Menopause: The Journal of The North American Menopause Society
Vol. 27, No. 5, pp. 000-000
DOI: 10.1097/GME.0000000000001503

ORIGINAL STUDY

Accelerated progression of waist-to-hip ratio but not body mass index associated with lower socioeconomic position: a cohort study of nonobese early postmenopausal Chinese women

Gary K.K. Chung, MPH,[1] Ruby H.Y. Yu, PhD,[2] Jean Woo, MD,[2] Francisco T.T. Lai, PhD,[1] Roger Y. Chung, PhD,[1] Eng-Kiong Yeoh, MBBS,[1] and Suzanne C. Ho, PhD[1]

Abstract

Objective: Menopausal changes are linked to increase in body fat mass and central fat distribution; nonetheless, the impact of socioeconomic position on such changes has rarely been examined. This cohort study assessed the temporal associations of socioeconomic position with changes in body mass index (BMI) and waist-to-hip ratio (WHR) among early postmenopausal women.

Methods: Between 2002 and 2004, 518 Hong Kong Chinese women aged 50 to 64 and within 10 years since menopause were recruited and followed up at 3 and 5 years. Weight, height, and waist and hip circumferences were measured by trained interviewers at baseline and follow-up interviews. Socioeconomic positions including educational attainment, economic activity status and household income level, and other baseline demographic characteristics, lifestyle behaviors, and mental health status were collected based on a structured questionnaire. In total, 287 and 267 women with no general and abdominal obesity, respectively, at baseline were included in multiple regression analyses.

Results: Mean intrapersonal increases in BMI and WHR between baseline and 5-year interview were 0.46 kg/m^2 and 2.80%, respectively. Women with no secondary education were 75% more likely to have a greater than-mean WHR increase than their more educated counterparts ($P = 0.039$). Also, having no secondary education ($P = 0.041$) and being a homemaker ($P = 0.034$) had accelerated surge in WHR. Nonetheless, baseline socioeconomic positions were not significantly associated with BMI changes.

Conclusions: Socioeconomic patterning was observed for the progression of WHR among nonobese Chinese women soon after menopause. Early postmenopausal stage may be a critical window for prevention of abdominal obesity among women with a lower educational attainment.

Key Words: Body mass index – Chinese – Cohort studies – Postmenopausal – Socioeconomic position – Waist-to-hip ratio – Women.

Menopausal transition is a critical period for changes in body composition among midlife women.[1,2] Although weight gain may be attributed to chronological aging rather than menopause, menopause per se has been independently associated with a substantial increase in fat mass, especially the visceral adipose tissue, and thus a central fat distribution,[3,4] plausibly due to changes in genetic expressions and the decreasing level of female sex hormones.[5] Previous research also demonstrated that, when compared to premenopausal women, postmenopausal women had a five-fold risk of having abdominal obesity, as measured by waist-to-hip ratio (WHR), after adjustment for body mass index (BMI).[6] Therefore, obesity, especially abdominal obesity, is one of the major public health challenges among women who become menopausal.

In addition to the general effect of physiological changes during menopause, differential exposures to exogenous social determinants may lead to different rates of menopausal changes in body composition among individual women.[5] Given the gene-environment interaction with obesity, socioeconomic disadvantages, as well as the associated poorer lifestyle behaviors, could potentially affect the progression

Received October 12, 2019; revised and accepted December 4, 2019.
From the [1]Jockey Club School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Sha Tin, Hong Kong; and [2]Department of Medicine and Therapeutics, Faculty of Medicine, The Chinese University of Hong Kong, Sha Tin, Hong Kong.
Funding/support: This work was supported by a grant from the Research Grants Council of Hong Kong (CUHK465807/07).
Financial disclosure/conflicts of interest: None reported.
Supplemental digital content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's Website (www.menopause.org).
Address correspondence to: Suzanne C. Ho, PhD, Emeritus Professor, Division of Epidemiology, The Jockey Club School of Public Health and Primary Care, Faculty of Medicine, The Chinese University of Hong Kong, Sha Tin, Hong Kong. E-mail: suzanneho@cuhk.edu.hk

of obesity.[7] Interestingly, there is consistent evidence showing that women, as compared with men, tend to be more vulnerable to the influence of socioeconomic disadvantages (such as being less educated, unemployed, or less skilled and having lower income) on obesity. Previous systematic reviews provided evidence of a stronger socioeconomic patterning of obesity among women in developed world regions,[8-10] whereas studies on recent trends of socioeconomic inequality in obesity also revealed more apparent disparities in obesity prevalence among women relative to men.[11-14] Although the mechanisms for the observed sex difference are not completely understood, the impact of socioeconomic disadvantages on the progression of obesity among women during early postmenopausal years plausibly play a part and hence deserve more research attention.

