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ORIGINAL ARTICLE

RELATIONSHIP BETWEEN VARIOUS OBESITY INDICES AND BRACHIAL-ANKLE PULSE WAVE VELOCITY ACCORDING TO AGE AMONG JAPANESE FEMALES

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Abstract The present study investigated the relationship between obesity and atherosclerosis according to age in the general female population. Six hundred fifty-five females were divided into 3 different age groups and the relationship between brachial-ankle pulse wave velocity (baPWV) and various obesity indices were investigated. In the youngest age group (20-39 years), BMI, percentage body fat and abdominal circumference were positively correlated with baPWV. In the middle-aged group (40-59 years), all four obesity indices (BMI, percentage body fat, abdominal circumference and the waist-to-hip ratio (WHR)) were positively correlated with baPWV. However, baPWV was found to be negatively correlated with BMI only in the oldest age group (60 years and over), though it was still positively correlated with WHR (but not abdominal circumference). The reason for this may be due to a gradual reduction of body weigh caused by some lifestyle-related diseases or aging. In this study, it was confirmed that abdominal obesity is a key indicator of arteriosclerosis, though the importance of BMI (general obesity) as an indicator may depend on the generation. Furthermore, our results suggested that abdominal circumference and WHR may have different significance as the indicators of arteriosclerosis.

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Key words: Obesity; obesity index; lifestyle-related diseases; brachial-ankle pulse wave velocity.

原　著

日本人女性における年代別の各種肥満指標と上腕・足首脈波伝播速度との関連

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抄録　動脈硬化の危険因子の一つに肥満があげられるが，女性において動脈硬化の指標である上腕・足首脈波伝播速度(baPWV)と各種の肥満指標を比較した報告は少ない．このため，本研究はこれらを年代毎に検討した．対象は平成18・19年度岩木健康増進プロジェクトに参加した女性655人であり，既往歴，喫煙・飲酒状況，運動習慣，腹囲，ウエストヒップ比(WHR)，BMI，体脂肪率，baPWV を調査とした．統計学的解析は，baPWV を従属変数，その他を独立変数として 4 つの肥満指標別に重回帰分析を行った．20-39歳では BMI，体脂肪率，腹囲，40-59歳では全部の肥満指標(BMI，体脂肪率，腹囲，WHR)が baPWV と正の相関を示した．しかし，60歳以上では，WHR(腹囲ではなく)は PWV と正の相関を示したが，BMI が baPWV と負の相関を示し，他の 2 つの年代とは反対の傾向であった．これはこの群で生活習慣病や加齢によって体重が次第に減少した者の存在の影響と推測された．したがって，動脈硬化との関連においては全年代で腹部肥満が重要であることが確認されたが，BMI(全身肥満)の重要度は年代によって異なることが示唆された．また，腹囲と WHR の意義が異なることが示唆された．

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Introduction

Atherosclerosis is one of the major causes of cardiovascular and cerebrovascular diseases and thus prevention of atherosclerosis is considered as an important key for the prevention for those diseases. Obesity is a major risk factor for atherosclerosis via dyslipidemia, diabetes mellitus and various other diseases[1-3].

The significance of obesity, however, may depend on the generation. For example, obesity is in the younger generation is related to the incidence of cerebrovasucular/cardiovascular diseases via dyslipidemia, high blood pressure and hyperglycemia. On the other hand, obesity in the older generation is a complex result of the long-term accumulation of obesity-related hazards, other conditions and ageing. Therefore, in order to examine the relationship between arteriosclerosis and obesity, we must analyze this among different generations.

Female obesity tends to be more complex in comparison to males. For example, female sex hormones such as estrogen are known to inhibit acceleration of atherosclerosis by acting directly on blood vessels as well as the serum cholesterol level and obesity[6, 7]. Secretion of such hormones is also closely related to physical conditions exclusive to females, including pregnancy, childbirth and menopause.

