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Sex-specific intergenerational trends in morbidity burden and multimorbidity status in Hong Kong community: an age-period-cohort analysis of repeated population surveys

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ABSTRACT

Objectives Prevalence of multimorbidity has been increasing worldwide. While population ageing undoubtedly contributes, secular trends have seldom been decomposed into age, period and cohort effects to investigate intergenerational differences. This study examines the birth cohort effect on morbidity burden and multimorbidity in Hong Kong community.

Design Sex-specific age-period-cohort analysis with repeated cross-sectional surveys.

Setting A territory-wide population survey database.

Participants 69 636 adults aged 35 or above who participated in the surveys in 1999, 2001, 2005 or 2008.

Main outcome measures Morbidity burden was operationalised as number of chronic conditions from a list of 14, while multimorbidity was defined as a dichotomous status of whether participants had two or more conditions.

Results For both sexes, there was an upward inflection (positive change) of risk of increased morbidity burden starting from cohort 1955–1959. For men born after 1945–1954, there was a trend of lower risk (relative risk=0.63, 95% CI 0.50 to 0.80 for 1950–1954 vs 1935–1939) which continued through subsequent cohorts but with no further declines. In women, there had been a gradual increase of risk, although only significant for cohort 1970–1974 (relative risk=1.90, 95% CI 1.08 to 1.34 vs 1935–1939). Similar results were found for dichotomous multimorbidity status.

Conclusions The trend of lower risk starting from men born in 1945–1954 may be due to a persistent decline in smoking rates since the 1980s. On the other hand, the childhood obesity epidemic starting from the late 1950s coincided with the observed upward inflection of risk for both sexes, that is, notably more drastic increase of risk in women and the levelling-off of the decline of risk in men. These findings highlight that the cohort effects on morbidity burden and multimorbidity may be sex-specific and contextual. By examining such effects in different world populations, localised sex-specific and generation-specific risk factors can be identified to inform policy-making.

Strengths and limitations of this study

► We adopted population-based survey data which are highly representative of the Hong Kong community-dwelling population.
► Sampling strategy and data collection methodology were highly consistent across years, that is, 1999–2008.
► We did not analyse institutionalised people who may have a significantly higher prevalence of multimorbidity.
► There may be self-report bias in the measure of morbidity burden and multimorbidity status.
► Repeated cross-sectional nature of the data renders causal inferences inappropriate.

INTRODUCTION

Multimorbidity, defined as the co-occurrence of two or more chronic health conditions in an individual,[1] is increasingly common as populations age.[2–5] It is consistently found to be associated with poorer quality of life,[6] greater healthcare utilisation,[7] and greater risk of mortality.[8] This problem is also characterised by a steep socioeconomic gradient whereby prevalence is significantly higher among socioeconomically deprived populations.[9 10] However, since secular trends of multimorbidity are seldom decomposed into separate temporal dimensions (biological age, calendar period and birth cohort[11]), it is largely unclear whether the increasing prevalence is solely driven by population ageing, or whether it also reflects changing risk in different birth cohorts.

In the study of temporal trends, intergenerational/cohort differences of disease frequencies have often been neglected with more focus on the effects of age and period, which represent, respectively, the biological ageing

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processes and the environmental factors happening at the time of data collection (eg, diagnosis). Birth cohort membership, on the other hand, represents the health-related exposures of the same generations; for instance, similar nutrition and consumption patterns, similar living environments such as housing types and similar quality of healthcare and other services during early life.[11][12] The comparison of cohorts, therefore, may reveal intergenerational differences of these exposures in relation to the trend of multimorbidity. Nonetheless, without proper statistical adjustments, risk differences across cohorts assuming the same age and period cannot be properly observed, and thus, the underlying factors of generation-specific risks that may potentially inform healthcare policies remain largely unknown. Existing literature on birth cohort effects on multimorbidity is also scarce, and the only identified study that investigated cohort effects on multimorbidity in Canada included a limited span of birth years that were grouped into five 10 year cohorts only.[13] Moreover, cohort effects depend on a wide range of population-specific factors.[14–16] Further research in different populations is therefore warranted to inform localised generation-specific policies and to predict the health status of the 'in-coming' older people who currently belong to younger cohorts.

This study examines the birth cohort effect on increased morbidity burden and multimorbidity in Hong Kong. Like the rest of the developed world, the city has a progressively ageing population, with the median age rising from 36.7 in 2001 to 43.4 in 2016.[17][18] In addition, the life experience across generations in Hong Kong has changed very rapidly during the past decades, which may be conducive to intergenerational differences in the prevalence of multimorbidity. Hong Kong experienced several waves of massive migration from Mainland China during the mid-1900s due to the World War II, the Chinese Civil War and the postwar political turmoil.[19] These healthy immigrants and their descendants constitute the vast majority of the modern population of Hong Kong.[19] During the post-war period, Hong Kong was one of the fastest growing economies in the world, achieving an annual growth rate of 9.5% from 1961 to 1982,[20] and experienced very rapid macroenvironmental socioeconomic transitions. These transitions have, in turn, resulted in multiple large changes in society, including substantial improvements in living standards, healthcare services, health literacy and public hygiene.

