human reproduction

Temporal trends in age at menarche and age at menopause: a population study of 312 656 women in Norway

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STUDY QUESTION: Have mean age at menarche or mean age at natural menopause changed from the 1939 birth cohort to the 1964 birth cohort?

SUMMARY ANSWER: We estimated a minor decrease in mean age at menarche and an increase by nearly 3 years in mean age at natural menopause.

WHAT IS KNOWN ALREADY: In the Western world, age at menarche decreased across birth cohorts from the early 1800s until the 1950s. Whether mean age at menarche has continued to decrease in birth cohorts after the 1950s remains uncertain. It is also uncertain whether mean age at natural menopause has changed across birth cohorts.

STUDY DESIGN, SIZE, DURATION: We performed a retrospective population study of 312 656 women who were born in Norway during the years 1936–1964.

PARTICIPANTS/MATERIALS, SETTING, METHODS: The data were obtained by two self-administered questionnaires from women who participated in the Norwegian breast cancer screening program (BreastScreen Norway) during the years 2006–2014. We used flexible parametric survival models with restricted cubic splines to estimate mean age at menarche, mean age at menopause and mean number of years between menarche and menopause according to the women's year of birth. The women who were still having menstrual periods contributed with follow-up time until the time of data collection, and the women who had reported surgical removal of the uterus and/or both ovaries prior to natural menopause contributed with follow-up time until the time of surgery.

MAIN RESULTS AND THE ROLE OF CHANCE: The mean age at menarche was 13.42 years (95% CI: 13.40–13.44 years) among women born during 1936–1939, and it was 13.24 years (95% CI: 13.22–13.25 years) among women born during 1960–1964. The mean age at natural menopause increased from 50.31 years (95% CI: 50.25–50.37 years) among women born during 1936–1939 to 52.73 years (95% CI: 52.64–52.82 years) among women born during 1960–1964. The mean number of years between menarche and menopause increased from 36.83 years (95% CI: 36.77–36.89 years) to 40.22 years (95% CI: 40.11–40.34 years).

LIMITATIONS, REASONS FOR CAUTION: Information about age at menarche and age at menopause was based on self-reports.

WIDER IMPLICATIONS OF THE FINDINGS: Late menopause is associated with increased risk of breast cancer but also with increased life expectancy. Thus, higher mean age at menopause may partly explain the increase in breast cancer incidence after menopause and the increase in life expectancy in recent time. Also, a longer interval between menarche and menopause could suggest that the number of years of female fecundity has increased.

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 Key words: birth cohort / menarche / menopause / population study / secular trend

Introduction

Menarche and menopause are milestones in a woman's reproductive life. Both age at menarche and age at natural menopause display considerable variation between women and may also vary across time periods (Parent *et al.*, 2003; Dratva *et al.*, 2009).

In the Western world, mean age at menarche decreased across birth cohorts from the early 1800s until the 1950s (Wyshak and Frisch, 1982; Rosenberg, 1991). This downward trend has been explained by improved living conditions and nutritional status among girls (Wyshak and Frisch, 1982). Some studies suggest that age at menarche has continued to decrease after 1950 (Mendoza *et al.*, 2010; Talma *et al.*, 2013; Lewington *et al.*, 2014; Gentry-Maharaj *et al.*, 2017; InterLace Study Team, 2019). However, others suggest that the downward trend has leveled off (Brundtland and Walloe, 1973; Wyshak and Frisch, 1982; Vercauteren and Susanne, 1985; Lindgren *et al.*, 1991; Parent *et al.*, 2003; Forman *et al.*, 2013; Bratke *et al.*, 2017).

