9 Chillón Martín MJ, Díez J de M, Moreno AF, Muñoz GS. COPD and endocrine and metabolic alterations. *Arch Bronconeumol* 2009;45:42–6.

10 Hurst JR, Vestbo J, Anzueto A, et al. Susceptibility to exacerbation in chronic obstructive pulmonary disease. *N Engl J Med* 2010;363:1128–38.

11 Montserrat-Capdevila J, Godoy P, Marsal JR, Barbe F. Predictive model of hospital admission for COPD exacerbation. *Respir Care* 2015;60:1288–94.

12 Rabe KF, Hurd S, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. *Am J Respir Crit Care Med* 2007;176:532–55.

13 Bestall JC, Paul EA, Garrod R, et al. Usefulness of the Medical Research Council (MRC) dyspnoea scale as a measure of disability in patients with chronic obstructive pulmonary disease. *Thorax* 1999;54:581–6.

14 Soler-Cataluña JJ, Martínez-García MA, Sánchez LS, et al. Severe exacerbations and BODE index: two independent risk factors for death in male COPD patients. *Respir Med* 2009;103:692–9.

15 Jones PW, Harding G, Berry P, et al. Development and first validation of the COPD assessment test. *Eur Respir J* 2009;34:648–54.

16 Zimmerman M, Martin J, Clark H, et al. Measuring anxiety in depressed patients: a comparison of the Hamilton anxiety rating scale and the DSM-5 Anxious Distress Specifier Interview. *J Psychiatr Res* 2017;93:59–63.

17 Gayle A, Dickinson S, Poole C, et al. Incidence of type II diabetes in chronic obstructive pulmonary disease: a nested case–control study. *NPJ Prim Care Respir Med* 2019;29:28.

18 Carrasco Garrido de Miguel Díez JR, Gutiérrez J, Centeno AM, et al. Negative impact of chronic obstructive pulmonary disease on the health-related quality of life of patients. Results of the EPIDEPOC study. *Health Qual Life Outcomes* 2006;23:31.

19 Biskobing DM. COPD and osteoporosis. *Chest* 2002;121:609–20.

20 Parappil A, Depczynski B, Collett P, Marks GB. Effect of comorbid diabetes on length of stay and risk of death in patients admitted with acute exacerbations of COPD. *Respirology* 2010;15:918–22.

21 Baker EH, Janaway CH, Philips BJ, et al. Hyperglycaemia is associated with poor outcomes in patients admitted to hospital with acute exacerbations of chronic obstructive pulmonary disease. *Thorax* 2006;61:284–9.

22 Antonelli Incalzi R, Fuso L, De Rosa M, et al. Co-morbidity contributes to predict mortality of patients with chronic obstructive pulmonary disease. *Eur Respir J* 1997; 10:2794–800.

23 Miller J, Edwards LD, Agustí A, et al. Comorbidity, systemic inflammation and outcomes in the ECLIPSE cohort. *Respir Med* 2013;107:1376–84.

24 Montserrat-Capdevila J, Godoy P, Marsal JR, Barbé-Illa F. Risk factors for mortality in patients with chronic obstructive pulmonary disease. *Aten Primaria* 2015;47: 498–504.

25 Zamarrón C, García Paz V, Morete E, Matías FDC. Association of chronic obstructive pulmonary disease and obstructive sleep apnea consequences. *Int J Chron Obstruct Pulmon Dis* 2008;3:671–82.

26 Shah SH, Sonawane P, Vaidya S, et al. Pulmonary function tests in type 2 diabetes mellitus and their association with glycemic control and duration of the disease. *Lung India* 2013;30:108–12.

27 Litonjua AA, Lazarus R, Sparrow D, et al. Lung function in type 2 diabetes: the Normative Aging Study. *Respir Med* 2005;99:1583–90.

28 Aparna A. Pulmonary function tests in type 2 diabetics and non-diabetic people -a comparative study. *J Clin Diagnostic Res* 2013;7:1606–8.

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Prevalence of three lifestyle factors among Australian adults from 2004 to 2018: an age–period–cohort analysis

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Background: It has been reported that current smoking, overweight/obesity and physical inactivity are significant modifiable risk factors of all-cause mortality, cardiovascular disease and cancer. However, the effects of age, period and cohort on the prevalence of the three lifestyle factors among Australian adults are still unclear. **Methods:** Our study analysed data from 2004 to 2005, 2007 to 2008, 2011 to 2012, 2014 to 2015 and 2017 to 2018 National Health Survey. We employed the age–period–cohort models to analyze the individual effects of age, period and cohort on the prevalence of current smoking, overweight/obesity and physical inactivity among Australian adults. **Results:** A total of 76 489 adults were included. Age, period and cohort all showed significant independent effects on prevalence of current smoking, overweight/obesity and physical inactivity ($P < 0.01$) except the cohort effect on physical inactivity in females ($P = 0.31$). The prevalence of current smoking decreased with age and period, and it first increased with birth cohort and then declined. For overweight/obesity prevalence, it increased with age until early-60s and then dropped. We found a positive period effect on overweight/obesity; however, the prevalence of overweight/obesity experienced several shifts with birth cohort. Physical activity prevalence raised with age, and it has several fluctuations for curves of period and cohort. **Conclusion:** Age effects showed a distinct pattern for the prevalence of the three lifestyle factors. The prevalence of overweight/obesity continued to rise during the study period. The raised physical inactivity prevalence in recent study cycles is also concerning. Recent birth cohorts may be at increased risk of overweight/obesity and physical inactivity.