Based on the findings from previous studies in Hong Kong that identified significant cohort effects (ie, intergenerational differences) in other population health indicators, most notably all-cause and cause-specific mortality,[14][21–25] we hypothesise a similar significant role of the birth cohort in determining the prevalence of morbidity burden and multimorbidity. Owing to the substantial differences between men and women in physiology and lifestyle as well as the rapid changes to the role of women in society, we further stratified the analyses by sex.

METHODS
Study population
The Thematic Household Survey (THS) on health-related topics conducted by the Government in 1999, 2001, 2005 and 2008 supplied the data for this study. By geographically stratified random sampling, each of the four rounds of survey covered 95% of the non-institutionalised residential population in Hong Kong (106 332 respondents aged 15 years or older) and collected cross-sectional self-reported data on chronic health conditions, healthcare utilisation and sociodemographic characteristics. In this study, we only included adults aged 35 years or older (n=69 636) since we primarily focused on non-communicable diseases. The publicly available online THS reports give more detailed descriptions of the sampling and data collection procedures.[26] During the period 1999–2008, there have been no major changes in the institutionalised population with annual number of hospital admissions remaining steadily at around 1.2 million and a discharge rate of around 160 per 1000 persons.[27] Also, the percentage of older persons living in elderly care homes was estimated at around 1.7% over the period.[28] Since this study only involves the analysis of anonymous secondary data, no ethical approval was required.

Patient and public involvement
The study did not involve patients. The survey data are available on request from the Food and Health Bureau of the Hong Kong SAR Government, a third party, to researchers who meet the criteria for access to confidential data.

Measures
Morbidity burden and multimorbidity
THS collected participants' self-report of whether they had been told by a medical doctor that they had any of the following 14 diseases: hypertension, high cholesterol, diabetes, heart disease, thyroid disease, liver disease, chronic bronchitis/emphysema/ bronchiectasis, asthma, chronic kidney disease, stroke, anaemia, skin disease, malignant neoplasm and immune disease. The primary study outcome was morbidity burden, defined as the count of how many of the 14 chronic diseases each individual had. Multimorbidity status, defined as an individual having two or more chronic diseases, was used as the secondary outcome.

Age, period and cohort effects
We used self-reported age (in years) to represent the temporal dimension of biological age, and used the 4 years of survey, that is, 1999, 2001, 2005 and 2008, to represent the calendar periods. The birth year was derived by subtracting the individuals' age from the year of survey and grouped into 15 5-year birth cohorts ranging from 1900 to 1904 to 1970–1974. In our study, the age effect represents the average change in the risk of increased morbidity burden and multimorbidity when a person advances in age, regardless of the year he/she

was born or the time he/she was surveyed. The period effect represents the variation in the risk across time (ie, different years of survey in this case), given the same age and birth cohort. Finally, the cohort effect represents the effect of being born in particular years compared with other years on the risk of increased morbidity burden and multimorbidity, with age and year of survey held constant.

Analysis
Hierarchical age-period-cohort analyses
To address the problem of collinearity between age, period and cohort (Period-age=cohort) in estimating relative risks, we adopted the hierarchical age-period-cohort modelling approach proposed by Yang and Land.[25 29] We constructed a series of generalised linear mixed models (Poisson regression) with the number of chronic diseases (ordinal, out of the listed 14) as the primary outcome to decompose the secular trends into age, period and cohort effects. We then conducted similar analyses (logistic regression) for multimorbidity status (binary) as the secondary outcome.

Since the effect of the biological ageing process should be relatively universal across individuals, we specified age effect as fixed. The cohort effect was also specified as fixed because of the uniqueness of the lifetime health-related exposures to each birth cohort, which would not be appropriately represented by a random effect assumed to be normally distributed.[30] We specified the period effects to be random because there is no reason to believe that any of the 4 years of survey have had a unique effect on multimorbidity. The Hausman specification test was also conducted to confirm the appropriateness of this model specification. We conducted an overall analysis with statistical adjustment for sex, followed by a sex-specific analysis. The Poisson model was formally written as follows:

$$\ln\left(E\left(y_{ijk}\right)\right) = \beta_{0jk} + \beta_1 Age_{ijk} + \beta_2 Age_{ijk}^2$$

$$\beta_{0jk} = \gamma_0 + \gamma_{1j} \sum_{j=2}^{J} Cohort_j + v_{0k}$$

$$v_{0k} \sim N\left(0, \tau_v\right)$$

where the expected number of chronic diseases y_{ijk} in individual i born in cohort j surveyed in year k was explained in a two-level random intercept model. v_{0k} represents the residual random effect of year k assumed to be following a normal distribution with mean 0 and variance τ_v. γ_0 is the model intercept. γ_1 represents the fixed effect of cohort j. J is the number of cohorts. Subsequently, we replicated these procedures using multimorbidity status as a secondary analysis (logistic regression). Relative risks and ORs were plotted and tabulated to observe the intergenerational trends.

