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ORIGINAL PAPER

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Age-period-cohort analysis of Swiss suicide data, 1881–2000

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Abstract At the end of the 19th century, male suicide rates in Switzerland were as high as the respective rates in recent decades, whereas female suicide rates were distinctly lower. An age-period-cohort analysis was performed to provide more information about the gender-specific changes over the last century. Suicide mortality has been reported in Switzerland since 1876 when the standardised registration of mortality data began. The analysed data cover the period 1881–2000. The statistical analyses were based on log-linear models and data aggregated by 10-year age-intervals and 10-year period-intervals. The results indicate similar age and period effects in males and females. The estimates representing age-specific risk increase steadily with age, with intermediate plateaus in the 20s and the 50s. The period-specific estimates follow the economic cycles. The birth cohort effects are stronger in males and weaker in females. In the males' estimates, there is a peak in cohorts born around 1840 and a low in cohorts born some 60–100 years later. The estimates increased again in generations born after World War II. In females, the birth cohort estimates are low in cohorts born in the first half of the 19th century and increase until the first half of the 20th century. Birth cohort effects remain an intriguing topic in epidemiology of suicide. A better understanding of birth cohort effects might open new doors to suicide prevention.

Key words age-period-cohort analysis · suicide · Switzerland

Introduction

There is a long research tradition in longitudinal and historical development of suicide rates [12, 43]. In the 1970s, a new era of longitudinal research began when the generation (or birth cohort) concept was introduced in analysis of mortality rates [45] and a major methodological breakthrough [35] opened the doors to statistical modelling of generational change.

At the same time the suicide rates were increasing among young people, posing the question whether generational change might play an important role in this development [18, 34]. Preliminary studies on birth cohort effects in suicide rates were conducted in the late 1970s [40, 50]. Since then, a number of descriptive studies, graphical analyses, and statistical age-period-cohort (APC) analyses have been completed in suicide research [2, 4, 5, 17, 18, 30, 34, 38–40, 42, 49, 50, 52, 55]. Most of these studies have found direct or indirect evidence of birth cohort effects, or, in other words, generational differences in suicide risk.

In this study, Swiss suicide data series were modelled using the APC approach. Preliminary analyses indicated that at the end of the 19th century, male suicide rates in Switzerland were as high as the respective rates in recent decades, whereas female suicide rates were lower than today [1]. Obviously, the suicide rates in Switzerland have developed differently over the 20th century. This study aims to distinguish the basic mechanisms of change, i. e., period related change and generation specific change, in male and female suicide rates.

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Data and methods

Data

The data cover the period 1881–2000. Suicide mortality has been assessed in Switzerland since 1876 with the introduction of a standardised registration of causes of death [36]. Since 1969 the data have been stored on individual computerised records. For the analyses, the data were aggregated into 10-year age- and period-intervals. The sex- and age-specific population data were derived from Swiss census data (a census every 10 years since 1880), thereby using simple interpolation to calculate the intermediate population values between censuses.

Since 1876, a total of more than 120,000 cases of suicide have been registered. As prescribed by Swiss law since 1876, deaths have to be certified by a physician. Suicide – like other violent causes of deaths – has a superordinate registration priority and, thus, is regularly registered as the main cause of death. Various factors bear on the reliability of historical suicide data reporting, including the desire to avoid the associated social stigma. Yet, violent causes of death require examinations by physicians and police and, more recently, a forensic medical unit.

APC analysis

APC analysis is usually based on the regular collection of age-stratified data pooled into so-called cohort tables [13]. The aim of this analysis is to disentangle the different effects of age (age effects), historical circumstances (period effects) and generational succession (birth cohort effects). In analyses using cohort tables with equal age- and period-intervals, the birth cohorts are represented directly by the diagonals. However, APC analysis is impeded by the redundancy between linear age, period and cohort effects: any two of the three dimensions age, period, and cohort fix the third – the so-called identification problem in APC analysis. A simultaneous estimation of all three linear effects cannot be accomplished without arbitrary additional model constraints. In analyses using cohort tables with equal age- and period-intervals, only one additional constraint is necessary, for example replacing one estimate by a constant value, or defining two estimates to be equal. However, one cannot choose a technical approach between different minimum restrictions in APC analysis, since the fits of all resulting models are equal. Each of these models leads to different linear effects [21, 22].