Existing literature on socioeconomic disadvantages and obesity among midlife women around menopause is scarce and limited. Most relevant studies adopted a cross-sectional design and were conducted among Western populations, which supported a higher level of obesity,[15] abdominal fat,[16] metabolic syndrome,[17] and unhealthy lipid profiles,[18] among postmenopausal women in poverty as compared with their wealthier counterparts. The sole relevant 12-year cohort study of midlife women, the Study of Women's Health Across the Nation in the United States, also showed a temporal association of socioeconomic disadvantages, especially in terms of low educational attainment, with obesity-related outcomes such as subclinical cardiovascular diseases and metabolic syndrome.[19,20] To the best of our knowledge, there is no relevant research on obesity, let alone a longitudinal study, in developed Asian settings for comparisons of these findings. In light of this, the present cohort study aimed to examine the impacts of socioeconomic position on the intrapersonal changes in BMI and WHR over follow-up years among early postmenopausal Chinese women at risk of developing obesity in Hong Kong, an advanced Asian economy which had undergone rapid socioeconomic development since the mid-20th century.[21]

METHODS

Study population and sampling methods

From 2002 to 2004, 518 Chinese women aged 50 to 64 years and within 10 years since menopause (defined as 12 months since the cessation of the last menses) were recruited for face-to-face interview and clinical assessment, with a response rate of 62.5% out of 829 invited women, into a cohort study on cardiovascular health of Hong Kong midlife women.[22,23] Random telephone dialing based on the residential telephone directory was adopted and at least six attempts were made at different times of the week before a woman was replaced. The woman with the most recent birthday was selected in case of having more than one eligible member in a household. Women with surgical menopause, cardiovascular diseases, and severe medical conditions (eg, cancer and renal failure) were excluded. All women provided written informed consent, and the study was approved by the Ethics Committee of the Chinese University of Hong Kong.

After recruitment, 10 women were further excluded due to postmenopausal bleeding. In total, 508 women were successfully recruited at baseline, and were followed up at year 3 (T1) and year 5 (T2),[24] of which 412 eligible women who had at least completed both baseline and T2 interviews were included in the study sample (Fig. 1). As the present study focused on potential differences between education groups among women at risk for general obesity or abdominal obesity, women with general or abdominal obesity at baseline were excluded separately. Therefore, two subsamples on BMI and WHR (N = 287 and 267, respectively) were included for analyses.

Data collection

Baseline data on demographic and socioeconomic characteristics, lifestyle behaviors, and mental health statuses were collected using a structured questionnaire and used as the independent baseline predictors, whereas obesity measures, as the time-varying dependent variables, were examined by anthropometric measurements over the three waves of interviews.

Baseline predictors

Socioeconomic position

Educational attainment was classified into ''no secondary education'' and ''at least secondary education,'' since universal secondary education had yet been achieved in Hong Kong by the time our sampled women were born before the 1970s.[25] The economic activity status was grouped into ''homemaker'' or ''employed.'' Household income was assessed by responses to a question with six ordinal options ranging from less than HK$5,000 to more than HK$99,999, and then regrouped into binary variables at the median income level of HKD$20,000.

Demographic characteristics

Age, as a continuous variable, was measured by the difference between the date of interview and the date of birth. Years since menopause was also estimated based on the time of the last menses. Marital status was grouped into ''married'' (including cohabitation) or ''nonmarried'' (including never married, widowed, divorced, and separated), whereas history of pregnancy was assessed by a question with binary (yes/no) options.

Lifestyle behaviors

Smoking status was categorized as ''ever smokers'' (including current smokers and past smokers) and ''never smokers,'' whereas alcohol use was grouped into ''regular drinkers'' (once a week or more) and ''nonregular drinkers.'' Daily dietary total energy intake, as a continuous variable, was estimated by a food frequency questionnaire validated in Chinese women.[22,23] In addition, women who reported frequent engagement in a given sport or exercise were deemed

