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Research Article

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Age period and birth cohort patterns in colorectal lesion detection in a Chinese hospital from 2010 to 2024

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Abstract

Background

Age, calendar period and birth cohort jointly shape patterns in colonoscopy-detected colorectal lesions. We examined these relationships in a hospital series while accounting for repeat examinations and gradual changes in pathological classification.

Methods

We analysed 71,942 colonoscopies in 57,726 patients aged 20–84 years at Xuanwu Hospital, Capital Medical University, during 2010–2024. Outcomes were any polyp, any serrated lesion, hyperplastic polyp (HP), sessile serrated lesion or traditional serrated adenoma (SSL/TSA), and colorectal cancer (CRC). Primary age-period-cohort (APC) models used 69,633 examinations at ages 30–84 because sparse CRC data prevented finite estimation in the youngest age groups. Categorical log-mean models with patient-clustered sandwich covariance estimated drift and nonlinear period and cohort components. Sensitivity analyses used first examinations, sex adjustment and an expanded age range.

Results

Any serrated lesion was detected in 11.16% of examinations at ages 20–84. In the primary APC analysis, its net drift was 14.85% per year (95% confidence interval 13.78–15.93). Period rate ratios were 0.31 (0.28–0.34) in 2010–2014 and 1.24 (1.18–1.30) in 2020–2024, relative to 2015–2019. Period curvature was evident, whereas cohort curvature was not (P=0.265). Net drift was 4.73% for any polyp, 13.61% for HP, 28.29% for SSL/TSA and −5.92% for CRC. Cohort curvature was detected for any polyp (P=0.001) and nominally for SSL/TSA (P=0.039); CRC evidence differed between all- and first-examination analyses. Drift directions persisted across sensitivity analyses.

Conclusions

Colorectal lesion detection showed marked temporal change, but evidence for nonlinear cohort variation differed by outcome and analysis. Gradual overlap of pathological criteria complicates serrated-lesion interpretation. These hospital-based associations do not identify independent causal age, period or cohort effects or changes in population incidence.

Keywords: age-period-cohort; birth cohort; colorectal polyp; serrated lesion; sessile serrated lesion; colorectal cancer; colonoscopy; China

Background

Colorectal cancer (CRC) is a major cause of cancer morbidity and mortality. Global estimates for 2022 included more than 1.9 million new cases and approximately 900,000 deaths, and China carries a substantial share of this burden [1, 2]. Prevention is possible because many CRCs develop through identifiable precursor lesions. Colonoscopic polypectomy interrupts the conventional adenoma-carcinoma sequence and has been associated with lower subsequent CRC incidence and mortality [3, 4].

The serrated pathway provides another route to CRC. Hyperplastic polyps (HPs), sessile serrated lesions (SSLs), and traditional serrated adenomas (TSAs) share serrated architecture but differ in malignant potential [5, 6, 7]. Serrated lesions, particularly SSLs, are subtle endoscopically and are sensitive to bowel preparation, withdrawal technique, endoscopist recognition, anatomical site, specimen handling, and pathological interpretation [5, 7, 8]. A meta-analysis of 129,001 average-risk individuals estimated detection of 19.0% for any serrated lesion and 2.5% for SSL, with substantial heterogeneity and lower estimates in Asian studies [8]. Historical Chinese series reported markedly lower serrated-polyp detection, highlighting the influence of setting and diagnostic practice [9].

Pathological classification has changed during the observation window. Historical labels include sessile serrated adenoma, sessile serrated polyp and SSL. The WHO fifth edition adopted SSL terminology in 2019 and revised the histological threshold [6, 7]. Additional tissue sections can lead to reclassification of lesions previously diagnosed as HP, and agreement between pathologists is imperfect [10, 11]. In routine practice, implementation can be gradual, with earlier and newer terminology coexisting. This can influence period patterns even without an equivalent change in underlying lesion occurrence.

China has expanded organised and opportunistic CRC screening, although access, adherence, and quality assurance remain uneven [12, 13]. Chinese studies have shown that colorectal polyps are common and associated with age and male sex, but most are cross-sectional or cover shorter intervals [14].

Longitudinal clinical databases can reveal changes in detection practice, provided that detection among examined patients is distinguished from population incidence or prevalence.

Age-period-cohort (APC) analysis describes temporal variation across age at examination, calendar period and birth cohort. Age patterns can reflect biological ageing and age-specific selection for colonoscopy. Period patterns can capture changes in referral, examination quality and diagnostic practice. Cohort patterns can be compatible with generational differences in exposure, but also depend on the model and observation window. Large screening-colonoscopy studies have used birth-cohort approaches to examine adenoma occurrence [15]. Because cohort equals period minus age, the three unrestricted linear effects cannot be estimated independently [16, 17].

We examined age, period and birth-cohort patterns in colorectal lesion detection during 2010–2024. Any serrated lesion was the principal serrated-spectrum outcome; HP and the combined SSL/TSA category were analysed separately. We distinguished overall linear drift from nonlinear period and cohort variation and assessed sensitivity to repeat examinations, sex adjustment and sparse younger-age data. The target quantity was detection per colonoscopy examination, not population incidence or prevalence.

Methods

Study design and setting

This retrospective repeated cross-sectional study used routinely collected colonoscopy and pathology records from Xuanwu Hospital, Capital Medical University, Beijing, China. The study period was 1 January 2010 through 31 December 2024. A colonoscopy examination was the unit of analysis. Reporting was guided by STROBE and RECORD [18, 19].