Introduction

A number of large-scale studies have confirmed that current smoking, overweight/obesity and physical inactivity are leading modifiable risk factors of all-cause mortality.[1–4] A US nationally representative survey indicated that current smoking was associated with more than 2-fold risk of all-cause mortality.[4] A recent meta-analysis of 239 cohort studies suggested that both overweight and obesity could substantially increase the risk of all-cause deaths.[1] A large cohort study, included more than 130 000 participants from 17 countries, observed that there a significant graded association between physical activity and all-cause mortality.[2] A large European cohort predicted that avoiding all inactivity would reduce all-cause mortality by 7.35%.[3] In addition, these three lifestyle factors were significant risk factors of cardiovascular disease (CVD)[2,5–7] and cancer.[8–10] Therefore, understanding the secular trends in the prevalence of these factors could provide evidence for health promotion policies. Additionally, the information could raise the awareness of healthy lifestyles among the general population. A few studies have explored the recent trends in the prevalence of smoking,[11] obesity[12–14] and physical inactivity[11,15] in Australian adults. However, they did not include the effects of age and birth cohort in the models, which could have dramatic influences on the temporal trend, and the age–period–cohort (APC) analyses were established to examine the influence of age, period and cohort simultaneously.

The National Health Surveys (NHS) were nationally representative surveys in Australia, and they have available data on the status of current smoking, overweight/obesity and physical inactivity. In the present study, we used five cycles of NHS to investigate the age, period and cohort effects on the prevalence of the three lifestyle factors among Australian adults.

Methods

Study design

The participants of the present study were from 2004 to 2005, 2007 to 2008, 2011 to 2012, 2014 to 2015 and 2017 to 2018 NHS. Those surveys were conducted by the Australian Bureau of Statistics (ABS) and were representative of the general health status in urban and rural areas across Australia. In details, households were selected using a random, multistage sampling method and one adult (18 years and over) was randomly selected for each selected household. Face-to-face interviews were performed to collect the data. Our study restricted to adults and those with missing information on smoking, body mass index (BMI) or physical activity were excluded ($n = 5196$). Finally, 76 489 subjects were included, yielding an overall response rate of 93.6%. All participants provided written informed consent, and our study was approved by the University of Queensland Medicine, Low and Negligible Risk Ethics Sub-Committee (approval number 2018000244).

Definitions of current smoking, overweight/obesity and physical inactivity

The participants were asked 'Do you currently smoke?' and 'Have you smoked at least 100 cigarettes in your entire life?' and those who responded yes to both questions were regarded as current smokers. The interviewers used stadiometer and digital scales to measure the height and weight of the participants and BMI was calculated as weight (kilogram) divided by height (metre square). Overweight/obesity was defined as a BMI value $\geq$25 kg/m^2. For moderate exercise, the participants were asked the total amount of time (min) they spent doing any exercise that caused a moderate increase in their heart rate or breathing last week (e.g. gentle swimming, social tennis, golf). For vigorous exercise, the participants were asked the total amount of time (min) that they spend doing any exercise that caused a large increase in their heart rate or breathing last week (e.g. jogging, cycling, aerobics, competitive tennis). Physical inactivity was defined as having <150 min of moderate, <75 min of vigorous and <150 min of moderate + vigorous exercise last week.

Table 1 Weighted prevalence of current smoking, overweight/obesity and physical inactivity among Australian adults, stratified by age, period and cohort