Whether mean age at natural menopause has changed remains uncertain. Some studies suggest that mean age at menopause has increased across birth cohorts from the beginning of 1900 until the 1950s (Rodstrom *et al.*, 2003; Nichols *et al.*, 2006; Dratva *et al.*, 2009; Lewington *et al.*, 2014; Park *et al.*, 2018). Few studies have investigated the trend in age at menopause across birth cohorts after 1950 (Duarte *et al.*, 2014; Gentry-Maharaj *et al.*, 2017; InterLace Study Team, 2019). One study found no trend in age at menopause in a multiethnic population (InterLace Study Team, 2019). The two other studies represent a large number of European postmenopausal women, and they report that age at menopause increased across birth cohorts from 1920 to 1932 (Duarte *et al.*, 2014) and 1925 to 1944 (Gentry-Maharaj *et al.*, 2017), respectively. Thereafter, age at menopause decreased.

If age at menarche or age at menopause changes across birth cohorts, the time interval between menarche and menopause may also change. A study from the USA reported that the number of years between menarche and menopause increased across birth cohorts from 1910 to 1939 (Nichols *et al.*, 2006). We are not aware of any recent studies about trends in the time interval between menarche and menopause.

Age at menarche and menopause and also the time interval between these events may influence women's fecundity and health (Cooper and Sandler, 1998; Jacobsen *et al.*, 2003; Wu *et al.*, 2014). Valid knowledge about temporal trends in age at menarche and menopause may therefore be important for the understanding of the disease burden in the female population. We investigated possible temporal changes in mean age at menarche, age at natural menopause and the time interval between menarche and natural menopause among 312 656 women who were born in Norway during the years 1936–1964. To avoid underestimation of age at menopause in the most recent birth cohorts, we used a time to event approach that allowed inclusion of women who still had menstrual periods.

Materials and Methods

Study design, recruitment and data collection

We performed a retrospective population study, and we aimed to include all women in Norway who were born during the years 1936–1964. The Norwegian breast cancer screening program (BreastScreen Norway) invites all women, 50–69 years of age, to biennial mammography. The BreastScreen Norway is administered by the Cancer Registry of Norway, and 84% of all women in the targeted age group have participated at least at one occasion (Sebuødegård *et al.*, 2016).

During the years 2006–2014, all women who participated in the BreastScreen Norway were asked to answer two self-administered questionnaires at their first screening examination (Tsuruda *et al.*, 2018). The questionnaires were sent by post along with the invitation to the screening examination, and they were returned at the screening site. The first questionnaire included questions about demographics, reproductive factors and lifestyles prior to the age of 50. The second questionnaire included questions about current health, menstruation and surgery on the uterus or ovaries. A total of 387 273 women, born during the years 1936–1964, completed both questionnaires and were eligible to participate in our study.

Study sample

Of the 387 273 women, we excluded women who reported that menstruation had never occurred ($n = 155$) and women with missing information or outlying values (<5 and > 25 years) on age at menarche ($n = 25 275$) (Supplementary Fig. S1). Thereafter, we excluded women with missing information or outlying values (<15 and >71 years) on age at menopause ($n = 28 404$). We also excluded women with missing information or outlying values on age at hysterectomy and/or bilateral oophorectomy ($n = 1101$). Since mean age at menarche and menopause may vary between countries (Kaplowitz, 2006; Dratva *et al.*, 2009), we excluded women who were not born in Norway or had missing information about country of birth ($n = 19 682$). Thus, a total of 312 656 women who were born in Norway during the years 1936–1964 could be included in our data analyses.

Study factors

Our main exposure variable was the woman's year of birth (as a continuous variable). In additional analyses, we grouped the woman's birth year into five-year intervals: 1936–1939 (reference), 1940–1944, 1945–1949, 1950–1954, 1955–1959 and 1960–1964.

Our outcome variables were age at menarche, age at natural menopause and number of years between menarche and menopause. Age at menarche was based on the following question: 'At what age (years old) did you have your first menstrual period?' Age at menopause was based on the following two questions: 'Are you still having menstrual periods?' (yes/yes, but unregularly/no) and 'If you no longer have menstrual periods, how old were you at your last menstrual period?' For descriptive purposes, we also categorized age at menopause into menopause before the age of 45 (early menopause, yes/no), and menopause before the age of 40 (primary ovarian insufficiency, yes/no).