Before 2000, invasive measurement was used to measure pulse wave velocity (PWV) by inserting a tonometer manually into the carotid artery and femoral artery (carotid-femoral pulse wave velocity, cfPWV). Because of this invasive nature of cfPWV measurement, blood pressure was measured instead to estimate the progression of atherosclerosis. However, recent research in Japan has seen the use of the brachial-ankle pulse wave velocity (baPWV), which is a non-invasive method allowing determination of the progression of atherosclerosis[8, 9]. This method is not only non-invasive, but is known to be strongly correlated with cfPWV[10]. Thus, it is considered to be suitable for use in regular health check-ups and epidemiological research involving the general population.

In the present study, the authors investigated the relationship between baPWV and various obesity indices (the percentage of body fat (% body fat), waist-to-hip ratio (WHR) and body mass index [BMI] and abdominal circumference) in different age groups in the Japanese general female population.

The present study was a cross-sectional study designed to investigate the association between various obesity indices and atherosclerosis in three age groups for the purpose of compensating for its weakness. We were able to use various confounding factors such as smoking habit, alcohol consumption, exercise habit and so on to adjust the values of baPWV and obesity indices.

Methods

Subjects

The subjects were 655 females who had participated in the Iwaki Health Promotion Project in 2006 and 2007. Those subjects taking antithrombotic drugs, antiplatelet drugs or those who did not complete the questionnaires or give written informed consent were excluded from the study. A self questionnaire was given out to each subject prior to the investigation and was collected on the day of the project.

The present study was approved by the Ethics Committee of the Hirosaki University Graduate School of Medicine and informed consent was obtained from each subject.

Investigation and Parameters

The parameters measured/surveyed in the present study were baPWV, age, gender, history of lifestyle-related diseases which could lead to or

accelerate atherosclerosis (hypertension, diabetes mellitus and dyslipidemia) and diseases caused by atherosclerosis and/or obesity (myocardial infarction, stroke and malignant neoplasm), medicinal condition (including antithrombotic and antiplatelet drugs), smoking habit, drinking habit and exercise habit. The smoking habit was scored by the number of cigarettes per day and an 'ex-smoker' was defined as a subject who had a history of cigarette smoking and had given up smoking at the time of the project. The exercise habit was scored by frequency (none, once per week, 2-3 times per week, 4-5 times per week and almost every day). The drinking habit was indicated as the amount of alcohol consumed per day (g/day) and an 'ex-drinker' was defined as a subject who had a history of alcohol drinking and had stopped drinking at the time of the project.

Four parameters, namely BMI, % body fat, abdominal circumference and WHR, were used as obesity indices. The height and weight of the subjects were measured and the BMI (kg/m^2) was calculated as weight (kg)/height (m^2). Percentage body fat was measured by the impedance method using the MC-190 system (TANITA, Tokyo, Japan). The abdominal circumference was measured at the point of the navel, and the abdominal circumference was measured at the midpoint between the iliac crest and the lower ribs. The hip circumference was measured as the maximal circumference over the buttocks. WHR was calculated as abdominal circumference divided by hip circumference. To assess the subjects' physique, a BMI of <18.5 was considered as "lean", ≦18.5 – <25.0 was considered as "average/normal" and≧25.0 was considered as "obese".

The baPWV is the velocity of the arterial wall vibration transmitted from the center to the periphery caused by heart contractions and was used as an indicator to determine the progression of atherosclerosis. To measure the baPWV, a Form PWV/ABI Bsystem (Omron Colin Co., Ltd. Tokyo, Japan) was used.

Statistical Analysis

Subjects were divided into three age groups according to their age (20-39 years (the youngest age group), 40-59 years (the middle-aged group) and 60 years and over (the oldest age group)).

A multiple linear regression analysis was carried out by using the baPWV as a dependant variable, and the number of cigarettes per day, history of smoking habit, the amount of alcohol consumed per day, history of drinking habit, frequency of exercise, and any history of hypertension, diabetes mellitus and dyslipidemia were used as independent variables. BMI, % body fat, abdominal circumference and WHR were used as indices of obesity for analysis. Each of those parameters (obesity indices) were interchanged and analyzed for each different age group.

For statistical analysis, SPSS ver.12.0J (SPSS Japan Inc., Tokyo, Japan) was used and all values at $p<0.05$ was considered statistically significant.

