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Sonographic assessment of carotid intima-media thickness in healthy young Thai adults

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ABSTRACT

Purpose: Early detection of carotid stenosis can reduce cardiovascular risk. In this study, the maximum-carotid intima-media thickness (CIMT), the mean-CIMT, and the presence of plaque were examined in healthy young Thai adults. Additionally, correlations between CIMT and cardiovascular risk factors were assessed.

Materials and Methods: Left and right carotid arteries of 302 participants (15-45 years old) were scanned, with CIMT measured at the far walls of the common carotid artery, carotid bulb, and internal carotid artery. Demographics and risk factors were assessed using a questionnaire. Ten random participants were re-scanned after 4 weeks.

Results: The study included 123 (40.70%) male and 179 (59.30%) female participants. The max-CIMT, mean-CIMT, and plaque thickness were 0.400±0.100, 0.403±0.095 and 1.520±0.814 mm, respectively. Male participants had significantly higher CIMT values for nearly all locations and age groups. The right-sided CIMT values were higher for all locations. The carotid bulb had the greatest CIMT values (0.437±0.178 mm), followed by the common (0.403±0.095 mm) and internal (0.361±0.099 mm) carotid arteries. Plaque was present in 18 locations (1.00%), affecting 15 participants (4.97%). These plaques were found in the right carotid bulb (n=9; 0.50%), left carotid bulb (n=7; 0.39%), and right internal carotid artery (n=2; 0.11%). Adjusted multivariable regression revealed significant positive associations between CIMT and male, increased age and "other" occupation ($P<0.05$).

Conclusion: Both max-CIMT and mean-CIMT were approximately 0.4 mm. Plaque was observed in 4.97% of patients, with an average thickness of 1.5 mm. The most influential risk factors for increased CIMT were sex, age, and occupation. ***(Imaging Sci Dent 2023; 53: 291-302)***

KEY WORDS: Carotid Intima-Media Thickness; Heart Disease Risk Factors; Ultrasonography; Young Adult

Introduction

Carotid stenosis is a condition characterized by varying degrees of narrowing of the carotid artery, classified as mild (less than 30%), moderate (30%-69%), and severe (70%-99%). The severity of carotid stenosis is directly proportional to the risk of cerebrovascular diseases or stroke. The European Carotid Surgery Trial conducted an analysis of the risks associated with progressive stenosis. The findings revealed a minimal 3-year risk of ipsilateral ischemic stroke for mild stenosis, an escalating incidence of stroke for moderate stenosis with an ambiguous benefit provided by surgery, and the emergence of adverse stroke events outweighing the surgical risk of 30-day perioperative death for severe stenosis.[1] The onset of this condition is marked by the accumulation of plaque within the artery, a process known as carotid atherosclerosis.

The carotid arterial wall is composed of 3 distinct layers: the intima, media, and adventitia. The pathogenesis of early carotid atherosclerosis results in an increase in vascular wall thickness and spontaneous vessel dilatation. Consequently, carotid intima-media thickness (CIMT) is utilized as a predictor for cerebrovascular diseases.[2] The European Society of Cardiology guidelines identify a 0.9 mm CIMT at the common carotid artery as indicative of the onset of asymptomatic vascular damage.[3] The Japan Society of Ultrasonics in Medicine highlights several CIMT parameters, but recom-

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mends mean-CIMT, maximum CIMT (max-CIMT), and the presence of plaque as predictors of cardiovascular diseases.[4] Mean-CIMT is calculated as the average of the bilateral common carotid artery values, whereas max-CIMT is the average value derived from all bilateral locations, including the common carotid artery, the carotid bulb and the internal carotid artery. The presence of plaque is defined as any focal thickening of the vascular wall exceeding 1 mm.[4] The predictive value for cardiovascular diseases is highest when max-CIMT is combined with the presence of plaque, while the lowest predictive value is associated with using mean-CIMT alone.[4,5] Over the past 30 years, the use of ultrasonography to measure CIMT has gained popularity in numerous studies for the detection of early vascular changes in patients at risk of cardiovascular diseases. It is considered an accurate screening method.[6-8] Asymptomatic carotid stenosis refers to the presence of carotid atherosclerosis without a recent history of ipsilateral carotid territory ischemic stroke or transient ischemic attack. Ultrasonographic screening of CIMT offers a sensitivity of 98% (95% CI, 97% to 100%) and a specificity of 88% (95% CI, 76% to 100%) for detecting carotid atherosclerosis of 50% or greater.[7] More than half of older individuals with asymptomatic carotid stenosis (those over 65 years) experience more stroke complications than younger age group.[9,10] However, although younger adults have lower mortality rates, a better potential for recovery and fewer disabilities, the recurrence of asymptomatic carotid stenosis in younger adults can lead to a higher risk of mortality.[10]

The evolving behaviors of young adults contribute to several major risk factors for carotid atherosclerosis. These actions include early initiation of smoking, frequent consumption of alcohol, and physical inactivity, which can lead to an increased body mass index (BMI), elevated blood pressure, and high blood sugar levels.[10] Moreover, early detection of carotid atherosclerosis could facilitate behavioral modifications at a younger age, a strategy suggested as the most effective prevention for cardiovascular diseases in the 21st century.[8] Numerous studies have explored the relationship between CIMT and risk factors for cardiovascular diseases in healthy young adults.[11-16] However, to date, no data has been published on this relationship in the healthy young Thai population. This study was conducted to determine the max-CIMT, mean-CIMT, and presence of plaque in healthy Thai adults aged 15-45 years. It also sought to correlate their CIMT values with associated risk factors for cardiovascular diseases, using non-invasive B-mode ultrasound.

