ASSOCIATION BETWEEN BODY ROUNDNESS INDEX AND METABOLIC RISK FACTORS FOR CARDIOVASCULAR DISEASE AMONG ACTIVE-DUTY MILITARY PERSONNEL IN THAILAND

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Abstract

Background: The body roundness index (BRI), which combines waist circumference (WC) and height, is a promising measure of body shape and central obesity. Active-duty members of the Royal Thai Army (RTA) showed an increase in metabolic risk factors for cardiovascular disease (CVD) from 2017 to 2021.

Objective: The study aimed to analyze health examination data of RTA personnel nationwide to evaluate the association between BRI and metabolic risk factors for CVD and assess the effect measure modification of sex onthis association.

Methods: We conducted a cross-sectional study in RTA personnel aged 20 to 60 years using health examination data in 2022. BRI was calculated from WC and height and categorized into four groups based on quartiles (1-4). Metabolic risk factors for CVD were defined as having at least one of the following: high blood pressure (BP) (≥ 140/90 mmHg), hyperglycemia (fasting plasma glucose ≥126 mg/dL), high total cholesterol (TC) (≥ 240 mg/dL), hypertriglyceridemia (≥150 mg/dL), and hyperuricemia (≥ 7 mg/dL for men and ≥ 6 mg/dL for women).

Results: A total of 109,821 RTA personnel were included in the analysis. The overall mean BRI was 3.5 (±1.2), with quartile-specific means of 2.2 (Q1), 3.0 (Q2), 3.6 (Q3), and 5.0 (Q4). Multivariable logistic regression revealed significant associations between BRI and metabolic risk factors for CVD: high BP (adjusted prevalence ratio [APR] 1.18, 1.28, 1.38 for Q2, Q3, Q4), hyperglycemia (APR 1.12, 1.31, 1.67), high TC (APR 1.21, 1.33, 1.25), hypertriglyceridemia (APR 1.27, 1.50, 1.59), and hyperuricemia (APR 1.11, 1.24, 1.26), all compared to Q1 (p-trend < 0.001). Higher BRI quartiles were associated with a greater likelihood of presenting composite metabolic risk factors, especially in the fourth quartile (APR 1.18 for men, 1.23 for women; p for interaction < 0.001).

Conclusion: Our results demonstrate that, among active-duty RTA personnel, a higher BRI is associated with a greater number of metabolic risk factors for CVD. BRI, a measure of central adiposity, is a useful tool for identifying individuals at increased risk of CVD.

Keywords: body roundness index, cardiovascular disease, hypertension, hyperglycemia, hyperlipidemia, hyperuricemia

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Introduction

Cardiovascular disease (CVD), including ischemic heart disease and stroke, raises mortality and morbidity rates worldwide.[1] About 17.9 million deaths worldwide in 2019 could be attributed to CVD, accounting for 32% of all fatalities.[2] Between 2000 and 2021, Thailand saw a more than 50% increase in deaths from CVD, which is now the country's leading cause of death among non-communicable diseases.[3]

Overweight and obesity are critical global health challenges associated with increased morbidity and mortality. The World Health Organization (WHO) defines obesity as an abnormal or excessive accumulation of body fat that poses health risks.[4] Over 2 billion adults globally were categorized as overweight or obese in 2021, and estimates indicate that by 2050, over 5 billion adults may be impacted.[5] There is strong evidence that obesity is becoming more common in Thailand among several populations, including the general public, young people, and military personnel.[6–9] Although it has limitations in accurately capturing body composition, body mass index (BMI) remains the principal metric used to assess obesity.[10] Thus, combining anthropometric measurements with BMI, such as waist circumference (WC) and waist-to-hip ratio, can improve the evaluation of CVD risk.[11]

The body roundness index (BRI), developed by Thomas et al., has recently emerged as a promising anthropometric indicator.[12] Unlike BMI, which considers weight and height, BRI takes WC and height into account while concentrating on body form and central obesity. Research on Chinese people showed that, even after controlling for conventional risk variables, a high BRI was associated with a 1.63-fold higher risk of CVD over six years.[13] Furthermore, studies on people in the United States showed a relationship between greater BRI and CVD, with BRI outperforming BMI, indicating that BRI might be a more reliable indicator of CVD risk. [14]

However, the clinical use of the BRI is hindered by its more complex calculation compared to BMI and by the lack of universal cut-off values. In Thailand, a recent study found promising BRI cut-offs for metabolic syndrome screening in working adults, supporting its utility in this population.[15] However, its relationship with specific cardiovascular metabolic risk factors remains unexplored, particularly among military personnel.

Surveillance data on CVD risk factors among active-duty Royal Thai Army (RTA) personnel in Thailand from 2017 to 2021 showed increases in obesity, high blood pressure (BP), and high total cholesterol (TC), as well as a growing trend in predicted 10-year CVD risk.[9,16–20] However, information on BRI characteristics and their association with metabolic risk factors for CVD within this military population is limited. In the current study, we used health examination data from active-duty RTA personnel nationwide in 2022 to examine the distribution of BRI across various characteristics. Additionally, we evaluated the association between BRI and metabolic risk factors for CVD, which included high BP, hyperglycemia, high TC, hypertriglyceridemia, and hyperuricemia. We also assess the effect measure modification of sex on the association

between BRI and metabolic risk factors for CVD among this population.

METHODS

Study design and subjects

We conducted a cross-sectional study using data from the 2022 annual health examinations of active-duty RTA personnel, with permission from the Royal Thai Army Medical Department (RTAMED). The details of these health examinations were published elsewhere by Sakboonyarat et al.[9,16–20] Briefly, active-duty RTA personnel aged 20 to 60 years nationwide were invited to participate in the health examinations conducted by the Armed Forces Research Institute of Medical Sciences, the Army Institution of Pathology, and 37 RTA hospitals across four geographical regions of Thailand. In 2022, a total of 126,258 active-duty RTA personnel participated in the health examination sessions. Of these, 109,821 individuals (87.0%) had available data on WC and height and were included in the analysis.

Data collection

During the annual health examination, participants completed a standardized questionnaire to collect information on their personal characteristics and lifestyle factors. The questionnaire included details such as sex, age, health insurance scheme, alcohol consumption, smoking status, and exercise habits. Additionally, trained staff conducted various measurements, including anthropometric data, BP readings, and blood tests.