Items	Current smoking	Overweight/obesity	Physical inactivity
Age (years)			
18–24	20.5 (19.2–21.8)	38.6 (37.1–40.2)	64.9 (63.4–66.5)
25–29	23.6 (22.2–25.0)	51.0 (49.5–52.6)	65.2 (63.7–66.8)
30–34	22.4 (21.3–23.6)	56.3 (54.8–57.9)	71.9 (70.2–73.6)
35–39	21.2 (20.2–22.3)	62.1 (60.8–63.5)	73.9 (72.6–75.1)
40–44	21.8 (20.6–23.1)	65.4 (64.2–66.7)	77.1 (75.9–78.4)
45–49	21.7 (20.5–22.8)	68.6 (67.3–69.9)	76.1 (74.9–77.4)
50–54	19.9 (18.6–21.1)	70.0 (68.6–71.4)	79.9 (78.6–81.2)
55–59	17.8 (16.6–19.1)	70.5 (69.1–71.8)	81.6 (80.3–82.9)
60–64	14.0 (12.8–15.1)	74.6 (73.3–75.8)	82.0 (80.8–83.3)
65–69	10.7 (9.7–11.7)	72.8 (71.3–74.4)	82.6 (81.3–83.9)
70–74	7.0 (6.0–7.9)	72.5 (70.9–74.1)	86.2 (84.8–87.5)
75–79	6.4 (5.4–7.4)	68.9 (66.9–70.9)	89.8 (88.5–91.1)
80–84	3.9 (2.9–4.8)	64.1 (61.5–66.6)	93.2 (91.9–94.4)
85+	2.4 (1.4–3.4)	54.6 (51.0–58.1)	94.5 (93.0–96.0)
Period (years)			
2004–05	22.9 (22.1–23.7)	53.5 (52.6–54.5)	71.1 (70.2–72.1)
2007–08	20.7 (19.8–21.7)	60.4 (59.3–61.6)	81.9 (81.0–82.9)
2011–12	17.7 (16.8–18.5)	63.4 (62.3–64.5)	75.8 (74.6–76.9)
2014–15	16.0 (15.1–16.9)	63.4 (62.4–64.4)	75.5 (74.5–76.6)
2017–18	15.2 (14.7–15.7)	67.0 (66.1–67.8)	76.9 (76.1–77.7)
Cohort (years)			
1915–19	4.5 (0.6–8.3)	35.5 (27.8–43.2)	89.0 (83.4–94.5)
1920–24	2.9 (1.8–4.1)	48.0 (43.5–52.5)	91.9 (89.8–94.0)
1925–29	3.3 (2.3–4.3)	58.9 (56.2–61.7)	91.6 (90.0–93.3)
1930–34	5.6 (4.7–6.6)	65.3 (62.8–67.9)	90.1 (88.8–91.3)
1935–39	8.3 (7.0–9.6)	71.2 (69.2–73.1)	86.2 (84.7–87.6)
1940–44	10.1 (9.0–11.1)	72.2 (70.8–73.6)	85.2 (83.8–86.6)
1945–49	12.3 (11.1–13.5)	72.8 (71.5–74.0)	82.8 (81.5–84.0)
1950–54	16.4 (15.0–17.8)	72.0 (70.6–73.5)	82.3 (80.8–83.8)
1955–59	20.0 (18.8–21.1)	69.9 (68.5–71.3)	80.2 (78.9–81.5)
1960–64	21.7 (20.5–22.8)	68.1 (66.7–69.5)	78.2 (77.0–79.5)
1965–69	21.8 (20.6–23.0)	66.8 (65.4–68.2)	75.6 (74.4–76.9)
1970–74	21.8 (20.7–23.0)	63.5 (62.2–64.7)	74.3 (73.0–75.5)
1975–79	24.1 (22.8–25.3)	59.9 (58.3–61.5)	73.0 (71.5–74.4)
1980–84	22.4 (21.0–23.9)	50.4 (48.8–51.9)	67.5 (66.0–69.0)
1985–89	20.3 (18.4–22.2)	49.6 (47.7–51.6)	68.7 (66.8–70.6)
1990–94	17.8 (16.0–19.6)	43.2 (41.2–45.3)	66.1 (64.1–68.1)
1995–99	16.5 (14.7–18.3)	45.9 (42.0–49.8)	64.9 (61.8–68.1)

Age, period and cohort

Age was based on the years when the respondents taken the survey and it was divided into 14 groups (18–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54, 55–59, 60–64, 65–69, 70–74, 75–79, 80–84 and over 85). There were five survey periods in our study (2004–05, 2007–08, 2011–12, 2014–15 and 2017–18). We allocated participants into 17 cohorts according to their birth years: 1915–19, 1920–24, 1925–29, 1930–34, 1935–39, 1940–44, 1945–49, 1950–54, 1955–59, 1960–64, 1965–69, 1970–74, 1975–79, 1980–84, 1985–89, 1990–94 and 1995–99.

Statistical analysis

First, we calculated and described the weighted prevalence and 95% confidence intervals (CIs) of current smoking, overweight/obesity and physical inactivity by age, period and cohort.