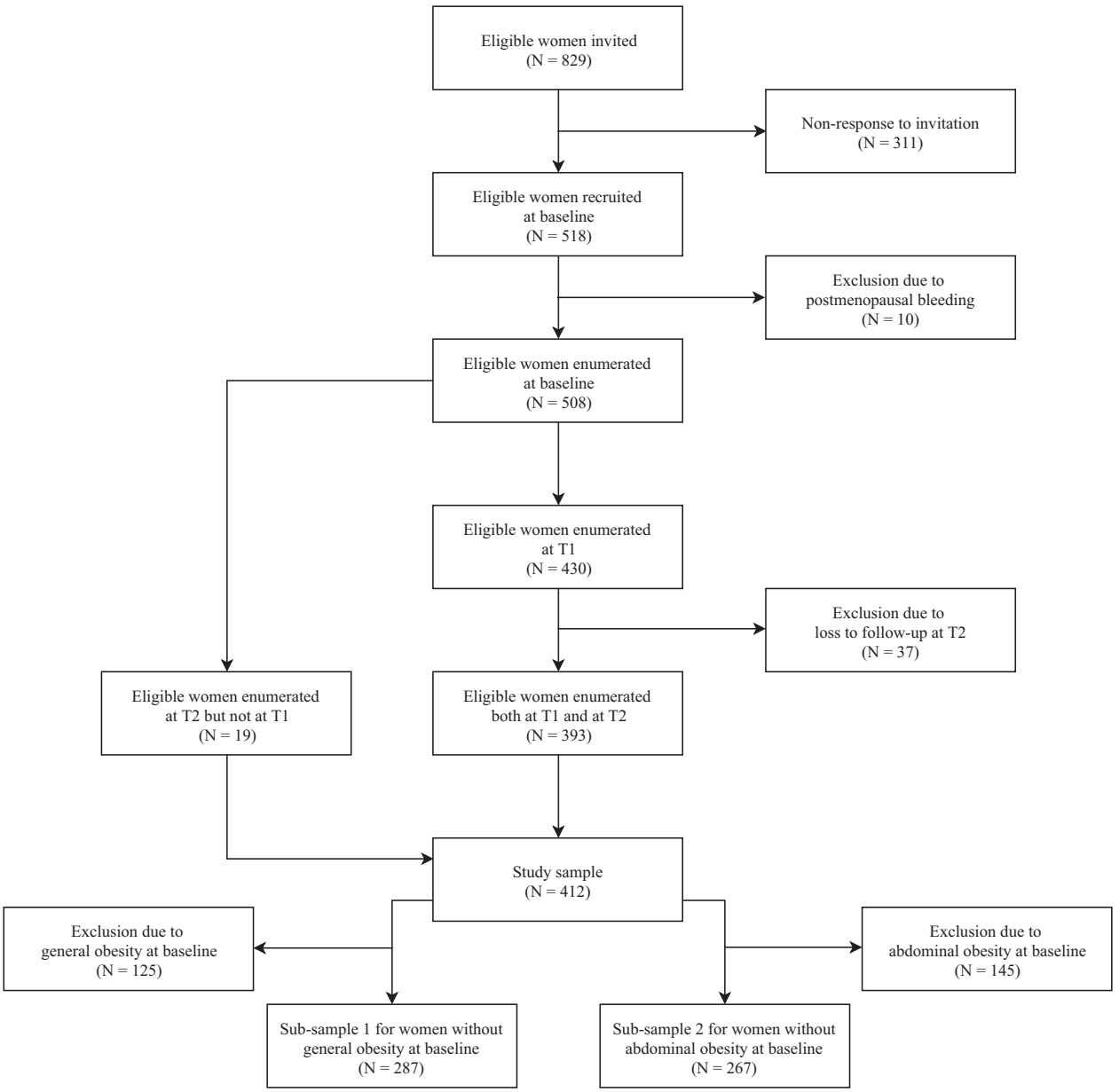

FIG. 1. Flowchart of the study from recruitment to analysis.

''physically active,'' or otherwise ''physically inactive.''[22] Sleep duration was categorized as a binary variable using ''6 hours per day'' as the cut-off.[26]

Mental health status

Depressive symptoms during the past week were 'assessed with the 20-item Center for Epidemiological Studies Depression Scale given its high reliability and validity in a range of populations.[27] Women scoring 16 or above out of the 60 were considered having high depressive symptoms.[24] Stress level over the last month was also estimated using the 10-item Perceived Stress Scale (PSS). PSS score was treated as a continuous variable as PSS is not a diagnostic instrument and has no predefined threshold for high perceived stress.[28]

Dependent variables

Obesity measures over the follow-up period

Anthropometric measurements at baseline and follow-up interviews were made by trained interviewers according to the study protocol. Height was measured to the nearest 0.5 cm with women barefoot, back against a wall, heels together, and eyes looking straight ahead, whereas weight was measured to the nearest 0.1 kg in light clothing using beam balance scales.[22] In addition, waist circumference was measured to the nearest 0.5 cm over the abdomen at the smallest diameter between the costal margin and iliac crest and with women breathing out gently, using a standard tape measure, whereas hip circumference was measured to the nearest 0.5 cm at the level of the greater trochanters with the tape kept

horizontal.[22] Two readings were recorded for each measure and their average value was used. BMI, calculated as weight in kilograms divided by height in meters squared with a cut-off BMI of 25 kg/m^2, was adopted as the measure of general obesity[29]; WHR, calculated as the ratio of waist circumference to hip circumference with a threshold of 85%, was employed as an index of abdominal obesity.[30] Baseline general and abdominal statues were also used as predictors of obesity outcomes.

Statistical analysis

Descriptive statistics of the basic characteristics of women in separate subsamples for analyses on general and abdominal obesity were presented as mean with standard deviation for continuous variables and count data with percentages for categorical variables. Graphic illustration was used to depict the progression of mean BMI and WHR over the follow-up period, stratified by socioeconomic position.

In addition to univariate analyses, multivariable analyses between socioeconomic positions and intrapersonal changes in BMI and WHR were conducted separately, with adjustments for baseline age, years since menopause, marital status, history of pregnancy, dietary total energy intake, physical activity level, sleep duration, depression, stress, and either general or abdominal obesity status depending on the outcome obesity measure. Smoking and alcohol use were not included for confounding control due to their low prevalence (<5%) among sampled women. To assess the effects of baseline socioeconomic positions on the progression of obesity measures, two analytical approaches were adopted to reflect both relative and absolute differences. First, we calculated the changes in BMI and WHR between baseline and T2 of each woman, and then adopted the mean values of intrapersonal changes as the cut-offs of binary outcome variables (ie, ''lower-than-mean'' and ''greater-than-mean'' changes). Therefore, we employed separate multiple binary logistic regressions to assess whether the baseline socioeconomic positions are associated with increased odds of having a greater-than-mean intrapersonal changes in BMI and WHR, respectively, over the study period. As for the second analytical approach, baseline socioeconomic position and all other potential confounders, together with their interaction terms with follow-up year (measured as the difference of the dates of follow-up interviews from that at baseline), were included in separate linear mixed-effects regression models on time-varying BMI and WHR, with a random intercept for individual women due to the longitudinal cohort design. The β coefficient of each interaction term represents the absolute difference between the corresponding baseline predictor statuses in the annual changes in BMI or WHR. Taking BMI change as an example, if the β coefficient of the interaction term between having no secondary education and follow-up year is 0.1, that means the change in BMI per follow-up year among women with no secondary education is 0.1 kg/m^2 higher than that among their better educated counterparts. As linear mixed-effects regression can accommodate missing data due to loss to follow-up at any particular survey year, we additionally conducted a sensitivity analysis on all women with available data at baseline, T1 and T2 to ensure the robustness of our results.

Data analyses were conducted using statistical software R 3.4.0 and all statistical tests were two-tailed with a significance level of $P < 0.05$.