Data source and study population

The source workbook contained 72,387 examination records from 58,082 patient identifiers. Eligible examinations occurred during the study period in patients aged 20-84 years and had non-missing patient identifier, sex, age, examination year, and outcome codes. We excluded 445 records outside the age

range, leaving 71,942 examinations from 57,726 patients. The age range retained complete 5-year groups while avoiding sparse extreme-age cells.

All records in the descriptive population had complete patient identifier, age, year, sex and outcome fields. Recorded age equalled examination year minus birth year and was not a verified birthday-based measure. No exact duplicate rows were found. Repeat examinations occurred in 8,575 patients, contributing 14,216 procedures beyond the first eligible examination. Descriptive and WHO-standardised analyses retained all 71,942 examinations at ages 20–84; the primary APC population was restricted to ages 30–84 as described below.

Outcome definitions and pathology transition

Five non-mutually exclusive outcomes were analysed: any colorectal polyp (POLYP), HP (HP), SSL or TSA (SS), any serrated lesion (ALL_SS), and CRC (Ca). The SS field represents the combined presence of SSL and/or TSA and does not identify SSL alone. This binary field does not separate the two subtypes. Positive codes had accompanying pathology text, but this alone does not validate classification accuracy. The broad polyp outcome was not equated with adenoma.

Any serrated lesion comprised HP, SSL and TSA and was defined as ALL_SS > 0. This definition agreed exactly with HP > 0 or SS > 0 in the eligible records. The value 2 indicated co-occurring HP and SS positivity in 260 examinations; these were counted once as positive for any serrated lesion. Combining subtypes may reduce sensitivity to relabelling between HP and SSL/TSA but cannot eliminate changes in ascertainment or historical coding.

Local pathological diagnostic criteria and terminology evolved gradually following WHO classification updates. Earlier and newer diagnostic practices coexisted during implementation; there was no discrete hospital-wide switch from one standard to another. Examinations were therefore not assigned to uniform pre-update and post-update diagnostic eras. Outcomes retained their recorded historical classifications, and tissue was not retrospectively reclassified. Variation in classification within and across calendar periods was considered when interpreting serrated-lesion patterns.

Age period and birth cohort analysis

The initial APC grid contained 13 five-year age groups (20–24 to 80–84) and three periods (2010–2014, 2015–2019 and 2020–2024). CRC had zero events at ages 20–29 in the first two periods, causing separation in the full categorical model. Following this diagnostic finding, all primary outcome models used the common age range 30–84: 11 age groups, three periods and 13 diagonal cohort categories with midpoints 1930–1990. This restriction was analysis-driven, not prespecified. Cohort indices were period midpoint minus age midpoint, rather than mutually exclusive groups of recorded birth years. The reference period was 2015–2019, with reference age 57.5 years and cohort 1960. Calendar groups did not represent diagnostic-standard eras.

We fitted modified Poisson log-mean models to binary examination outcomes, using Poisson score equations and robust covariance rather than assuming Poisson outcome variance [20]. Grouped fitting used positive examination counts with the logarithm of total examinations as an offset. The full-rank design comprised an intercept, linear age and period terms, and categorical age, period and cohort deviations. Each deviation had zero unweighted mean and zero unweighted linear trend across its distinct category midpoints. No spline basis, knots, penalty or continuity correction was used. The primary design had 24 parameters in 33 age-period cells; curvature tests used 9, 1 and 11 degrees of freedom for age, period and cohort, respectively.

Sandwich covariance was computed from examination-level scores summed within patient, with the finite-sample CR1 correction. No additional dispersion multiplier was applied. We retained zero-event cells and checked convergence, design rank, fitted probabilities and grouped residual diagnostics. Pointwise 95% confidence intervals were obtained from linear contrasts on the log scale and then transformed; curvature was assessed by joint Wald tests. All APC estimates, tests and Figures 2–4 were derived from these same fitted models. Additional file 1 specifies the equations, contrasts, covariance and diagnostics.

Supporting statistical analyses

Continuous characteristics were summarised as mean and standard deviation and categorical characteristics as counts and percentages. For ages 20–84, annual detection proportions used eligible examinations as denominators. Direct age standardisation used WHO 2000–2025 percentage weights, restricted and renormalised to these 13 age groups [21]. Standardisation was descriptive and was not an input to the APC models. No single full-period average annual percentage change was used to summarise the non-monotonic SSL/TSA curve.

Annual age-standardised detection was calculated as $100 \times \Sigma w_i(y_i^t/n_i^t)$, where y_i^t and n_i^t are positive and total examinations in age group i and year t, and the weights w_i sum to 1. All age-year cells had observations. The estimates describe diagnostic yield among examined patients and have no person-time denominator. Additional file 1 gives the weights and annual values.

Net drift was $100 \times (\exp(d) - 1)$, where d was the period slope in the stated constrained decomposition. Local drift was the equally weighted least-squares slope of fitted log detection over the three periods within each age group, transformed to percentage change per year. Period rate ratios combined d with period deviations. Cohort plots displayed exponentiated differences in cohort deviations relative to 1960, excluding linear drift; these were labelled cohort curvature ratios, not overall generational risk ratios. Age curves displayed fitted detection within the observed reference period and were not longitudinal life-course trajectories [16, 17].

We repeated the complete APC model using each patient's earliest eligible examination at ages 30–84, selected by the recorded date. This was the first observed eligible examination, not necessarily the first lifetime colonoscopy. Additional models included sex as a main effect or expanded the age range to 20–84 for non-CRC outcomes. Each age-range model used the same constraint rule on its own category grid. The expanded CRC model was not reported because finite estimation failed. Annual SSL/TSA detection remained descriptive; no year was imposed as a pathological change point.