Information about surgery on the uterus was based on the following questions: 'Have you had your uterus removed?' (no/yes/don't know), and 'If yes, how old were you at the time of surgery?' The questions about surgery on the ovaries were as follows: 'Have you had both your ovaries removed?' (no/no, I have only had one ovary removed/yes/don't know), 'If yes, how old were you at the time of surgery?'

Statistical methods

To avoid underestimation of age at natural menopause in the most recent birth cohorts, we applied time to event analyses. In the analyses of reported age at menopause according to birth year, the time to event was from birth until attained age at menopause. The women who were still having menstrual periods (16.6%) or had irregular menstrual periods (7.7%) contributed with follow-up time until their attained age at data collection (censoring). The women who reported hysterectomy (6.3%), bilateral oophorectomy (0.6%) or both surgeries (3.0%) prior to menopause contributed with follow-up time until their attained age at surgery. We used the same approach when estimating the trend in the number of years between menarche and natural menopause, but in these analyses the time to event was from menarche until menopause or censoring (time of data collection or surgery). When estimating age at menarche according to birth year, the time to event was from birth until menarche, and all women contributed with follow-up time until menarche.

We estimated restricted mean age at menarche, natural menopause and number of years between menarche and natural menopause according to birth year (as a continuous variable and in five-year intervals) by applying flexible parametric survival models (the stpm2 command in Stata) (Crowther and Lambert, 2014). In our analyses, age at menopause was restricted by the highest reported age at menopause in the cohort (71 years). Thus, the restricted mean time to menopause can be interpreted as mean time to menopause. For the younger birth cohorts, the calculations of restricted mean age at menopause were performed assuming fixed baseline hazard and proportional hazards. The proportional hazards assumption was evaluated by the Schoenfeld residuals, and by inspection of the log–log plots. By using restricted cubic splines with four degrees of freedom (five knots), we allowed for possible non-linear trends (Crowther and Lambert, 2014).

In additional analyses, we estimated the association of birth year with age at menarche, age at natural menopause and number of years between menarche and menopause as crude hazard ratios by applying flexible parametric survival models. We calculated 95% CI for the estimated restricted means and for the hazard ratios. All data analyses were performed by using Stata/SE version 14.2 (StataCorp, College Station, TX, USA).

The participation rate in the Breast Screen Norway was lowest among women with low education (Le *et al*., 2018), and low education has been associated with late menarche (Deardorff *et al*., 2014) and early menopause (Gold *et al*., 2013). In supplementary analyses, we therefore studied the mean age in menarche, mean age at menopause and mean number of years between menarche and menopause according to birth cohort within levels of completed education (less than high school, high school, college/university). It may be argued that menopause before the age at 40 and after the age at 60 years is not part of the normal distribution of age at menopause, but rather a consequence of disease, treatment or errors in reporting. Thus, we performed supplementary analyses after exclusion of women with menopause before the age of 40 years and after the age of 60 years ($n = 11\,628$).

Ethical considerations

This study was approved by the Regional Committee for Medical and Health Research Ethics (reference no. 2014/1711 REK South-East D). All women received written information. By returning the questionnaires the women agreed to participate.

Results

Mean age at data collection was 56.8 years (SD 5.8 years, range 48–71 years), mean reported age at menarche was 13.23 years (95% CI: 13.22–13.24 years) and mean reported age at natural menopause was 51.10 years (95% CI: 51.07–51.11 years). Of all women, 65.8% had reached natural menopause (Table I). The proportion was highest among women born in 1936–1939 (88.7%) and lowest among women born in 1960–1964 (31.1%).

The mean age at menarche displayed a weak *u*-shaped pattern across birth cohorts (Fig. 1A). Thus, mean age at menarche was 13.42 years (95% CI: 13.40–13.44 years) among women born during 1936–1939 and decreased to 13.18 years (95% CI: 13.17–13.19 years) among women born during 1955–1959. Among women born during 1960–1964, mean age at menarche was 13.24 years (95% CI: 13.22–13.25 years) (Table II).