Materials and Methods

A total of 302 participants, satisfying the inclusion and exclusion criteria, were recruited from the outpatient pool at the Radiology Clinic, Faculty of Dentistry, Chulalongkorn University between June 2020 and September 2021. The inclusion criteria specified healthy Thai individuals, aged between 15 and 45 years, with no known medical conditions or regular medication use. The exclusion criteria ruled out those with a history of carotid endarterectomy, recent tracheostomy, or pregnancy. The clinical information collected from each participant included demographic information such as age, sex, occupation, education level, and salary level. Additionally, data regarding the United States Centers for Disease Control and Prevention's primary cardiovascular risk factors were gathered through a self-reported questionnaire. These factors included cigarette smoking, alcohol consumption, physical activity, and a history of familial diseases such as diabetes mellitus, dyslipidemia, hypertension, coronary heart disease, and stroke. Physical measurements were also taken, including blood pressure, pulse rate, body weight, body height, waist circumference (following the World Health Organization [WHO] protocol), and neck circumference (measured at the seventh cervical vertebra or the most protruding part of the neck). Following these measurements, pulse pressure and BMI were calculated. Pulse pressure was determined as the difference between systolic and diastolic blood pressure (mmHg), while BMI was calculated as weight (kg) divided by the square of height (m^2).

The ultrasonographic assessment of CIMT was conducted with the participants in a semi-upright position, utilizing a high-resolution B-mode ultrasound device (Xario 100; Canon Medical Systems USA, Inc., Tustin, CA, USA) equipped with a 7.5-MHz linear probe and a focus depth of 30-40 mm. This was in accordance with the protocols of the Japan Society of Ultrasonics in Medicine.[4] Three operators, consisting of a third-year resident in oral and maxillofacial radiology and 2 oral and maxillofacial radiologists, were trained and calibrated for this task under the guidance of a medical ultrasound radiologist. Each participant was separately scanned by at least 2 operators, with 10 participants examined by all 3 operators. The CIMT was measured at the far wall in the longitudinal plane using a manual measurement mode at 3 locations on each side, as depicted in Figure 1. To assess intra-operator repeatability, 10 cases were randomly selected and rescanned by the same operators after a 4-week interval. All participants provided informed consent, and the study received approval from the

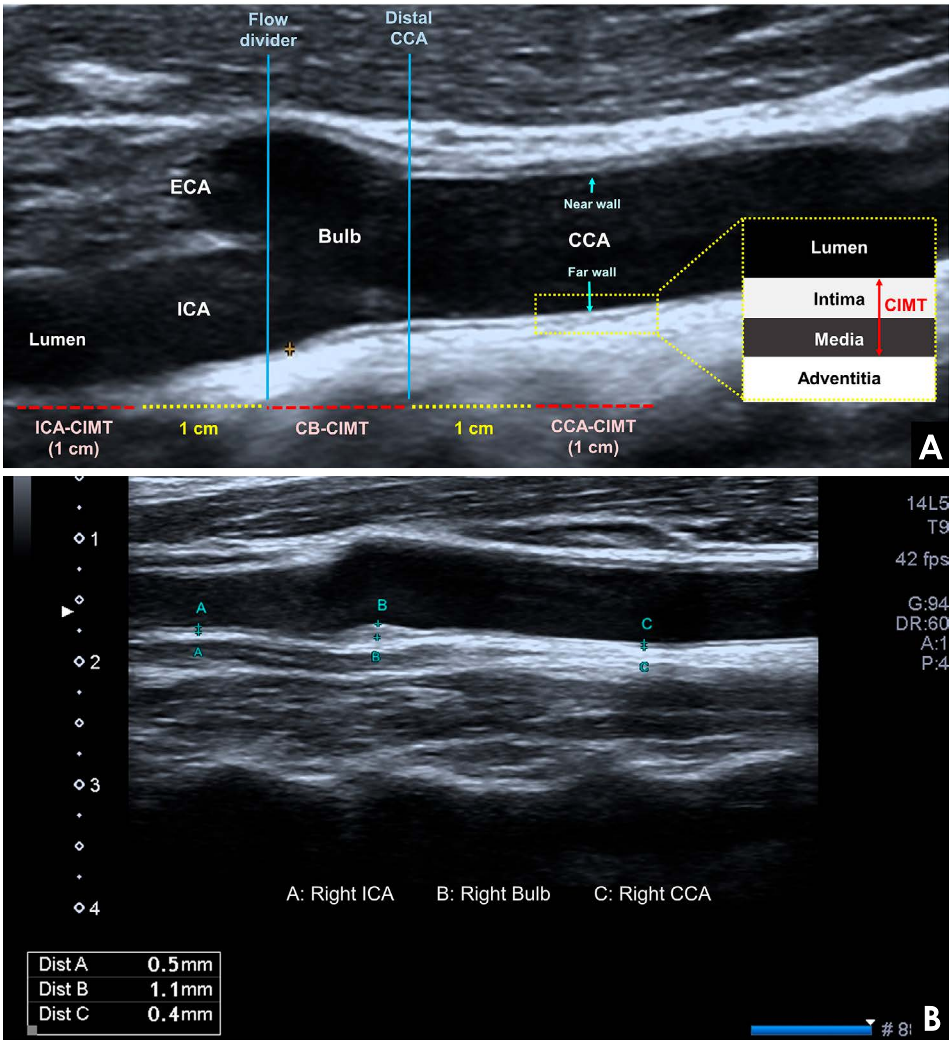

Fig. 1. A. Carotid intima-media thickness (CIMT) is defined as the distance between the lumen-intima interface (the upper bright line) and the media-adventitia interface (the lower bright line) on the far wall. The protocols for measuring CIMT were applied bilaterally at 3 locations: the common carotid artery (1 centimeter below the distal common carotid artery), the carotid bifurcation (from the flow divider to the distal common carotid artery), and the internal carotid artery (1 centimeter above the flow divider). B. Sonographic image of CIMT measurement at the 3 levels.

Human Research Ethics Committee at Chulalongkorn University (HREC-DCU 2020-049).

The CIMT values obtained from multiple operators were averaged for subsequent analysis. Three parameters - max-CIMT, mean-CIMT, and the presence of plaque - were computed. The Shapiro-Wilk and Kolmogorov-Smirnov tests were utilized for normality testing. Following this, to test for any relationship among clinical profiles with participant's sex, Pearson chi-square analysis was conducted for non-parametric categorical data, while the Mann-Whitney *U* test was utilized for non-parametric continuous data. To compare CIMT values among risk factors, the Mann-Whitney *U* test (for 2 non-parametric groups) and the Kruskal-Wallis test (for more than 2 non-parametric groups) were used. Multiple regression analysis was performed to identify the risk factors that were significantly associated with increased CIMT in young adults. Results were reported with 95% confidence intervals (CIs). The intraclass correlation coefficient (ICC) was used to determine inter- and intra-operator reliability, and the values were interpreted based on the method proposed by Altman.[17] All statistical analysis was performed with SPSS version 22.0 (IBM, Armonk, NY, USA).

