case for women in Q4, where the proportion reporting falls in the past 12 months were

Figure 1. Association of WC and WHR quartile with self-reported fall, TUG ≥13.5s and high fall risk



A: WC quartile and self-reported fall rates among men and women. B: WC quartile and TUG >13.5s among men and women. C: WC quartile and high risk of fall among men and women. D: WHR quartile and self -reported fall rates among men and women. E: WHR quartile and TUG >13.5s among men and women. F: WHR quartile and high risk of fall among men and women.

Table 3. Showing sex-specific odds ratio and corresponding 95% confidence interval for multivariate analyses for fall and high risk of falls by waist circumference using Q1 category as the reference category

	≥1 Fall in Past 12 Months (n=300)			High Fall Risk* (n=559)		
Men	vs. Q1 (WC <87cm)			vs. Q1 (WC <87cm)		
	Q2 (87cm ≤WC ≤93cm)	Q3 (93cm <WC <101cm)	Q4 (WC ≥101cm)	Q2 (87cm ≤WC ≤93cm)	Q3 (93cm <WC <101cm)	Q4 (WC ≥101cm)
Unadjusted	0.65 (0.35-1.23)	1.12 (0.63-1.97)	1.25 (0.69-2.24)	0.92 (0.57-1.50)	1.75 (1.10-2.71)*	1.71 (1.05-2.78)*
Model 1	0.61 (0.32-1.17)	1.05 (0.58-1.90)	1.12 (0.60-2.10)	0.78 (0.46-1.31)	1.67 (1.01-2.77)*	1.39 (0.82-2.38)
Model 2	0.54 (0.21-1.06)	0.83 (0.42-1.67)	0.73 (0.30-1.82)	0.72 (0.41-1.25)	1.46 (0.81-2.64)	1.08 (0.49-2.39)
Model 3	0.54 (0.27-1.07)	0.85 (0.40-1.72)	0.75 (0.30-1.88)	0.70 (0.40-1.23)	1.46 (0.80-2.69)	1.08 (0.48-2.42)
Model 4	0.57 (0.29-1.15)	0.86 (0.40-1.75)	0.82 (0.31-2.09)	0.75 (0.42-1.32)	1.51 (0.81-2.81)	1.22 (0.53-2.81)
Women	vs. Q1 (WC <81cm)			vs. Q1 (WC <81cm)		
	Q2 (81cm ≤WC ≤87cm)	Q3 (87cm <WC <97cm)	Q4 (W ≥97cm)	Q2 (81cm ≤WC ≤87cm)	Q3 (87cm <WC <97cm)	Q4 (W ≥97cm)
Unadjusted	1.28 (0.78-2.10)	2.07 (1.31-3.25)**	1.55 (0.96-2.50)	1.05 (0.69-1.60)	1.77 (1.20-2.64)**	2.41 (1.60-3.64)**
Model 1	1.33 (0.81-2.20)	2.34 (1.44-3.79)**	1.97 (1.15-3.39)*	1.03 (0.66-1.60)	1.83 (1.18-2.83)**	2.71 (1.67-4.41)**
Model 2	1.20 (0.71-2.03)	1.94 (1.13-3.35)*	1.37 (0.65-2.87)	0.93 (0.59-1.48)	1.53 (0.93-2.50)	1.89 (0.97-3.68)
Model 3	1.29 (0.76-2.18)	1.98 (1.11-3.44)*	1.37 (0.65-2.89)	0.99 (0.62-1.59)	1.54 (0.94-2.54)	1.83 (0.93-3.59)
Model 4	1.32 (0.77-2.24)	2.05 (1.17-3.60)*	1.42 (0.66-3.02)	0.98 (0.61-1.57)	1.49 (0.89-2.49)	1.76 (0.89-3.50)

Model 1=Adjusted for age, ethnicity, marital status and education level. Model 2=Model 1 and body mass index. Model 3=Model 2 and high cholesterol, high blood pressure and diabetes. Model 4=Model 3 and dominant handgrip strength. **P*-value <0.05; ***P*-value <0.01; +Falls in the past 12 months or TUG ≥13.5 seconds.

significantly higher compared to Q1 after adjustment for differences in socio-demographics, OR=1.97; 95% CI=1.15 to 3.39, but was subsequently attenuated after the addition of BMI, OR=1.37; 95% CI=0.65 to 2.87. However, the odds of women in Q3 OR=1.77; 95% CI=1.20 to 2.64 and Q4 OR=2.41; 95% CI=1.60 to 3.64 falling in the high fall risk group remained significant after adjustment sociodemographic but was subsequently attenuated after additional adjustment for BMI, OR=1.53; 95% CI=0.93 to 2.50 and OR=1.89; 95% CI=0.97 to 3.68 respectively.