Since no solution seems obvious for the identification problem in APC analysis, a pragmatic procedure was chosen. Given that the age main-effect model provided a distinct better fit than analogous period and cohort main-effect models, age was implemented as a mandatory component in preliminary two-factor models, and, furthermore, as the target factor for subsequent constraints. Preliminary age-period (AP) and age-cohort (AC) models served to develop two alternative full APC models, which were calculated by restricting the age estimates (for example, the first age estimate) according to the AP or AC model. The alternative full models will be denoted as the APc and the ApC model. They provide the boundaries for the real APC model, i. e., the range within which the definitive APC solution should be found.

In order to compare alternative models, the relative improvement of the model fit was considered by the parameter R' discussed by Hagenaars [20]. R' mimics the R^2 concept within the domain of log-linear analysis. The calculations were based on logit models and were completed with the CATMOD procedure of the SAS package [46].

Results

The trends of sex-specific (rough) suicide rates in Switzerland since 1881 are shown in Fig. 1. There is an increasing trend in the suicide rates of Swiss women since the end of the 19th century, whereas the suicide rates of men have decreased after reaching a peak in the 1930s. There are other noteworthy features like the impact of World War I on male suicide rates and the converse effect of World War II on female suicide rates.

The age-specific suicide rates by cohort indicate a distinct change of age shapes in males. The age-specific suicide rates in males followed an inverse U-shape in cohorts born around 1850. In later cohorts, the age shapes changed to a more or less straightforward increase over the life span (Fig. 2). In female suicide rates (Fig. 3) the change of the age shapes is not immediately obvious. For both sexes, the rates of the elderly have increased recently.

APC analyses were conducted first for one- and two-factor models. The sequence of model fits (and consecutive comparison of the model's deviance with the deviance of the baseline model) shows the predominance of age effects (Table 1). Besides the age effects, period and cohort effects seem to be of similar magnitude in males, whereas in females period effects are more relevant than cohort effects. In males the R' indicates that

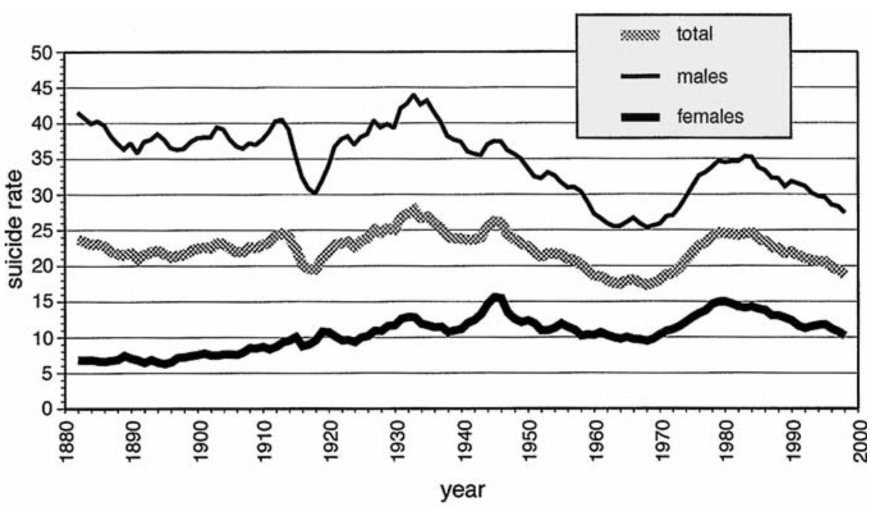

Fig. 1 Suicide rates (deaths per 100,000) by sex, Switzerland, 1881–2000 (rough rates, 5 year moving averages)

Fig. 2 Age-specific suicide rates, males, by cohort, Switzerland, 1881–2000; the curves are segregated into 10-year age intervals