Participants' height and body weight (BW) were measured and documented. WC was assessed at the umbilical level using a plastic tape and recorded in centimeters. An automatic oscillometric blood pressure monitor was used to measure blood pressure in accordance with Thai standards for the management of hypertension.[21] Before their BP was measured, participants were told to refrain from smoking and caffeine for at least half an hour. Talking was also not allowed during this time. Well-trained personnel took two BP readings, and the average was noted. Laboratory testing, including fasting plasma glucose (FPG), TC, triglycerides (TG), and serum uric acid, was conducted in participants aged 35 and older. Prior to the blood test, participants had to fast for at least 8 hours. All collected data were sent to RTAMED in Bangkok, Thailand.

Outcomes, exposure, and covariates

The metabolic risk factors for CVD, including hyperuricemia, elevated blood lipids, elevated blood glucose, and elevated BP, were examined in this study. The outcomes were defined using two approaches: continuous and categorical variables. High systolic blood pressure (SBP) was defined as SBP ≥ 140 mmHg, and high diastolic blood pressure (DBP) was defined as DBP ≥ 90 mmHg. High BP was classified as either SBP ≥ 140 mmHg or DBP ≥ 90 mmHg.[20] Hyperglycemia was defined as FPG ≥ 126 mg/dL.[17] High TC was defined as TC ≥ 240 mg/dL[19], and hypertriglyceridemia was defined as TG ≥ 150 mg/dL.[18] Hyperuricemia was defined as serum uric acid levels ≥ 7.0 mg/dL in men or ≥ 6.0 mg/dL in women.[22] The composite of metabolic risk factors for CVD was defined as having at least one of the following risk factors: high BP, hyperglycemia, high TC, hypertriglyceridemia, or hyperuricemia.

The exposure in this study was BRI, calculated using WC and height.[12] The formula for calculating BRI is as follows :

$$364.2 - 365.5 \times \sqrt{1 - \left[\frac{\left(\frac{\text{WC in cm}}{2\pi} \right)}{(0.5 \times \text{height in cm})} \right]^2}$$

BRI was categorized into four groups based on quartiles (1 to 4). The covariates included demographic characteristics such as age, sex, geographical region, and health insurance scheme, as well as lifestyle factors and BMI. The geographical region was classified as Bangkok, Central, Northeast, North, and South. The health insurance scheme included civil servant medical benefits, social security, and universal health coverage. Regular exercise was defined as engaging in physical activity for at least 30 minutes per day, three days per week. Smoking status was divided into four groups: (1) never smoked, (2) ex-smoker (defined as smoke-free for 12 months), (3) irregular current smoker, and (4) regular current smoker.[23] Alcohol consumption was categorized into four groups as well: (1) never consumed, (2) ex-drinker (defined as alcohol-free for 12 months), (3) irregular current drinker, and (4) regular current drinker.[23] BMI was calculated as BW in kilograms divided by height in meters squared.[9]

Statistical analysis

We conducted data analyses using Stata Statistical Software: Release 17 (StataCorp, 2021). The characteristics of the study participants were analyzed using descriptive statistics. Categorical variables were presented as percentages, while continuous variables were presented as means and standard deviations (SD). Chi-square tests and ANOVA were used to compare participants' characteristics across BRI categories, as appropriate.

To evaluate the association between BRI and metabolic risk factors for CVD, we used linear regression analysis for continuous outcomes and logistic regression analysis for binary outcomes. A multivariable analysis was performed, adjusting for covariates including age, sex, geographical region, health insurance scheme, exercise, smoking status, alcohol use, and BMI. For the multivariable linear regression, we estimated the adjusted β coefficient with a 95% confidence interval (CI). In the case of multivariable logistic regression, we used the post-estimation margins command to estimate the adjusted prevalence ratio (APR) with a 95% CI.

In addition, we employed multivariable logistic regression to evaluate the sex-specific association between BRI and the prevalence of metabolic risk factors for CVD. We then tested for interactions to determine whether sex modifies the association between BMI and these metabolic risk factors for CVD. A two-sided *p*-value of less than 0.05 was considered statistically significant.

Due to limitations in the available data, we were unable to include dietary lifestyle factors in the primary analysis; therefore, potential confounders may exist. To address unmeasured confounding, we performed a sensitivity analysis using E-values estimated through the Evalue package.[24]

Ethics consideration

The study was reviewed and approved by the Institutional Review Board of the RTAMED (Approval number: S056h/65_Exp), following the international guidelines, entailing the Declaration of Helsinki, the Belmont Report, the Council for International Organizations of Medical Sciences Guidelines, and the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use-Good Clinical Practice (ICH-GCP). According to the use of secondary data, the Institutional Review Board of the RTAMED approved a waiver of informed consent documentation.

Results

Characteristics of study participants

Table 1 presents the characteristics of 109,821 active-duty RTA personnel. The overall mean age of participants was 37.5 years (±10.8), and the majority were men (88.9%). Approximately one-third of the participants resided in the central regions (31.3%), followed by Bangkok (19.3%), the North (19.0%), the Northeast (17.1%), and the South (13.3%). In total, 33.7% of participants had a BMI between 25.0 and 29.9 kg/m², while 10.7% had a BMI of 30 kg/m² or higher. The overall prevalence of high SBP, high DBP, and high BP was 19.1%, 13.9%, and 23.4%, respectively. The prevalence rates for