RESULTS

Characteristics of the study population

Profiles of both subsamples were highly comparable, with a mean age of 56 years and slightly more than one-third of women with no secondary education (Table 1). Specifically, for the baseline obesity measures, 25.1% of women without general obesity at baseline were abdominally obese, whereas 19.5% of those without abdominal obesity at baseline were generally obese. The mean intrapersonal increases in BMI and WHR between baseline and T2 were 0.46 kg/m^2 and 2.80%, respectively.

Trends of obesity measures by socioeconomic position

In general, both obesity measures increased over follow-up time, with a sharper continuous surge in mean WHR (Fig. 2). The extent of increase in mean BMI over time was similar between socioeconomic groups. As for mean WHR, disparity between socioeconomic groups was negligible at baseline; however, the extent of increase was substantially higher among women with no secondary education and slightly higher among homemakers. In addition, despite surges in BMI and WHR between baseline and T1, the rising trend became less pronounced for WHR and leveled off for BMI between T1 and T2.

Baseline predictors of obesity progression over the follow-up period

Results from binary logistic regression showed that women with no secondary education were 75% more likely to have a greater-than-mean intrapersonal WHR change (odds ratio = 1.75; 95% confidence interval [CI] = 1.03-2.99) when compared with their better educated counterparts; nonetheless, such an educational patterning did not apply to BMI change (Table 2). No significant associations were found for other socioeconomic predictors with both obesity measures.

Linear mixed-effects regression analysis showed that women with no secondary education (β = 0.227; 95% CI = 0.009-0.444) and homemakers (β = 0.247; 95% CI = 0.020-0.475), as well as those with general obesity at baseline (β = 0.384; 95% CI = 0.129-0.639, data not shown), were independently associated with a faster increase in WHR over the follow-up time (Table 3). Again, baseline socioeconomic position did not significantly predict disparities in BMI changes. Sensitivity analysis on all women with available data at baseline, T1 and T2 showed highly consistent patterns (see Table, Supplemental Digital Content 1, http://links.lww.com/MENO/A536, which shows the results of sensitivity analysis on all women with available data at baseline, T1 and T2).

TABLE 1. *Baseline characteristics of respondents in separate subsamples*

	BMI <25 kg/m^2 at baseline (N = 287)	WHR <85% at baseline (N = 267)
	Mean ± SD or N (%)	Mean ± SD or N (%)
Socioeconomic position		
Educational attainment, % primary level or below	108 (37.6)	93 (34.8)
Economic activity status, % homemaker	193 (67.2)	185 (69.3)
Household income, % < HKD$20,000	155 (54.8)[a]	151 (57.0)[b]
Demographic characteristics		
Age, y	56.11 ± 3.18	56.21 ± 3.26
Years since menopause, y	5.01 ± 2.67	5.15 ± 2.64
Marital status, % married/cohabitating	224 (78.0)	213 (79.8)
Ever pregnant, %	265 (92.3)	248 (92.9)
Lifestyle behaviors		
Ever smokers, %	7 (2.4)	6 (2.2)
Regular drinkers, %	9 (3.1)	11 (4.1)
Dietary total energy intake, kcal/d	1,368.34 ± 427.48	1,360.15 ± 439.98
Physically inactive, %	128 (44.6)	119 (44.6)
Sleep duration, % <6 h/d	76 (26.5)	73 (27.3)
Mental health statuses		
CES-D score, % ≥16	55 (19.2)	48 (18.0)
PSS score	11.51 ± 6.99	11.55 ± 6.76
Obesity measures		
BMI ≥25 kg/m^2	N/A	52 (19.5)
WHR ≥85%	72 (25.1)	N/A
Mean intrapersonal BMI change between baseline and T2, kg/m^2	0.46 ± 1.58	N/A
Mean intrapersonal WHR change between baseline and T2, %	N/A	2.80 ± 4.66
Mean follow-up time		
Baseline to T1, y	3.23 ± 0.38	3.22 ± 0.38
Baseline to T2, y	5.20 ± 0.42	5.21 ± 0.43

BMI, body mass index; CES-D, Center for Epidemiologic Studies Depression Scale; PSS, Perceived Stress Scale; WHR, waist-to-hip ratio.
[a]Missing data: 4.
[b]Missing data: 2.

DISCUSSION

Longitudinal data on socioeconomic patterning of the progression of obesity measures among early postmenopausal women are scarce, both worldwide and among Chinese women. Our findings showed a more apparent increase in mean WHR than that in mean BMI among women during early postmenopause, which echoed previous research on the independent effect of menopause on central fat distribution rather than on weight gain.[3] Although socioeconomic positions were not significant predictors of BMI changes, the progression of WHR was socioeconomically patterned especially in terms of educational attainment, with a faster increase among women with no secondary education; and also homemakers. Moreover, women with general obesity at baseline had an accelerated progression of WHR.

Our particularly interesting finding is that educational attainment exerted an independent impact on the progression of WHR even in the midlife of the early postmenopausal women, which lent support to the plausible influence of socioeconomic disadvantages on menopausal changes in body composition and fat distribution. In the existing literature, three main mechanisms, namely the materialist, behavioral, and psychosocial pathways, have been proposed to explain socioeconomic inequality in health. As the observed temporal associations of lower educational attainment with the progression of WHR remained significant after adjustments for baseline lifestyle factors and mental health statuses, the materialist pathway (ie, financial inaccessibility to tangible material conditions including healthy food, decent shelter, and healthcare and social services) may be the main driver of the accelerated progression of WHR among these midlife women with a lower educational attainment. Previous research on the independent effect of deprivation of basic necessities of life on abdominal obesity but not on general obesity[31] also supported the potential role of material conditions in central fat distribution among the Asian population.