Results

Six hundred fifty-five female subjects participated in the study. They were composed of 58 females with ages between 20 and 39 years (the youngest age group), 241 females with ages between 40 and 59 years (the middle-aged group), and 356 females of 60 years and over (the oldest age group).

Table 1 shows the characteristics of subjects in each age group. As shown in the table, baPWV and obesity indices (BMI, % body fat, abdominal circumference and WHR) were found to increase with age. No subjects in the youngest age group were found to have any lifestyle-related diseases (hypertension, diabetes mellitus or dyslipidemia) and the prevalence tended to increase in the oldest age groups. In terms of

Table 1 Characteristics of the subjects

	Youngest group (n=58)	Middle-aged group (n=241)	Oldest group (n=356)
baPWV (cm/sec)	1112.0 ± 87.2	1369.5 ± 212.7	1752.7 ± 325.6
Body weight (kg)	52.1 ± 7.3	54.8 ± 7.5	52.9 ± 7.3
BMI (kg/m^2)	20.6 ± 2.9	22.8 ± 3.0	23.4 ± 3.0
Body fat percentage (%)	25.4 ± 6.4	29.3 ± 6.5	31.2 ± 6.6
Abdominal circumference (cm)	70.2 ± 7.4	75.4 ± 8.1	79.5 ± 8.4
Waist-to-hip ratio	0.78 ± 0.07	0.82 ± 0.06	0.84 ± 0.06
Prevalence of hypertension	0 (0.0)	34 (14.1)	175 (49.2)
Prevalence of diabetes mellitus	0 (0.0)	4 (1.7)	49 (5.3)
Prevalence of dyslipidemia	0 (0.0)	8 (3.3)	49 (6.7)
Smoking habit			
Non-smoker	34 (58.6)	197 (81.7)	342 (96.1)
Smoker < 1 pack/day	9 (15.5)	19 (7.9)	6 (1.7)
Smoker ≥ 1 pack/day	1 (1.7)	3 (1.2)	2 (0.6)
Ex-smoker	14 (24.1)	22 (9.1)	6 (1.7)
Drinking habit			
Non-drinker	31 (53.4)	158 (65.6)	315 (88.5)
Drinker < 20g/day	20 (34.5)	48 (19.9)	30 (8.4)
Drinker 20-39g/day	4 (6.9)	14 (5.8)	3 (0.8)
Drinker 40-59 g/day	1 (1.7)	5 (2.1)	3 (0.8)
Drinker ≥ 60 g/day	1 (1.7)	9 (3.7)	2 (0.6)
Ex-drinker	1 (1.7)	7 (2.9)	3 (0.8)
Physical activity			
0 time/week	49 (84.5)	201 (83.4)	270 (75.8)
Once/week	6 (10.3)	18 (7.5)	26 (7.3)
2-3 time/week	3 (5.2)	7 (2.9)	19 (5.3)
4-5 time/week	0 (0.0)	6 (2.5)	12 (3.4)
6 time/week or everyday	0 (0.0)	9 (3.7)	29 (8.1)

Mean ± SD or n (%)
baPWV: Brachial-ankle pulse wave velocity, BMI: Body mass index

smoking and drinking habits, the prevalence was the highest in the youngest age group and tended to decrease in other age groups (the middle-aged group and the oldest group). In terms of the exercise habit, only 5.8% of the total subjects had exercised regularly.

Tables 2 shows the results obtained by the multiple linear regression analyses using baPWV as a dependent variable. In the youngest age group, BMI, % body fat and abdominal circumference were positively correlated with baPWV (p=0.03, p=0.02 and p=0.04, respectively). In the middle-aged group, the same analysis showed the positive correlations between baPWV and BMI, % body fat, abdominal circumference and WHR (p=0.03, P=0.06, p=0.003 and p=0.002, respectively). On the other hand, baPWV was negatively correlated with BMI (p=0.04), and positively correlated with WHR (p=0.01) in the oldest age group.