3.4.3. Waist-Hip Ratio in men

There was no significant difference in history of falls between men in Q2, Q3 and Q4 compared to Q1 in all adjusted models (Table 4). As for high fall risk group, men in Q2 were less likely to be considered in

Table 4. Showing sex-specific odds ratio and corresponding 95% confidence interval for multivariate analyses for fall and high risk of falls by waist-to-hip ratio categories using Q1 category as the reference category

Men	≥1 fall in past 12 months (n=300)			High Fall Risk* (n=559)		
	vs. Q1 (WHR <0.92)			vs. Q1 (WHR <0.92)		
	Q2 (0.92 ≤WHR ≤0.94)	Q3 (0.94 <WHR <0.99)	Q4 (WHR ≥0.99)	Q2 (0.92 ≤WHR ≤0.94)	Q3 (0.94 <WHR <0.99)	Q4 (WHR ≥0.99)
Unadjusted	0.83 (0.42-1.63)	1.10 (0.62-1.94)	1.45 (0.84-2.51)	0.63 (0.36-1.11)	1.52 (0.97-2.40)	2.60 (1.65-4.08)**
Model 1	0.82 (0.41-1.64)	0.97 (0.54-1.77)	1.09 (0.60-1.96)	0.59 (0.33-1.07)	1.44 (0.88-2.34)	1.89 (1.15-3.11)*
Model 2	0.76 (0.38-1.53)	0.86 (0.46-1.60)	0.90 (0.47-1.73)	0.57 (0.31-1.04)	1.35 (0.81-2.24)	1.72 (1.01-2.96)*
Model 3	0.78 (0.39-1.59)	0.84 (0.45-1.58)	0.81 (041-1.58)	0.57 (0.31-1.04)	1.26 (0.75-2.13)	1.53 (0.87-2.66)
Model 4	0.71 (0.34-1.47)	0.83 (0.44-1.57)	0.78 (0.40-1.53)	0.51 (0.28-0.95)*	1.25 (0.73-2.12)	1.44 (0.82-2.53)
Women	Vs. Q1 (WHR <0.84)			Vs. Q1 (WHR <0.84)		
	Q2 (0.84 ≤WHR ≤0.87	Q2 (0.84 ≤WHR ≤0.87)	Q2 (0.84 ≤WHR ≤0.87)	Q2 (0.84 ≤WHR ≤0.87)	Q3 (0.87 <WHR ≤0.93)	Q4 (WHR >0.93)
Unadjusted	1.17 (0.71-1.91)	1.15 (0.72-1.83)	1.87 (1.20-2.92)**	1.19 (0.78-1.83)	1.51 (1.01-2.25)*	2.48 (1.66-3.71)**
Model 1	1.17 (0.71-1.92)	1.18 (0.73-1.91)	2.02 (1.24-3.28)**	1.11 (0.71-1.73)	1.38 (0.91-2.11)	2.06 (1.32-3.22)**
Model 2	1.07 (0.65-1.78)	1.10 (0.68-1.78)	1.80 (1.10-2.95)*	0.99 (0.63-1.55)	1.25 (0.82-1.92)	1.77 (1.12-2.79)*
Model 3	1.13 (0.68-1.88)	1.14 (0.70-1.86)	1.82 (1.10-3.01)*	1.03 (0.65-1.63)	1.24 (0.80-1.92)	1.76 (1.11-2.80)*
Model 4	1.10 (0.66-1.85)	1.16 (0.71-1.91)	1.84 (1.10 -2.06)*	1.01 (0.64-1.61)	1.24 (0.80-1.93)	1.60 (1.00-2.57)

Model 1=Adjusted for age, ethnicity, marital status and education level. Model 2=Model 1 and body mass index. Model 3=Model 2 and high cholesterol, high blood pressure and diabetes. Model 4=Model 3 and dominant handgrip strength. *P-value <0.05; **P-value <0.01; +Falls in the past 12 months or TUG ≥13.5 seconds.

the group compared to men in Q1 after adjustment for age, ethnicity, marital status, education, BMI, hypercholesterolaemia, hypertension, diabetes and dominant grip strength, OR=0.51; 95% CI=0.28 to 0.95. Men in Q4, however, were more likely to be considered at high risk of falls compared to men in Q1 after adjustment for ethnicity, marital status, education and BMI, OR= 1.74; 95% CI=1.72 to 2.96, but this relationship was attenuated after additional adjustment for medical history, OR=1.53; 95% CI=0.87 to 2.66, suggesting that the increased risk of falls among individuals WHR within Q4 could be explained by the presence of the medical conditions hyperlipidaemia, hypertension and diabetes after adjusting for baseline differences in sociodemographic and BMI.

