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Body mass index trajectories and all-cause mortality in older Chinese adults: Hong Kong's Elderly Health Service Cohort

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ABSTRACT

Background Weight loss at older ages appears to be associated with higher mortality in Western and some East Asian countries, despite differences in the prevalence of obesity; whether it is relevant to China is unknown. We examined the association of body mass index (BMI) trajectories with all-cause mortality in older Chinese adults by sex and baseline age (65–69 years, 70+ years).

Methods 54 160 participants aged 65 or above from Hong Kong's Elderly Health Service Cohort with at least five BMI measurements were included. We identified distinct BMI trajectories using group-based trajectory modelling. We assessed the associations of BMI trajectories with mortality risk using a Cox model stratified by sex and age.

Results Compared with 'normal weight, stable', the 'low-normal weight, decreasing' had higher mortality risk in both sexes and age groups (eg, HR 1.43, 95% CI 1.24 to 1.66 in men aged 65–69 years). The 'overweight, stable' and 'obese, stable' had lower mortality risk, especially in men at older ages. However, the proportion in the 'low-normal weight, decreasing' was greater at 70+ years than at 65–69 years, while the proportion in the 'overweight, stable' and 'obese, stable' was lower in the older group.

Conclusions Decreasing BMI is a likely symptom of ill health in older adults. Inconsistency between the risks and the proportion in each BMI trajectory group by age suggests the observed associations could be driven by changes in weight and preferential recruitment of survivors. Maintaining a healthy weight remains relevant at older ages.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Body mass index (BMI) trajectories and mortality risk associations in older people may vary by ethnicity, given differences in baseline BMI and obesity prevalence; whether the associations are universal or context-specific remain to be elucidated, considering the understudied roles of sex and baseline age in survivorship.

WHAT THIS STUDY ADDS

⇒ This prospective cohort study of older Chinese adults shows that compared with the 'normal weight, stable' group, the 'low-normal weight, decreasing' group had higher mortality risk in both sexes and age groups; but inverse associations for the 'overweight, stable' and 'obese, stable' groups were only found in men, especially at older ages but less clearly in women, indicating the possibility of selection bias.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ This study suggests that decreasing BMI could also be a symptom of increasing ill-health in older Chinese adults, implying the need for close monitoring; maintaining a healthy weight remains highly relevant at older ages.

INTRODUCTION

Optimal weight maintenance is a well-established determinant of longevity.[1] Associations of body mass index (BMI) with all-cause mortality have been extensively examined. Paradoxical findings of overweight associated with lower mortality than normal weight have caused confusion, with some public health advice suggesting that older people do not need to worry about overweight.[2] Such an 'obesity paradox' is now recognised as an artefact partly arising from confounding by senescence and ill-health causing weight loss and death among older adults[3] and partly arising from inevitably only including survivors. A J-shaped curve for midlife BMI on mortality has also been observed with higher risk in low and high BMI groups and optimal BMI often in the overweight range, generating a complex relation of BMI with mortality in older people.[4] Randomised controlled trials (RCTs) have shown that intentional weight loss is not associated with higher mortality at older ages,[5] including older overweight or obese adults.[6] However, observationally, it is difficult to distinguish intentional and unintentional weight loss. Better understanding of how changes in BMI with age relate to mortality in older adults is imperative to providing helpful advice. In addition, such understanding may identify older adults at higher mortality risk.

BMI trajectories and their associations with longevity likely vary by ethnicity, given varying midlife obesity rates determine the characteristics of those who survive to old age. In the USA, a majority of middle-to-older adults were classified as on an 'overweight, stable' trajectory (overweight at baseline and BMI slightly increased during follow-up), and they also had the lowest mortality risk.[7–9] A smaller proportion had 'obese, increasing'

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and 'obese, decreasing' (obese at baseline and BMI increased or decreased at follow-up) trajectories which had higher mortality risk.[7–9] In Japan and Korea, older adults classified into 'low-normal, decreasing' and 'high-normal, decreasing' trajectories had higher mortality risk.[10 11] These studies were relatively small (n=1480 to 29,311) and used BMI based on self-reported weight and height, limiting the interpretation of BMI trajectories on mortality.