Second, since the birth cohort was determined by the survey period and age (cohort = period − age), we used APC models to fit the individual effects of age, period and cohort. The restricted cubic splines for the age, period and cohort terms were combined with the generalized linear model (a Poisson family error structure

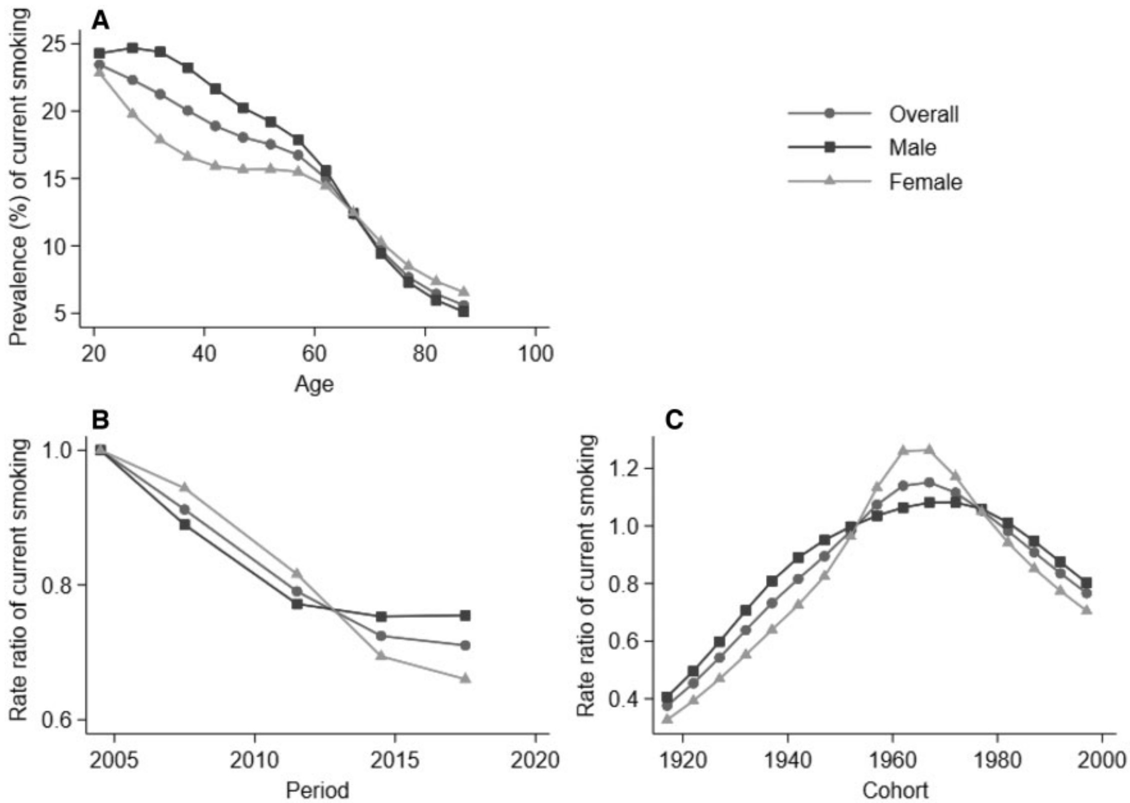

Figure 1 The estimated effects of age (A), period (B) and cohort (C) for prevalence of current smoking