Sensitivity analyses
A series of sensitivity analyses was conducted. First, to investigate the possible role of changing lifestyle patterns, we replicated the main analyses with the count of mainly lifestyle-related diseases (ie, hypertension, high cholesterol, diabetes, heart disease, chronic kidney disease, stroke, malignant neoplasm) as the outcome. Second, we replicated the analyses with the period effect specified as fixed to examine how results might change with a different model specification. Third, we adopted the leave-one-out approach where we replicated the primary analyses by omitting one of the 14 listed diseases in each replication. Last, since hypertension and high cholesterol were the main drivers of the increase in the prevalence of multimorbidity, we conducted a further replication with those two conditions omitted.

There were no missing data in the study since only information on age, sex, survey year and presence of self-report chronic diseases (with absence of self-reports being treated as non-case) were needed for the analyses. We conducted all the analyses in the R statistical environment (V.3.3.3), and implemented generalised linear mixed models using the R package 'lme4'.[31]

RESULTS
Sample characteristics
Table 1 shows the sample characteristics by the year of survey. An alternative tabulation of the information by sex is presented as online supplementary table ST1. Across the years of survey, the sex ratio was reasonably balanced. The ageing of the Hong Kong population over the period is apparent from the changing age composition of the sample: 14.0% participants were aged 70 years or older in 1999 compared with 17.1% in 2008. Except for thyroid disease, an increase is observed in the proportion of participants reporting a diagnosis for all the listed diseases. In 1999, 3.5% of the participants were classified as multimorbid (reporting two or more diseases), while the figure increased to 8.8% in 2008. Figure 1 shows the proportion of multimorbid participants by age and sex across the years of survey.

Age-period-cohort analyses
Hausman specification test results confirmed the appropriateness of specifying fixed cohort effects and random period effects (online supplementary table ST2). Relative risk estimates were consistently lower in earlier cohorts born in the first half of the 20th century than in the reference 1935–1939 cohort in all three models (overall, male and female, figures 2 and 3), possibly due to healthy survivor effect in that the very old people who lived long enough to be surveyed may be healthier. Nevertheless, the relative risks were non-significant, possibly because of smaller numbers of older people surveyed. The age effects (fixed) in the analyses all showed a general increase of risk with increased age but with a slight decline at an advanced age (as illustrated by relative risks for the squared standardised age <1) possibly due to a healthy survivor effect.

Overall model
In the overall analysis (men and women combined) as shown in figure 2 and online supplementary table ST3,