All tests were two-sided and exploratory; nominal P values were not adjusted for multiple outcomes or sensitivity analyses. Confidence bands were pointwise, not simultaneous. Analyses used Python 3.12.14,

158 pandas 2.2.3, NumPy 2.3.5 and SciPy 1.17.0 with the accompanying custom APC code (version 1.0). A
159 separate optimisation algorithm checked fitted log means to within 10^{-6}, and a redundant categorical
160 design verified the fitted model space.

161 ## Results

162 ### Study population

163 The descriptive population included 71,942 examinations from 57,726 patients aged 20–84. Mean age per
164 examination was 55.4 years (SD 13.0), and 36,779 examinations (51.1%) were in males. Volume
165 increased from 16,994 in 2010–2014 to 32,148 in 2020–2024. The proportion aged 20–49 increased from
166 24.5% to 37.5% (Table 1). The primary APC population comprised 69,633 examinations from 55,510
167 patients aged 30–84; the remaining 2,309 examinations were retained in descriptive analyses.

168 At ages 20–84, any polyp was detected in 22,984 examinations (31.95%), any serrated lesion in 8,030
169 (11.16%), HP in 6,488 (9.02%), SSL or TSA in 1,802 (2.50%) and CRC in 1,701 (2.36%). Outcomes
170 could coexist within an examination. The 1,802 SS-positive examinations cannot be interpreted as an
171 SSL-specific count.

172 ### Annual age standardised detection

173 Figure 1 shows WHO-standardised detection proportions. Any serrated lesion increased from 0.56% in
174 2010 to 11.28% in 2024, HP from 0.56% to 10.10%, and any polyp from 11.40% to 26.48%. CRC
175 decreased from 2.15% to 0.99%. These endpoint comparisons describe a non-linear time course; they are
176 not estimates of constant annual change.

177 No SSL/TSA-positive examination was recorded in 2010, but positive records occurred in subsequent
178 early years. The WHO-standardised proportion reached 4.96% in 2016 and was 1.54% in 2024. This non-
179 monotonic combined-category pattern cannot establish when SSL itself was first diagnosed or distinguish
180 changes in SSL from changes in TSA. Additional file 1 provides annual counts and proportions.

Age period and cohort patterns for any serrated lesion

For any serrated lesion, net drift at ages 30–84 was 14.85% per year (95% CI 13.78–15.93). Period curvature was evident (Wald χ^2=274.42, 1 df, P<0.001), whereas cohort curvature was not (χ^2=13.44, 11 df, P=0.265; Table 2). Period rate ratios were 0.31 (0.28–0.34) in 2010–2014 and 1.24 (1.18–1.30) in 2020–2024, relative to 2015–2019. In the reference period, fitted detection was 7.97% at age midpoint 32.5, 13.12% at 57.5 and 9.38% at 82.5 (Figure 2). These are cross-sectional model estimates, not independent age effects.

Net and local drift across outcomes

Net drift was positive for any polyp (4.73% per year; 95% CI 4.32–5.15), HP (13.61%; 12.49–14.74) and SSL/TSA (28.29%; 24.11–32.61), and negative for CRC (−5.92%; −7.47 to −4.34; Figure 3A and Table 2). The large SSL/TSA summary spans very uncommon early recording and subsequent non-monotonic detection. It is not a constant biological growth rate or a causal effect of diagnostic reclassification.

Local drifts for any serrated lesion were positive across the 11 primary age groups, ranging from 9.61% to 16.89% per year (Figure 3B). The curves summarise temporal change at fixed grouped age, not changes experienced by an individual while ageing. Confidence intervals at boundary ages were wider, and curve differences alone were not treated as formal between-age comparisons.

Birth cohort patterns across outcomes

After removing linear drift, cohort curvature was detected for any polyp (χ^2=31.17, 11 df, P=0.001) and nominally for SSL/TSA (χ^2=20.50, 11 df, P=0.039). It was not detected for any serrated lesion, HP (P=0.211) or CRC (P=0.062; Figure 4 and Table 2). These tests concern nonlinear departures under the specified APC model; a non-significant test does not establish absence of cohort-related variation. CRC period curvature was also not significant (P=0.769).

The 1930 and 1990 diagonal cohorts each contributed one age-period cell, and the 1935 and 1985 cohorts contributed two; central cohorts contributed three. Boundary uncertainty and the short observation window limited interpretation. Cohort curvature ratios were not interpreted as total risk differences

between generations, because linear drift had been removed and the data represented selected hospital examinations.

Supporting analyses

Restricting the complete APC model to first eligible examinations retained 55,510 patients. Drift directions were unchanged for all five outcomes (Table 3). Any serrated lesion had net drift of 15.33% per year (95% CI 14.14–16.53), with non-significant cohort curvature (P=0.595). CRC net drift was −7.32% (−8.89 to −5.72); its cohort-curvature P value changed from 0.062 in all examinations to 0.006 in first examinations. Thus, annual directions were consistent but the evidence for every cohort component was not.

Sex-adjusted models gave similar net drifts; any serrated lesion had 14.92% per year (95% CI 13.85–16.00) and cohort-curvature P=0.353. At ages 20–84, non-CRC net drifts remained positive. SSL/TSA cohort curvature changed from P=0.039 in the primary model to P=0.054 in the expanded model. Primary grouped Pearson statistics divided by residual degrees of freedom ranged from 0.45 to 2.20; all observed-cell fitted probabilities were between zero and one. Supporting results and diagnostics are reported in Additional file 1.