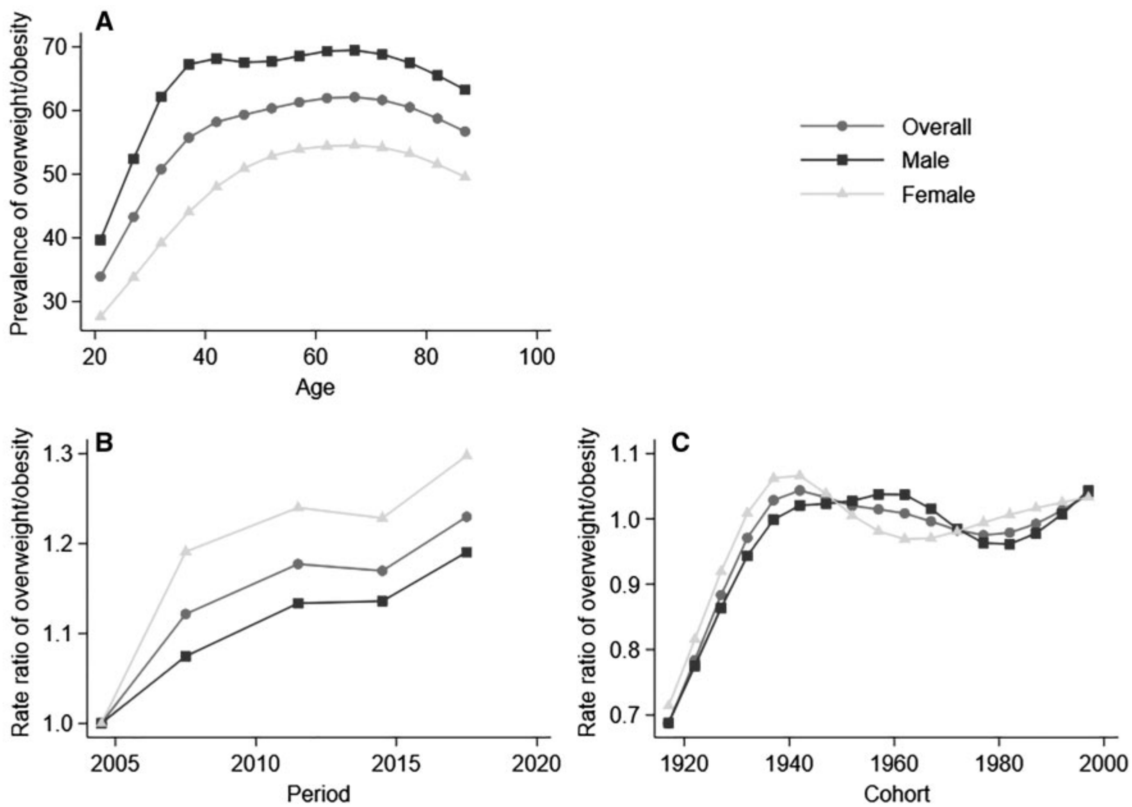

Figure 2 The estimated effects of age (A), period (B) and cohort (C) for prevalence of overweight/obesity

and a log link function). Matrix transformation was made to the spline basis vectors for the period and cohort effects. We used five knots each for age, period and cohort effects.[16] The contribution of each individual variable to the model was assessed by backward deletion from the full model and the resulting change in deviance was assessed as an approximate chi-square distribution using the change in model degrees of freedom to obtain a *P*-value.[17] For example, the deviance/degree of freedom of age was obtained by

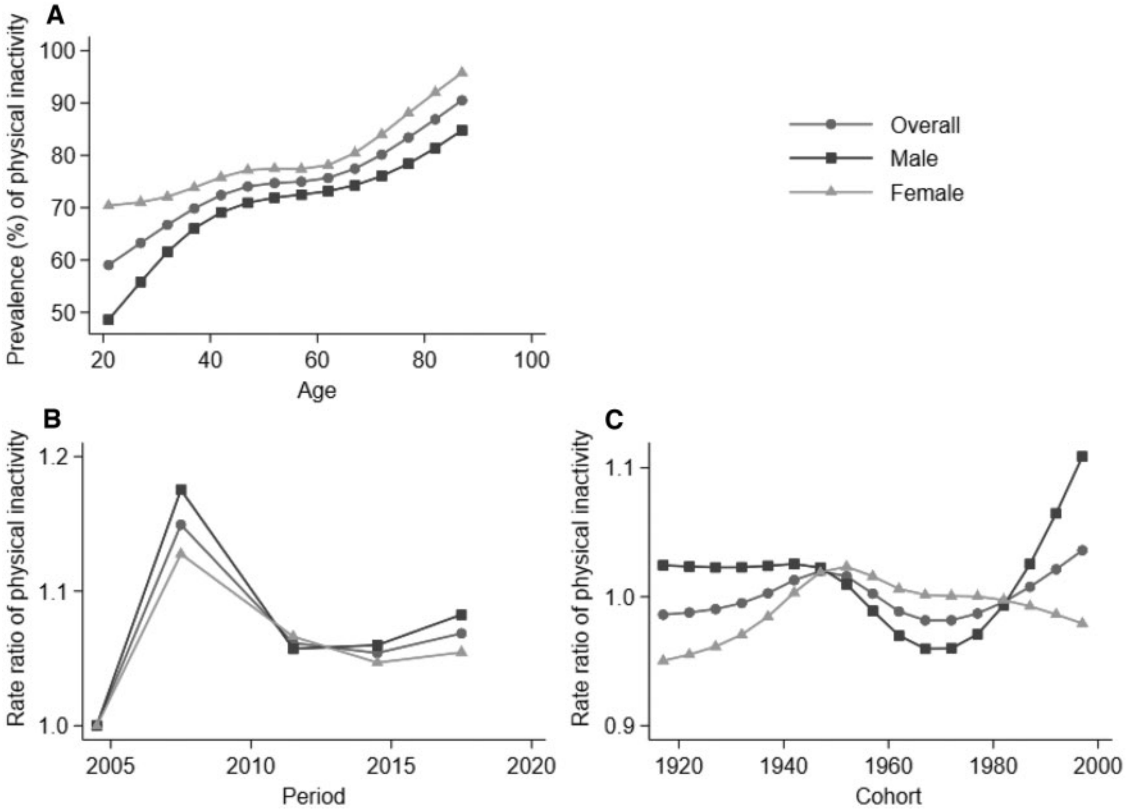

Figure 3 The estimated effects of age (A), period (B) and cohort (C) for prevalence of physical inactivity

subtract deviance/degree of freedom of APC models from those of period–cohort models. Results for the APC models were presented as prevalence (%) for age effects and rate ratios for cohort and period effects in graphical forms.[16,17] The analyses were carried out by *apcfit* package in the Stata software (version 16.0) and a two-tailed *P*-value <0.05 indicating statistical significant.