Table 1 Sample characteristics by year of survey*

Year of survey	1999	2001	2005	2008	Total
N	17 229	17 700	17 311	17 396	69 636
Sex (%)					
Male	8533 (49.5)	8640 (48.8)	8441 (48.8)	8432 (48.5)	34 046 (48.9)
Female	8696 (50.5)	9060 (51.2)	8870 (51.2)	8964 (51.5)	35 590 (51.1)
Age (%)					
35–39	3375 (19.6)	3081 (17.4)	2432 (14.0)	2214 (12.7)	11 102 (15.9)
40–44	3309 (19.2)	3391 (19.2)	2854 (16.5)	2531 (14.5)	12 085 (17.4)
45–49	2441 (14.2)	2571 (14.5)	2842 (16.4)	2730 (15.7)	10 584 (15.2)
50–54	1979 (11.5)	2285 (12.9)	2504 (14.5)	2595 (14.9)	9363 (13.4)
55–59	1155 (6.7)	1252 (7.1)	1749 (10.1)	1899 (10.9)	6055 (8.7)
60–64	1359 (7.9)	1241 (7.0)	1190 (6.9)	1385 (8.0)	5175 (7.4)
65–69	1199 (7.0)	1316 (7.4)	1101 (6.4)	1064 (6.1)	4680 (6.7)
70–74	1080 (6.3)	1206 (6.8)	1064 (6.1)	1163 (6.7)	4513 (6.5)
75–79	636 (3.7)	700 (4.0)	780 (4.5)	819 (4.7)	2935 (4.2)
80–84	451 (2.6)	413 (2.3)	498 (2.9)	651 (3.7)	2013 (2.9)
85–89	182 (1.1)	171 (1.0)	211 (1.2)	231 (1.3)	795 (1.1)
90–94	53 (0.3)	60 (0.3)	65 (0.4)	94 (0.5)	272 (0.4)
95–99	10 (0.1)	12 (0.1)	21 (0.1)	19 (0.1)	62 (0.1)
100+	0 (0.0)	1 (0.0)	0 (0.0)	1 (0.0)	2 (0.0)
Birth cohort (%)					
1900–1904	10 (0.1)	4 (0.0)	0 (0.0)	0 (0.0)	14 (0.0)
1905–1909	53 (0.3)	32 (0.2)	8 (0.0)	2 (0.0)	95 (0.1)
1910–1914	182 (1.1)	101 (0.6)	45 (0.3)	25 (0.1)	353 (0.5)
1915–1919	451 (2.6)	301 (1.7)	164 (0.9)	116 (0.7)	1032 (1.5)
1920–1924	636 (3.7)	568 (3.2)	395 (2.3)	279 (1.6)	1878 (2.7)
1925–1929	1080 (6.3)	987 (5.6)	711 (4.1)	674 (3.9)	3452 (5.0)
1930–1934	1199 (7.0)	1276 (7.2)	978 (5.6)	886 (5.1)	4339 (6.2)
1935–1939	1359 (7.9)	1290 (7.3)	1087 (6.3)	1149 (6.6)	4885 (7.0)
1940–1944	1155 (6.7)	1152 (6.5)	1084 (6.3)	1083 (6.2)	4474 (6.4)
1945–1949	1979 (11.5)	1779 (10.1)	1691 (9.8)	1491 (8.6)	6940 (10.0)
1950–1954	2441 (14.2)	2507 (14.2)	2141 (12.4)	2025 (11.6)	9114 (13.1)
1955–1959	3309 (19.2)	3128 (17.7)	2993 (17.3)	2643 (15.2)	12 073 (17.3)
1960–1964	3375 (19.6)	3279 (18.5)	2657 (15.3)	2709 (15.6)	12 020 (17.3)
1965–1969	0 (0.0)	1296 (7.3)	2789 (16.1)	2436 (14.0)	6521 (9.4)
1970–1974	0 (0.0)	0 (0.0)	568 (3.3)	1878 (10.8)	2446 (3.5)
Self-reported chronic diseases (%)					
Hypertension	1337 (7.8)	1567 (8.9)	2304 (13.3)	2839 (16.3)	8047 (11.6)
High cholesterol	142 (0.8)	143 (0.8)	313 (1.8)	1027 (5.9)	1625 (2.3)
Diabetes	712 (4.1)	841 (4.8)	925 (5.3)	1173 (6.7)	3651 (5.2)
Heart disease	440 (2.6)	528 (3.0)	537 (3.1)	503 (2.9)	2008 (2.9)
Thyroid disease	129 (0.7)	128 (0.7)	142 (0.8)	127 (0.7)	526 (0.8)
Liver disease	66 (0.4)	80 (0.5)	110 (0.6)	132 (0.8)	388 (0.6)
Chronic bronchitis/emphysema/ bronchiectasis	99 (0.6)	160 (0.9)	124 (0.7)	144 (0.8)	527 (0.8)
Asthma	112 (0.7)	131 (0.7)	151 (0.9)	190 (1.1)	584 (0.8)

Continued

Table 1 Continued					
Year of survey	1999	2001	2005	2008	Total
Chronic kidney disease	55 (0.3)	97 (0.5)	75 (0.4)	74 (0.4)	301 (0.4)
Stroke	94 (0.5)	128 (0.7)	118 (0.7)	194 (1.1)	534 (0.8)
Anaemia	13 (0.1)	19 (0.1)	34 (0.2)	57 (0.3)	123 (0.2)
Skin disease	92 (0.5)	88 (0.5)	90 (0.5)	198 (1.1)	468 (0.7)
Malignant neoplasm	139 (0.8)	142 (0.8)	159 (0.9)	169 (1.0)	609 (0.9)
Immune disease	6 (0.0)	18 (0.1)	45 (0.3)	56 (0.3)	125 (0.2)
Number of chronic diseases (%)					
None	14 523 (84.3)	14 549 (82.2)	13 420 (77.5)	12 517 (72.0)	55 009 (79.0)
One	2102 (12.2)	2412 (13.6)	2872 (16.6)	3343 (19.2)	10 729 (15.4)
Two	495 (2.9)	593 (3.4)	837 (4.8)	1163 (6.7)	3088 (4.4)
Three	96 (0.6)	120 (0.7)	150 (0.9)	298 (1.7)	664 (1.0)
Four	10 (0.1)	20 (0.1)	29 (0.2)	59 (0.3)	118 (0.2)
Five or more	3 (0.0)	6 (0.0)	3 (0.0)	16 (0.1)	28 (0.0)

*Percentage reported in brackets, which may not add up to 100% due to rounding.

there was a substantial decline in the relative risk of an additional morbidity compared with the 1935–1939 cohort from 0.96 (0.89 to 1.04) for the 1940–1944 cohort to 0.79 (0.67 to 0.93) for the 1950–1954 cohort with a subsequent flattening. Women were estimated to have a 13% elevated risk (RR=1.13, 1.10 to 1.16) of having an additional chronic disease compared with men.