Discussion

Principal findings

This hospital series showed increasing detection of polyps and serrated lesions and decreasing CRC yield over 15 years. In the primary APC models, any serrated lesion had positive drift and marked period curvature, but no clear evidence of nonlinear cohort variation. Any polyp showed cohort curvature, whereas evidence for SSL/TSA and CRC was sensitive to the analysis population. These findings favour a cautious account of temporal and cohort patterns rather than a claim that every lesion subtype has a distinct generational trend.

The distinction between drift and curvature changes the interpretation of the cohort results. Linear period and cohort contributions cannot be separated without constraints. Our cohort plots therefore emphasised

nonlinear departures after removing drift. A positive drift together with a cohort-curvature curve near one is compatible with strong overall temporal change and little evidence for additional nonlinear cohort structure; it does not identify which generational or calendar-time exposure produced that change.

Interpretation in relation to previous evidence

In the reference period, fitted serrated-lesion detection was lower at younger adult ages, higher through much of middle and older adulthood, and lower in the oldest group. This cross-sectional pattern can reflect lesion biology, referral and age-specific colonoscopy use as well as the cohorts represented at each age. It cannot establish when lesions developed or how detection changes within the same person. The restricted APC age range further prevents extrapolation to adults younger than 30.

The serrated period pattern is compatible with contemporaneous changes in referral, equipment, withdrawal technique, specimen submission and pathological recognition. Examination quality affects lesion yield; longer withdrawal times are associated with greater serrated and adenomatous polyp detection, and adenoma detection is associated with interval-cancer risk [22, 23, 24]. Positive drifts in both the broad serrated outcome and HP suggest that the recorded increase extended beyond the SSL/TSA label alone. These potential mechanisms were not individually measured.

Local pathological practice evolved gradually, with earlier and newer diagnostic criteria and terminology used concurrently. Classification could therefore vary within the same APC period as well as between periods. The period patterns may reflect both changes in lesion detection and changes in classification; the available records cannot separate these contributions. Neither WHO publication dates nor the rise in SS coding around 2016 identifies a local switch date. Including a period component in an APC model does not by itself correct outcome misclassification or isolate the effect of diagnostic changes.

Histological reassessment and interobserver-agreement studies support concern about changing ascertainment [10, 11]. However, their SSL-specific findings cannot be transferred directly to our combined SS field, which also contains TSA. The 1,802 positive examinations and the rise around 2016 represent SSL and/or TSA, not SSL alone. Combining these with HP reduces some effects of within-

spectrum relabelling but does not guarantee stable ascertainment. Historical reports or slide review would be needed to separate the subtypes consistently.

Declining CRC yield should be distinguished from population-based cohort patterns. Studies in the United States and several other settings have reported increasing CRC risk in more recent cohorts [25, 26]. Our denominator was colonoscopy examinations, so a growing volume of procedures in people with lower pre-test probability could reduce cancer yield without reducing population incidence. Moreover, CRC cohort curvature was sensitive to exclusion of repeat examinations. These results do not establish protective generational exposures or the effect of a screening programme.

Age period and cohort interpretation

The identity cohort = period − age prevents unrestricted estimation of the three linear effects [16, 17]. We used explicit zero-mean and zero-linear-trend constraints for deviations, retained the combined temporal drift, and reported nonlinear cohort contrasts separately. Changing the category grid can change the drift decomposition, even when the underlying fitted pattern is similar. Consequently, comparison across age-range sensitivity analyses should emphasise broad patterns and uncertainty rather than treating every coefficient as the same population parameter.

Only three five-year periods were available. Full categorical modelling avoided undocumented smoothing choices but left limited information for cohort curvature and boundary estimates. The age restriction followed a separation diagnosis in CRC and was not a prespecified eligibility rule. The 20–84-year extension supported drift directions for non-CRC outcomes, but it did not rescue the expanded CRC model or remove uncertainty about cohort shapes. Nominal P values near 0.05, particularly for SSL/TSA, warrant caution in an exploratory multiple-outcome analysis.

Strengths and limitations

Strengths include the large examination dataset, 15-year observation window, confirmed meanings of the serrated outcome codes, explicit WHO standardisation and fully specified APC design. Patient-clustered covariance addresses within-patient dependence, and first-examination analyses refitted the same

complete APC model rather than substituting a separate annual-trend model. Aggregate counts, fitted coefficients, covariance matrices and executable code make the analysis auditable.

The single-centre, examination-based design does not estimate population incidence, prevalence or screening effectiveness. Structured indications, bowel preparation, caecal intubation, withdrawal time, endoscopist identity and lesion characteristics were unavailable for these models. Changes in referral and surveillance could therefore confound temporal patterns. Age was a calendar-year measure, and diagonal cohort categories do not isolate exact birth-year groups. Historical diagnostic criteria overlapped, SS combined SSL and TSA, and coding validation still requires documentation. Cluster-robust covariance does not correct outcome misclassification, an incorrect mean model, shared provider effects or selection into colonoscopy. Boundary cohorts were sparse, some grouped residual diagnostics exceeded the Poisson benchmark, and nominal significance was not adjusted for multiple comparisons. Replication with more periods, validated pathology and indication data is needed.

Conclusions

At Xuanwu Hospital, colorectal lesion detection displayed marked temporal change during 2010–2024. Serrated-lesion yield increased and CRC yield decreased, but nonlinear cohort evidence differed across outcomes and sensitivity analyses. Gradual coexistence of pathological criteria and the combined SSL/TSA field limit subtype-specific interpretation. The APC findings describe the examined hospital population and do not establish independent causal age, period or cohort effects.