Discrepancies between settings may reflect differences in baseline BMI or in the prevalence of obesity, with weight loss at older ages generally associated with higher mortality in relatively thinner East Asian populations.[12 13] Whether the association of BMI trajectories with mortality risk is universal or context-specific remains to be elucidated. In addition, few previous studies have considered whether the effect of BMI trajectories is open to survival bias. Only survivors of long-term exposures (such as obesity) can be recruited at older ages.[14 15] As such, it is difficult to identify whether associations of BMI with mortality at older ages represent the effects of BMI or are a reflection of the attributes of those who survived to recruitment. To address this conundrum, we considered BMI trajectories over time by age at recruitment (65–69 years and 70+years) and sex. Inconsistency between estimates and the proportion of people in the older age group would suggest the estimates represent more than events that occurred after recruitment. We therefore assessed the association of BMI trajectories with all-cause mortality stratified by age at recruitment and sex in an understudied older Chinese population.

METHODS

Data sources

Hong Kong's Elderly Health Service (EHS) cohort is a large, contemporaneous, prospective cohort study of older Chinese adults (aged ≥65 years) in Hong Kong enrolled at the 18 territory-wide Elderly Health Centres of the Department of Health since July 1998, as detailed elsewhere.[16] It aims to promote understanding of ageing in a global context and to exploit Hong Kong as a sentinel for Chinese populations currently experiencing very rapid economic development. The initial cohort enrolled 66 820 participants from 01 July 1998 to 31 December 2001 at all the Elderly Health Centres; all older adults in Hong Kong were encouraged to enrol for preventive health services at a nominal annual fee.[16] At the centres, nurses and doctors provided physical check-ups and health assessments using clinical examinations and a structured questionnaire including demographics, lifestyle, socioeconomic position, health status, self-rated health, physical functioning, social contact, depressive symptoms and cognitive functioning. Smoking, alcohol consumption and physical activity collected at recruitment (baseline) were used in the analysis. Smoking was categorised as never smoker, that is, people 'who had never smoked as much as one cigarette a day or equivalent for the duration of 1 year'; ex-smoker, that is, 'ever-smoker who had quitted smoking completely for at least 6 months'; and current smoker, that is, people 'who currently smoked daily or occasionally for at least 1 year'.[17] Alcohol consumption was categorised based on drinking status (never, social, regular or ex-drinker),[18] the number of days per week of alcohol use (except never drinker) and the amount per occasion in categories for regular drinkers ('who drank at least 1 day per week in the past 1 month') and for excessive drinkers was based on the units per day and number of drinking days per week. Physical activity[19] was categorised based on the participants' number of days per week performing physical activity in the previous month, and the duration of physical activity per day, from which they were categorised into estimated hours per week. Height and weight were measured according to standard protocols. The participants were expected to re-attend at regular intervals. Vital status was ascertained via record linkage to the Death Registry, which is very complete. Up to 31 December 2017, 185 538 participants had enrolled in the EHS Cohort, comprising about 15.3% Hong Kong's population aged ≥65 years in 2017.[20]

EXPOSURE

The exposure was BMI trajectories. BMI was calculated using height and weight measured by nurses during the health assessments. Among those with at least one BMI measurement, the number of BMI measurements ranged from one to 18 with an average of four. The median follow-up duration was 8.6 years (IQR 3.8 to 12.8), and the median time between measurements was 1.4 years (IQR 1.2 to 1.6). Considering no universally accepted standard for the optimal number of BMI measurements for generating trajectories exists, and five to six measurements were available per participant, we included participants with at least five BMI measurements to characterise the trajectories.