Sex-specific models
In the analysis of men as also shown in figure 3 and online supplementary table ST3, there was a significant decline of risk from cohort 1940–1944 (RR=0.96, 0.86 to 1.07) to cohort 1945–1949 (RR=0.82, 0.69 to 0.97) but without further apparent changes in later cohorts (ie, a levelling-off of the decline in the 1950s). In women, the estimated relative risk increased from 0.20 (0.03 to 1.37) in cohort 1905–1909 to 1.90 (1.08 to 3.34) in cohort 1970–1974, without any significant difference of the risk between neighbouring cohorts, but a more drastic increase was observed after those born in 1955–1959. Based on the sex-specific models, we also predicted the average number of chronic diseases assuming an age of 50 years and in period 2008 to facilitate interpretation of the cohort effects, and we visualised our results in online supplementary figure SF1. Furthermore, our secondary analysis using binary classification of multimorbidity status as the outcome shows no essential difference in the results (online supplementary table ST4).

Sensitivity analyses
The replication of the main analyses with number of lifestyle-related diseases as the study outcome yielded essentially the same results: a decline of risk from cohorts born in 1940–1944 to those in 1950–1954 in the overall analysis and in men; and an increase of risk in women from cohort 1905–1909 to cohort 1970–1974 (online supplementary table ST5). The alternative model with period

effects specified as fixed (online supplementary table ST6) showed no apparent differences in cohort effects from the main analyses, but it showed an increased period effect from 1999 to 2008. Finally, the replications of analyses with certain diseases omitted showed no substantial differences from the primary findings either (online supplementary tables ST7–8).

The results of these sensitivity analyses support the robustness of the main findings because results did not differ significantly for different model specifications, different selections of included diseases, and whether only lifestyle-related diseases were considered in defining multimorbidity.

DISCUSSION
Summary of findings
The analyses confirmed the hypothesised sex-specific role of the birth cohort effect in the determination of the risk of morbidity burden and multimorbidity. There were notable differences in the cohort effects between men and women. Specifically, there was an obvious decline in the risk of having increased morbidity burden and of having multimorbidity in men born between 1945 and 1954 compared with the preceding cohorts, and this reduction was sustained but did not further increase in later cohorts (the 1950s and after). In contrast, there was a steady increase in estimated relative risk in women from cohort 1905–1909 to cohort 1970–1974, with more apparent increase after the late 1950s cohort; however, none of these were statistically significant except the relative risk of the latest cohort 1970–1974.

Interpretations
This study extends and complements previous research on the secular trends of morbidity burden and multimorbidity
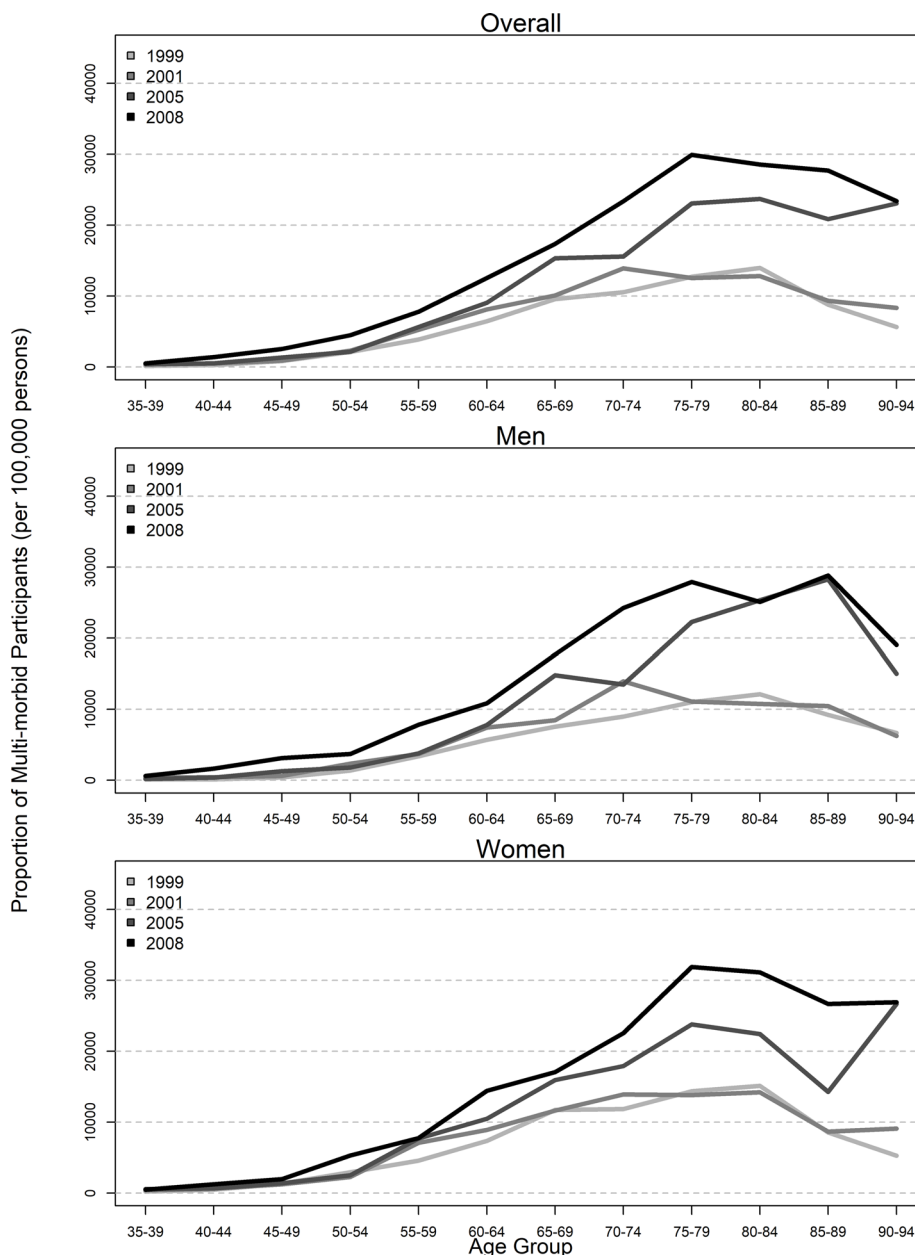
Figure 1 Proportion of multimorbid participants by age and sex across the years of survey.