The mean age at menopause increased by almost 3 years across birth cohorts, from 50.31 years (95% CI: 50.25–50.37 years) among women born during 1936–1939 to 52.73 years (95% CI: 52.64–52.82 years) among women born during 1960–1964 (Table II). The women who were born during 1945–1949, deviated from the increasing trend (Fig. 1B) and reached menopause earlier (mean 50.70 years, 95% CI: 50.66–50.73 years) than the women born during 1940–1944 (mean 50.80 years, 95% CI: 50.76–50.83 years) (Table II).

In total, 6.5% of the women reported menopause before the age of 45, and 1.3% reported menopause before the age of 40 (Table I). The proportion of women with menopause before the age of 45 or before the age of 40 decreased across birth cohorts from 1936 until 1964.

The decrease in mean age at menarche along with the increase in mean age at menopause across birth cohorts resulted in an increase in the number of years between menarche and menopause (Fig. 1C). The estimated mean number of years increased from 36.83 years (95% CI: 36.77–36.89 years) among women born during 1936–1939 to 40.22 years (95% CI: 40.11–40.34 years) among women born during 1960–1964 (Table II). The women born during 1945–1949 deviated from an almost linear increase in the time interval between menarche and menopause (Fig. 1C, Table II).

We found similar results, independent of the women's level of education (Supplementary Table SI). Also after exclusion of women with menopause before the age of 40 years and after the age of 60 years, we found similar increase in mean age at menopause across birth cohorts as in our main analyses (Supplementary Table SII).

Discussion

Summary of findings

In this population study of 312 656 women who were born in Norway during the years 1936–1964, age at menarche did not change substantially across birth cohorts. However, age at natural menopause and the time interval between menarche and menopause increased by ∼3 years.

Table I Study characteristics according to year of birth among 312 656 women in the BreastScreen Norway (2006–2014).

	Total N (%)	1936–1939 N (%)	1940–1944 N (%)	1945–1949 N (%)	1950–1954 N (%)	1955–1959 N (%)	1960–1964 N (%)
Number of women	312 656 (100.0)	17 409 (5.6)	45 831 (14.7)	63 716 (20.4)	70 507 (22.6)	72 789 (23.3)	42 404 (13.6)
Natural menopause	205 731 (65.8)	15 442 (88.7)	40 036 (87.4)	55 719 (87.5)	51 617 (73.2)	29 729 (40.8)	13 188 (31.1)
<45 years at menopause[a]	19 333 (6.5)	1456 (8.9)	3428 (7.9)	4427 (7.3)	4121 (6.1)	3865 (5.5)	2036 (5.0)
<40 years at menopause[b]	4062 (1.3)	269 (1.6)	673 (1.5)	905 (1.5)	825 (1.2)	851 (1.2)	539 (1.3)
Surgery on uterus and ovaries prior to menopause							
Hysterectomy	19 607 (6.3)	1097 (6.3)	3153 (6.9)	4012 (6.3)	4418 (6.3)	4452 (6.1)	2475 (5.8)
Bilateral oophorectomy	1908 (0.6)	132 (0.8)	358 (0.8)	445 (0.7)	459 (0.7)	348 (0.5)	166 (0.4)
Hysterectomy and bilateral oophorectomy	9390 (3.0)	694 (4.0)	2060 (4.5)	2716 (4.3)	2114 (3.0)	1276 (1.8)	530 (1.3)
Oral contraceptive use[c]							
Yes	166 408 (55.0)	3774 (22.7)	15 610 (35.5)	28 151 (45.9)	37 852 (55.4)	47 580 (67.0)	33 441 (80.6)
No	136 282 (45.0)	12 877 (77.3)	28 384 (64.5)	33 150 (54.1)	30 425 (44.6)	23 387 (33.0)	8059 (19.4)
Educational level[d]							
Less than high school	78 707 (25.5)	8497 (50.0)	19 196 (42.6)	21 364 (33.9)	16 031 (23.0)	10 237 (14.2)	3382 (8.1)
High school	129 694 (42.0)	5304 (31.2)	15 267 (33.9)	24 657 (39.2)	29 992 (42.9)	34 243 (47.5)	20 231 (48.2)
College/university	100 595 (32.6)	3198 (18.8)	10 578 (23.5)	16 919 (26.9)	23 829 (42.1)	27 690 (38.4)	18 381 (43.8)