Apart from the three major pathways, the lifecourse perspective could have also played a role in the educational patterning of abdominal obesity.[32,33] Adverse exposures in earlier life may have set a trajectory to affect individual health outcomes in the midlife. Notably, educational attainment does not only proxy one's socioeconomic position in adulthood but is also regarded as an indicator of early-life socioeconomic circumstances because it captures the transition from childhood socioeconomic status determined by their parents to their own socioeconomic status achieved in early adulthood.[34] Given that universal free education had not been provided by the Hong Kong Government until 1978,[35] our sampled women who were born around the 1950s generally had lower opportunities for secondary education when compared to men under the overt gender bias and hence only girls with a more affluent family background could afford to receive better education back then.[36] Therefore, educational attainment may be a particularly important socioeconomic indicator among women under the context of Hong Kong as it is more reflective of their early-life living standards. Moreover, under

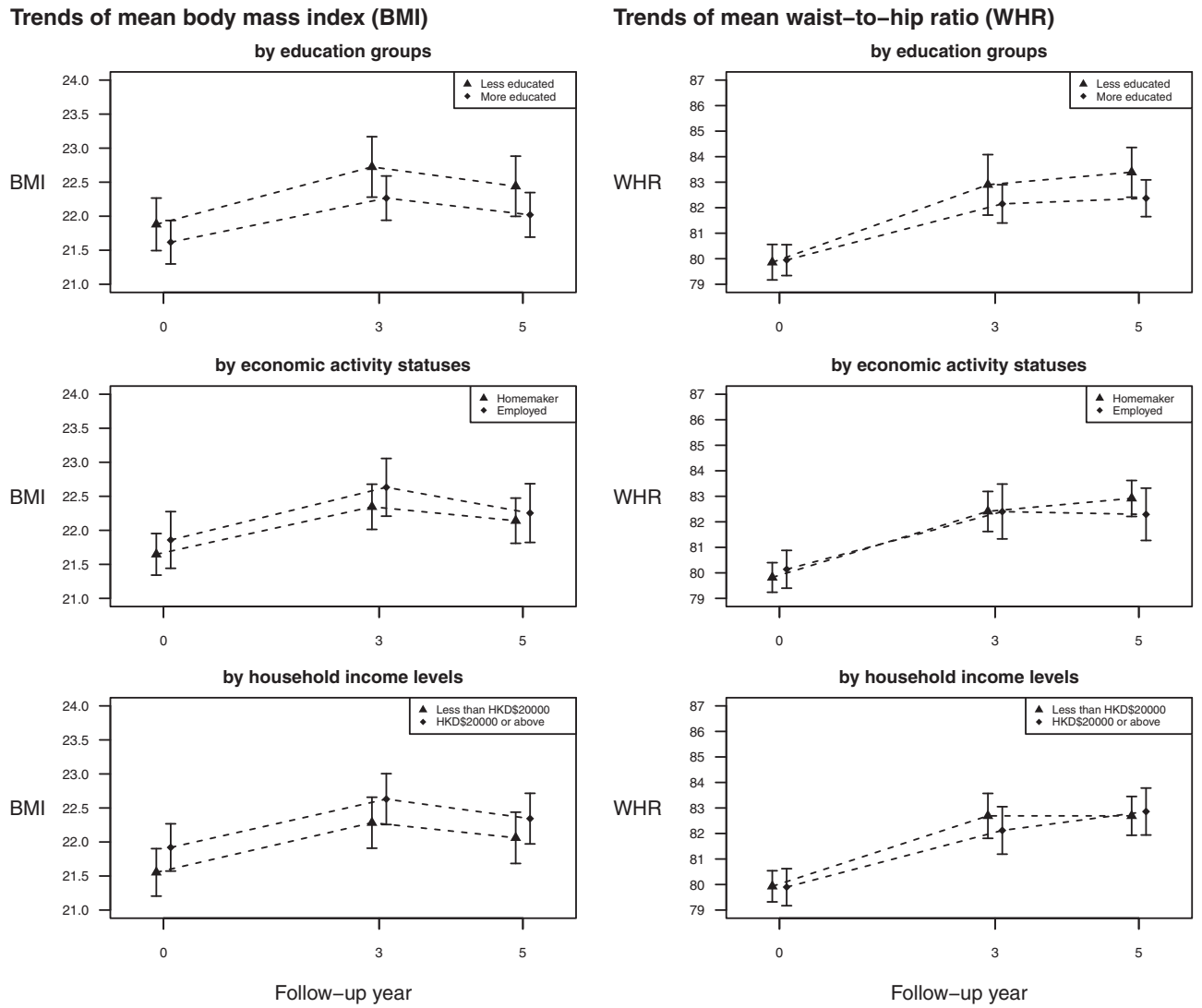

FIG. 2. Trends of body mass index (BMI) and waist-to-hip ratio (WHR) by socioeconomic position.

the patriarchal culture among Asia populations, women of lower social status tend to have restricted access to household resources in a family.[36] This may in part explain why household income level had minimal impact on menopausal changes in body compositions and did not attenuate the effect of educational attainment as observed in our study.