Discussion

The obesity indices related to baPWV in the youngest age group were BMI, % body fat and abdominal circumference. In other words, both abdominal obesity and general obesity were associated with baPWV. Recent studies have revealed that adipocyte and adipose tissue dysfunction are the primary defects in obesity and lead to ectopic fat accumulation including abdominal obesity as a consequence[11]. Because adipocyte and adipose tissue dysfunction cause secretion of a proinflammatory and atherogenic

Table 2 Associations between obesity indices and baPWV by multiple regression analysis

		Standard partial regression coefficient	p	R^2
youngest group	BMI	0.30	0.03	0.20
	% Body fat	0.32	0.02	0.21
	Abdominal circumference	0.28	0.04	0.19
	WHR	0.19	0.17	0.15
middle-aged group	BMI	0.14	0.03	0.06
	% Body fat	0.12	0.06	0.05
	Abdominal circumference	0.24	0.003	0.10
	WHR	0.28	0.002	0.11
old-aged group	BMI	-0.11	0.04	0.03
	% Body fat	-0.08	0.16	0.02
	Abdominal circumference	0.04	0.51	0.02
	WHR	0.14	0.01	0.04

Adjustment items: smoking habit, alcohol consumption, exercise habit, smoking habit in the past and alcohol drinking in the past

adipokine pattern, abdominal obesity is suggested to have an association with atherosclerosis[12]. In this context, the results obtained from the present study were opposite from what had been found in previous studies. However, some epidemiological studies which determined atherosclerosis by PWV showed the possibility that general obesity as well as abdominal obesity were the risk factors of atherosclerosis[13, 14], and the same result was found in the cross-sectional study determining atherosclerosis by the intima-media thickness (IMT) of the carotid arteries[15]. Although the precise mechanism(s) of IMT still remains unknown, the present study suggested that not only the accumulation of visceral fat but also the increase of fat mass in the whole body were associated with atherosclerosis in the youngest group.

There were positive correlations between WHR and baPWV in the middle-aged group which suggested their associations with abdominal obesity and atherosclerosis. Czerinchow et al. reported that cfPWV was associated not with BMI, fat mass or % body fat but with abdominal circumference, and atherosclerosis was suggested to be related with abdominal obesity among middle-aged males and females[16]. Although the subjects included males and females, the previous study measured the high-sensitive C-reactive protein (hs-CRP) as a parameter of atherosclerosis, which showed a positive correlation with WHR[17]. WHR and abdominal circumference are the indices to evaluate abdominal obesity rather than general obesity. Thus, accumulation of visceral fat and its effect on atherosclerosis in the middle-aged group need to be considered when evaluating their obesity and body weight.

On the other hand, baPWV was negatively correlated with BMI, and positively correlated with WHR (not abdominal circumference) in the oldest age group, representing opposite findings compared with other age groups. Apart from the present study, a few previous reports[17] had also found a negative correlation between obesity and baPWV. The reason for this may be that the body weight of some of the subjects had gradually reduced due to some lifestyle-related diseases or aging. From the results obtained in this study, general obesity is no longer considered as a major risk factor for atherosclerosis in the oldest age group.

As a summary of the present study, baPWV was positively correlated with general obesity

indices (BMI and % body fat) and abdominal obesity indices (abdominal circumference and WHR) in the youngest and middle age groups. However, in the youngest age group, baPWV was correlated with general obesity indices more than abdominal obesity indices, and an adverse relationship was seen in the middle-aged group. Thus, our findings suggest that primary prevention is necessary to give priority to general obesity more than abdominal obesity in the youngest age group, but in the middle age group, primary prevention of abdominal obesity should be placed above general obesity. For the oldest age group, baPWV was positively correlated with WHR (but not abdominal circumference), and was negatively correlated with BMI.

Therefore, it was confirmed that abdominal obesity is an important related indicator of arteriosclerosis, though the importance of BMI (general obesity) may depend on the generation. Furthermore, it is suggested that certain differences in meaning exist between abdominal circumference and WHR.

The present study was carried out as a population-based cross-sectional study and there were some limitations due to the following:

1. The histories of lifestyle-related diseases and pharmaceutical intake were self-reported by each subject and these data might be imprecise.
2. Data on subjects' menopausal situation was not obtained though the present study was carried out in females. As the age of menopause is usually between 40 and 59 years old, both pre- and post-menopause females were included in the middle-aged group. Thus, a post-menopause subgroup in such age group might have shown a similar relationship to the oldest age group, which would have produced a negative correlation between obesity indices and baPWV.