List of abbreviations

APC: age-period-cohort; CI: confidence interval; CRC: colorectal cancer; HP: hyperplastic polyp; RR: rate ratio; SD: standard deviation; SSL: sessile serrated lesion; TSA: traditional serrated adenoma; SS: source field for SSL and/or TSA; ALL_SS: source field for all serrated lesions including HP; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology; RECORD: REporting of studies Conducted using Observational Routinely-collected health Data.

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of Xuanwu Hospital, Capital Medical University (approval No. XS20260701005-2; approved on 29.07.2026). The requirement for informed consent was waived by the Ethics Committee because of the retrospective nature of the study and the use of routinely collected, de-identified data.

Consent for publication

Not applicable. The manuscript contains no identifiable individual-level information, images, or videos.

Availability of data and materials

The aggregate annual data used in this study and the supporting analytical code are provided with this article and its supplementary materials. Individual-level patient records are not publicly available because they contain potentially identifiable clinical information and are subject to institutional and ethical restrictions. Access to de-identified individual-level data may be considered upon reasonable request to the corresponding author, subject to approval by Xuanwu Hospital, Capital Medical University, and, where required, the institutional ethics committee, as well as the execution of an appropriate data-use agreement. No public repository was used for the individual-level data.

Competing interests

The authors declare that they have no competing interests.

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Authors contributions

JC contributes to data sorting, data analysis, and drafting of the manuscript. DP contributes to data analysis.DZ contributes to data sorting. HZ contributes to study conception and drafting of the manuscript.

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Not applicable.

Use of generative artificial intelligence

ChatGPT (OpenAI) assisted with supporting analysis code. The tool was not used to make clinical diagnoses and is not an author.

Additional files

Additional file 1. Supporting methods and results. WHO weights and annual detection at ages 20–84; APC parameterisation and contrast definitions; sensitivity analyses, model diagnostics and reproducibility details for the primary 30–84-year models.

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Table 1. Examination characteristics at ages 20–84 by calendar period

Characteristic	Overall	2010-2014	2015-2019	2020-2024
Examinations, n	71,942	16,994	22,800	32,148
Age, mean (SD), years	55.4 (13.0)	56.6 (12.8)	56.9 (12.1)	53.8 (13.6)
Male, n (%)	36,779 (51.1)	8,677 (51.1)	11,796 (51.7)	16,306 (50.7)
Age 20-49 years, n (%)	21,774 (30.3)	4,169 (24.5)	5,558 (24.4)	12,047 (37.5)
Age 50-64 years, n (%)	31,726 (44.1)	8,517 (50.1)	11,287 (49.5)	11,922 (37.1)
Age 65-84 years, n (%)	18,442 (25.6)	4,308 (25.4)	5,955 (26.1)	8,179 (25.4)
Any polyp, n (%)	22,984 (31.95)	4,047 (23.81)	7,845 (34.41)	11,092 (34.50)
Any serrated lesion, n (%)	8,030 (11.16)	614 (3.61)	2,755 (12.08)	4,661 (14.50)
Hyperplastic polyp, n (%)	6,488 (9.02)	576 (3.39)	2,042 (8.96)	3,870 (12.04)
SSL or TSA, n (%)	1,802 (2.50)	41 (0.24)	800 (3.51)	961 (2.99)
Colorectal cancer, n (%)	1,701 (2.36)	545 (3.21)	581 (2.55)	575 (1.79)

Counts and percentages use examinations as denominators. Outcomes are non-mutually exclusive. SS denotes SSL and/or TSA; any serrated lesion includes HP, SSL and TSA. The primary APC models used the subset aged 30–84.

Table 2. Primary age period cohort results at ages 30–84

Outcome	Net drift (95% CI), % per year	Period curvature, χ^2 (df, P)	Cohort curvature, χ^2 (df, P)
Any polyp	4.73 (4.32 to 5.15)	124.37 (1, <0.001)	31.17 (11, 0.001)
Any serrated lesion	14.85 (13.78 to 15.93)	274.42 (1, <0.001)	13.44 (11, 0.265)
Hyperplastic polyp	13.61 (12.49 to 14.74)	94.53 (1, <0.001)	14.41 (11, 0.211)
SSL or TSA	28.29 (24.11 to 32.61)	229.29 (1, <0.001)	20.50 (11, 0.039)
Colorectal cancer	-5.92 (-7.47 to -4.34)	0.09 (1, 0.769)	18.93 (11, 0.062)

All models used 69,633 examinations from 55,510 patients. Wald tests and 95% confidence intervals use patient-clustered CR1 sandwich covariance. Period curvature has 1 df and cohort curvature 11 df. Net drift is a combined linear trend under the stated constraints, not a separately identified period or cohort effect. SSL/TSA is the combined SS outcome.

Table 3. Complete APC sensitivity analysis using first eligible examinations

Outcome	All examinations, net drift/year (95% CI), %	First eligible examination, net drift/year (95% CI), %
Any polyp	4.73 (4.32 to 5.15)	5.33 (4.89 to 5.76)
Any serrated lesion	14.85 (13.78 to 15.93)	15.33 (14.14 to 16.53)
Hyperplastic polyp	13.61 (12.49 to 14.74)	14.03 (12.79 to 15.28)
SSL or TSA	28.29 (24.11 to 32.61)	28.75 (23.96 to 33.73)
Colorectal cancer	-5.92 (-7.47 to -4.34)	-7.32 (-8.89 to -5.72)

Both analyses cover ages 30–84 with the same categorical grid and constraint rule. The first-examination analysis contains 55,510 patients. Covariance is patient-clustered; with one examination per patient this reduces to a heteroskedasticity-robust sandwich with the stated finite-sample correction. CRC cohort-curvature inference differs between analyses; drift-direction consistency does not establish robustness of every APC component.