Apart from the educational patterning, it is also worth noting that baseline general obesity predicted a faster increase in WHR among early postmenopausal women. Menopausal changes in female sex hormones, notably the decline in estrogen and thus the relative hyperandrogenemia, have been a major contributor to the redistribution of fat from gynoid to an android pattern.[5] Estrogens promote the deposition of fat in the subcutaneous tissue via genomic action with transcription factors for regulating gene expression and also via nongenomic action by activating specific receptors on the cell membrane.[5] Although the level of estrogen decreases progressively during the menopausal transition, the ovary continues to secrete androgens which promote the accumulation of abdominal fat.[4,37] Decline in the hepatic production of sex hormone–binding globulin around menopause also contributes to an increased level of free androgen, leading to relative hyperandrogenemia.[38] Therefore, given these mechanisms via menopause-induced hormonal changes, general obesity at baseline may provide a greater reserve of total body fat to be redistributed and hence accumulated at the abdominal cavity over time.[5]

These hormonal effects related to menopause may also explain the more evident surge in obesity measures over the earlier follow-up period and subsequent leveling-off observed in this study. Given that the levels of sex hormones become more stabilized with years since menopause,[39] their impact on body composition and central fat distribution among older postmenopausal women is not likely as strong as that during early postmenopausal years. This finding may echo previous studies supporting menopause as one of the critical life stages

TABLE 2. *Effects of baseline socioeconomic position on the odds of having greater-than-mean changes in body mass index and waist-to-hip ratio between baseline and T2 based on logistic regressions*

	Having an intrapersonal BMI change >0.46 kg/m^2				Having an intrapersonal WHR change >2.80%			
	Univariate model		Adjusted model[a]		Univariate model		Adjusted model[b]	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Socioeconomic position								
Primary education level or below	0.79 (0.48-1.28)	0.336	1.26 (0.75-2.12)	0.379	1.71 (1.03-2.84)	0.039	1.75 (1.03-2.99)	0.039
Homemaker	1.06 (0.65-1.75)	0.807	1.23 (0.70-2.15)	0.469	1.20 (0.71-2.03)	0.487	1.34 (0.76-2.37)	0.316
Household income <HKD$20,000	1.32 (0.82-2.12)	0.254	0.75 (0.45-1.24)	0.264	1.03 (0.63-1.68)	0.902	0.93 (0.55-1.58)	0.800

BMI, body mass index; CI, confidence interval; OR, odds ratio; WHR, waist-to-hip ratio.
[a]Adjusted for baseline age, years since menopause, marital status, history of pregnancy, dietary total energy intake, physical activity level, sleep duration, depression, stress, and abdominal obesity status.
[b]Adjusted for baseline age, years since menopause, marital status, history of pregnancy, dietary total energy intake, physical activity level, sleep duration, depression, stress, and general obesity status.

for obesity development, in particular abdominal obesity, among women.[3,4,6]

Based on our results, Chinese women with a lower educational attainment, associated with an accelerated progression of WHR during early postmenopausal years, are anticipated to be more susceptible to cardiometabolic events in the near future, given that abdominal obesity, rather than general obesity, is particularly associated with insulin resistance, dyslipidemia, metabolic syndrome, and cardiovascular diseases among midlife and older women in developed Asian settings.[40] Since the difference in WHR by education groups was negligible among nonabdominally obese women at baseline, the early postmenopausal stage could be a critical window for prevention targeted to apparently healthy midlife women with a lower educational attainment. To further alleviate abdominal obesity and its associated cardiometabolic disease burden among women in the long run, continuous improvement in women's early-life living conditions and education opportunities through tackling the intergenerational poverty cycle and gender biases may be another important policy direction. Moreover, the differential patterning of the progressions of BMI and WHR urged distinctive strategies for the prevention of general and abdominal obesity, especially given that, relative to nonobese postmenopausal women, an excess risk of all-cause mortality was found among those with normal weight and abdominal obesity but a reduced risk was found among those with general obesity without abdominal obesity.[41] Therefore, further research on the mediating mechanisms specifically linking socioeconomic position to central fat distribution is warranted.

The present study has several strengths. Temporal sequence could be established because of our cohort design that used baseline variables to predict intrapersonal changes in obesity measures over follow-up years. Comprehensive confounding adjustments, including a range of demographic and socioeconomic characteristics, lifestyle behaviors, and mental health statuses, were employed. Also, we restricted our sample to women with no general or abdominal obesity at baseline. Because people being obese before midlife may be more genetically susceptible to obesity[42] and more likely to actively control their obesity conditions,[43] the impact on obesity of menopausal changes per se would have been distorted if obese women at baseline were included in the analyses. With the specific focus on apparently healthy nonobese midlife Chinese women aged 50 to 64 years and within 10 years of menopause, our results on an accelerated progression of WHR among women with a lower educational attainment could be better applied to this homogeneous group of early

TABLE 3. *Effects of baseline socioeconomic position on annual changes in body mass index and waist-to-hip ratio over the follow-up period based on linear mixed-effects models*

	BMI change, kg/m^2				WHR change, %			
	Univariate model[a]		Adjusted model[b]		Univariate model[a]		Adjusted model[c]	
	β (95% CI)[d]	*P*	β (95% CI)[d]	*P*	β (95% CI)[d]	*P*	β (95% CI)[d]	*P*
Socioeconomic position × follow-up year								
Primary education level or below	0.025 (-0.037-0.088)	0.428	0.022 (-0.043-0.087)	0.500	0.209 (-0.001-0.418)	0.052	0.227 (0.009-0.444)	0.041
Homemaker	0.023 (-0.041-0.087)	0.490	0.036 (-0.033-0.104)	0.310	0.219 (0.005-0.432)	0.045	0.247 (0.020-0.475)	0.034
Household income <HKD$20,000	0.015 (-0.046-0.077)	0.626	-0.004 (-0.067-0.060)	0.912	-0.013 (-0.217-0.191)	0.900	-0.089 (-0.303-0.125)	0.414