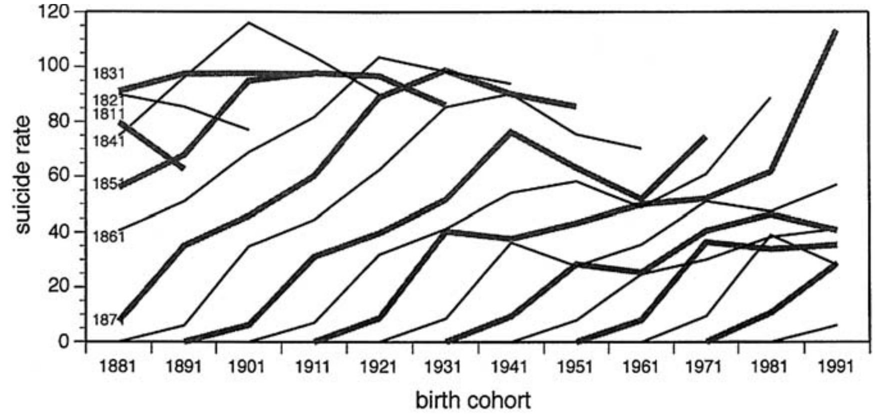

Fig. 3 Age-specific suicide rates, females, by cohort, Switzerland, 1881–2000; the curves are segregated into 10-year age intervals

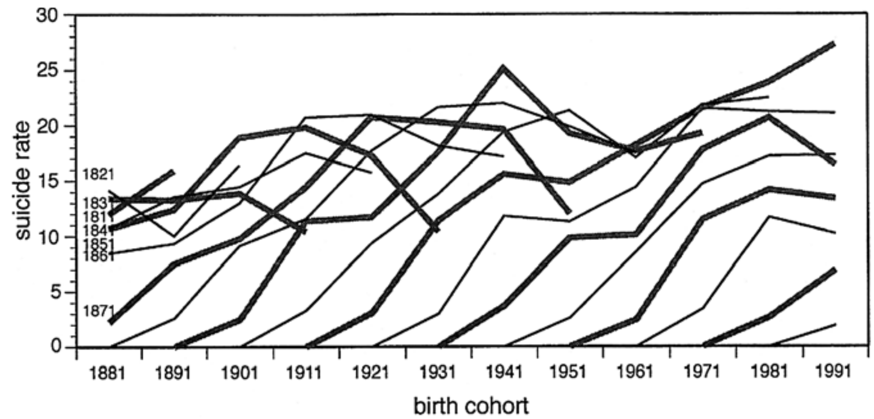

Table 1 Deviance of subsequent APC analysis models of Swiss suicide data, 1881–2000; 10-year period and age intervals (age 10–80+), by sex

	Males		Females	
Model	df	deviance	df	deviance
1. intercept	95	34876	95	8934
2. A	88	6265	88	877
3. P	84	32578	84	8051
4. C	77	20571	77	7032
5. AP	77	1975	77	306
6. AC	70	1527	70	491
7. PC	66	6911	66	2264
8. APC*	60	842	60	178

* with 1 restricted parameter

the APC model absorbs 57 % of the deviance in the AP model and 98 % of the deviance in the baseline model. In females, these percentages are 42 % and 98 %, respectively.

Figs. 4 and 5 depict the estimates derived from the APC analyses. The A-section shows the shape of the age-estimates, the P-section shows the period estimates and the C-section shows the cohort estimates. The bold and the grey lines represent two different APC solutions, the first one (APc) based on the preliminary AP model and the other one (ApC) based on the preliminary AC model. As mentioned above, they predetermine the range of solutions for the real model.

APc and ApC models of male suicide rates (Fig. 4) suggest a moderate range of full APC solutions. After adjustment for birth cohort effects, the results indicate similar age and period effects in males and females. The estimates representing age-specific risk increase steadily with age, with intermediate plateaus in the 20s and the 50s. The period-specific estimates show no trend in females and at most a slightly decreasing trend in males. Furthermore, the period-specific estimates parallel the major economic cycles. The male period estimates peak in the 1930s during the depressed economic conditions of the 1930s, whereas the female period estimates peak a decade later – probably due to a specific adverse effect of World War II. Both shapes yield a low in the 1890s and in the 1960s, i. e., periods of economic growth and prosperity. This parallelism between economic and suicide cycles ends in the 1990s when the suicide estimates unexpectedly drop.