Table 1. Characteristics of study participants by body roundness index quartile

Characteristics	Overall	Body roundness index quartile				*p*-value
		Quartile 1	Quartile 2	Quartile 3	Quartile 4	
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	
Total N	109,821	27476	27570	27337	27438	
Body roundness index						
mean (SD)	3.5 (1.2)	2.2 (0.4)	3.0 (0.2)	3.6 (0.2)	5.0 (1.0)	<0.001
median (Q1–Q3)	3.3 (2.7–4.0)	2.3 (2.0–2.5)	3.0 (2.9–3.1)	3.6 (3.5–3.8)	4.7 (4.3–5.4)	
min-max	0.04–11.00	0.04–<2.69	2.69–<3.30	3.30–<4.00	4.00–11.00	
Age (years)						<0.001
20–24	9023 (8.2)	4575 (50.7)	2178 (24.1)	1270 (14.1)	1000 (11.1)	
25–29	22438 (20.4)	8171 (36.4)	5895 (26.3)	4417 (19.7)	3955 (17.6)	
30–34	21395 (19.5)	5496 (25.7)	5901 (27.6)	5138 (24.0)	4860 (22.7)	
35–39	15814 (14.4)	3308 (20.9)	4229 (26.7)	4175 (26.4)	4102 (25.9)	
40–44	10480 (9.5)	1858 (17.7)	2550 (24.3)	2946 (28.1)	3126 (29.8)	
45–49	10205 (9.3)	1505 (14.7)	2355 (23.1)	3021 (29.6)	3324 (32.6)	
50–54	8685 (7.9)	1212 (14.0)	2004 (23.1)	2664 (30.7)	2805 (32.3)	
55–60	11781 (10.7)	1351 (11.5)	2458 (20.9)	3706 (31.5)	4266 (36.2)	
mean (SD)	37.5 (10.8)	33.1 (9.7)	36.8 (10.4)	39.6 (10.8)	40.7 (10.8)	<0.001
Sex						<0.001
Men	97655 (88.9)	22631 (23.2)	25262 (25.9)	25291 (25.9)	24471 (25.1)	
Women	12166 (11.1)	4845 (39.8)	2308 (19.0)	2046 (16.8)	2967 (24.4)	
Regions						<0.001
Bangkok	21174 (19.3)	5878 (27.8)	4116 (19.4)	4701 (22.2)	6479 (30.6)	
Central	34348 (31.3)	9375 (27.3)	8742 (25.5)	8394 (24.4)	7837 (22.8)	
Northeast	18828 (17.1)	4649 (24.7)	5443 (28.9)	4808 (25.5)	3928 (20.9)	
North	20900 (19.0)	4090 (19.6)	5672 (27.1)	5826 (27.9)	5312 (25.4)	
South	14571 (13.3)	3484 (23.9)	3597 (24.7)	3608 (24.8)	3882 (26.6)	
Health insurance scheme						<0.001
Civil servant medical benefits	105950 (96.7)	26186 (24.7)	26797 (25.3)	26577 (25.1)	26390 (24.9)	
Social security	2855 (2.6)	916 (32.1)	578 (20.2)	543 (19.0)	818 (28.7)	
Universal health coverage	823 (0.8)	288 (35.0)	160 (19.4)	186 (22.6)	189 (23.0)	
Body mass index, kg/m^2						<0.001
18.5–22.9	32993 (30.1)	19530 (59.2)	9950 (30.2)	2953 (9.0)	560 (1.7)	
<18.5	2292 (2.1)	2122 (92.6)	105 (4.6)	33 (1.4)	32 (1.4)	
23.0–24.9	25777 (23.5)	4475 (17.4)	11040 (42.8)	8426 (32.7)	1836 (7.1)	
25.0–29.9	36932 (33.7)	1235 (3.3)	6301 (17.1)	14923 (40.4)	14473 (39.2)	
≥30	11762 (10.7)	98 (0.8)	166 (1.4)	984 (8.4)	10514 (89.4)	
mean (SD)	25.0 (4.0)	27.4 (2.2)	23.7 (2.1)	25.6 (2.3)	29.4 (3.7)	<0.001
Systolic blood pressure, mmHg						<0.001
<140	88189 (80.9)	25140 (28.5)	23220 (26.3)	21194 (24.0)	18635 (21.1)	
≥140	20779 (19.1)	2171 (10.4)	4185 (20.1)	5997 (28.9)	8426 (40.6)	
mean (SD)	127.9 (15.7)	121.1 (13.8)	126.4 (14.7)	130.0 (15.3)	134.3 (15.9)	<0.001
Diastolic blood pressure, mmHg						<0.001
<90	93774 (86.1)	25817 (27.5)	24397 (26.0)	22792 (24.3)	20768 (22.1)	
≥90	15194 (13.9)	1494 (9.8)	3008 (19.8)	4399 (29.0)	6293 (41.4)	
Mean (SD)	77.3 (11.6)	72.3 (10.3)	76.1 (11.0)	79.0 (11.2)	82.0 (11.5)	<0.001

Table 1. Characteristics of study participants by body roundness index quartile (Cont.)

Characteristics	Overall	Body roundness index quartile				*p*-value
		Quartile 1	Quartile 2	Quartile 3	Quartile 4	
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	
High blood pressure, mmHg						<0.001
SBP <140 and DBP <90	83466 (76.6)	24491 (29.3)	22129 (26.5)	19861 (23.8)	16985 (20.3)	
SBP ≥140 or DBP ≥90	25502 (23.4)	2820 (11.1)	5276 (20.7)	7330 (28.7)	10076 (39.5)	
Fasting plasma glucose, mg/dL						<0.001
<126	46473 (90.2)	8509 (18.3)	11347 (24.4)	13249 (28.5)	13368 (28.8)	
≥126	5030 (9.8)	462 (9.2)	894 (17.8)	1395 (27.7)	2279 (45.3)	
mean (SD)	102.5 (34.8)	95.6 (29.4)	99.7 (32.0)	103.0 (34.7)	108.4 (38.8)	<0.001
Total cholesterol, mg/dL						<0.001
<240	40697 (73.7)	7446 (18.3)	9774 (24.0)	11290 (27.7)	12187 (29.9)	
≥240	14519 (26.3)	1991 (13.7)	3399 (23.4)	4524 (31.2)	4605 (31.7)	
mean (SD)	214.0 (49.5)	209.0 (48.9)	213.9 (47.4)	217.0 (50.9)	214.2 (50.0)	<0.001
Triglyceride, mg/dL						<0.001
<150	31908 (60.1)	6996 (21.9)	8365 (26.2)	8593 (26.9)	7954 (24.9)	
≥150	21194 (39.9)	2109 (10.0)	4359 (20.6)	6616 (31.2)	8110 (38.3)	
mean SD	163.0 (123.6)	126.0 (97.9)	150.6 (116.3)	172.0 (128.5)	185.5 (131.4)	<0.001
Serum uric acid, mg/dL						<0.001
<7 in men, <6 in women	35404 (64.6)	7053 (19.9)	8929 (25.2)	9796 (27.7)	9626 (27.2)	
≥7 in men, ≥6 in women	19408 (35.4)	2290 (11.8)	4139 (21.3)	5919 (30.5)	7060 (36.4)	
mean SD	6.4 (1.8)	5.9 (1.7)	6.3 (1.8)	6.5 (1.8)	6.6 (1.7)	<0.001
Exercise						<0.001
No	9306 (8.6)	2228 (23.9)	2509 (27.0)	2377 (25.5)	2192 (23.6)	
Irregular exercise	40615 (37.6)	9497 (23.4)	9506 (23.4)	10018 (24.7)	11594 (28.5)	
Regular exercise	58140 (53.8)	15284 (26.3)	15041 (25.9)	14514 (25.0)	13301 (22.9)	
Smoking						<0.001
Never	56064 (51.3)	14559 (26.0)	14019 (25)	13795 (24.6)	13691 (24.4)	
Ex-smoker	17649 (16.2)	3642 (20.6)	4390 (24.9)	4691 (26.6)	4926 (27.9)	
Current smoker (irregular)	15867 (14.5)	4034 (25.4)	4184 (26.4)	3839 (24.2)	3810 (24.0)	
Current smoker (regular)	19730 (18.1)	5121 (26.0)	4863 (24.6)	4875 (24.7)	4871 (24.7)	
Alcohol use						<0.001
Never	27451 (25.1)	7396 (26.9)	6676 (24.3)	6503 (23.7)	6876 (25.0)	
Ex-drinker	13709 (12.5)	3202 (23.4)	3506 (25.6)	3415 (24.9)	3586 (26.2)	
Current drinker (irregular)	60617 (55.4)	14954 (24.7)	15390 (25.4)	15350 (25.3)	14923 (24.6)	
Current drinker (regular)	7569 (6.9)	1807 (23.9)	1894 (25.0)	1942 (25.7)	1926 (25.4)	