Results

A total of 1,812 CIMT values were recorded from 302 young Thai adults. Their clinical profiles are presented in Table 1. The participants included 123 men (40.70%) and 179 women (59.30%), with a mean age of 32.13 ± 9.37 years. Most participants were salaried employees (61.59%: including both private sector employees and government officers) and students (19.87%). The majority held a bachelor's degree (60.60%) and had standard incomes (57.95%). No significant relationship was found between sex and age or socioeconomic status ($P>0.05$). Significantly more

Table 1. Clinical profile of enrolled participants by sex

		Males (n = 123)	Females (n = 179)	All (n = 302)
Age (years)		31.68 ± 7.71	32.44 ± 10.36	32.13 ± 9.37
Body mass index (kg/m^2)*		24.51 ± 4.33	23.31 ± 5.52	23.80 ± 5.09
Waist circumference (cm)*		85.71 ± 11.96	77.13 ± 13.15	80.62 ± 13.35
Neck circumference (cm)*		37.66 ± 2.99	32.76 ± 2.84	34.75 ± 3.77
Systolic blood pressure (mmHg)*		128.15 ± 15.02	116.23 ± 13.38	121.08 ± 15.22
Diastolic blood pressure (mmHg)*		77.11 ± 12.83	70.89 ± 10.85	73.43 ± 12.07
Pulse rate (bpm)*		79.62 ± 13.00	82.46 ± 12.04	81.30 ± 12.50
Pulse pressure (mmHg)*		51.03 ± 11.14	45.34 ± 10.20	47.66 ± 10.94
Occupation				
Student		20 (6.62%)	40 (13.25%)	60 (19.87%)
Employee		22 (7.28%)	29 (9.60%)	51 (16.89%)
Government officer		64 (21.19%)	71 (23.51%)	135 (44.70%)
Businessman		8 (2.65%)	9 (2.98%)	17 (5.63%)
Freelancer		8 (2.65%)	19 (6.29%)	27 (8.94%)
Other †		1 (0.33%)	11 (3.64%)	12 (3.97%)
Education				
Under bachelor's degree		29 (9.60%)	40 (13.25%)	69 (22.85%)
Bachelor's degree		77 (25.50%)	106 (35.10%)	183 (60.60%)
Above bachelor's degree		17 (5.63%)	33 (10.93%)	50 (16.56%)
Salary (baht/month)				
< 15,000		36 (11.92%)	48 (15.89%)	84 (27.81%)
15,000-40,000		72 (23.84%)	103 (34.11%)	175 (57.95%)
> 40,000		15 (4.97%)	28 (9.27%)	43 (14.24%)
Smoking*				
None		85 (28.15%)	172 (56.95%)	257 (85.10%)
Current smoker		23 (7.62%)	3 (0.99%)	26 (8.61%)
Ex-smoker		15 (4.97%)	4 (1.32%)	19 (6.29%)
Alcohol consumption (drinks‡/day)*				
None		72 (23.84%)	164 (54.30%)	236 (78.15%)
1-2		35 (11.59%)	14 (4.64%)	49 (16.23%)
3-4		7 (2.32%)	1 (0.33%)	8 (2.65%)
> 4		9 (2.98%)	0 (0.00%)	9 (2.98%)
Physical activity (mins/week)*				
< 75		54 (17.88%)	119 (39.40%)	173 (57.28%)
75-150		28 (9.27%)	28 (9.27%)	56 (18.54%)
151-300		25 (8.28%)	20 (6.62%)	45 (14.90%)
> 300		16 (5.30%)	12 (3.97%)	28 (9.27%)
Familial history				
Hypertension*	No	71 (23.51%)	66 (21.85%)	137 (45.36%)
	Yes	52 (17.22%)	113 (37.42%)	165 (54.64%)
Dyslipidemia*	No	101 (33.44%)	118 (39.07%)	219 (72.52%)
	Yes	22 (7.28%)	61 (20.20%)	83 (27.48%)
Coronary heart disease	No	116 (38.41%)	161 (53.31%)	277 (91.72%)
	Yes	7 (2.32%)	18 (5.96%)	25 (8.28%)
Stroke	No	116 (38.41%)	157 (51.99%)	273 (90.40%)
	Yes	7 (2.32%)	22 (7.28%)	29 (9.60%)
Diabetes mellitus*	No	68 (22.52%)	73 (24.17%)	141 (46.69%)
	Yes	55 (18.21%)	106 (35.10%)	161 (53.31%)

*: $P < 0.05$ compared with males for each risk factor, †: motorbike taxi-driver, housewife, and worker for hire, ‡: 1 drink = 10 g ethanol

Table 2. Sex-based comparison of carotid intima-media thickness (CIMT) and CIMT parameters for various locations and age groups (unit: mm)