In female suicide rates (Fig. 5), the range of solutions suggested by the APc and the ApC variants is very limited. There, the trend appears to be associated with cohort effects, whereas period effects result in a stationary series.

The curvilinear component in birth cohort effects

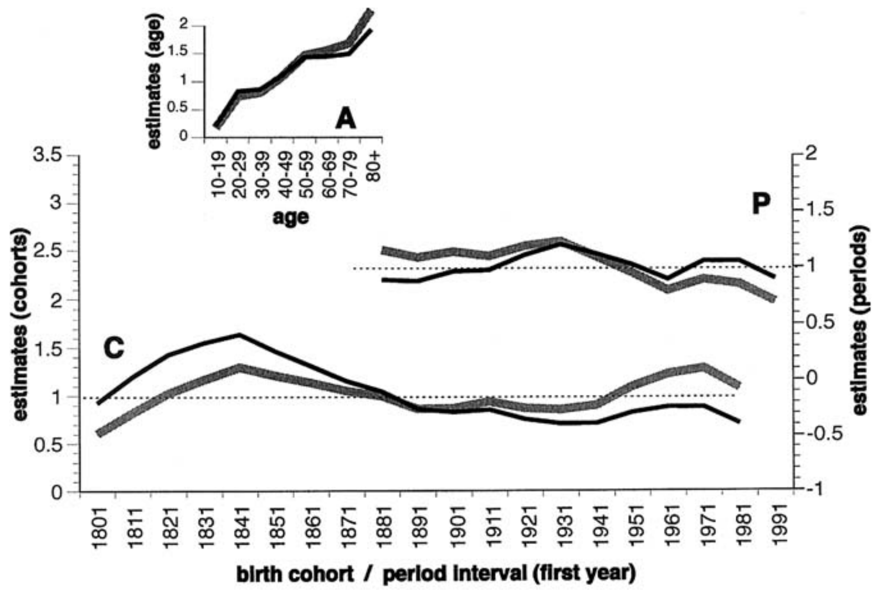

Fig. 4 APC analysis of Swiss male suicide data, 1881–2000: estimates of alternative APc (grey line) and ApC (bold line) models

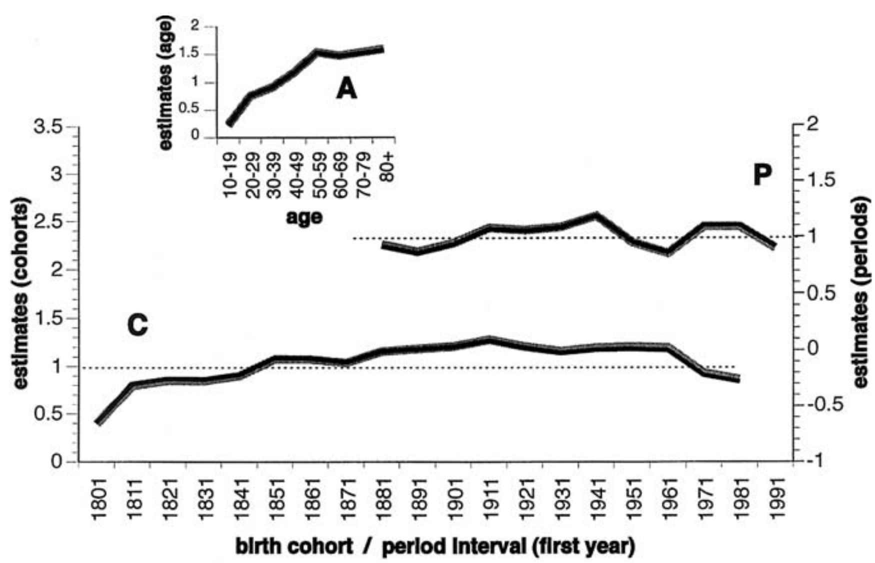

Fig. 5 APC analysis of Swiss female suicide data, 1881–2000: estimates of alternative APc (grey line) and ApC (bold line) models