STATISTICAL ANALYSIS

We compared baseline characteristics between the included and excluded participants using Cohen's *w* and Cohen's *d* respectively for categorical and continuous variables. To generate trajectories, we used group-based trajectory modelling to categorise the participants according to similar patterns of BMI changes. First, we used a subsample (20% of the entire eligible cohort), based on random sampling within each group of participants with the same number of repeated measurements, that could be maximally included for efficiency to identify BMI trajectories. We considered trajectory models with two to five groups using a B-spline curve of degree three (ie, assuming cubic patterns of changes in BMI across waves since study entry) to take advantage of our large cohort and to ensure sufficient granularity. We imputed missing data with a missing-at-random assumption. To obtain the imputed dataset with all participants having the same number of repeated measurements (10 waves), the participants with nine measurements or below were imputed by repeated sampling of the measurements with replacement, and those with 11 measurements or above were imputed by randomly selecting the required number of measurements among the available measurements.[21] We selected the optimal model (ie, the number of distinct trajectories) based on the Bayesian Information Criterion, the proportion of participants assigned in each subgroup, the average and minimum posterior probability of assignment (with the recommended threshold >0.7),[22] as well as the appropriateness for comparison with previous studies. Based on the identified optimal model, we estimated the posterior probabilities belonging to each of the distinct trajectories for each participant. We then assigned each participant to a predicted trajectory with the minimal difference between the observed and predicted observations at the last measurement.[23]

Given the average age was 70.5 years in this study, we categorised baseline age into 65–69 years and 70+ years. We examined the associations of BMI trajectories with all-cause mortality risk by age (65–69 years and 70+ years) and sex using a Cox proportional hazard model, from which the HR with 95% CI was reported. We adjusted for confounders

Table 1 Baseline characteristics for 54 160 Hong Kong older Chinese adults in the observational study of body mass index trajectories and total mortality from Hong Kong's Elderly Health Service Cohort

	Overall	Normal weight, stable	Low-normal weight, decreasing	Overweight, stable	Obese, stable	Obese, decreasing
Baseline characteristics	(n=54 160)	(n=15 479)	(n=7818)	(n=16 941)	(n=10 703)	(n=3219)
Age (years), mean (SD)	70.46 (4.47)	70.56 (4.56)	71.43 (5.04)	70.31 (4.33)	70.06 (4.13)	69.75 (3.89)
Age group (years)						
65–69	27 842 (51.4%)	7876 (50.9%)	3466 (44.3%)	8906 (52.6%)	5791 (54.1%)	1803 (56.0%)
70	26 318 (48.6%)	7603 (49.1%)	4352 (55.7%)	8035 (47.4%)	4912 (45.9%)	1416 (44.0%)
Sex						
Women	34 840 (64.3%)	9682 (62.5%)	5061 (64.7%)	10 486 (61.9%)	7143 (66.7%)	2468 (76.7%)
Men	19 320 (35.7%)	5797 (37.5%)	2757 (35.3%)	6455 (38.1%)	3560 (33.3%)	751 (23.3%)
Education						
Illiterate	12 099 (22.3%)	3047 (19.7%)	1449 (18.5%)	3713 (21.9%)	2782 (26.0%)	1108 (34.4%)
Literate but no formal education	7774 (14.4%)	2036 (13.2%)	1109 (14.2%)	2350 (13.9%)	1713 (16.0%)	566 (17.6%)
Primary	20 946 (38.7%)	6213 (40.1%)	3068 (39.2%)	6596 (38.9%)	4033 (37.7%)	1036 (32.2%)
Secondary or above	13 338 (24.6%)	4182 (27.0%)	2192 (28.0%)	4280 (25.3%)	2175 (20.3%)	509 (15.8%)
Type of housing						
Public or aided	21 811 (40.3%)	6175 (39.9%)	3071 (39.3%)	6821 (40.3%)	4395 (41.1%)	1349 (41.9%)
Private (rented)	2189 (4.0%)	621 (4.0%)	359 (4.6%)	651 (3.8%)	427 (4.0%)	131 (4.1%)
Private (self-owned)	28 091 (51.9%)	8100 (52.3%)	3989 (51.0%)	8880 (52.4%)	5506 (51.4%)	1616 (50.2%)
Others	2069 (3.8%)	583 (3.8%)	399 (5.1%)	589 (3.5%)	375 (3.5%)	123 (3.8%)
Public assistance						
Yes	47 918 (88.5%)	13 711 (88.6%)	6694 (85.6%)	15 182 (89.6%)	9504 (88.8%)	2827 (87.8%)
No	6241 (11.5%)	1768 (11.4%)	1124 (14.4%)	1759 (10.4%)	1198 (11.2%)	392 (12.2%)
Smoking status						
Never smoker	39 707 (74.2%)	11 320 (74.0%)	5503 (71.0%)	12 371 (73.9%)	7957 (75.5%)	2556 (80.8%)
Ex-smoker	9733 (18.2%)	2744 (17.9%)	1397 (18.0%)	3207 (19.2%)	1944 (18.4%)	441 (13.9%)
Current smoker	4046 (7.6%)	1238 (8.1%)	847 (10.9%)	1156 (6.9%)	637 (6.0%)	168 (5.3%)
Alcohol consumption						
Never drinker	42 168 (77.9%)	12 128 (78.4%)	6121 (78.3%)	13 137 (77.5%)	8242 (77.0%)	2540 (78.9%)
Ex-drinker	3193 (5.9%)	841 (5.4%)	490 (6.3%)	988 (5.8%)	676 (6.3%)	198 (6.2%)
Social drinker	6471 (11.9%)	1807 (11.7%)	850 (10.9%)	2069 (12.2%)	1364 (12.7%)	381 (11.8%)
Moderate drinker	1577 (2.9%)	462 (3.0%)	247 (3.2%)	496 (2.9%)	298 (2.8%)	74 (2.3%)
Excessive drinker	750 (1.4%)	241 (1.6%)	110 (1.4%)	251 (1.5%)	122 (1.1%)	26 (0.8%)
Physical activity (hours per week)						
None	6469 (11.9%)	1791 (11.6%)	1018 (13.0%)	1897 (11.2%)	1330 (12.4%)	433 (13.5%)
<1.5 hours	4402 (8.1%)	1262 (8.2%)	675 (8.6%)	1346 (7.9%)	812 (7.6%)	307 (9.5%)
1.5-<3.0 hours	9726 (18.0%)	2794 (18.1%)	1587 (20.3%)	2939 (17.3%)	1808 (16.9%)	598 (18.6%)
3.0-<4.5 hours	4458 (8.2%)	1285 (8.3%)	584 (7.5%)	1517 (9.0%)	855 (8.0%)	217 (6.7%)
4.5+hours	29 103 (53.7%)	8347 (53.9%)	3953 (50.6%)	9241 (54.5%)	5898 (55.1%)	1664 (51.7%)