	Locations and age groups	Males (n = 123)	Females (n = 179)	All (n = 302)
Max-CIMT*		0.434 ± 0.110	0.377 ± 0.085	0.400 ± 0.100
CIMT from all locations (common carotid artery, carotid bulb, and internal carotid artery)	Right-CIMT*	0.437 ± 0.115	0.381 ± 0.098	0.404 ± 0.109
	Left-CIMT*	0.431 ± 0.124	0.374 ± 0.090	0.397 ± 0.109
	15-25 years*	0.370 ± 0.082	0.333 ± 0.056	0.349 ± 0.070
	26-35 years*	0.438 ± 0.096	0.367 ± 0.073	0.396 ± 0.090
	36-45 years*	0.482 ± 0.120	0.417 ± 0.094	0.443 ± 0.109
Mean-CIMT*		0.424 ± 0.102	0.389 ± 0.087	0.403 ± 0.095
Common carotid artery CIMT	Right-CIMT*	0.424 ± 0.117	0.386 ± 0.101	0.401 ± 0.109
	Left-CIMT*	0.405 ± 0.115	0.368 ± 0.091	0.383 ± 0.103
	15-25 years	0.361 ± 0.078	0.342 ± 0.076	0.350 ± 0.077
	26-35 years*	0.434 ± 0.104	0.380 ± 0.070	0.402 ± 0.090
	36-45 years	0.464 ± 0.095	0.429 ± 0.091	0.443 ± 0.094
Carotid bulb CIMT	Right-CIMT*	0.498 ± 0.212	0.401 ± 0.154	0.441 ± 0.186
	Left-CIMT*	0.500 ± 0.277	0.387 ± 0.138	0.433 ± 0.213
	Total*	0.499 ± 0.224	0.394 ± 0.123	0.437 ± 0.178
	15-25 years	0.414 ± 0.161	0.361 ± 0.100	0.385 ± 0.131
	26-35 years*	0.495 ± 0.222	0.378 ± 0.116	0.426 ± 0.176
	36-45 years*	0.568 ± 0.249	0.431 ± 0.134	0.484 ± 0.198
Internal carotid artery CIMT	Right-CIMT*	0.390 ± 0.149	0.355 ± 0.125	0.369 ± 0.136
	Left-CIMT*	0.369 ± 0.092	0.343 ± 0.108	0.353 ± 0.102
	Total*	0.379 ± 0.096	0.349 ± 0.100	0.361 ± 0.099
	15-25 years*	0.331 ± 0.063	0.296 ± 0.055	0.311 ± 0.061
	26-35 years*	0.384 ± 0.066	0.340 ± 0.084	0.358 ± 0.079
	36-45 years	0.413 ± 0.126	0.393 ± 0.117	0.401 ± 0.120
Thickness of plaque	Right side	1.250 ± 0.219	1.050 ± 0.087	1.196 ± 0.209
	Carotid bulb	1.014 ± 0.474	1.050 ± 0.087	1.025 ± 0.390
	Internal carotid artery	1.450 ± 0.283	–	1.450 ± 0.283
	Left side			
	Carotid bulb	1.236 ± 0.687	1.000 ± 0.000	1.206 ± 0.771
	Total*	1.696 ± 0.894	1.038 ± 0.075	1.520 ± 0.814
	15-25 years	1.350 ± 0.000	–	1.350 ± 0.000
	26-35 years	1.817 ± 1.198	1.075 ± 0.106	1.520 ± 0.941
	36-45 years	1.693 ± 0.909	1.000 ± 0.000	1.539 ± 0.845

*: $P < 0.05$ compared by sex

male participants were related to almost all risk factors. The general behaviors that displayed significant relationships with female included smoking, alcohol consumption, and physical activity ($P < 0.05$). Significantly higher proportions of female participants also had familial disease histories, including hypertension, dyslipidemia, and diabetes mellitus ($P < 0.05$).

Table 2 presents the values and parameters of CIMT. It reveals a significantly thicker CIMT in male compared to female ($P < 0.05$), with the exceptions of the youngest and oldest groups for mean-CIMT, the youngest group for carotid bulb CIMT, the oldest group for internal carotid artery CIMT and all age groups for the presence of plaque. The right CIMT values were greater in all locations. The carotid bulb exhibited the highest CIMT values, followed by the common carotid artery and the internal carotid artery, with measurements of 0.437 ± 0.178, 0.403 ± 0.095 and 0.361 ± 0.099 mm, respectively. The max-CIMT, mean-CIMT, and plaque thickness in the Thai young adults were 0.400 ± 0.100 mm, 0.403 ± 0.095 mm, and 1.520 ± 0.814 mm, respectively. Figure 2 and 3 show the participants with plaque presence. Table 3 summarizes the data regarding the presence of plaque. Plaque was found in 18 CIMT values (1.00%) across 15 participants (4.97%). Of these, 3

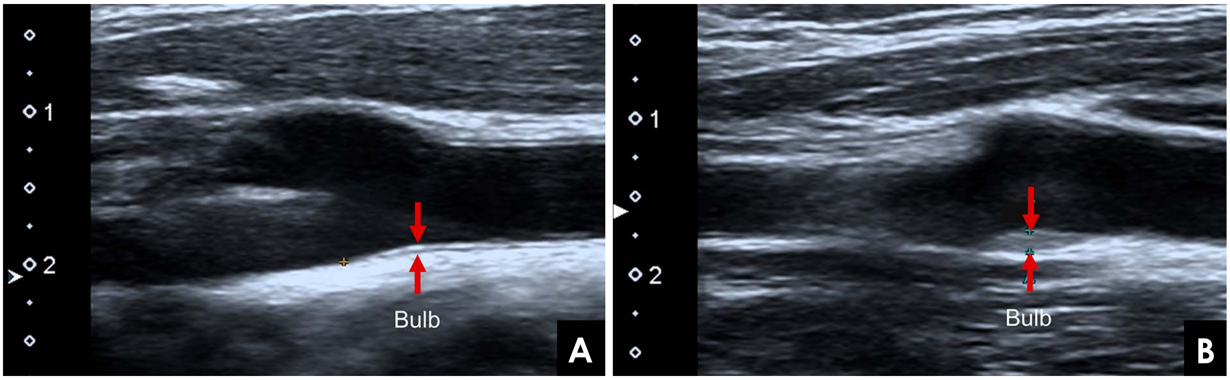

Fig. 2. A. Sonographic images depict the normal carotid intima-media thickness of a healthy 31-year-old man. B. The accumulation of plaque at the carotid bifurcation in a matched non-smoker and non-alcohol consumer with high systolic/diastolic blood pressure of 146/100 millimeters of mercury and a pulse rate of 100 beats per minute.