SD: standard deviation, SBP: systolic blood pressure, DBP: diastolic blood pressure

hyperglycemia, high TC, high TG, and hyperuricemia were 9.8%, 26.3%, 39.9%, and 35.4%, respectively. The characteristics of the participants stratified by BRI quartile are shown in **Table 1.** The overall mean BRI was 3.5 (±1.2), with specific mean values of 2.2 (±0.4) in Q1, 3.0 (±0.2) in Q2, 3.6 (±0.2) in Q3, and 5.0 (±1.0) in Q4.

Linear regression model to determine the association between BRI and metabolic risk factors for CVD

A positive association between BRI and metabolic risk factors for CVD was observed, even after adjusting for covariates (**Table 2**). Specifically, there was a positive relationship with BP: the adjusted β-coefficients for SBP were 1.14, 2.18, and 2.97 for BRI quartiles 2, 3, and 4, respectively, when compared to quartile 1 (p-trend < 0.001). For DBP, the coefficients were 0.87, 1.77, and 2.47, respectively (p-trend < 0.001). Additional positive associations included FPG with coefficients of 0.70, 2.14, and 5.29; TC with coefficients of 5.30, 8.24, and 5.00; TG with coefficients of 15.64, 32.43, and 38.56; and serum uric acid levels with coefficients of 0.13, 0.23, and 0.24. All comparisons were against BRI quartile 1, with a p-trend < 0.001 for all associations.

Logistic regression model to determine the association between BRI and metabolic risk factors for CVD

Figure 1 shows the adjusted prevalence of metabolic risk factors for CVD by BRI quartile among active-duty RTA personnel. Higher BRI quartiles are associated with increased prevalence of high BP, hyperglycemia, high TC, hypertriglyceridemia, and hyperuricemia. The composite metabolic risk factor prevalence was 40.8%, 44.4%, 47.5%, and 48.2% across BRI quartiles 1-4, respectively. **Table 3** details a multivariable logistic regression analysis highlighting significant associations between BRI and various metabolic risk factors for CVD: high BP (APR 1.18, 1.28, 1.38 for quartiles 2, 3, and 4), hyperglycemia (APR 1.12, 1.31, 1.67), high TC (APR 1.21, 1.33, 1.25), hypertriglyceridemia (APR 1.27, 1.50, 1.59), and hyperuricemia (APR 1.11, 1.24, 1.26), all compared to quartile 1 (p-trend < 0.001). Additionally, participants with a higher BRI were more likely to present with a composite of metabolic risk factors or at least one metabolic risk factor, with APRs of 1.09, 1.17, and 1.18 for quartiles 2, 3, and 4, respectively, compared to quartile 1 (p-trend <0.001).

Table 4 illustrates the sex-specific associations between BRI and metabolic risk factors for CVD. The findings are consistent with the primary analysis; however, there is no statistically significant association between BRI and high TC in women. We observed effect measure modification of sex on the relationship between BRI and metabolic risk factors for CVD, including high BP, high TC, and hypertriglyceridemia. Compared to individuals in the first BRI quartile, those in the fourth BRI quartile had a higher prevalence of composite metabolic risk factors for CVD, with APRs of 1.18 in men and 1.23 in women (p for interaction < 0.001).

According to a sensitivity analysis, the E-value for the APR to identify the association between the unmeasured confounder and the BRI associated with CVD risk factors is presented in **Supplementary Table 1**.

Discussion

We observed an association between BRI and metabolic risk factors for CVD among a nationwide sample of active-duty RTA personnel in Thailand, after adjusting for covariates, including BMI. Our robust evidence from linear and logistic regression analysis highlights that BRI, an alternative anthropometric measure of body fat distribution, is positively associated with various metabolic risk factors for CVD, including high BP, hyperglycemia, high TC, hypertriglyceridemia, and hyperuricemia. An effect measure modification of sex on this association was observed.