3.4.4. Waist-Hip Ratio in women

Women in Q4 remained significantly more likely to fall in the last 12 months compared to those in Q1 following adjustments for all potential confounders and mediators, OR=1.84; 95% CI=1.10 to 2.06. The increased proportion in the high fall risk among women in Q3 compared to Q1 in the unadjusted model, OR=1.51; 95% CI=1.01 to 2.25 was attenuated by adjustment for age, ethnicity, marital status and education, OR=1.38; 95% CI=0.91 to 2.11. The significant increase in risk of falls observed among women in Q4 compared to Q1 remained significant after adjustment for age, ethnicity, marital status, education, BMI, hyperlipidaemia, hypertension and diabetes, OR=1.76; 95% CI=1.11 to 2.80, was subsequently attenuated after additional adjustment for dominant grip strength, OR=1.60, 95% CI=1.00 to 2.57. This indicated that the increased proportion at high fall risk observed in women with WHR in Q3 compared to Q1 was explained by differences in sociodemographics while the greater proportion of those with high fall risk among women with WHR in Q4 compared to Q1 was potentially mediated by loss of muscle strength measured with grip strength after accounting for differences in sociodemographic, BMI and medical history.

3.4.5. Waist Circumference and Waist-Hip Ratio cut-offs for falls and falls risk

The WHR index best determined the presence of self-reported fall and high fall risk among both men and women was determined using the area under ROC. The area under ROC for WHR and fall was 0.574 (95% CI=0.53, 0.62) and 0.548 (95% CI=0.48, 0.61) for both men and women respectively. The optimal cut-off points for WHR as an estimation of fall occurrence in the previous 12 months in men was 0.92 with a sensitivity of 39.7% and specificity of 72.3%. The optimal WHR cut-off for self-reported fall for women was 1.02, 22.6% sensitivity and 90.0% specificity. The area under ROC for high fall risk is 0.604 (95% CI=0.56, 0.65) and 0.605 (95% CI=0.57, 0.65) for both men and women respectively. The optimal cut-off point for WHR with high fall risk in men was 0.96, with 56.0% sensitivity and 64.8% specificity, and for women was 0.90, with 49.4% sensitivity and 69.0% specificity.

4. DISCUSSION

The relationship between WC and WHR with falls and falls risk differed between men and women in the MELoR study. Among men, fall occurrence in the preceding 12 months was not influenced by WC or WHR. However, when we considered high fall risk, defined as the presence of fall in the previous

12-months or impaired gait and balance determined with TUG, men with WHR in the fourth quartile were significantly more likely to be considered at high risk of falling independent of BMI, but this was accounted by medical history. Conversely, men in the second quartile were less likely to have increased risk of falls after adjustment for potential confounders or mediators indicating a "J" shaped relationship between WHR and fall risk in men. In women, however, individuals with WC in Q3 were significantly more likely to have self-reported falls compared to Q1, but not those with WC in Q4. For women, however, those with WC in the third quartile were more to have self-reported falls, while only women within the highest quartile WHR were significantly more likely to have self-reported falls and high falls risk. The "J" shaped relationship was not apparently among women.

The International Diabetes Federation 2006 Consensus Worldwide Definition of the Metabolic Syndrome recommended ethnic specific values for WC of ≥90cm for Non-European men and ≥80cm for Non-European women.[9] However, the World Health Organization (WHO) Expert Consultation in 2008 recommended that cut-offs for WC should be tailored to outcomes[9] leading to numerous subsequent studies being published on suitable local cut-offs for difference outcomes for various geographical locations as well as ethnic groups.[16,17] The WHO recommended cut-offs for WHR were ≥0.90 for men and ≥0.85 for women though lower cut-offs have been recommended for Asian.[9] Recent published studies with regards to the relative values of WHR and WC in determining abdominal obesity has been conflicting with a Korean study demonstrating stronger associations between WHR and subclinical atherosclerosis[18] while the Malaysian study found stronger correlation between WC and BMI compared to WHR and BMI.[19] To add further to the controversy, the above studies have involved mainly general adult populations, with many excluding those aged 65 years or over. Alterations in body shape and body composition are well-established with increasing age. Therefore, appropriate cut-offs for older men and women for both WC and WHR remain elusive.