Figure legends

Figure 1. Annual WHO-standardised detection at ages 20–84. Detection is expressed per 100 eligible colonoscopy examinations. WHO 2000–2025 weights were restricted and renormalised to these ages. The SS outcome is SSL and/or TSA, not SSL alone. Annual counts and estimates are in Additional file 1.

Figure 2. Primary APC model for any serrated lesion at ages 30–84. A, fitted detection across age groups within 2015–2019, including the cohorts represented at each age; this is not a longitudinal age curve. B, period rate ratios incorporating net drift and period deviations, relative to 2015–2019. C, exponentiated cohort-deviation contrasts relative to 1960, with linear drift removed. Shading indicates pointwise patient-clustered 95% confidence intervals. The panels represent different model functions, not independently identified causal effects.

Figure 3. Net and local drift at ages 30–84. A, net drift for all five outcomes with patient-clustered 95% confidence intervals. B, local drift for any serrated lesion, HP and CRC, calculated from equally weighted slopes of fitted log detection across three periods within each age group. SSL/TSA is the combined SS field; its full-period summary is sensitive to changing classification and does not imply constant biological growth.

Figure 4. Nonlinear cohort contrasts at ages 30–84. Ratios compare exponentiated cohort deviations with the 1960 cohort on a logarithmic axis; linear drift is excluded. They are curvature ratios, not overall generational risk ratios. Coloured bands are pointwise patient-clustered 95% confidence intervals. Grey zones identify boundary cohorts contributing fewer than three age-period cells. Cohort midpoints label diagonals of the grouped age-period grid.

Figure 1

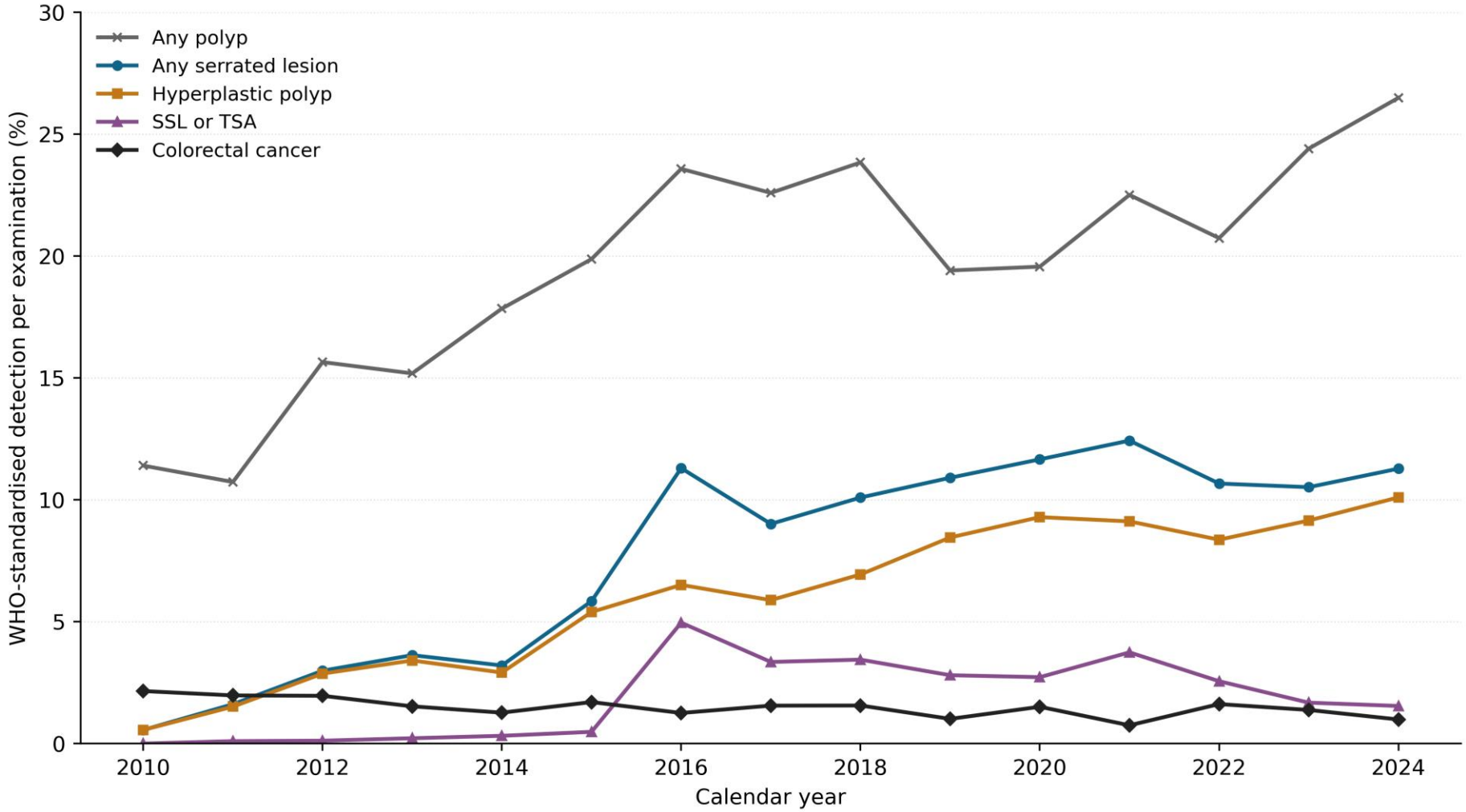

Any polyp
Any serrated lesion
Hyperplastic polyp
SSL or TSA
Colorectal cancer
WHO-standardised detection per examination (%)
0
5
10
15
20
25
30
2010
2012
2014
2016
2018
2020
2022
2024
Calendar year