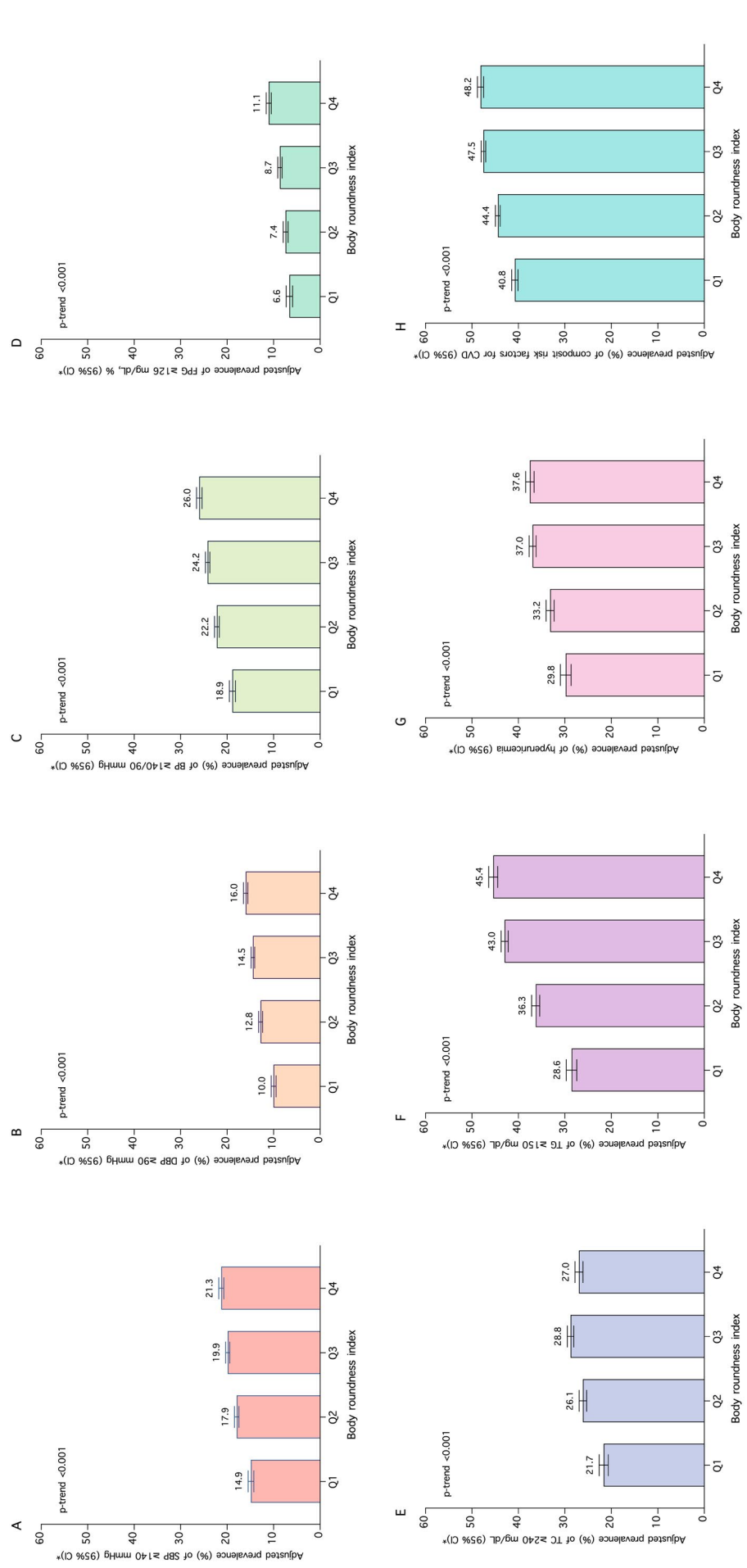
Our study demonstrated a dose-response relationship, showing a clear association between higher BRI and an increased prevalence of a composite set of metabolic risk factors for CVD. After adjusting for baseline covariates, including BMI, we found that the adjusted prevalence of the composite risk factors for CVD among individuals in BRI quartiles 2, 3, and 4 was estimated to be 9%, 17%, and 18% higher, respectively, than in BRI quartile 1. This pattern was consistent in both men and women. While a positive association was observed between higher BRI and various metabolic risk factors for CVD, this was not the case for TC. The adjusted

Table 2. Multivariable linear regression analysis for the association between BRI and metabolic risk factors for CVD in active-duty RTA personnel

Metabolic risk factors for CVD	Body roundness index				*p* for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Systolic blood pressure					
Unadjusted β (95% CI)	Ref.	5.25 (5.00–5.50)	8.88 (8.63–9.13)	13.20 (12.95–13.46)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	1.14 (0.89–1.39)	2.18 (1.90–2.46)	2.97 (2.61–3.34)	<0.001
p-value		<0.001	<0.001	<0.001	
Diastolic blood pressure					
Unadjusted β (95% CI)	Ref.	3.84 (3.65–4.02)	6.67 (6.48–6.85)	9.66 (9.47–9.84)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	0.87 (0.69–1.06)	1.77 (1.56–1.98)	2.47 (2.20–2.74)	<0.001
p-value		<0.001	<0.001	<0.001	
Fasting plasma glucose					
Unadjusted β (95% CI)	Ref.	4.03 (3.09–4.97)	7.29 (6.38–8.19)	12.71 (11.82–13.61)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	0.70 (-0.24–1.64)	2.14 (1.15–3.13)	5.29 (4.08–6.50)	<0.001
p-value		0.142	<0.001	<0.001	
Total cholesterol					
Unadjusted β (95% CI)	Ref.	4.92 (3.61–6.23)	7.93 (6.67–9.19)	5.19 (3.94–6.43)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	5.30 (4.01–6.58)	8.24 (6.89–9.59)	5.00 (3.36–6.65)	<0.001
p-value		<0.001	<0.001	<0.001	
Triglyceride					
Unadjusted β (95% CI)	Ref.	24.61 (21.34–27.89)	46.01 (42.85–49.17)	59.54 (56.41–62.68)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	15.64 (12.29–18.99)	32.43 (28.91–35.95)	38.46 (34.16–42.77)	<0.001
p-value		<0.001	<0.001	<0.001	
Serum uric acid					
Unadjusted β (95% CI)	Ref.	0.43 (0.38–0.47)	0.63 (0.59–0.68)	0.74 (0.69–0.78)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted β (95% CI)*	Ref.	0.13 (0.09–0.17)	0.23 (0.19–0.28)	0.24 (0.19–0.30)	<0.001
p-value		<0.001	<0.001	<0.001	

*Adjusted for age, sex, geographical region, health insurance scheme, alcohol intake, smoking status, exercise, and body mass index

CI: confidence interval, CVD: cardiovascular disease, BRI: body roundness index, RTA; Royal Thai Army



*Adjusting for age, sex, geographical region, health insurance scheme, alcohol intake, smoking status, exercise, and body mass index

Figure 1. Average adjusted prediction of the prevalence of (A) high systolic blood pressure, (B) high diastolic blood pressure, (C) high blood pressure, (D) hyperglycemia, (E) high total cholesterol, (F) hypertriglyceridemia, (G) hyperuricemia, and (H) composite of metabolic risk factors for CVD, stratified by body roundness index quartile