by further decomposing temporal trends into dimensions of age, period and cohort in the population of Hong Kong.[2–4] As far as we know, this is the first study in Asia to investigate the potential role of the birth cohort in determining changing morbidity burden and multimorbidity. A recent Canadian study is the only one we know of which tested the cohort effects on multimorbidity, finding a monotonic increase in the risk of multimorbidity in each of the successive 10 year cohorts (1925–1974). The Canadian study did not report differing cohort effects by sex, while our findings suggest that the cohort effects on morbidity burden and multimorbidity in Hong Kong are highly sex-specific, suggesting the potential differences in the role of intergenerational effects on health between the two populations.[13]

The Canadian study attributed the increase in multimorbidity over time to an increasing prevalence of obesity in the population.[32] This is a plausible explanation for part of the cohort effects observed in both sexes in this study and is consistent with the observation described in a previous study in Hong Kong.[8] Hong Kong experienced a growth in infant and childhood obesity starting from around the late 1950s[33–35] which coincided with the upward inflection (positive second-order change of slope) of morbidity burden and multimorbidity for the late 1950s to early 1960s cohorts for both sexes in this study, namely, the levelling off of the decline of risk in men and a more drastic increase of risk in women. This cohort effect may imply that infancy and early childhood are probably critical periods when early life exposure affects
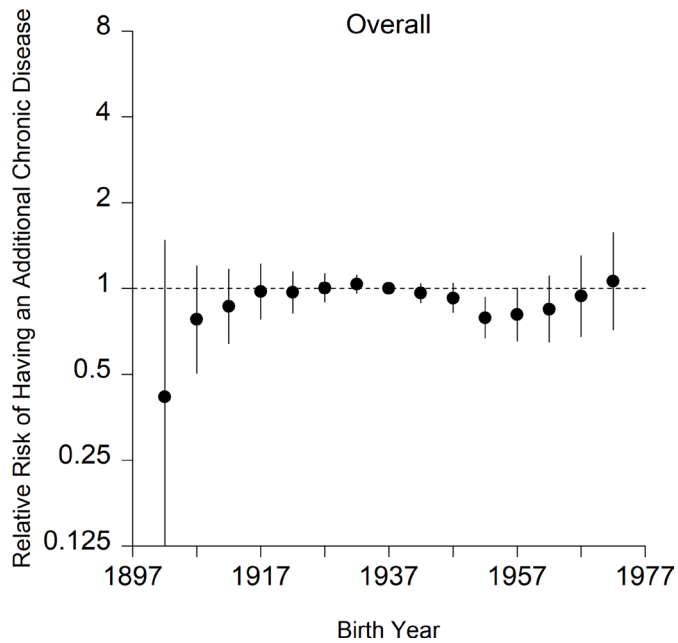
Figure 2 Age-adjusted and sex-adjusted relative risks of an additional self-reported chronic disease in an individual by birth cohorts Hong Kong. Cohort 1935–1939 serves as the referent cohort. Bars represent the 95% CI of the relative risks.

later risks of morbidity, or that there may be cumulative impact of lifetime obesity starting in early life that drives risk of morbidity. This is also consistent with the literature that childhood obesity affects later adult health risk, especially in cardiovascular and metabolic diseases.[36 37]