Table 3. Distribution of plaque presence by age group and location

	Male		Female		All	
	Cases n (%)	Plaque presence n (%)	Cases n (%)	Plaque presence n (%)	Cases n (%)	Plaque presence n (%)
Age group						
15-25 years (n = 82)	1 (0.33%)	1 (0.06%)	–	–	1 (0.33%)	1 (0.06%)
26-35 years (n = 107)	3* (0.99%)	4 (0.22%)	2 (0.66%)	2 (0.11%)	5 (1.66%)	6 (0.33%)
36-45 years (n = 113)	7† (2.32%)	9 (0.50%)	2 (0.66%)	2 (0.11%)	9 (2.98%)	11 (0.61%)
Total	11 (3.64%)	14 (0.78%)	4 (1.32%)	4 (0.22%)	15 (4.97%)	18 (1.00%)
Location						
Right (n = 906)	8 (2.65%)	8 (0.44%)	3 (0.99%)	3 (0.17%)	11 (3.64%)	11 (0.61%)
Carotid bulb	6 (1.99%)	6 (0.33%)	3 (0.99%)	3 (0.17%)	9 (2.98%)	9 (0.50%)
Internal carotid artery	2 (0.66%)	2 (0.11%)	–	–	2 (0.66%)	2 (0.11%)
Left (n = 906)						
Carotid bulb	6 (1.99%)	6 (0.33%)	1 (0.33%)	1 (0.06%)	7 (2.32%)	7 (0.39%)
Total	11‡ (3.64%)	14 (0.77%)	4 (1.32%)	4 (0.23%)	15‡ (4.97%)	18 (1.00%)

N: number, *: 1 bilateral case, †: 2 bilateral cases, ‡: 3 bilateral cases at right and left carotid bulb

cases (0.99%) were bilateral, all of which were found in male participants and located in the carotid bulb. The remaining 12 cases (3.97%) were unilateral, affecting 8 men and 4 women. The frequency of plaque presence was highest in the right carotid bulb, followed by the left carotid bulb and the right internal carotid artery, with frequencies of 9 (0.50%), 7 (0.39%) and 2 (0.11%), respectively. Plaque presence was more common in older than in younger participants.

Table 4 presents comparisons of CIMT parameters in relation to associated risk factors. Sex and salary had significant impacts on all CIMT parameters. Age, occupation, BMI, systolic blood pressure, pulp pressure, and waist circumference significantly influenced only the max-CIMT and mean-CIMT. In contrast, education, pulse rate, physical activity, and familial history exerted no significant effect on any of the CIMT parameters.

The significant risk factors identified in Table 4 were subsequently incorporated into regression models, as depicted in Table 5. In the univariable regression analysis for plaque presence, none of the risk factors yielded a positive result. In the multivariable regression analysis, age and occupation (specifically, "other" occupations) had significant positive associations with both max-CIMT and mean-CIMT ($P < 0.05$). Sex was found to be significantly associated solely with an increase in max-CIMT. The R^2 values for the multivariable linear regression analysis of max-CIMT and mean-CIMT were 0.255 and 0.265, respectively.

Table 4. Carotid intima-media thickness (CIMT) parameters across various risk factor groups ($N = 302$ participants; $n_p = 15$ participants with plaque presence)

Variables	Number (%)	Median max-CIMT (IQR)	Median mean-CIMT (IQR)	Number(%)	Median thickness of plaque (IQR)
Sex: Male	123 (40.7)	0.417 (0.110)[a]	0.400 (0.150)[a]	11 (73.3)	1.250 (1.250)[a]
Female	179 (59.3)	0.367 (0.110)[a]	0.375 (0.120)[a]	4 (26.7)	1.000 (0.110)[a]
Age group					
15-25 years	82 (27.2)	0.338 (0.080)[ac]	0.325 (0.100)[ac]	1 (6.7)	1.350 (0.000)
26-35 years	107 (35.4)	0.383 (0.100)[ab]	0.375 (0.100)[ab]	5 (33.3)	1.150 (1.120)
36-45 years	113 (37.4)	0.433 (0.110)[bc]	0.450 (0.130)[bc]	9 (60.0)	1.100 (1.000)
Occupation					
Student	60 (19.9)	0.329 (0.080)[abcde]	0.325 (0.140)[abcde]	1 (6.7)	1.150 (0.000)
Employee	51 (16.9)	0.392 (0.140)[a]	0.400 (0.150)[a]	5 (33.3)	1.100 (0.750)
Government officer	135 (44.7)	0.400 (0.100)[b]	0.400 (0.130)[b]	5 (33.3)	1.250 (1.230)
Businessman	17 (5.6)	0.392 (0.150)[c]	0.375 (0.100)[c]	3 (20.0)	1.050 (0.325)
Freelancer	27 (8.9)	0.388 (0.160)[d]	0.413 (0.160)[d]	–	–
Other [†]	12 (4.0)	0.408 (0.150)[e]	0.465 (0.113)[e]	1 (6.7)	1.725 (0.000)
Education					
Under bachelor's degree	69 (22.8)	0.383 (0.170)	0.400 (0.150)	4 (26.7)	1.075 (0.520)
Bachelor's degree	183 (60.6)	0.383 (0.110)	0.375 (0.120)	8 (53.3)	1.175 (0.090)
Above bachelor's degree	50 (16.6)	0.409 (0.104)	0.414 (0.095)	3 (20.0)	1.100 (1.050)
Salary (baht/month)					
$<15{,}000$	84 (27.8)	0.358 (0.140)[ab]	0.350 (0.130)[ab]	3 (20.0)	1.050 (0.050)
15,000-40,000	175 (57.9)	0.392 (0.120)[a]	0.400 (0.100)[a]	10 (66.7)	1.300 (1.430)[a]
$>40{,}000$	43 (14.2)	0.404 (0.100)[b]	0.425 (0.180)[b]	2 (13.3)	1.000 (0.000)[a]
BMI (kg/m^2)					
<18.5	30 (9.9)	0.392 (0.110)	0.375 (0.100)[ab]	2 (13.3)	1.250 (0.150)
18.5-24.9	169 (56.0)	0.375 (0.120)[a]	0.375 (0.120)[c]	9 (60.0)	1.150 (1.420)
25-29.9	74 (24.5)	0.419 (0.082)[a]	0.425 (0.130)[ac]	2 (13.3)	1.700 (1.300)
≥ 30	29 (9.6)	0.383 (0.080)	0.439 (0.102)[b]	2 (13.3)	1.125 (0.250)
Systolic blood pressure (mmHg)					
<140	268 (88.7)	0.383 (0.120)[a]	0.375 (0.120)[a]	12 (80.0)	1.100 (0.300)
≥ 140	34 (11.3)	0.429 (0.110)[a]	0.468 (0.098)[a]	3 (20.0)	1.650 (0.250)
Diastolic blood pressure (mmHg)					
<90	278 (92.1)	0.383 (0.120)[a]	0.375 (0.130)	11 (73.3)	1.100 (0.350)
≥ 90	24 (7.9)	0.442 (0.150)[a]	0.437 (0.101)	4 (26.7)	1.450 (1.750)
Pulse rate (bpm)					
≤ 100	288 (95.4)	0.383 (0.110)	0.375 (0.130)	15 (100)	1.150 (0.650)
>100	14 (4.6)	0.392 (0.150)	0.350 (0.120)	–	–
Pulse pressure (mmHg):					
≤ 60	266 (88.1)	0.383 (0.120)[a]	0.375 (0.130)[a]	13 (86.7)	1.150 (0.970)
>60	36 (11.9)	0.412 (0.110)[a]	0.450 (0.180)[a]	2 (13.3)	1.175 (0.350)
Waist circumference (cm)					
Female ≤ 80, Male ≤ 90	211 (69.9)	0.375 (0.120)[a]	0.375 (0.120)[a]	8 (53.3)	1.125 (0.280)
Female >80, Male >90	91 (30.1)	0.408 (0.100)[a]	0.425 (0.180)[a]	7 (46.7)	1.250 (1.350)