including socioeconomic (education, housing and public assistance) and lifestyle attributes (smoking, alcohol use and physical activity). We assessed whether the BMI trajectories differed by age group using a $\chi 2$ test. We assessed whether the associations varied by age group or sex by deriving the z-statistic based on differences in the stratum-specific estimates and obtaining the two-tailed *p* value for interaction, with $p<0.05$ indicating the presence of an age or sex difference.[24]

Statistical analyses were conducted using R V.4.1.2 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Of the original 185 538 participants, a total of up to 54 160 older Chinese adults with five or more BMI measurements were included (online supplemental appendix figure1). Two-thirds were women, where the average age was 70.5 years (SD 4.5) (table 1). One-third were illiterate or had received no formal education. Two-fifths lived in public or aided housing, with one-tenth receiving public assistance. Most were non-smokers (74% never and 18% ex-smokers), and non-drinkers (80% never and 6% ex-drinkers). Half of the participants engaged in physical activity for 4.5+ hours weekly. The included and excluded participants (due to insufficient number of repeated measurements) were similar in baseline characteristics, with small Cohen's effect sizes (online supplemental appendix table 1).

Figure 1 shows the predicted BMI trajectories derived from 541 600 BMI measurements (of which 446 144 (82.4%) were actual measurements) after fitting repeated BMI measurements based on a subsample (20% of the entire eligible participants) to the group-based trajectory models. Five distinct BMI trajectories (BMI at baseline and