We applied the person weights and group Jackknife method with 60 replicate weights, as recommended by the ABS, to reflect the estimates for the in-scope populations as well as considering the sampling errors. All the analyses were conducted in overall adults, males and females, respectively.

Results

Basic characteristics

Among the 76 489 subjects, 17 686, 15 014, 12 862, 14 560 and 16 367 were from 2004 to 2005, 2007 to 2008, 2011 to 2012, 2014 to 2015 and 2017 to 2018 NHS, respectively. The weighted prevalence of males was 49.8% (35 980/76 489), and the median (interquartile range) of age was 47 (30) years. In the combined participants of five surveys, physical inactivity had the highest weighted prevalence (76.3%, 95% CI 75.9–76.8%), followed by overweight/obesity (62.0%, 95% CI 61.5–62.4%) and current smoking (18.2%, 95% CI 17.8–18.6%).

APC analyses

Table 1 presented the weighted prevalence of the three lifestyle factors by age, study period and birth cohort in the overall population and the results in sex-specific subgroups were displayed in Supplementary table S1. The effects of age, period and cohort on prevalence of current smoking, overweight/obesity and physical inactivity are presented in Supplementary tables S2–S4. Age, period and cohort showed significant effects on prevalence of current smoking and overweight/obesity in overall participants, males and females (Supplementary tables S2 and S3). For physical inactivity prevalence, age, period and cohort have significant effects in the total population and men. For women, age and period were significant but cohort was not (Supplementary table S4). For all the three factors, APC models were most optimal as they have the smallest deviances (Supplementary tables S2–S4). Figures 1–3 illustrated the fitted models with the independent effects of age, period and cohort.

For current smoking prevalence, we noticed negative age and period effects in both sexes (figure 1A and B) and those who were born around 1970s have the highest risk of current smoking (figure 1C).

We observed the prevalence of overweight/obesity increased with age until 60–64 and then dropped, and it is generally consistent in males and females (figure 2A). Overweight/obesity prevalence has increased steadily over survey time, and the positive period effect was more apparent in females (figure 2B). Overweight/obesity prevalence increased with birth cohort until 1960–64 for males and 1935–39 for females and then declined. However, overweight/obesity prevalence began to raise for males born after 1980–84 and for females born after 1965–69 (figure 2C).

The prevalence of physical inactivity monotonously increased with age in both sexes (figure 3A). Both men and women experienced a sharp increase in physical inactivity prevalence from 2004–05 to 2007–08. For men, the prevalence declined between 2007–08 and 2011–12 and then slightly increased afterwards. For women, it constantly dropped from 2007–08 to 2014–15 before a subtle raise in 2017–18 (figure 3B). The curve for cohort, among men, appeared to be flat until 1945–49 and subsequently it demonstrated a J-shaped relationship, with a nadir at 1965–69. Although the cohort effect was non-significant in females ($P = 0.31$), we observed a U-shaped relationship, with the highest prevalence observed for those who were born in 1950–54 (figure 3C).

Discussion

Using five recent cycles of NHS, the current study examined the age, period and cohort effects on the prevalence of current smoking, overweight/obesity and physical inactivity among Australian adults. Current smoking prevalence declined with age and period and, with recency of birth cohort, it first increased and then dropped. For the prevalence of overweight/obesity, it increased with age until age 60–64 and then declined. Overweight/obesity prevalence raised over the study period; however, it undergone several fluctuations with birth cohort. We observed a positive association between physical activity prevalence and age. There are several shifts for the period and cohort curves and males and females have different patterns.

We found physical inactivity prevalence increased with age, and it underwent several fluctuations over the study period. Recently born cohorts of men are at increased risk of physical inactivity. However, women in recent birth cohorts have reduced physical inactivity risk. There are several studies examining age, period and cohort effects on the prevalence of physical inactivity.[18,19] Using APC model and four cycles of NHS from 1990 to 2005, a study reported that leisure-time physical activity reduced with age and increased with study period. However, they found the cohort effect was non-significant.[18] Another study analysed data of more cycles of NHS (1989–2011), they observed the prevalence of physical inactivity was stable across the study period, but they did not include age and birth cohort in the statistical model.[19] The measurement of physical activity should be considered for explaining the results. A study indicated a moderate agreement between self-reported and accelerometer-measured physical activity, and participants are prone to report more vigorous activity and less sedentary time.[20] Therefore, accelerometer should be applied to measure physical activity in future studies.