Figure 2

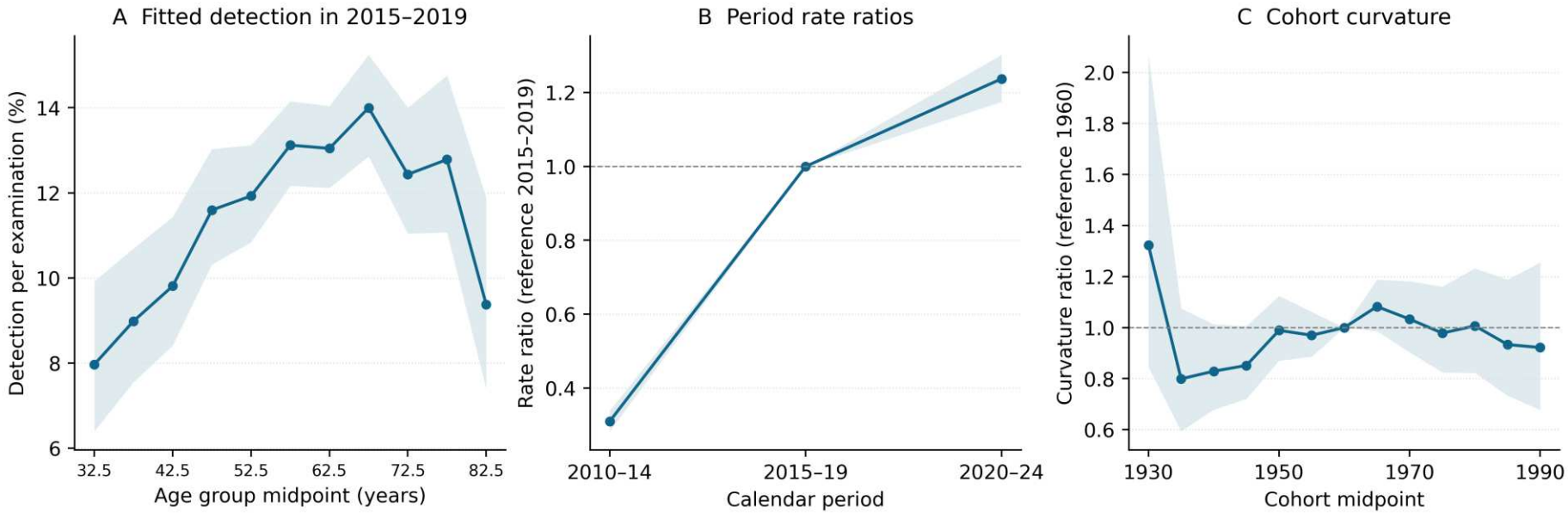

A Fitted detection in 2015–2019
Detection per examination (%)
6
8
10
12
14
32.5
42.5
52.5
62.5
72.5
82.5
Age group midpoint (years)
B Period rate ratios
Rate ratio (reference 2015–2019)
0.4
0.6
0.8
1.0
1.2
2010–14
2015–19
2020–24
Calendar period
C Cohort curvature
Curvature ratio (reference 1960)
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
1930
1950
1970
1990
Cohort midpoint