A potential explanation for the substantial decline of risk in men born in the late 1940s and the early 1950s is the drastic drop in the smoking rate in the early 1980s

and the continued decline thereafter.[38] The subanalysis of lifestyle-related morbidity burden also supported this speculation since the similar decline of risk from cohorts born in 1940–1944 to those in 1950–1954 was even more drastic than in the primary analysis and continued to be statistically significant in younger cohorts. Towards the late 1970s, the evidence of the adverse health effects of smoking became widely recognised internationally and locally. In 1982, the Smoking (Public Health) Ordinance was enacted in Hong Kong.[39] It was documented that during the 2 years after the enactment, there was a 16% reduction in the number of smokers.[39] The reason we believe this change has had a much stronger effect in men than in women is that 88.5% of smokers in 1982 and 85.3% of the 143 800 quitters in the following 2 years were men.[39] These men probably enjoyed the health benefits of smoking cessation at a relatively younger age, especially those born in or after the 1940s.[40 41] These large changes in smoking are known to be associated with particularly rapid declines in lung cancer mortality in the cohorts born in the late 1940s and the early 1950s.[14] Although the Canadian population saw a decline in total smoking rate from 32.0% in 1975 to 26.6% in 1986,[42] it is not as dramatic as in Hong Kong where, by 2015, the average daily smoking rate was only 10.5%.[38]

Women, in contrast, experienced slowly increasing risk of increased morbidity burden in successive birth cohorts although only statistically significantly increased in the final 1970–1974 cohort. There is no clear explanation for this, although enhanced health awareness and a better diagnosis of asymptomatic conditions may contribute, facilitated by better education of women of later generations in Hong Kong. The British colonial government
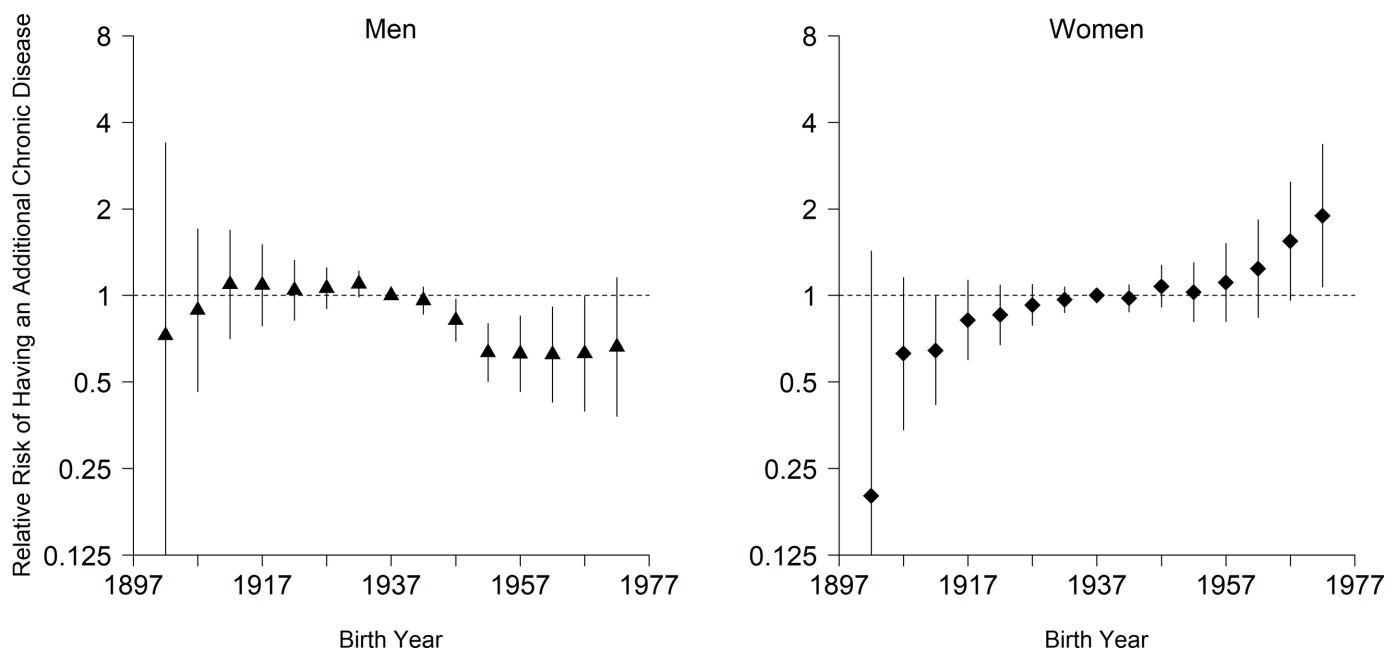

Figure 3 Sex-specific age-adjusted relative risks of an additional self-reported chronic disease in an individual by birth cohorts in Hong Kong. Cohort 1935–1939 serves as the referent cohort. Bars represent the 95% CI of the relative risks. Triangles represent men and rhombi represent women.

introduced a policy of free and compulsory 6 year education (primary schooling) in 1971, and 9-year education (primary and junior secondary schooling) in 1978 which enabled many girls who would have gone to work to attend school instead. From 2001 to 2011, the proportion of women aged 45 or older who had completed secondary education increased from 28.3% to 45.9%.[17 43] Better access to the healthcare services for women across generations, due to better education and improvements in services may explain increases in diagnosed morbidity. Other research has shown a decline in the risk of death from chronic diseases in women across generations in Hong Kong,[14] consistent with increasing diagnosis and active management of conditions like hypertension.