Our results displayed that the prevalence of overweight/obesity increased with age until 60s when it declined. We observed the prevalence of overweight/obesity has raised over the study period, and recent birth cohorts have a greater risk of overweight/obesity. Using 1990–2000 NHS and APC model, a study reached similar age and period effects on the prevalence of overweight and obesity in Australian adults.[17] They reported that the prevalence of overweight and obesity constantly increased with birth cohorts, whereas our study found males born in 1960–80 and females born in 1940–60 have a downward trend of overweight/obesity prevalence. Two studies, based on data from 1980 to 2007 NHS and 1995 to 2012 NHS, explored the secular trends of BMI and obesity without considering the effects of age and birth cohort.[12,13] They found BMI values and obesity prevalence have significantly increased over the study period, which was consistent with our findings. We observed males have higher prevalence of overweight/obesity than females across all age groups (figure 2A) whereas a recent study found the global prevalence of overweight/obesity was higher in females than in males after age of 60 or so.[21] We used BMI values to define overweight and obesity; however, recent studies suggested waist-to-height ratio, compared to BMI, has better performance in prediction of whole-body fat percentage,[22] hypertension[23] and diabetes.[23] More studies should pay attention to the appropriate measurements of overweight and obesity.

Our findings illustrated that the prevalence of current smoking decreased with age and period, and it declined in recent birth cohorts. A large-scale UK study also noted the negative dose–response relationship between age and smoking prevalence.[24] In addition, a recent meta-analysis suggested older adults (≥60 years) have a significantly higher prevalence of ideal smoking status, defined as being non-smokers or quitted smoking for over 1 year, than young adults (<60 years).[25] In agreement with our results, a few studies also reported the reduced current smoking prevalence with study period.[4,11] Based on a study conducted in New South Wales, the prevalence of current smoking decreased from 20.4% in 2002 to 15.0% in 2012.[11] The US National Health and Nutrition Examination Survey indicated current smoking prevalence has reduced from 27.9% in 1988–94 to 22.6% in 2005–10.[4] We found that those who were born after 1970s have declined prevalence of current smoking. An Italian study found the mean age at which the smokers started smoking was 18 years.[26] Therefore, persons born in 1970s would have had more exposure to tobacco control policies that were initiated in 1990s in Australia, as they were around 20 years old.[27] We used self-reported questionnaire to determine the smoking status; however, a systematic review has shown that self-reports, compared to cotinine level, tend to underestimate the smoking status.[28] More studies are warranted on the cut-points of cotinine to measure smoking status accurately.

Our study has certain strengths. We used five recent cycles of large-scale nationally representative surveys, and they are able to provide an accurate estimation on the prevalence of the three lifestyle factors in Australian adults. Additionally, we applied APC models to analyze the age, period and cohort effects simultaneously. However, our study has certain limitations. First, we are unable to explore the effects of the three factors on the mortality and risk of cancer and CVD as we do not have those data. Second, physical activity and current smoking were self-reported and objective measurements may improve the accuracy of the factors. We used BMI values to measure overweight/obesity; however, other anthropometric indicators-defined overweight/obesity may improve the prediction of future health outcomes than BMI-defined overweight/obesity. Third, we did not report the prevalence of other lifestyle-related factors, such as dietary pattern, total cholesterol and fasting plasma glucose, because their information was not available in our datasets. Fourth, we cannot completely rule out the selection bias, although we used nationally representative surveys and sampling weights.

In summary, our findings indicated that the prevalence of current smoking has declined with age and over the study period. Persons born around the 1970s had the highest prevalence of current smoking. The prevalence of overweight/obesity increased over the study period and those aged 60 years or so had the highest prevalence of overweight/obesity. We noticed recent birth cohorts were at raised risk of overweight/obesity. The prevalence of physical inactivity increased with age and increased in recent study cycles. We found a U-shaped relationship between physical inactivity prevalence and birth cohort in males; however, it turned into a reversed U-shape in females.

Supplementary data

Supplementary data are available at *EURPUB* online.

Conflicts of interest: None declared.

Key points

- The prevalence of current smoking decreased with age and study period and it displayed a reversed U-shaped relationship with birth cohort.
- Those aged 60 years had the highest prevalence of overweight/obesity and the prevalence of overweight/obesity increased over the study period.
- There were fluctuations for the overweight/obesity-birth cohort association and those born recently had an increased risk of overweight/obesity.
- The prevalence of physical inactivity increased with age and increased over the study period.
- There was a U-shaped association between physical inactivity prevalence and birth cohort in men; however, there was a reversed U-shaped in women.

References

1 Global BMI Mortality Collaboration, Di Angelantonio E, Bhupathiraju SN, Wormser D, et al. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet* 2016;388:776–86.

2 Lear SA, Hu W, Rangarajan S, et al. The effect of physical activity on mortality and cardiovascular disease in 130 000 people from 17 high-income, middle-income, and low-income countries: the PURE study. *Lancet* 2017;390:2643–54.

3 Ekelund U, Ward HA, Norat T, et al. Physical activity and all-cause mortality across levels of overall and abdominal adiposity in European men and women: the European Prospective Investigation into Cancer and Nutrition Study (EPIC). *Am J Clin Nutr* 2015;101:613–21.