[a]Exclusion of women with hysterectomy and/or bilateral oophorectomy before the age of 45 (N = 15 329).
[b]Exclusion of women with hysterectomy and/or bilateral oophorectomy before the age of 40 (N = 7241).
[c]N = 302 690 women due to missing information about oral contraceptives.
[d]N = 308 996 women due to missing information about educational level.

Table II Temporal trends in age at menarche, age at menopause and number of years between menarche and menopause among 312 656 women in the BreastScreen Norway, born during the years 1936–1964.

	No. women	Age at menarche (years)				Age at menopause (years)				Interval[a] (years)			
		Mean	95% CI	HR	95% CI	Mean	95% CI	HR	95% CI	Mean	95% CI	HR	95% CI
Birth cohort													
1936–1939	17 409	13.42	13.40–13.44	Reference		50.31	50.25–50.37	Reference		36.83	36.77–36.89	Reference	
1940–1944	45 831	13.32	13.30–13.33	1.08	1.06–1.10	50.80	50.76–50.83	0.88	0.86–0.90	37.44	37.39–37.48	0.86	0.85–0.88
1945–1949	63 716	13.29	13.28–13.30	1.10	1.08–1.12	50.70	50.66–50.73	0.90	0.89–0.92	37.35	37.31–37.38	0.88	0.86–0.90
1950–1954	70 507	13.21	13.20–13.22	1.17	1.15–1.19	50.93	50.90–50.97	0.85	0.83–0.86	37.80	37.76–37.84	0.79	0.78–0.81
1955–1959	72 789	13.18	13.17–13.19	1.20	1.18–1.22	51.86	51.80–51.91	0.68	0.67–0.70	39.18	39.11–39.25	0.59	0.58–0.60
1960–1964	42 404	13.24	13.22–13.25	1.15	1.13–1.17	52.73	52.64–52.82	0.57	0.55–0.58	40.22	40.11–40.34	0.49	0.48–0.50

The associations of birth cohort with age at menarche, age at menopause and number of years between menarche and menopause are estimated as crude HRs with 95% CI by applying flexible parametric models.
[a]Interval = number of years between menarche and menopause.
HR = hazard ratio.

Strengths and limitations

To our knowledge, this is the largest study yet to apply a time to event approach for investigation of temporal trends in age at menopause and the interval between menarche and menopause. By using such a data analytic approach, we could also include women who still had menstrual periods and the biases caused by oversampling of women with early menopause were minimized. More than 50% of the women in the most recent birth cohorts still had menstrual periods.

We used data from the BreastScreen Norway, which invites all women in Norway at the age of 50–69 years to participate. Among the women who participated, 63% answered both questionnaires in our study and could thereby be included in the data analyses (Tsuruda et al., 2018). Women with low education are underrepresented in the BreastScreen Norway (Le et al., 2018), and low education has been associated with late menarche (Deardorff et al., 2014) and early menopause (Gold et al., 2013). However, in women with high and low education we found similar trends in age at menarche and menopause across birth cohorts.