Over the period of 1999–2008, except for a voluntary cervical screening programme for women introduced in March 2004,[44] no territory-wide screening programmes for the general population have been launched and no major changes in healthcare policies were introduced.[45] The increasing trend of morbidity burden across periods observed in online supplementary table ST6 may reflect an actual increase of morbidity burden and/or, like our speculations on the cohort effects in women, be attributed to a heightened health awareness and better access to healthcare services among the city's population. Future research which covers a longer study period may be conducted for a more focused examination of the period effects.

Public health implications
The findings of this study enable us to project the possible trend of the healthcare burden associated with the younger cohorts as they age. Specifically, we may anticipate a relatively lower risk of morbidity in the younger cohorts of men who will all become part of the older population by year 2020 (ie, starting from those born in the late 1940s and the early 1950s) than the current older men (ie, born before the late 1940s). Since the lack of further decline of the risk of morbidity burden among men born after the late 1950s may be explained by increasing childhood obesity as discussed above, the Government may consider further promoting physical exercise and healthy diets and lifestyle among the younger cohorts to further minimise the risk of morbidity burden and multimorbidity. On the other hand, we expect a greater likelihood of women of the younger cohorts to be identified as having increased morbidity burden and multimorbidity than the current older women, possibly due to the childhood obesity problem in the late 1950s and increased diagnosis in younger generations due to altered help-seeking behaviour and access to health services. However, since almost all relative risks for women are not statistically significant, we should be cautious with our interpretations. But if this is the case, the Government may accordingly consider increasing the capacity and resources of the healthcare system to cope with the rising demand for treating chronic diseases, which might further increase among the in-coming older women. On the flip side,

increasing disease rates in women due to the enhancement of health awareness might not necessarily be a bad thing because if treated, they will reduce morbidity and subsequently mortality down the line. Following this argument, this then begs the question whether the lack of increase of morbidity burden risk in men suggests that it is rather the men who are being underdiagnosed. Given that men do not seek help as often as women, better disease screening and promotion of health awareness may be warranted.

Limitations
Despite the data being population-representative, there are several limitations. First, the presence of chronic diseases was self-reported, and there may be recall bias (most likely recalling fewer diseases) especially among older people, the risk in whom could thus be underestimated. However, in population surveys where a large sample is collected, it is usually not feasible to require formal documentation of diagnosis. Second, the comprehensiveness of the list of chronic diseases is limited by data availability across surveys. The observed sex-specific patterns may depend on the selection of diseases and may not be identical when another list is used. For example, it is known that prevalence of musculoskeletal diseases varies significantly by sex.[46] Although this list is far from exhaustive, a previous systematic review has shown that estimated prevalence of multimorbidity varies relatively little for studies having 12 or more conditions.[47] Our list also overlapped with those adopted in many other previous studies.[48] Third, since the THS only covered the non-institutionalised residential population of Hong Kong, hospitalised patients or older people in residential care homes, who were likely to have more chronic diseases, were not included in this study. Fourth, as the dataset is formed by repeated cross-sectional surveys, within-subject changes could not be investigated. Fifth, we did not apply weighting to our analyses in this study mainly because of the limitations of survey weightings in multivariable analyses, namely the contested approaches to weighting regression coefficients, difficulties in evaluating SEs for the weighted regression coefficients and the inevitable arbitrary choice of factors to be considered for the weighting.[49] As a representative stratified sampling frame have been consistently adopted across the series of the population survey, the unweighted results should be sufficiently generalisable. Sixth, we did not consider the various socioeconomic, lifestyle and healthcare access-related factors at the individual level which may explain part of the intergenerational differences. However, the objective of an age-period-cohort modelling is to identify time-dependent effects of age, period and cohort, from which macroenvironmental risk factors can be identified. Therefore, if we adjust the aforementioned individual-level factors in the age-period-cohort model, we may attenuate part of the total time-dependent effects of age, period and cohort which are in fact the main interest of this study. Although these individual-level factors are a

very promising direction for future research, we decided not to investigate them at this stage. Last, the period effect was limited by a short span of 10 years with only four period levels which may render part of the results of the mixed effects models less reliable. However, we replicated the analysis with period effects specified as fixed and obtained very similar birth cohort effects. The inclusion of period effects may serve as a multivariable adjustment which should have effectively addressed the change of diagnostic practice over the ten-year period when interpreting the estimated cohort effects. Future researchers with adequate accumulated data that cover a longer period of surveys should examine the period effect in more depth.

CONCLUSION

While ageing is a prevalent trend in all developed countries, cohort effects may be sex-specific and contextual. By delineating the cohort effects on morbidity burden and multimorbidity across generations, specific risk factors can be identified to inform localised policy-making. Other countries may also refer to our findings that point to the possible impact of reduction in smoking rates on the decreased risk as well as the possible impact of childhood obesity on the increased risk of morbidity burden and multimorbidity. Further cohort studies are warranted to investigate these associations.

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