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References

1) Campbell RK. Type 2 diabetes: where we are today: an overview of disease burden, current treatments, and treatment strategies. J Am Pharm Assoc 2009;49:S3-9.

2) Okay DM, Jackson PV, Marcinkiewicz M, Papino MN. Exercise and obesity. Prim Care 2009;36:379-93.

3) Kypreos KE, Karagiannides I, Fotiadou EH, Karavia EA, Brinkmeier MS, Giakoumi SM, Tsompanidi EM. Mechanisms of obesity and related pathologies: role of apolipoprotein E in the development of obesity. FEBS J 2009;276:5720-8.

4) Yamauchi T, Kadowaki T. Physiological and pathophysiological roles of adiponectin and adiponectin receptors in the integrated regulation of metabolic and cardiovascular diseases. Int J Obes (Lond) 2008;32:S13-8.

5) Oda E. The metabolic syndrome as a concept of adipose tissue disease. Hypertens Res 2008;31: 1283-91.

6) Guetta V, Quyyumi AA, Prasad A, Panza JA, Waclawiw M, Cannon RO 3rd. The role of nitric oxide in coronary vascular effects of estrogen in postmenopausal women. Circulation 1997;96:2795-801.

7) Skafar DF, Xu R, Morales J, Ram J, Sowers JR. Clinical review 91: Female sex hormones and cardiovascular disease in women. J Clin Endocrinol Metab 1997;82:3913-8.

8) Gong W, Lu B, Yang Z, Ye W, Du Y, Wang M,

Li Q et al. Early-stage atherosclerosis in newly diagnosed, untreated type 2 diabetes mellitus and impaired glucose tolerance. Diabetes Metab 2009;35(6):458-62.

9) Kato A, Takita T, Furuhashi M, Kumagai H, Hishida A. A Small Reduction in the Ankle-Brachial Index Is Associated with Increased Mortality in Patients on Chronic Hemodialysis. Nephron Clin Pract 2010;114(1):c29-c37.

10) Tanaka H, Munakata M, Kawano Y, Ohishi M, Shoji T, Sugawara J, Tomiyama H et al. Comparison between carotid-femoral and brachial-ankle pulse wave velocity as measures of arterial stiffness. J Hypertens 2009;27(10):2022-7.

11) Blüher M. Adipose tissue dysfunction in obesity. Exp Clin Endocrinol Diabetes 2009;117:241-50.

12) Lear SA, Humphries KH, Kohli S, Frohlich JJ, Birmingham CL, Mancini GB. Visceral adipose tissue, a potential risk factor for carotid atherosclerosis: results of the Multicultural Community Health Assessment Trial (M-CHAT). Stroke 2007;38(9):2422-9.

13) Mizia-Stec K, Gasior Z, Zahorska-Markiewicz B, Holecki M, Haberka M, Mizia M, Gomułka S et al. The indexes of arterial structure and function in women with simple obesity: a preliminary study. Heart Vessels 2008;2:224-9.

14) Wildman RP, Mackey RH, Bostom A, Thompson T, Sutton-Tyrrell K. Measures of obesity are associated with vascular stiffness in young and older adults. Hypertension 2003;42:468-73.

15) Reed D, Dwyer KM, Dwyer JH. Abdominal obesity and carotid artery wall thickness. The Los Angeles Atherosclerosis Study. Int J Obes Relat Metab Disord 2003;27:1546-51.

16) Czernichow S, Bertrais S, Oppert JM, Galan P, Blacher J, Ducimetiere, Hercberg S, Zureik M. Body composition and fat repartition in relation to structure and function of large arteries in middle-aged adults (the SU.VI.MAX study). Int J Obes (Lond) 2005;29:826-32.

17) Lapice E, Maione S, Patti L, Cipriano P, Rivellese AA, Riccardi G, Vaccaro O. Abdominal adiposity is associated with elevated C-reactive protein independent of BMI in healthy nonobese people. Diabetes Care 2009;32:1734-6.