Information about age at menarche and menopause was based on self-report. Previous studies have found moderate to high agreement of age at menarche as reported in adulthood with the true age at menarche (Cooper et al., 2006; Must et al., 2002). The agreement
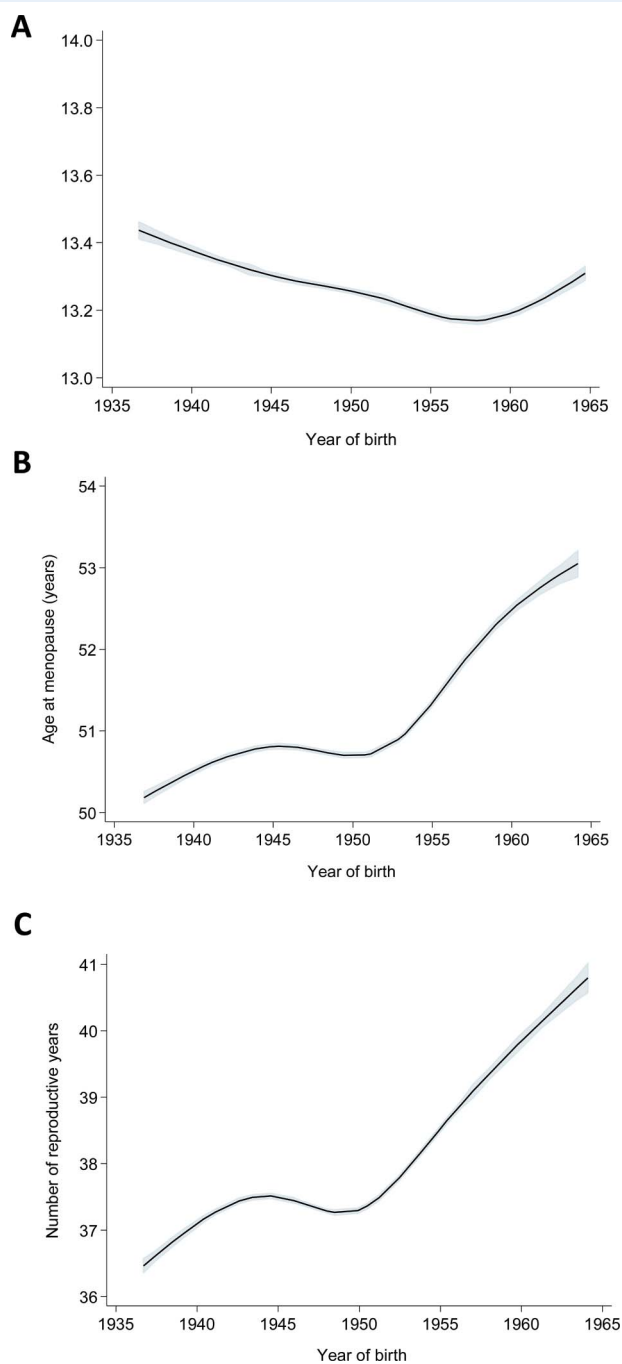
Figure 1 Temporal trends in age at menarche, age at menopause and the number of years between menarche and menopause among 312 656 women born in Norway, during the years 1936–1964. Flexible parametric survival models were used to estimate (**A**) mean age at menarche, (**B**) mean age at menopause and (**C**) mean number of years between menarche and menopause.

between self-reported and true age at menopause is also found to be high (Rodstrom *et al.*, 2005).

Age at menopause is typically defined retrospectively as 12 months without menstrual periods (Soules *et al.*, 2001). In our study, the time

since the last menstrual period was not reported. Menstrual cycles could possibly reoccur for women who reported their last menstrual period close to the data collection, and some women may have been misclassified according to menopausal status. Such error in reporting would most likely have occurred among the youngest women in our study, and age at menopause may have been underestimated in the youngest birth cohorts. In accordance with a previous study (Hahn *et al.*, 1997), we also observed a digit preference for menopause ages ending in 0, 2 and 5 (not shown). Digit preference may represent errors in the reporting of age at menopause, but there is no reason to believe that such erroneous reporting can explain our findings.