The degree of inter-observer reliability - as determined by 3 observers using the average measured ICC with 2-way random effects and an absolute model - was 0.745, indicating strong agreement. The intra-observer reliability, as measured using the 2-way random effects and a consistency-model ICC, yielded values of 0.629, 0.550, and 0.458, which were classified as indicating moderate to strong agreement levels.

Table 4. Continued

Variables		Number (%)	Median max-CIMT (IQR)	Median mean-CIMT (IQR)	Number(%)	Median thickness of plaque (IQR)
Neck circumference (cm)						
Female ≤ 35, Male ≤ 38		240 (79.5)	0.375 (0.120)	0.375 (0.120)[a]	11 (73.3)	1.150 (0.650)
Female > 35, Male > 38		62 (20.5)	0.408 (0.090)	0.442 (0.107)[a]	4 (26.7)	1.150 (1.890)
Smoking						
None		257 (85.1)	0.375 (0.120)[a]	0.375 (0.130)	10 (66.7)	1.150 (0.820)
Current smoker		26 (8.6)	0.392 (0.130)	0.422 (0.200)	2 (13.3)	2.350 (2.200)
Ex-smoker		19 (6.3)	0.425 (0.080)[a]	0.425 (0.130)	3 (20.0)	1.050 (0.050)
Alcohol consumption (drinks/day)						
None		236 (78.1)	0.375 (0.110)[ab]	0.375 (0.130)	–	–
1-2		49 (16.2)	0.417 (0.120)[a]	0.400 (0.130)	9 (60.0)	1.100 (0.250)
3-4		8 (2.6)	0.408 (0.060)	0.363 (0.110)	3 (20.0)	2.350 (0.900)
> 4		9 (3.0)	0.425 (0.080)[b]	0.375 (0.190)	3 (20.0)	1.100 (0.100)
Physical activity (mins/week)						
< 75		173 (57.3)	0.375 (0.110)	0.375 (0.130)	6 (40.0)	1.125 (2.230)
75-150		56 (18.5)	0.383 (0.110)	0.375 (0.140)	2 (13.3)	1.750 (1.200)
151-300		45 (14.9)	0.408 (0.100)	0.400 (0.130)	3 (20.0)	1.000 (0.325)
> 300		28 (9.3)	0.383 (0.140)	0.413 (0.095)	4 (26.7)	1.175 (0.300)
Familial history						
Hypertension	no	137 (45.4)	0.392 (0.140)	0.375 (0.140)	8 (53.3)	1.100 (1.040)
	yes	165 (54.6)	0.383 (0.090)	0.400 (0.150)	7 (46.7)	1.250 (0.650)
Dyslipidemia	no	219 (72.5)	0.375 (0.120)	0.375 (0.130)	11 (73.3)	1.150 (1.300)
	yes	83 (27.5)	0.392 (0.100)	0.375 (0.150)	4 (26.7)	1.075 (0.230)
Coronary heart disease	no	277 (91.7)	0.375 (0.110)	0.400 (0.130)	15 (100)	1.150 (0.650)
	yes	25 (8.3)	0.395 (0.102)	0.398 (0.109)	–	–
Stroke	no	273 (90.4)	0.383 (0.110)	0.375 (0.130)	13 (86.7)	1.150 (0.480)
	yes	29 (9.6)	0.400 (0.150)	0.391 (0.088)	2 (13.3)	1.675 (1.350)
Diabetes mellitus	no	141 (46.7)	0.383 (0.120)	0.375 (0.150)	8 (53.3)	1.125 (1.06)
	yes	161 (53.3)	0.383 (0.110)	0.375 (0.120)	7 (46.7)	1.425 (0.650)

IQR: interquartile range, a-e: $P < 0.05$ for comparisons between the same letters, †: motorbike taxi-driver, housewife, and worker for hire