Figure 3

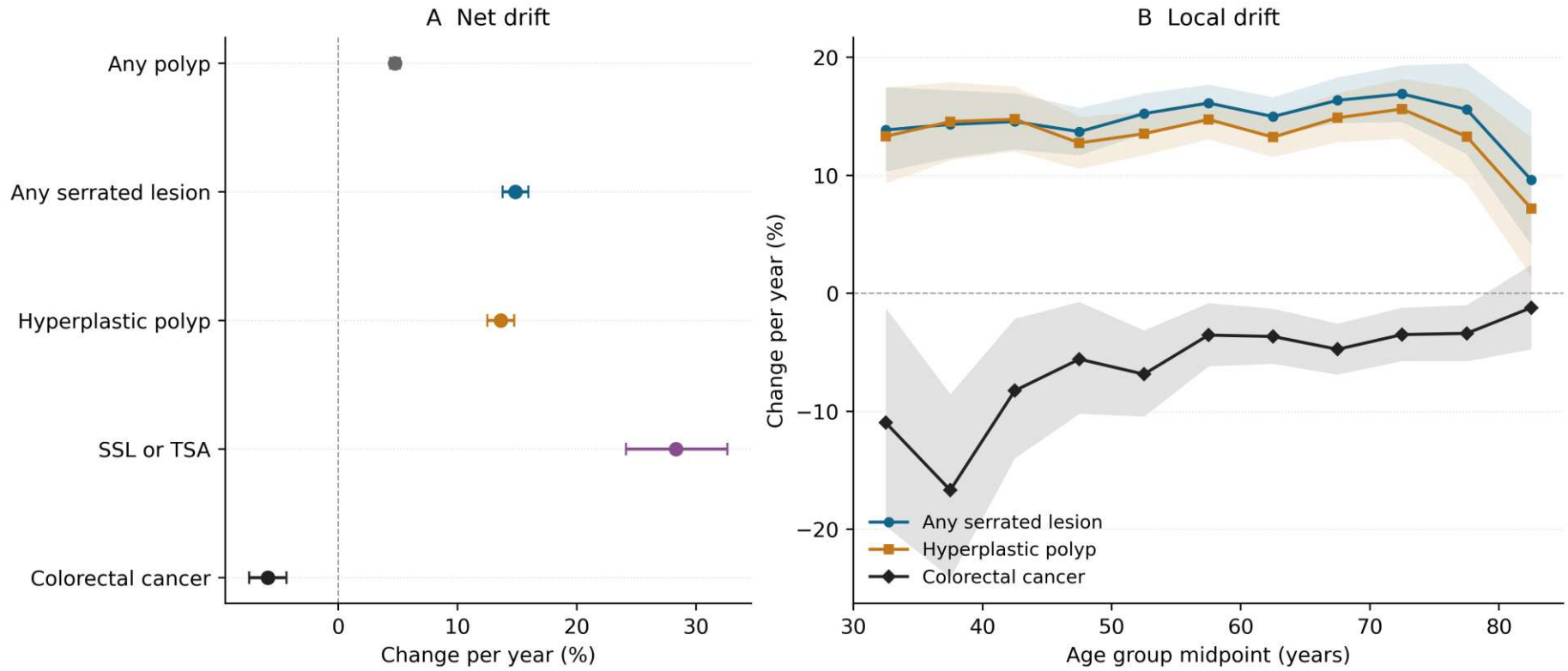
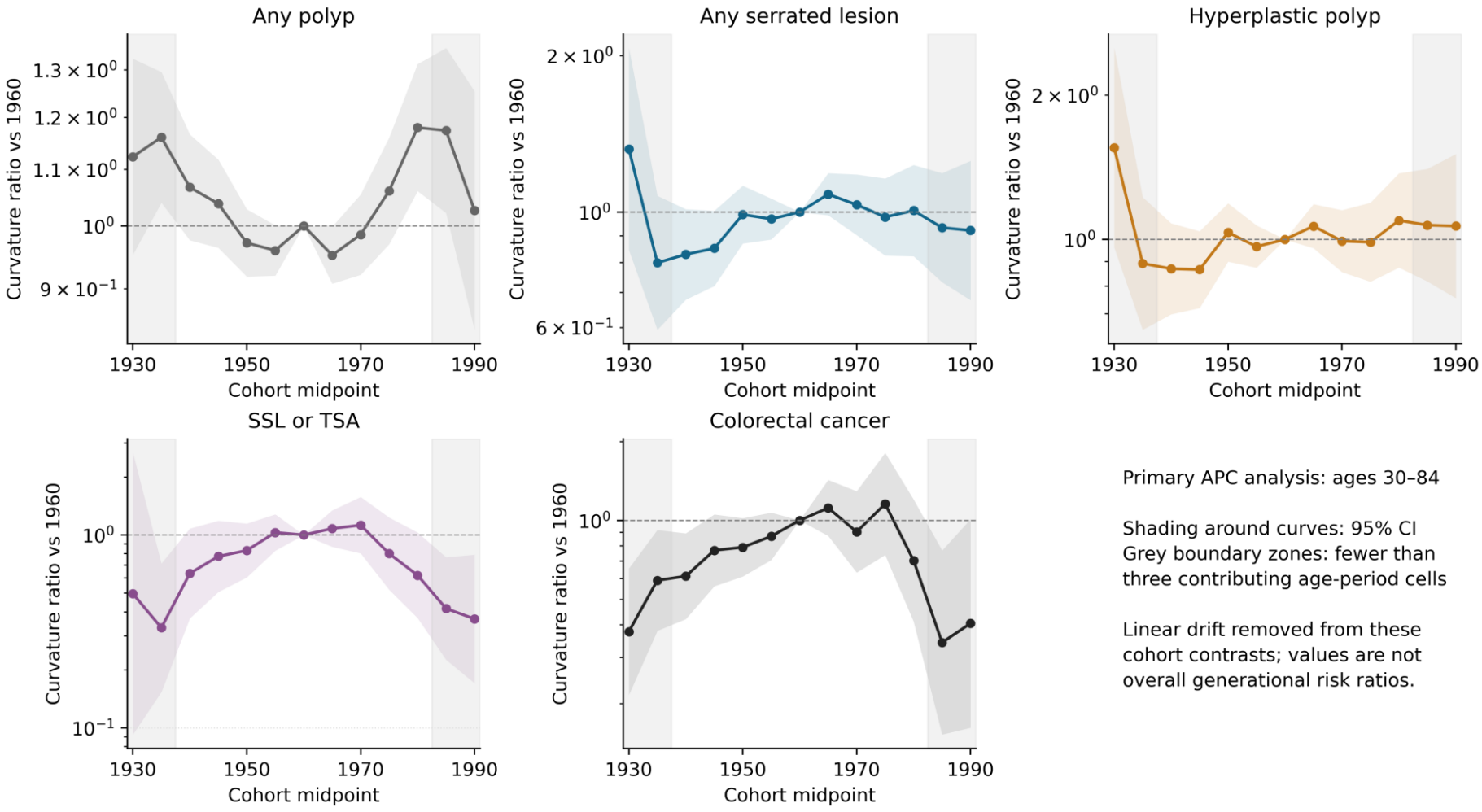

A Net drift
Any polyp
Any serrated lesion
Hyperplastic polyp
SSL or TSA
Colorectal cancer
0
10
20
30
Change per year (%)
B Local drift
20
10
0
−10
−20
Change per year (%)
Any serrated lesion
Hyperplastic polyp
Colorectal cancer
30
40
50
60
70
80
Age group midpoint (years)

Figure 4


Any polyp
Any serrated lesion
Hyperplastic polyp
SSL or TSA
Colorectal cancer
Curvature ratio vs 1960
Cohort midpoint
1930
1950
1970
1990
Primary APC analysis: ages 30–84
Shading around curves: 95% CI
Grey boundary zones: fewer than three contributing age-period cells
Linear drift removed from these cohort contrasts; values are not overall generational risk ratios.