Errors in reporting may have been most common among older women, since the time from menarche and menopause to study participation was longer for older than for younger women. However, there is little reason to believe that the older women systematically reported a later age at menarche and earlier age at menopause than the younger women. Unsystematic errors in reporting would rather have underestimated than overestimated the association of birth year with age at menarche and age at menopause in our study (Clarke *et al.*, 1999).

Comparison with other studies

In many Western countries, mean age at menarche has decreased from 15–17 years among women born in the early 1800s to 13–13.5 years among women born in the 1950s (Tanner, 1973; Wyshak and Frisch, 1982; Rosenberg, 1991). Some studies suggest that age at menarche has continued to decrease in birth cohorts after 1950 (Kaplowitz, 2006; Mendoza *et al.*, 2010; Talma *et al.*, 2013; Lewington *et al.*, 2014; Gentry-Maharaj *et al.*, 2017; Meng *et al.*, 2017; InterLace Study team, 2019). Other studies, however, suggest that the decreasing trend in age at menarche has leveled off after the 1950 birth cohort (Brundtland and Walloe, 1973; Wyshak and Frisch, 1982; Vercauteren and Susanne, 1985; Lindgren *et al.*, 1991; Parent *et al.*, 2003; Forman *et al.*, 2013; Bratke *et al.*, 2017), and such a finding is in agreement with our results.

Age at natural menopause has been reported to increase across birth cohorts from the beginning of 1900 until the 1950s (Rodstrom *et al.*, 2003; Nichols *et al.*, 2006; Dratva *et al.*, 2009; Lewington *et al.*, 2014; Park *et al.*, 2018). A study from the USA supports such an increase and reports that age at menopause increased from 49.1 years in the 1915 birth cohort to 50.5 years in the 1939 birth cohort. This study also reports that the number of years between menarche and menopause increased from 36.9 to 37.7 years across the birth cohorts (Nichols *et al.*, 2006). However, the evidence of an increase in age at menopause across birth cohorts before 1950 is inconsistent (Dratva *et al.*, 2009; Gentry-Maharaj *et al.*, 2017; InterLace Study Team, 2019). Also, it is not known whether age at menopause has continued to increase among women born after 1950. Recent analyses of 172 125 women born during 1900–1959 in 10 different countries did not support a change in age at menopause across birth cohorts (InterLace Study Team, 2019). However, an increase in age at menopause was reported among 5288 European women born during 1940–1973 (Dratva *et al.*, 2009). In another study of ~200 000 postmenopausal women in the UK, age at menopause increased across the birth cohorts from 1925 to 1944, but decreased across the birth cohorts from 1945 to 1955 (Gentry-Maharaj *et al.*, 2017). A similar reversed trend in age at menopause was

reported among postmenopausal Portuguese women born during the years 1900–1963, and the decrease was observed after the 1932 birth cohort (Duarte et al., 2014). These two European studies had excluded women who were still having menstrual periods. Thus, women with early menopause may have been overrepresented, particularly in the most recent birth cohorts. Such overrepresentation of women with early menopause may have resulted in an underestimation of mean age at menopause that may explain the reversed trend in these studies.

Interpretations

Our results suggest that mean age at menarche remained almost unchanged across birth cohorts in Norway from 1936 to 1964. The previously reported decrease in age at menarche during the 1800s until the 1950s has been explained by improved nutritional status and health among women (Rees, 1993). However, it is possible that there is a biological lower limit of mean age at menarche in a population and that this limit is around 13 years. Such biological lower limit of the mean age at menarche may explain the minimal changes in our study.

We found that mean age at menopause increased from 50.31 years among women born during 1936–1939 to 52.73 years among women born during 1960–1964. Although it is out of our scope to explain the temporal trends, such an increase could possibly be a result of changes in women's lifestyles. High body mass index is associated with late menopause (Zhu et al., 2018), and mean body mass index has increased among Norwegian women during the 1900s (Midthjell et al., 1999).