Table 3. Multivariable logistic regression analysis for the association between BRI and metabolic risk factors for CVD in active-duty RTA personnel

Metabolic risk factors for CVD	Body roundness index				*p* for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
High systolic BP					
Unadjusted PR (95% CI)	Ref.	1.92 (1.83–2.02)	2.77 (2.65–2.91)	3.92 (3.75–4.09)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.20 (1.14–1.26)	1.32 (1.26–1.39)	1.66 (1.57–1.75)	<0.001
p-value		<0.001	<0.001	<0.001	
High diastolic BP					
Unadjusted PR (95% CI)	Ref.	2.01 (1.89–2.13)	2.96 (2.80–3.13)	4.25 (4.03–4.49)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.28 (1.21–1.36)	1.45 (1.36–1.53)	1.60 (1.50–1.71)	<0.001
p-value		<0.001	<0.001	<0.001	
High BP					
Unadjusted PR (95% CI)	Ref.	1.86 (1.79–1.95)	2.61 (2.51–2.72)	3.61 (3.47–3.75)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.18 (1.13–1.22)	1.28 (1.23–1.33)	1.38 (1.32–1.44)	<0.001
p-value		<0.001	<0.001	<0.001	
Hyperglycemia					
Unadjusted PR (95% CI)	Ref.	1.42 (1.27–1.58)	1.85 (1.67–2.05)	2.83 (2.57–3.11)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.12 (1.00–1.26)	1.31 (1.17–1.47)	1.67 (1.47–1.90)	<0.001
p-value		0.052	<0.001	<0.001	
High total cholesterol					
Unadjusted PR (95% CI)	Ref.	1.22 (1.17–1.28)	1.36 (1.29–1.42)	1.3 (1.24–1.36)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.21 (1.15–1.27)	1.33 (1.26–1.40)	1.25 (1.17–1.33)	<0.001
p-value		<0.001	<0.001	<0.001	
Hypertriglyceridemia					
Unadjusted PR (95% CI)	Ref.	1.48 (1.41–1.55)	1.88 (1.80–1.96)	2.18 (2.09–2.27)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.27 (1.22–1.33)	1.50 (1.44–1.57)	1.59 (1.51–1.67)	<0.001
p-value		<0.001	<0.001	<0.001	
Hyperuricemia					
Unadjusted PR (95% CI)	Ref.	1.29 (1.24–1.35)	1.54 (1.48–1.6)	1.73 (1.66–1.8)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*	Ref.	1.11 (1.07–1.16)	1.24 (1.19–1.30)	1.26 (1.20–1.32)	<0.001
p-value		<0.001	<0.001	<0.001	
Composite of metabolic risk factors for CVD					
Unadjusted PR (95% CI)	Ref.	1.69 (1.65–1.74)	2.24 (2.19–2.3)	2.64 (2.58–2.7)	<0.001
p-value		<0.001	<0.001	<0.001	
Adjusted PR (95% CI)*`	Ref.	1.09 (1.07–1.11)	1.17 (1.14–1.19)	1.18 (1.15–1.21)	<0.001
p-value		<0.001	<0.001	<0.001	

*Adjusted for age, sex, geographical region, health insurance scheme, alcohol intake, smoking status, exercise, and body mass index PR: prevalence ratio, CI: confidence interval, CVD: cardiovascular disease, BP: blood pressure, BRI: body roundness index, RTA; Royal Thai Army

Table 4. Multivariable logistic regression analysis for the association between BRI and metabolic risk factors for CVD in active-duty RTA personnel stratified by sex

Metabolic risk factors for CVD	Body roundness index				*p* for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
High systolic BP					
Men					
Adjusted PR (95% CI)*	Ref.	1.19 (1.14–1.26)	1.32 (1.26–1.39)	1.39 (1.32–1.48)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.25 (1.02–1.54)	1.41 (1.15–1.73)	1.87 (1.49–2.33)	<0.001
p-value	Ref.	0.033	0.001	<0.001	
***p* for interaction**		0.320	0.111	<0.001	
High diastolic BP					
Men					
Adjusted PR (95% CI)*	Ref.	1.26 (1.19–1.34)	1.43 (1.35–1.52)	1.57 (1.47–1.67)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.63 (1.24–2.14)	1.66 (1.25–2.20)	2.22 (1.63–3.02)	<0.001
p-value	Ref.	0.001	0.001	<0.001	
***p* for interaction**		0.346	0.795	0.098	
High BP					
Men					
Adjusted PR (95% CI)*	Ref.	1.16 (1.12–1.21)	1.27 (1.22–1.33)	1.35 (1.29–1.42)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.24 (1.04–1.48)	1.29 (1.08–1.55)	1.71 (1.40–2.08)	<0.001
p-value	Ref.	0.015	0.005	<0.001	
***p* for interaction**		0.415	0.676	<0.001	
Hyperglycemia					
Men					
Adjusted PR (95% CI)*	Ref.	1.10 (0.97–1.24)	1.25 (1.14–1.45)	1.61 (1.41–1.84)	<0.001
p-value	Ref.	0.145	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.46 (1.01–2.12)	1.51 (1.03–2.21)	2.39 (1.60–3.59)	<0.001
p-value	Ref.	0.047	0.036	<0.001	
***p* for interaction**		0.379	0.898	0.436	
High total cholesterol					
Men					
Adjusted PR (95% CI)*	Ref.	1.24 (1.17–1.31)	1.38 (1.31–1.47)	1.31 (1.22–1.40)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.09 (0.95–1.23)	1.04 (0.90–1.20)	0.94 (0.80–1.12)	0.558
p-value	Ref.	0.205	0.562	0.486	
***p* for interaction**		0.590	0.012	<0.001	

Table 4. Multivariable logistic regression analysis for the association between BRI and metabolic risk factors for CVD in active-duty RTA personnel stratified by sex