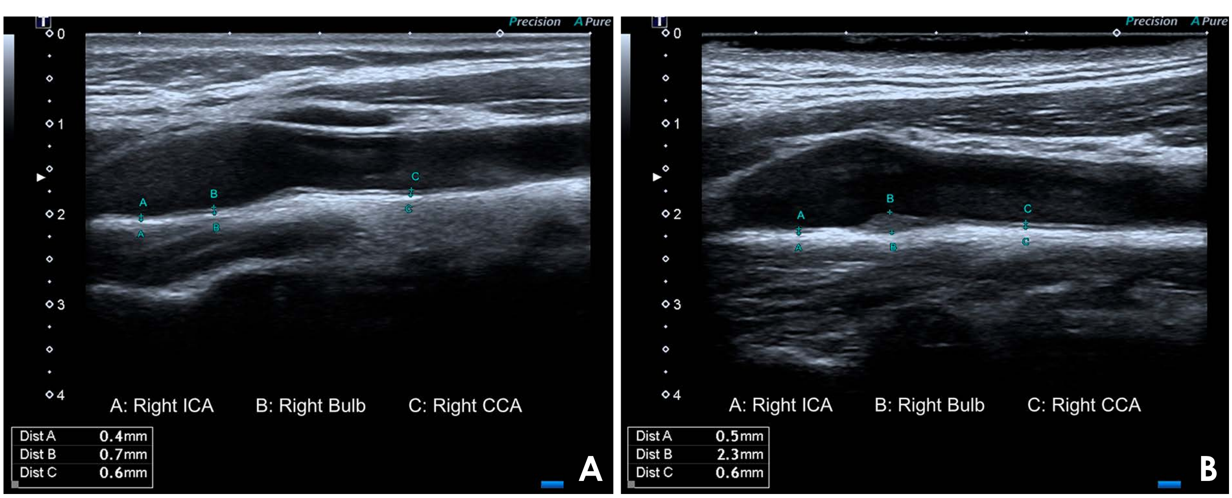

Fig. 3. Sonographic images illustrat the comparison of carotid intima-media thickness between a 43-year-old male non-smoker (A) and a matched smoker participant (B).

Table 5. Association between risk factors and carotid intima-media thickness (CIMT) parameters

Variables	Max-CIMT			Mean-CIMT			Plaque presence	
	Univariable		Multivariable (R^2=0.255)	Univariable		Multivariable (R^2=0.265)	Univariable	
	B (SE)	R^2	B (SE)	B (SE)	R^2	B (SE)	B (SE)	R^2
Female	−0.057 (0.011)*	0.079	−0.054 (0.017)*	−0.035 (0.011)*	0.033	−0.003 (0.016)	−0.658 (0.458)	0.137
Age	0.004 (0.001)*	0.127	0.003 (0.001)*	0.004 (0.001)*	0.125	0.002 (0.001)*	−	
Occupation		0.108			0.106			
Student (ref)								
Employee	0.064 (0.018)*		0.031 (0.022)	0.077 (0.017)*		0.027 (0.021)	−	
Government officer	0.059 (0.015)*		0.018 (0.020)	0.064 (0.014)*		0.016 (0.018)	−	
Businessman	0.088 (0.026)*		0.036 (0.028)	0.069 (0.025)*		0.015 (0.026)	−	
Freelance	0.060 (0.022)*		0.031 (0.024)	0.081 (0.021)*		0.045 (0.023)	−	
Other†	0.154 (0.030)*		0.100 (0.032)*	0.119 (0.029)*		0.062 (0.030)*	−	
Salary		0.018				0.062		0.003
<15,000 (ref)								
15,001-40,000	0.030 (0.013)*		−0.002 (0.016)	0.042 (0.012)*		0.009 (0.015)	0.715 (0.520)	
>40,001	0.032 (0.019)		−0.015 (0.022)	0.071 (0.017)*		0.021 (0.020)	−0.050 (0.721)	
Body mass index	0.003 (0.001)*	0.016	0.000 (0.002)	0.005 (0.001)*	0.066	−0.001 (0.002)	−	
Systolic blood pressure	0.001 (0.000)*	0.033	0.000 (0.000)	0.002 (0.000)*	0.086	0.001 (0.000)	−	
Diastolic blood pressure	0.001 (0.000)*	0.030	0.000 (0.001)	−		−	−	
Pulse pressure	0.001 (0.001)	0.004	0.000 (0.001)	0.002 (0.000)*	0.040	0.001 (0.001)	−	
Waist circumference	0.001 (0.000)*	0.039	0.000 (0.001)	0.002 (0.000)*	0.099	0.000 (0.001)	−	
Neck circumference	0.007 (0.001)*	0.068	0.001 (0.003)	0.008 (0.001)*	0.112	0.005 (0.003)	−	
Smoking		0.024		0.014				
None (ref)								
Current smoker	0.031 (0.020)		−0.006 (0.022)	−		−	−	
Ex-smoker	0.055 (0.024)*		0.008 (0.024)	−		−	−	
Alcohol consumption		0.033						
None (ref)								
1-2	0.041 (0.016)*		0.016 (0.016)	−		−	−	
3-4	0.008 (0.036)		−0.021 (0.034)	−		−	−	
>4	0.067 (0.034)*		0.019 (0.034)	−		−	−	

*: $P<0.05$, ref: reference group, SE: standard error, †: motorbike taxi-driver, housewife, and worker for hire

Discussion

The healthy young adults who participated in this study did not report any known medical issues. However, some may have had undetected (occult) health conditions, such as first-stage hypertension. Most of the participants led typical metropolitan lifestyles, either pursuing degrees or holding steady jobs with a bachelor's degree, earning a standard salary, and engaging in limited physical activity. Despite displaying normal markers for central and upper obesity (waist circumference >90 cm in men and >80 cm in women18 and neck circumference >38 cm in men and >35 cm in women[19]), the average BMI was slightly overweight according to the WHO Asian BMI classification.[20] The proportion of male participants who were either current or former smokers, as well as those at all non-zero levels of alcohol consumption, was significant. Interestingly, despite leading healthier lifestyles overall, a significant percentage of female participants (39.40%) exhibited less-than-optimal exercise levels as recommended by the United States Department of Health and Human Services.[21] Additionally, they had a greater tendency to report a family history of cardiovascular diseases.

The present study generally revealed higher risk factors for cardiovascular diseases and increased CIMT in healthy young men, a finding that aligns with previous studies of young adults.[11-16,22-24] The discrepancy in risk factors and CIMT between sexes could account for the earlier onset of atherosclerosis in men compared to women.[23,24] The increase in CIMT with age observed in this study, as well as in several others,[12-14,22-24] could be attributed to the reduced elasticity of the vascular walls over time. This loss of elasticity can make the walls more susceptible to damage from the shear stress of blood flow. In this study, the mean-CIMT and the CIMT of the internal carotid artery were significantly thicker on the right side than on the left ($P < 0.05$). This finding contradicts the proposal by Luo et al.[25] that higher flow intensity from the aortic arch occurs on the left side. Further investigation into this topic may be warranted.