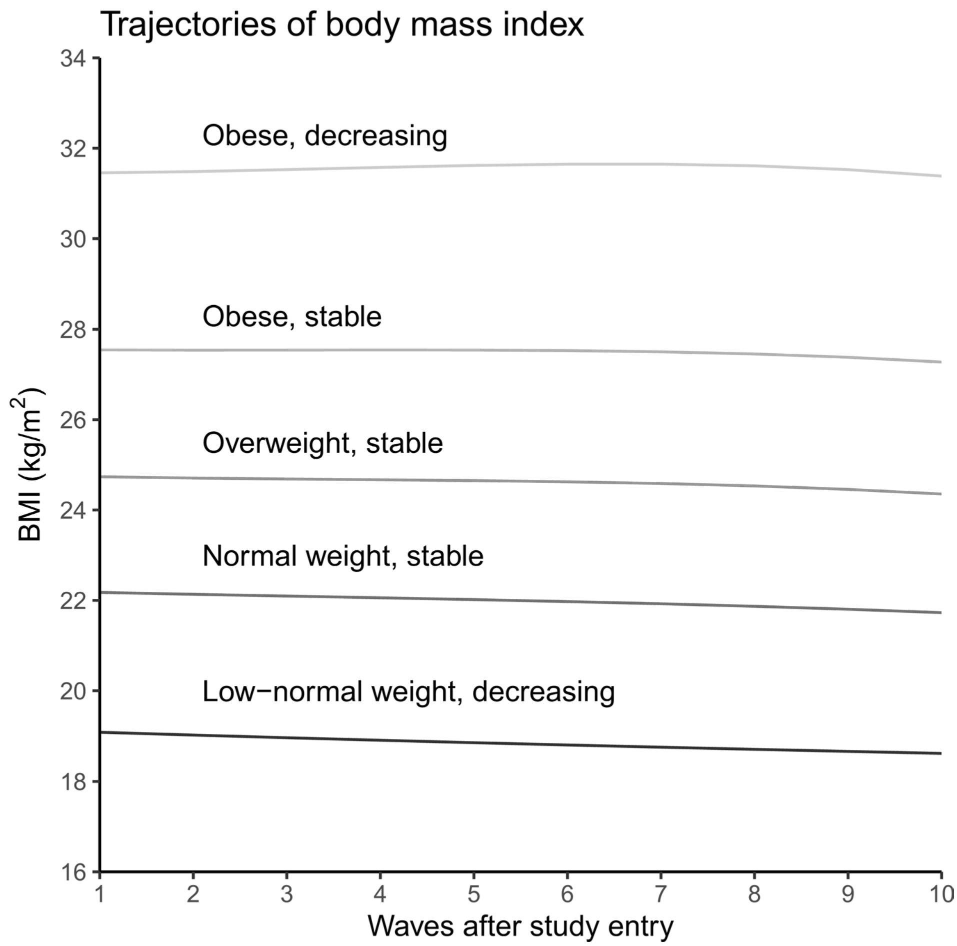

Figure 1 The five-group trajectories of body mass index in older Chinese adults from Hong Kong's Elderly Health Service Cohort.

during follow-up) were identified: 'low-normal weight, decreasing' (13.2%) (ie, lower-than-normal BMI at baseline, and BMI decreased during follow-up), 'normal weight, stable' (29.6%), 'overweight, stable' (32.6%), 'obese, stable' (19.4%) and 'obese, decreasing' (5.2%). This five-trajectory model had the lowest Bayesian Information Criterion value compared with the two- to four-group models (online supplemental appendix table 2), with acceptable sample sizes in each group (>5%) and average posterior probability of assignment (≥0.97) exceeding the threshold (>0.7).

Figure 2 shows the associations of the BMI trajectories with mortality by age group and sex, adjusted for socioeconomics (education, housing and public assistance) and lifestyle (smoking, alcohol use and physical activity). The log-log survival plots show the proportional hazard assumption was generally met (online supplemental