4 Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA* 2012;307:1273–83.

5 Khan SS, Ning H, Wilkins JT, et al. Association of body mass index with lifetime risk of cardiovascular disease and compression of morbidity. *JAMA Cardiol* 2018;3:280–7.

6 Hackshaw A, Morris JK, Boniface S, et al. Low cigarette consumption and risk of coronary heart disease and stroke: meta-analysis of 141 cohort studies in 55 study reports. *BMJ* 2018;360:j5855.

7 Banks E, Joshy G, Korda RJ, et al. Tobacco smoking and risk of 36 cardiovascular disease subtypes: fatal and non-fatal outcomes in a large prospective Australian study. *BMC Med* 2019;17:128.

8 Moore SC, Lee IM, Weiderpass E, et al. Association of leisure-time physical activity with risk of 26 types of cancer in 1.44 million adults. *JAMA Intern Med* 2016;176:816–25.

9 Chen W, Xia C, Zheng R, et al. Disparities by province, age, and sex in site-specific cancer burden attributable to 23 potentially modifiable risk factors in China: a comparative risk assessment. *Lancet Glob Health* 2019;7:e257–69.

10 Gharahkhani P, Ong JS, An J, et al. Effect of increased body mass index on risk of diagnosis or death from cancer. *Br J Cancer* 2019;120:565–70.

11 Ding D, Do A, Schmidt HM, Bauman AE. A widening gap? Changes in multiple lifestyle risk behaviours by socioeconomic status in New South Wales, Australia, 2002-2012. *PLoS One* 2015;10:e0135338.

12 Keating C, Backholer K, Gearon E, et al. Prevalence of class-I, class-II and class-III obesity in Australian adults between 1995 and 2011-12. *Obes Res Clin Pract* 2015;9:553–62.

13 Gearon E, Backholer K, Stevenson C, et al. Trends in body mass index according to educational attainment for urban Australian adults between 1980 and 2007. *Int J Obes* 2015;39:1019–26.

14 Merema M, O'Connell E, Joyce S, et al. Trends in body mass index and obesity prevalence in Western Australian adults, 2002 to 2015. *Health Promot J Austr* 2019;30:60–5.

15 Devonshire-Gill KR, Norton KI. Australian adult physical activity sufficiency trend data: positive, prevalent, and persistent changes 2002-2012. *J Phys Act Health* 2018;15:117–26.

16 Ananth CV, Keyes KM, Wapner RJ. Pre-eclampsia rates in the United States, 1980-2010: age-period-cohort analysis. *BMJ* 2013;347:f6564.

17 Allman-Farinelli MA, Chey T, Bauman AE, et al. Age, period and birth cohort effects on prevalence of overweight and obesity in Australian adults from 1990 to 2000. *Eur J Clin Nutr* 2008;62:898–907.

18 Allman-Farinelli MA, Chey T, Merom D, et al. The effects of age, birth cohort and survey period on leisure-time physical activity by Australian adults: 1990-2005. *Br J Nutr* 2008;101:609–17.

19 Chau J, Chey T, Burks-Young S, et al. Trends in prevalence of leisure time physical activity and inactivity: results from Australian National Health Surveys 1989 to 2011. *Aust N Z J Public Health* 2017;41:617–24.

20 Dyrstad SM, Hansen BH, Holme IM, Anderssen SA. Comparison of self-reported versus accelerometer-measured physical activity. *Med Sci Sports Exerc* 2014;46:99–106.

21 Ng M, Fleming T, Robinson M, et al. Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2014;384:766–81.

22 Swainson MG, Batterham AM, Tsakirides C, et al. Prediction of whole-body fat percentage and visceral adipose tissue mass from five anthropometric variables. *PLoS One* 2017;12:e0177175.

23 Zhang Y, Gu Y, Wang N, et al. Association between anthropometric indicators of obesity and cardiovascular risk factors among adults in Shanghai, China. *BMC Public Health* 2019;19:1035.

24 Fidler JA, West R. Changes in smoking prevalence in 16-17-year-old versus older adults following a rise in legal age of sale: findings from an English population study. *Addiction* 2010;105:1984–8.

25 Peng Y, Cao S, Yao Z, Wang Z. Prevalence of the cardiovascular health status in adults: a systematic review and meta-analysis. *Nutr Metab Cardiovasc Dis* 2018;28:1197–207.

26 Muttarak R, Gallus S, Franchi M, et al. Why do smokers start? *Eur J Cancer Prev* 2013;22:181–6.

27 Woodward A, Kawachi I. Tobacco control in Australia. *Tob Control* 2003;12(Suppl 2):ii1–2.

28 Connor Gorber S, Schofield-Hurwitz S, Hardt J, et al. The accuracy of self-reported smoking: a systematic review of the relationship between self-reported and cotinine-assessed smoking status. *Nicotine Tob Res* 2009;11:12–24.