Metabolic risk factors for CVD	Body roundness index				*p* for trend
	Quartile 1	Quartile 2	Quartile 3	Quartile 4	
Hypertriglyceridemia					
Men					
Adjusted PR (95% CI)*	Ref.	1.29 (1.23–1.35)	1.52 (1.45–1.59)	1.59 (1.51–1.68)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.20 (0.95–1.32)	1.47 (1.25–1.73)	1.71 (1.43–2.06)	<0.001
p-value	Ref.	0.169	<0.001	<0.001	
***p* for interaction**		0.004	0.009	0.024	
Hyperuricemia					
Men					
Adjusted PR (95% CI)*	Ref.	1.13 (1.08–1.18)	1.24 (1.19–1.30)	1.26 (1.19–1.33)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	0.97 (0.84–1.13)	1.19 (1.02–1.38)	1.34 (1.12–1.59)	<0.001
p-value	Ref.	0.743	0.029	0.001	
***p* for interaction**		0.030	0.244	0.994	
Composite of metabolic risk factors for CVD					
Men					
Adjusted PR (95% CI)*	Ref.	1.01 (1.08–1.12)	1.17 (1.15–1.20)	1.18 (1.15–1.21)	<0.001
p-value	Ref.	<0.001	<0.001	<0.001	
Women					
Adjusted PR (95% CI)*	Ref.	1.05 (0.98–1.13)	1.07 (0.99–1.16)	1.23 (1.12–1.34)	<0.001
p-value	Ref.	0.155	0.075	<0.001	
***p* for interaction**		<0.001	<0.001	<0.001	

*Adjusted for age, geographical region, health insurance scheme, alcohol intake, smoking status, exercise, and body mass index

PR: prevalence ratio, CI: confidence interval, CVD: cardiovascular disease, BP: blood pressure, BRI: body roundness index, RTA; Royal Thai Army

prevalence of high TC was 21.7%, 26.1%, 28.8%, and 27.0% among individuals in BRI quartiles 1, 2, 3, and 4, respectively. These findings were also consistent across both men and women.

We found that sex modifies the association between high BRI and metabolic risk factors for CVD. Specifically, individuals in the highest BRI quartile (Q4) exhibited a 35% higher prevalence of high BP in men and a 71% higher prevalence in women compared to those in the lowest quartile (Q1). For hypertriglyceridemia, the prevalence was 59% higher in men and 71% higher in women in Q4 versus Q1. Conversely, high TC was 31% higher in men but 6% lower in women in Q4 compared to Q1. Our findings highlight that women RTA personnel with a BRI in the highest quartile (Q4; BRI ≥4.0) should be aware that they are more prone to have multiple metabolic risk factors for CVD when compared to men with a comparable BRI quartile.

Previous studies have shown a relationship between BRI and the incidence of CVD, indicating that a higher BRI is associated with an increased risk of CVD.[13] Comparative

analyses of BMI, a traditional anthropometric measure, have demonstrated that BRI is superior in predicting CVD and diabetes risk.[25] Unlike BMI, which does not directly measure body composition, BRI incorporates waist circumference as a cofactor, serving as a surrogate measure of central obesity. Central obesity is linked to visceral fat, insulin resistance, dyslipidemia, and a heightened risk of CVD. (11) Therefore, BRI may be a better predictor of CVD risk than BMI. As a new indicator of abdominal obesity, the potential mechanisms linking BRI to CVD risk include: central obesity, which is associated with insulin resistance and glucose intolerance, leading to hyperinsulinemia, atherogenic changes in blood lipid levels, hypertension, and diabetes. All of these factors contribute to an increased risk of CVD.[25–27]

Potential confounders may still exist even after incorporating covariates into the multivariable analysis. Our sensitivity analysis indicated that a minimal level of unmeasured confounding would be needed to alter the association between BRI and each metabolic risk factor, as well as the overall metabolic risk for CVD. Therefore, the results should be interpreted with caution.

Our research demonstrated that metabolic risk variables for CVD are more common in active-duty RTA personnel with a higher BRI. RTA personnel's yearly health checkups should include BRI evaluations, as they may help determine and communicate their risk. Based on our findings, targeted treatments and counseling should be implemented. Specifically, individuals with a high BRI, defined as a score of 4.0 or greater, should be closely monitored and encouraged to adopt lifestyle modifications aimed at reducing their metabolic risk factors for CVD and potential CVD events in the future. Further research is needed to assess how lifestyle changes affect BRI alterations in this study group and how BRI affects CVD events over the long run.

Our study's strengths included a large sample size, and our conclusions offer insights that may improve primary prevention strategies for CVD in this population. However, this study does have some limitations. First, it was designed as a cross-sectional study, so we cannot establish a causal relationship between exposure and outcomes. Second, we included only participants with WC and height data required to calculate the BRI in our analysis. Because data on each CVD metabolic risk factor were not uniform, we evaluated the association between BRI and each risk factor separately, using available data. Since the missing data may not be random, this could introduce selection bias. Third, we did not have the opportunity to assess dietary habits among this population. Consequently, although we used a multivariable analysis to account for confounders, residual confounding may still be present and bias the findings. Fourth, the study enrolled active-duty RTA personnel, who comprised a significantly higher proportion of male participants (88.9% of the sample). The results were consistent for both sexes, but we also showed sex-specific relationships between BRI and metabolic risk factors for CVD, which is in line with the real situation in this military group.

Conclusion

Our findings indicate that a higher BRI is significantly associated with an increased prevalence of metabolic risk factors for CVD among active-duty RTA personnel. An effect measure modification of sex on this association was observed. In addition to BMI, BRI, which is an anthropometric indicator of central obesity, may be a useful tool for identifying those who are more likely to develop CVD, enabling early identification.

Availability of data and materials

The data that support the findings of this study are available from the Royal Thai Army Medical Department, but restrictions apply to their availability. These data were used under license for the current study and are therefore not publicly available. Data are, however, available from the authors upon reasonable request and with permission of the Royal Thai Army Medical Department (contact Boonsub Sakboonyarat via boonsub1991@pcm.ac.th).

Authors' contributions

JP conceived the study, interpreted the data, and drafted the manuscript. NW, NT, KJ, PS,

PH, MM, RR conducted the study concept, data collection, and data interpretation. BS conceived the study, analyzed and interpreted the data, and wrote and edited the manuscript. All authors read and approved the final manuscript.