Menopause is estimated to occur when less than 1000 ovarian follicles remain in the ovaries (Faddy et al., 1992). The ovaries are fully developed by the 20th week of fetal life, and atresia of the ovarian follicles follows thereafter (Wallace and Kelsey, 2010). Growth restriction during fetal life may possibly impair ovarian development, and poor nutritional status during early life could increase the rate of follicle atresia and thereby decrease age at menopause (Mishra et al., 2009; Bjelland et al., 2019). Therefore, the increase in birthweight across birth cohorts (Fudvoye and Parent, 2017) could possibly explain part of the increase in age at menopause.

In our study, the increasing trend in age at menopause halted among women who were born at the end and immediately after the Second World War. This finding could possibly be explained by stress or insufficient supply of nutrients during their fetal life (Sadrzadeh et al., 2018). It is known that daughters of pregnant women who were exposed to the Dutch Hunger Winter in 1944–1945, reached menopause early (Elias et al., 2003). Our findings do not suggest a change in age at menarche among women born during or immediately after the Second World War. Some studies have, however, observed a delay in age at menarche among girls who were approaching puberty during war times (van Noord and Kaaks, 1991; Prebeg and Bralic, 2000). The oldest women in our study were born in 1936, and they did not approach puberty until after the Second World War.

Many childbirths have been associated with high age at menopause (Dorjgochoo et al., 2008; Gold et al., 2013), and changes in reproductive patterns could influence mean age at menopause in the population. However, the mean number of childbirths remained unchanged across the birth cohorts after 1944 in our study (not shown). Thus, changes in number of childbirths cannot explain the changes in age at menopause.

It has also been suggested that the use of hormonal contraceptives may delay menopause (van Noord et al., 1997; Gold et al., 2013). Oral contraceptives became generally available in Norway in the mid-1960s, and the use of oral contraceptives increased across birth cohorts in our study (Table I). Thus, increased use of oral contraceptives is consistent with an increase in age at menopause.

Prolonged exposure and high levels of estrogens when not counterbalanced by progesterone may increase the risk of estrogen sensitive breast cancers (Key and Pike, 1988), and endometrial cancer (Pettersson et al., 1986). Late menopause is associated with increased risk of breast cancer (Collaborative Group on Hormonal Factors in Breast Cancer, 1997; Ellingjord-Dale et al., 2017) and endometrial cancer (Xu et al., 2004). Thus, the increased age at menopause and increased number of years between menarche and menopause may have resulted in increased cumulative exposure to endogenous estrogen. It is therefore possible that part of the increased incidence in postmenopausal breast cancer and endometrial cancer during recent years could be attributed to an overall higher age at menopause in the population.

As opposed to breast cancer, the risk of cardiovascular disease, dementia and osteoporosis seem to be decreased in women with late menopause (Ossewaarde et al., 2005; Gallagher, 2007; Gilsanz et al., 2019). Late menopause has also been associated with decreased all-cause mortality (Jacobsen et al., 2003; Ossewaarde et al., 2005). Thus, it is conceivable that the increase in life expectancy for women in Norway during the last decades (Leon, 2011) in part could be explained by the increased age at menopause.

Our results suggest that the mean number of years between menarche and menopause has increased by ∼3 years. This finding should encourage studies of possible changes in fecundity, particularly at advanced reproductive age.

Conclusions

Our population study of 312 656 women born in Norway suggest minor changes in age at menarche across birth cohorts from 1936 to 1964. However, age at menopause and also the time interval between menarche and menopause have increased by ∼3 years.

Authors' roles

A.E. and E.K.B. had the original idea for this study. M.S.G., A.E., J.M.G. and E.K.B. discussed the design and planned the data analytic approaches. M.S.G. and E.K.B. performed the data analyses. M.S.G., A.E. and E.K.B. interpreted the results and wrote the manuscript. J.M.G. and S.H. contributed with interpretation of the results, critically revised the article. E.K.B. is the guarantor of the study. All authors had full access to the data and can take responsibility for the integrity of the data and the accuracy of the data analyses. All authors have approved the submitted version of the manuscript.

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Conflict of interest

None to declare.

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