Socioeconomically, the present investigation revealed associations between all CIMT parameters and income, but no such associations were found with education. Only max-CIMT and mean-CIMT displayed relationships with occupation. The results also indicated a significantly thinner CIMT in the lowest-income group compared to all higher income levels, a finding that diverges from a study by Bruno et al., which reported a significant association between CIMT and lower education, but not income level.[26] The present research also revealed a significantly thinner CIMT among students. Meanwhile, the "other" occupation category demonstrated a statistically significant relationship with increased CIMT, even after adjustment for other negative risk factors. Despite the small size of this category (12 participants; 4.00%), the occupation of motorbike taxi driver was found to be associated with risky behaviors such as current smoking, light alcohol consumption, and minimal or no physical activity. Conversely, housewives and hired workers tended to exhibit minimal or no physical activity only.

The Centers for Disease Control and Prevention have reported that 90% and 99% of youth in the United States experience their first instance of smoking by the ages of 18 and 26 respectively, with 200 young individuals initiating smoking daily.[27] Most studies,[28,29] with the exception of the report by Ayer et al.,[30] have also demonstrated a significant positive correlation between exposure to environmental tobacco smoke and CIMT in children. A systematic review has indicated that the severity of these adverse effects is contingent upon the dosage of exposure, which is determined by factors such as the duration and intensity of exposure, the aging of the environmental tobacco smoke constituents, and the race and age of the children at the time of exposure.[28] Johnson's study further collaborated the positive correlation between smoking and an increase in CIMT among young adults.[15] The present study found a significantly thinner max-CIMT in non-smokers when compared to former smokers, but not when compared to current smokers.

The decrease in alcohol tolerance with age is influenced by several factors, including muscle mass, fat deposition, body water, liver metabolism, medication usage, and others. These factors account for the varied results observed in previous studies. O'Keefe et al.[31] have reported that light to moderate drinking can have cardioprotective benefits. In a separate study, Juonala and colleagues[32] found that CIMT values ranged from 0.57 ± 0.004 mm to 0.59 ± 0.006 mm and 0.60 ± 0.012 mm for light, moderate, and heavy drinkers, respectively. However, the present study revealed no protective effect of lower drinking levels, as a significantly thinner max-CIMT was observed among non-drinkers compared to both light and heavy drinkers. Furthermore, the significant difference in the proportion of non-drinking women to drinking men could be a contributing factor, as could the relatively small number of moderate drinkers studied.

BMI, waist circumference, and neck circumference are indicators of body fat deposition, which can contribute to metabolic disorders that lead to cardiovascular diseases due to pro-inflammatory reactions.[33-35] Freedman and colleagues noted that the BMI of young adults was not significantly associated with increased CIMT, a finding that did not change until they reach old age.[33] In the present study, the max-CIMT displayed a significant difference only between the normal BMI group and the overweight group. However, the mean-CIMT displayed significant differences not only between the underweight and overweight groups but also between the underweight and obese groups. This finding aligns with previous research suggesting that an increase in BMI significantly affects CIMT.[11-16,33-35] An above-standard waist circumference significantly exacerbates both mean-CIMT and max-CIMT, while neck circumference is significantly associated only with mean-CIMT. Del Brutto and colleagues[36] found that the distribution of subcutaneous adipose tissue in the upper body or neck circumference, becomes more pronounced later in life.

Increases in systolic blood pressure, diastolic blood pressure, pulse rate, and pulse pressure are indicative of vessel-related conditions that can result in hypertension. Furthermore, damage to the vascular endothelium is often linked with the initial stages of atherosclerosis.[34] Prior research conducted on younger participants has demonstrated a correlation between CIMT and both blood pressure[12,14-16] and pulse pressure.[37] The present findings align with this rationale and previous studies, with the exception of pulse rate. This discrepancy could potentially be attributed to the small proportion of participants at risk (less than 10%).

Over the past decade, physical activity has been shown to yield significant antioxidant and anti-inflammatory effects. Regular physical activity in daily life can prevent dyslipidemia in adults, irrespective of obesity status, metabolic disease, or cardiovascular diseases.[21,38,39] Moderate endurance exercise was reported to be associated with a slower progression of CIMT in adolescents.[38] Oikonen et al.[11] also demonstrated a direct association between CIMT and ideal physical activity. However, in the present study, no significant difference was found in the CIMT parameters in relation to the duration of physical activity. Similarly, a study by Konigstein et al.[39] found no benefit to CIMT from increasing the level of exercise in adulthood. However, the present questionnaire was designed to assess only the duration, and not the intensity, of activity. Furthermore, the responses in the questionnaire may reflect current physical activity, which has a weaker influence on CIMT than early physical activity from childhood to adulthood.[39]

Regarding familial history, despite the significant proportion of women in this study with a familial history of hypertension, dyslipidemia, or diabetes mellitus, no significant difference was found in their CIMT values. This is consistent with the findings of Liu and colleagues,[40] who proposed that genetics did not strongly predict a child's CIMT until middle age. They further suggested that both genetic and environmental exposures contribute to CIMT.

Although the max-CIMT and mean-CIMT yield similar results, their methodologies differ somewhat. The max-CIMT incorporates all 6 locations on both sides of the neck, whereas the mean-CIMT includes only 2 locations from each side. Furthermore, the common carotid artery location is the simplest to scan and measure, irrespective of neck extension or circumference. Consequently, using the mean-CIMT could be a quick and effective method to screen for subclinical atherosclerosis in healthy young adults. However, since the carotid bulb and internal carotid artery are the only 2 locations in which plaque is present, the max-CIMT may offer superior evaluation for the detection and prediction of cardiovascular disease risk in older individuals.

In conclusion, the max-CIMT, mean-CIMT, and plaque thickness in this study's cohort of young Thai adults were 0.400 ± 0.100 mm, 0.403 ± 0.095 mm, and 1.520 ± 0.814 mm, respectively. Men exhibited a greater CIMT than women. Plaque was present in 4.97% of participants, and its prevalence increased with age. The most influential risk factors for increased CIMT were identified as sex, age, and "other" occupations, specifically motorbike taxi driver, housewife, and hired worker. The presence of these risk factors could be beneficial for future health programs targeting this age group in Thailand.

Conflicts of Interest: None

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