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References

1. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study. J Am Coll Cardiol 2020; 76: 2982–3021.
2. World Health Organization. Cardiovascular diseases (CVDs) [Internet]. Geneva: World Health Organization; 2021 [cited 2025 Jul 20]. Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds
3. World Health Organization. WHO Mortality Database [Internet]. Geneva: World Health Organization; 2021 [cited 2025 Jul 20]. Available from: https://platform.who.int/mortality/themes/theme-details/topics/topic-details/MDB/cardiovascular-diseases
4. World Health Organization. Obesity [Internet]. Geneva: World Health Organization; 2025 [cited 2025 Jul 20]. Available from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
5. Ng M, Gakidou E, Lo J, Abate YH, Abbafati C, Abbas N, et al. Global, regional, and national prevalence of adult overweight and obesity, 1990–2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021. Lancet 2025; 405: 813–38.
6. Aekplakorn W. Thai National Health Examination Survey VI (2019-2020) [Internet]. Nonthaburi: Health Systems Research Institute; 2021 [cited 2023 Oct 3]. Available from: https://online.fliphtml5.com/bcbgj/znee/#p=187
7. Jongcherdchootrakul K, Poovieng J, Hempatawee N, Hatthachote P, Mungthin M, Rangsin R, et al. Rising trends in body mass index and obesity prevalence among young Thai men: a 16-year analysis of new military conscript data (2009–2024). BMC Res Notes. 2026; [Epub ahead of print].
8. Sakboonyarat B, Pornpongsawad C, Sangkool T, Phanmanas C, Kesonphaet N, Tangthongtawi N, et al. Trends, prevalence and associated factors of obesity among adults in a rural community in Thailand: serial cross-sectional surveys, 2012 and 2018. BMC Public Health 2020; 20: 850.
9. Sakboonyarat B, Poovieng J, Jongcherdchootrakul K, Srisawat P, Hatthachote P, Mungthin M, et al. Rising trends in obesity prevalence among Royal Thai Army personnel from 2017 to 2021. Sci Rep 2022; 12: 7726.
10. Adab P, Pallan M, Whincup PH. Is BMI the best measure of obesity? BMJ [Internet]. 2018;360:k1274. Available from: https://www.bmj.com/content/360/bmj.k1274
11. Medina-Inojosa JR, Batsis JA, Supervia M, Somers VK, Thomas RJ, Jenkins S, et al. Relation of waist-hip ratio to long-term cardiovascular events in patients with coronary artery disease. Am J Cardiol 2018; 121: 903–9.
12. Thomas DM, Bredlau C, Bosy-Westphal A, Mueller M, Shen W, Gallagher D, et al. Relationships between body roundness with body fat and visceral adipose tissue emerging from a new geometrical model. Obesity (Silver Spring). 2013; 21: 2264–71.

13. Yang M, Liu J, Shen Q, Chen H, Liu Y, Wang N, et al. Body roundness index trajectories and the incidence of cardiovascular disease: evidence from the China health and retirement longitudinal study. J Am Heart Assoc 2024; 13: e034768.
14. He X, Zhu J, Liang W, Yang X, Ning W, Zhao Z, et al. Association of body roundness index with cardiovascular disease in patients with cardiometabolic syndrome: a cross-sectional study based on NHANES 2009-2018. Front Endocrinol (Lausanne). 2025; 16: 1524352.
15. Somdee T, Somdee T, Yangyuen S, Mungvongsa A, Khiewkhern S, Puapittayathorn T, et al. Screening tools for metabolic syndrome based on anthropometric cut-off values among Thai working adults: a community-based study. Ann Saudi Med 2023; 43: 291–7.
16. Poovieng J, Jongcherdchootrakul K, Srisawat P, Mungthin M, Rangsin R, Sakboonyarat B. Rising trends in current tobacco use among active-duty personnel of the Royal Thai Army in Thailand from 2017 to 2022 and its associated metabolic risk factors for cardiovascular disease in 2022. J Southeast Asian Med Res 2024; 8: e0198.
17. Sakboonyarat B, Sangkool T, Poovieng J, Jongcherdchootrakul K, Srisawat P, Hatthachote P, et al. Trends in the prevalence of type 2 diabetes among Royal Thai Army personnel and associated factors from 2017 to 2021. J Southeast Asian Med Res 2023; 7: e0160.
18. Sakboonyarat B, Poovieng J, Jongcherdchootrakul K, Srisawat P, Hatthachote P, Mungthin M, et al. Prevalence of hypertriglyceridemia among Royal Thai Army personnel and its related cardiometabolic risk factors, from 2017 to 2021. BMC Public Health. 2022; 22: 1569.
19. Sakboonyarat B, Poovieng J, Jongcherdchootrakul K, Srisawat P, Hatthachote P, Mungthin M, et al. Trends in serum total cholesterol and high total cholesterol prevalence among Royal Thai Army personnel in Thailand, 2017–2022. High Blood Press Cardiovasc Prev 2023; 30: 1–12.
20. Sakboonyarat B, Poovieng J, Srisawat P, Hatthachote P, Mungthin M, Rangsin R, et al. Prevalence, awareness, and control of hypertension and associated factors among Royal Thai Army personnel in Thailand from 2017 to 2021. Sci Rep 2023; 13: 6946.
21. Kunanon S, Chattranukulchai P, Chotruangnapa C, Kositanurit W, Methavigul K, Boonyasirinant T, et al. 2019 Thai guidelines on the treatment of hypertension: executive summary. J Med Assoc Thai 2021; 104: 1729–38.
22. Lertsakulbunlue S, Sangkool T, Bhuriveth V, Mungthin M, Rangsin R, Kantiwong A, et al. Associations of triglyceride-glucose index with hyperuricemia among Royal Thai Army personnel. BMC Endocr Disord 2024; 24: 17.
23. Sakboonyarat B, Rangsin R, Mittleman MA. Incidence and risk factors of metabolic syndrome among Royal Thai Army personnel. Sci Rep 2022; 12: 1–11.
24. Linden A, Mathur MB, VanderWeele TJ. Conducting sensitivity analysis for unmeasured confounding in observational studies using E-values: the evalue package. Stata J 2020; 20: 162–75.
25. Liu Y, Liu X, Guan H, Zhang S, Zhu Q, Fu X, et al. Body roundness index is a superior obesity index in predicting diabetes risk among hypertensive patients: a prospective cohort study in China. Front Cardiovasc Med 2021; 8: 736073.
26. Piché ME, Tchernof A, Després JP. Obesity phenotypes, diabetes, and cardiovascular diseases. Circ Res 2020; 126: 1477–500.
27. Bhupathiraju SN, Hu FB. Epidemiology of obesity and diabetes and their cardiovascular complications. Circ Res 2016; 118: 1723–35.