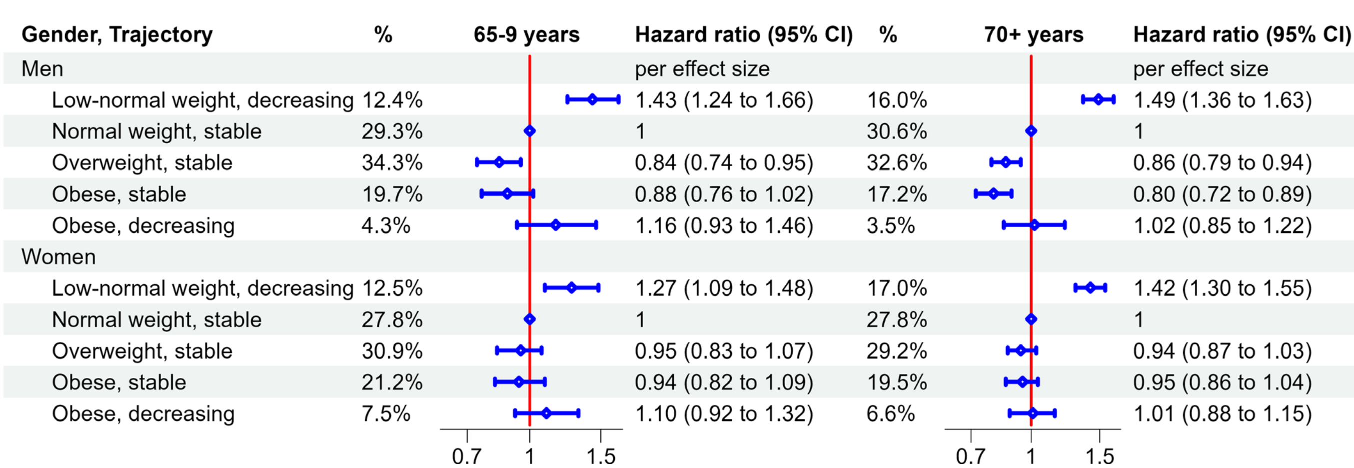

Figure 2 Associations of body mass index trajectories with all-cause mortality stratified by sex and baseline age for older Chinese adults from Hong Kong's Elderly Health Service Cohort. CI, confidence interval. Adjusted for socio-demographics and lifestyle (education, housing, public assistance, smoking, alcohol use, physical activity). Mean baseline age by group: men 65-69 (67.2 years), men 70+ (74.0 years), women 65-69 (67.0 years), women 70+ (74.1 years).

appendix figure 2). The BMI trajectories differed by age group ($\chi2$ p value: <0.0001). The associations of BMI trajectories with mortality varied by age and sex (p value for interaction: age<0.0001, sex<0.0001, age and sex<0.0001). Compared with the 'normal weight, stable' group, the 'low-normal weight, decreasing' BMI group was consistently associated with higher mortality risk in both sexes and age groups; however, the proportion of men and women in the 'low-normal weight, decreasing' group was higher at 70+ than at 65–69 years. Compared with the 'normal weight, stable' group, the 'overweight, stable' and 'obese, stable' groups had lower mortality risk, particularly in men; however, the proportion of men and women in the 'overweight, stable' and 'obese, stable' groups was lower at 70+ than at 65–69 years. The 'obese, decreasing' group tended to have a higher mortality risk in both sexes at 65–69 years but not at 70+ years.

DISCUSSION

This is the first study examining the role of BMI trajectories in all-cause mortality in older Chinese adults in Hong Kong. Consistent with Japanese and Korean studies, the 'low-normal weight, decreasing' group had the highest mortality risk in both sexes and age groups.[10 11] Both the 'overweight, stable' and 'obese, stable' groups were associated with lower mortality risks, especially in men compared with the 'normal weight, stable' group that are universally observed in the USA,[7–9] Japan[10] and Korea.[11] However, our study adds by showing that the proportions of older participants across different BMI trajectory groups did not match with the expected proportions based on what we observed in the younger participants, suggesting differential survival by age at recruitment.

Our finding that the 'low-normal weight, decreasing' group had the highest mortality risk is consistent with observations in the West and some East Asian populations despite varying baseline BMI.[7–11] Older adults with low-normal weight at baseline and falling BMI during follow-up might not be able to maintain energy balance and physiological reserve. Being underweight has been associated with higher infection-related mortality risks in older adults whose immune function fades with ageing making them less resistant to infection.[25] Decreasing BMI in older adults occurs from adiposity, muscle or bone loss, so frailty might promote inflammation.[25] Weight loss can also trigger changes in neuroendocrine hormones including an increase in growth hormone,[26] which might link to higher mortality risks as observed in transgenic mice and people with acromegaly.[27] Two meta-analyses have shown weight loss associated with increased all-cause mortality risk across ethnicity.[28 29] In particular, unintentional weight loss was positively associated with all-cause mortality, and being obese at baseline did not alter the risk imposed by unintentional weight loss.[30] As such, higher mortality risk among the 'low-normal weight, decreasing' group is possibly because unintentional weight loss is a symptom of ill health, such as cancer. Falling BMI may reflect underlying ill health or subclinical disease that leads to unintentional weight loss and predisposes to higher mortality risk.[31 32] With multimorbidity and polypharmacy generally increasing with advanced age, unintentional weight loss may occur perhaps due to chronic inflammation, higher energy metabolism, impaired physical functioning or medication use that affects the sense of taste or induces nausea, though the exact aetiology remains unclear.[33]