BMI, body mass index; CI, confidence interval; WHR, waist-to-hip ratio.
[a]Variables included the corresponding socioeconomic position, follow-up year, and their interaction term.
[b]Adjusted for baseline age, years since menopause, marital status, history of pregnancy, dietary total energy intake, physical activity level, sleep duration, depression, stress, abdominal obesity status, and their corresponding interaction terms with follow-up year.
[c]Adjusted for baseline age, years since menopause, marital status, history of pregnancy, dietary total energy intake, physical activity level, sleep duration, depression, stress, general obesity status, and their corresponding interaction terms with follow-up year.
[d]β coefficient of the corresponding interaction term between socioeconomic position and follow-up year.

postmenopausal women. There are, however, several caveats as well. First, because this cohort study was not designed based on a priori hypothesis on socioeconomic position and obesity, the sample size may not be adequate and therefore our findings should be interpreted with caution. Nonetheless, our observed consistent and significant associations of education level with WHR based on the two analytical approaches may suggest that the educational patterning is strong enough to be detected in a relatively small sample size. Second, residual confounding may exist due to differences in genetic composition, supplement use, and treatment-seeking behaviors, despite comprehensive adjustments for potential confounders. Last, because this study specifically focused on nonobese early postmenopausal Chinese women, our finding could not be generalized to women already with general or abdominal obesity before the postmenopausal stage and women at other life stages or of other ethnic groups.

CONCLUSIONS

The progression of WHR, rather than that of BMI, was socioeconomically patterned among Chinese women during early postmenopausal years in Hong Kong. Lower educational attainment, which partly reflects early-life adverse conditions, may exert an independent latent effect on menopausal changes in body composition and thus central fat distribution. Our results suggested the potential value in targeting early postmenopausal women with a lower educational attainment for prevention of abdominal obesity and related cardiometabolic events.

Acknowledgments: The authors acknowledge support from the Centre of Research and Promotion of Women's Health of the Chinese University of Hong Kong for the study, and are thankful to all women who participated in the study.