Despite difficulties in determining optimal cut-offs for WC and WHR among older adults, the median WC and WHR for both men and women in our population exceed that of recommended cut-offs suggesting a high level of abdominal obesity in our population. The parameter estimate which represents the odds ratio for those within the second WHR quartile among men, however, appeared lower than that in lowest WHR quartile, suggesting a possible "J" curve within the univariate relationship between WHR and falls risk. The "J" shaped curve is a well-established medical statistical finding between BMI and health outcome.[20] Furthermore, only those in the highest quartiles for WC and WHR for men and women were consistently more likely to be considered at high risk of falls. This suggests that men with the lowest WHR may experience a slight increased risk of falling, while those with slightly higher WHR may be a protective factor against high risk of fall and only those with extreme abdominal obesity more at higher risk of falls. The presence of "J" shaped curve for WHR and high risk of fall among men could reflect the possibility of obesity paradox in our MELoR population. Previous studies suggested the presence of obesity paradox with mortality outcomes[21] but no studies that have been conducted with risk of falls as the outcome. The "J" shaped relationship was not apparent in women but a stronger relationship between WC and WHR and falls and falls risk was observed among those within the highest WC and WHR quartiles.

Both men and women at the highest WHR quartiles had approximately two times higher odds of falling compared with those with WHR at the lowest quartiles. The Shihpai Eye Study dataset involving 2,405 individuals, also found an associated between increased WHR and falls.[22] Another two studies conducted in Taiwan and the United States found an independent association between central adiposity and falls and also found that fallers with central adiposity were significantly more likely to sustain injuries and experience a reduction in quality of life.[23,24] A recent study conducted among 3,383 older adults in the Health and Retirement Study, a longitudinal study in the United States, reported that older adults with central adiposity (measured by waist circumference) were more likely to experience falls.[25] It was suggested that individuals who were centrally obese have an altered lumbosacral angle leading to a distinct lumbar lordosis.[25] Increased lumbosacral angle leading to a higher centre of gravity may reduce postural stability, hence increasing the risk of fall. Corbeil, et al[26] also suggested that older adult with central obesity with abnormal fat distribution increases the weight on the ankle, yielding loss of stability over the ankle region, hence increasing the risk of fall. The relationship between WC and falls or increased falls risk in our study was less convincing. The measure of WC identified the presence of abdominal obesity without taking into account fat accumulation or muscle bulk in the hip and hence will not accurately reflect body shape. The apparent inconsistencies may be explained by potential geographical variations or differences in sample size with fall prevalence in the United States appearing higher than that of Asia.[27]

The association between WHR with increased falls risk was independent of BMI. The waist to hip ratio reflects body shape, which could still be unfavourable despite a normal BMI. For instance, an older individual may have a normal BMI with slightly increased WC but could have a markedly increased WHR if fat accumulation was predominantly visceral in nature and hip circumference was low or normal with reduced muscle bulk and absence of fat accumulation in the hip area. The attenuation of the relationship between WHR and falls risk after the additional of medical comorbidities suggests that conditions such as diabetes which also leads to presence of falls risk factors such as peripheral neuropathy, visual disturbance, cognitive impairment and osteoarthritis could account for the excess falls risk associated with grossly increased WHR.[28]

As this is the first study to look on the association between central obesity and falls among community-dwelling Malaysians aged 55 years and above, our findings will therefore assist healthcare professionals and policy makers when formulating fall prevention interventions. Limitations of the current study included the use of self-reported falls. Participants may have poor recall of their history of fall in the past 12 months leading to underreporting.[29] Our study had included those aged 55 to 64 years, as 55 years was the retirement age at the time the study was conceived, raising potential concerns that falls risk among those aged 55 to 64 years associated with adiposity may differ from those aged 65 years and above. However, a previously published study suggested that the prevalence of falls in those aged 60 to 64 years, was similar to those aged 65 to 69 years and 70 to 74 years, though those aged 55 to 59 years did fall less.[27] We refrained from conducting subsample analyses due to sample size limitations. The absence of recognized WC and WHR cut-offs for older adults also limits our ability to determine obesity status based on WC and WHR in our population. In particular, WHR would also be influenced by lower-limb girdle muscle mass which is likely to affect stability. Nevertheless, our study has uniquely exposed the potential relationship between central obesity and falls risk. Future studies should examine in greater detail the rationale for the increased risk of falls only among those with markedly increased WHR, the increased self-reported falls among those with moderately increased WC but not grossly increased WC, and paradoxically the protective effect of those with borderline increased WHR above those with WHR below recommended cut-offs.

A 'J' shaped relationship was apparent among men between WHR and probability of being considered at high risk of falls. Among women, those with WC in the third quartile and WHR in the highest quartile were significantly more likely to have fallen in the past 12 months compared to those in the first quartile. Our study therefore found a non-linear relationship between WC and WHR with falls or risk of falls. Larger prospective studies should be conducted to investigate the mechanisms by which central adiposity is related to falls in older adults, and the paradoxical increased in falls risk among men with reduced WHR. Additionally, future studies should also be performed to identify interventions that could alter their body composition and to improve leg muscle function to reduce their risk of fall.

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CONFLICTS OF INTEREST

The author and co-authors declare no conflict of interest.

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