This study also showed that the 'overweight, stable' and 'obese, stable' groups had lower mortality risk, especially in men, consistent with observations in Western and East Asian older populations. Rather than suggesting any benefits of being overweight or obese, such associations have been suggested to be explained as confounding by ill-health[31] and selection bias.[15] Specifically, selection bias may explain why the 'low-normal weight, decreasing' group had the highest mortality rate at 65–69 years and yet comprised a larger proportion of the sample at 70+ years, presumably because only people with low weight survive to be recruited at 70+ years age. Obesity is a well-known risk factor for cardiovascular disease, the leading global cause of mortality.[34] People who were exposed to harmful exposures such as overweight or obesity could have already died at earlier ages and hence would not be able to survive to be recruited at older ages.[14] We cannot rule out the presence of selection bias in this study given the inverse associations for the 'overweight, stable' and 'obese, stable' groups were only found in men, especially in older ages. More men than women could have died prematurely because Hong Kong women have longer lifespan than men despite their fairly high overall life expectancy.[35] Also, fewer and fewer survivors at older ages could have made harmful exposures (eg, obesity) appear protective.[36] Selection bias could also explain why the 'obese, decreasing' group tended to have higher mortality risks in 65–69 years, but the association disappeared in older ages of 70+ years probably because of the depletion of the susceptibles (ie, obese survivors) who had already started losing weight as a symptom of dying.[37]

Our study took advantage of the population-based EHS cohort with a large sample size, BMI based on measured rather than self-reported height and weight, vital status ascertained using record linkage to a complete Death Registry, a long follow-up period, and minimal recall and response bias; however, some limitations have to be considered. First, enrolment and follow-up at the EHS centre are voluntary. The EHS attendees may be more health-conscious, but the EHS service is highly affordable and accessible. The EHS cohort comprises nearly one sixth of the older Chinese population in Hong Kong. Second, random measurement error of height and weight is possible, which may affect precision, for which our large sample size compensates. Third, as in other longitudinal studies on trajectories, the number and timing of repeated BMI measurements varied by participants. This reflects actual health service utilisation, and hence our findings can be applicable to primary care settings. Lastly, we were not able to consider the issues of weight loss in severe illness because this is an epidemiological study rather than an investigation of patient management; however, that does not detract from the importance of such questions.

CONCLUSIONS

Decreasing BMI may be a symptom of increasing ill-health in older adults, implying the need for close monitoring including serial body weight measurements, nutritional screening and assessment of signs or symptoms of illness causing nutrient loss.[38] People with higher BMI at older ages may represent more strongly selected survivors of high BMI, rather than people for whom BMI is protective. Maintaining a healthy weight in older ages is relevant across populations. Our findings have some consistency with current guidelines for older people in Hong Kong[38 39] and may have wider applicability.

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Contributors KMK conceptualised ideas, performed the literature review, directed analytic strategy, acquired data, conducted data analysis, interpreted findings, drafted the manuscript, and supervised and implemented the study from conception to completion. LSY acquired data, interpreted findings and reviewed the manuscript critically. GML interpreted findings and reviewed the manuscript critically. CMS conceptualised ideas, suggested analytic strategy, interpreted findings and revised drafts of the manuscript critically. KMK and CMS had full access to all the data (including statistical reports) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. CMS is the guarantor. All authors read and approved the final manuscript.

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Competing interests No competing interest.

Patient consent for publication Not applicable.

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Data availability statement Data may be obtained from a third party and are not publicly available.

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