REFERENCES

1. Al-Safi ZA, Polotsky AJ. Obesity and menopause. *Best Pract Res Clin Obstet Gynaecol* 2015;29:548-553.
2. Kapoor E, Collazo-Clavell ML, Faubion SS. Weight gain in women at midlife: a concise review of the pathophysiology and strategies for management. *Mayo Clin Proc* 2017;92:1552-1558.
3. Lovejoy JC, Champagne CM, De Jonge L, Xie H, Smith SR. Increased visceral fat and decreased energy expenditure during the menopausal transition. *Int J Obes (Lond)* 2008;32:949-958.
4. Ho SC, Wu S, Chan SG, Sham A. Menopausal transition and changes of body composition: a prospective study in Chinese perimenopausal women. *Int J Obes (Lond)* 2010;34:1265-1274.
5. Kozakowski J, Gietka-Czernel M, Leszczynska D, Majos A. Obesity in menopause – our negligence or an unfortunate inevitability? *Prz Menopauzalny* 2017;16:61-65.
6. Donato GB, Fuchs SC, Oppermann K, Bastos C, Spritzer PM. Association between menopause status and central adiposity measured at different cutoffs of waist circumference and waist-to-hip ratio. *Menopause* 2006;13:280-285.
7. Rask-Andersen M, Karlsson T, Ek WE, Johansson A. Gene-environment interaction study for BMI reveals interactions between genetic factors and physical activity, alcohol consumption and socioeconomic status. *PLoS Genet* 2017;13:e1006977.
8. Cohen AK, Rai M, Rehkopf D, Abrams B. Educational attainment and obesity: a systematic review. *Obes Rev* 2013;14:989-1005.
9. Gonzalez D, Nazmi A, Victora CG. Childhood poverty and abdominal obesity in adulthood: a systematic review. *Cadernos Saude Publica* 2009;25 (suppl 3):S427-S440.
10. El-Sayed AM, Scarborough P, Galea S. Unevenly distributed: a systematic review of the health literature about socioeconomic inequalities in adult obesity in the United Kingdom. *BMC Public Health* 2012;12:18.
11. Charafeddine R, Van Oyen H, Demarest S. Trends in social inequalities in obesity: Belgium, 1997 to 2004. *Prev Med* 2009;48:54-58.
12. Yoo S, Cho HJ, Khang YH. General and abdominal obesity in South Korea, 1998-2007: gender and socioeconomic differences. *Prev Med* 2010;51:460-465.
13. Devaux M, Sassi F. Social inequalities in obesity and overweight in 11 OECD countries. *Eur J Public Health* 2013;23:464-469.
14. Chung GKK, Lai FTT, Yeoh EK, Chung RY. Educational inequality in physician-diagnosed hypertension widened and persisted among women from 1999 to 2014 in Hong Kong. *Sci Rep* 2019;9:14361.
15. Navarro MC, Sosa M, Saavedra P, et al. Anthropometric and gynaecological history according to the socioeconomic status of postmenopausal women: poverty and the menopause. *Menopause Int* 2010;16:12-17.
16. Cota D, Vicennati V, Ceroni L, Morselli-Labate AM, Pasquali R. Relationship between socio-economic and cultural status, psychological factors and body fat distribution in middle-aged women living in Northern Italy. *Eat Weight Disord* 2001;6:205-213.
17. Wamala SP, Lynch J, Horsten M, Mittleman MA, Schenck-Gustafsson K, Orth-Gomer K. Education and the metabolic syndrome in women. *Diabetes Care* 1999;22:1999-2003.
18. Wamala SP, Wolk A, Schenck-Gustafsson K, Orth-Gomer K. Lipid profile and socioeconomic status in healthy middle aged women in Sweden. *J Epidemiol Community Health* 1997;51:400-407.
19. Thurston RC, El Khoudary SR, Derby CA, et al. Low socioeconomic status over 12 years and subclinical cardiovascular disease: the study of women's health across the nation. *Stroke* 2014;45:954-960.
20. Montez JK, Bromberger JT, Harlow SD, Kravitz HM, Matthews KA. Life-course socioeconomic status and metabolic syndrome among midlife women. *J Gerontol B Psychol Sci Soc Sci* 2016;71:1097-1107.
21. Chung RY, Lai FT, Chung GK, Yip BH, Wong SY, Yeoh EK. Socioeconomic disparity in mortality risks widened across generations during rapid economic development in Hong Kong: an age-period-cohort analysis from 1976 to 2010. *Ann Epidemiol* 2018;28:743.e4-752.e4.
22. Yu RH, Ho SC, Ho SS, Chan SS, Woo JL, Ahuja AT. Carotid atherosclerosis and the risk factors in early postmenopausal Chinese women. *Maturitas* 2009;63:233-239.
23. Chung GKK, Yu RHY, Ho SSY, Woo J, Ho SC. Associations of consuming specific fruit and vegetable subgroups with LDL-C status in early postmenopausal Chinese women. *Menopause* 2018;25:436-443.
24. Ho SC, Liang Z, Yu RH, Sham A. Association of life events and depressive symptoms among early postmenopausal Chinese women in Hong Kong. *Menopause* 2017;24:180-186.
25. Hong Kong Government. *Secondary education in Hong Kong over the next decade*. Hong Kong: The Government Printer; 1974.
26. Ko GT, Chan JC, Chan AW, et al. Association between sleeping hours, working hours and obesity in Hong Kong Chinese: the 'better health for better Hong Kong' health promotion campaign. *Int J Obes (Lond)* 2007;31:254-260.
27. Williams DR, Gonzalez HM, Neighbors H, et al. Prevalence and distribution of major depressive disorder in African Americans, Caribbean blacks,;1; and non-Hispanic whites: results from the National Survey of American Life. *Arch Gen Psychiatry* 2007;64:305-315.
28. White RS, Jiang J, Hall CB, et al. Higher Perceived Stress Scale scores are associated with higher pain intensity and pain interference levels in older adults. *J Am Geriatr Soc* 2014;62:2350-2356.
29. WHO/IASO/IOTF. The Asia-Pacific Perspective: Redefining Obesity and Its Treatment. Health Communications Australia: Melbourne. 2000.
30. Alberti KG, Zimmet PZ. Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1: diagnosis and classification of diabetes mellitus provisional report of a WHO consultation. *Diabet Med* 1998;15:539-553.
31. Chung GK, Chung RY, Chan DC, et al. The independent role of deprivation in abdominal obesity beyond income poverty. A population-based household survey in Chinese adults. *J Public Health (Oxf)* 2019;41:476-486.
32. Hallqvist J, Lynch J, Bartley M, Lang T, Blane D. Can we disentangle life course processes of accumulation, critical period and social mobility? An analysis of disadvantaged socio-economic positions and myocardial infarction in the Stockholm Heart Epidemiology Program. *Soc Sci Med* 2004;58:1555-1562.
33. Kawachi I, Subramanian SV, Almeida-Filho N. A glossary for health inequalities. *J Epidemiol Community Health* 2002;56:647-652.

34. Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). *J Epidemiol Community Health* 2006;60:7-12.
35. Education Bureau. *Report on Review of 9-year Compulsory Education*. Hong Kong: The Government Printer; 1997.
36. Whitehead M, Pennington A, Orton L, et al. How could differences in 'control over destiny' lead to socio-economic inequalities in health? A synthesis of theories and pathways in the living environment. *Health Place* 2016;39:51-61.
37. Wich BK, Carnes M. Menopause and the aging female reproductive system. *Endocrinol Metab Clin North Am* 1995;24:273-295.
38. Haffner SM, Katz MS, Dunn JF. Increased upper body and overall adiposity is associated with decreased sex hormone binding globulin in postmenopausal women. *Int J Obes* 1991;15:471-478.
39. Harlow SD, Gass M, Hall JE, et al. Executive summary of the Stages of Reproductive Aging Workshop + 10: addressing the unfinished agenda of staging reproductive aging. *J Clin Endocrinol Metab* 2012;97:1159-1168.
40. Goh VHH, Hart WG. Excess fat in the abdomen but not general obesity is associated with poorer metabolic and cardiovascular health in premenopausal and postmenopausal Asian women. *Maturitas* 2018;107:33-38.
41. Sun Y, Liu B, Snetselaar LG, et al. Association of normal-weight central obesity with all-cause and cause-specific mortality among postmenopausal women. *JAMA Netw Open* 2019;2:e197337.
42. Hruby A, Manson JE, Qi L, et al. Determinants and consequences of obesity. *Am J Public Health* 2016;106:1656-1662.
43. Santos I, Sniehotta FF, Marques MM, Carraca EV, Teixeira PJ. Prevalence of personal weight control attempts in adults: a systematic review and meta-analysis. *Obes Rev* 2017;18:32-50.