best distinguishes male and female suicide rates in APC analysis. The male cohort estimates show a peak in cohorts born around 1840 and a low in cohorts born some 60–100 years later. Obviously, the cohort estimates provide a clue in helping to understand the high baseline of male suicide rates around 1900. In cohorts born after World War II the estimates show another intermediate peak. In females, the shape of birth cohort estimates is smoother and indicates a slightly elevated suicide risk for cohorts born during the 20th century, with the exception of the most recent cohorts. In males, the highest birth cohort estimates are more than twice the lowest; in females, the maximum ratio is 1.5 times (excluding the peripheral cohorts which rely on singular cells).

Discussion

At the end of the 19th century, the suicide sex ratio (female-male ratio) in Switzerland was 1:6. 100 years later the sex ratio has reduced to about 1:2.5. This study tackled the contradictory long-term trends of male and female suicide rates by means of APC analysis. It attempted to answer the questions whether the extraordinary high former suicide rates in males were associated with birth cohort effects, period effects or both.

The results suggest that birth cohort effects play a crucial role in the change of male suicide rates in Switzerland. First of all, there is a curvilinear component which contributed largely to high male suicide rates around 1900, and, secondly, a linear component which probably contributed to the decrease of male suicide rates. In females, birth cohort effects take on a smoother form and have a slight upward trend. After the adjustment for birth cohort, the sex-specific age and period effects in males and females appear similar.

Focus on birth cohort effects and differentiation from period effects

The focus of this analysis is on birth cohort effects in suicide. The research of the last 25 years has produced inconsistent results. This is partly due to problems of method, since a majority of APC analyses have used descriptive/graphical approaches [4, 5, 18, 34, 39, 40, 42, 49, 50] which are typically less conclusive than studies using statistical modelling. Moreover, short time-periods in the analysis often limit the value of the conclusions.

Up until now, only a few studies have provided insights in changes of birth cohort effects over 100 years or more [4, 5, 38, 49, 55]. High suicide rates in middle aged and elderly men between 1900–1930 [38, 55] approximate the experience in Switzerland, i. e., probably elevated birth cohort risk for suicide in the 19th century. In studies covering shorter periods the rates of elderly and younger men depict contrary trends [18, 19], further suggesting far-reaching historical change in suicide birth cohort effects.

For contemporaneous research and prevention, the finding of increasing birth cohort risk in male post-war generations is clearly more challenging. This increase was shown in several Western countries [30]. The "suicide epidemics" in the 1970s, which entailed a remarkable increase of suicide rates in young people, is partly due to the birth cohort effects in males.

However, nothing similar can be detected in female birth cohorts. Although the female suicide rates increased in the 1970s as well, this increase was solely owing to period effects. In addition, this is only one of several discrepancies between the patterns of male and female birth cohort risk estimates. Sex-specific differences in birth cohort effects have been demonstrated consistently in other studies [2, 18].

From a strategic point of view, the sex-specific differences in birth cohort effects not only provide a major challenge but also a promising opportunity to improve the understanding of the underlying mechanisms. Different mechanisms for male and female birth cohort effects may be at work, and any hypotheses have to adjust to this possibility.

A further major challenge is to differentiate clearly between birth cohort effects and period effects. The origin of birth cohort effects is historical change, that is a type of period effect – however, with specific characteristics. Birth cohort effects represent a type of latent, life span risk. They contribute to generation differences, independently of later historical influences and age-related factors. Secondly, birth cohort effects emerge generally early in life, i. e., before or around birth, in childhood or in youth. Typical biological candidate variables are "weight at birth" [14, 37], or changes in gene expression due to prenatal infectious diseases. Typical social variables promoting birth cohort effects are "opportunities for formation" and "opportunities for entering in a professional career", "chance to marry" or, more generally, the relative size of a cohort with respect to other cohorts – thus determining cohort-specific life chances [51].

Most period-specific changes (availability of lethal suicide methods, economic cycles, wars etc.), which are known to immediately influence suicide risk [8, 12, 32], do not automatically qualify for birth cohort effects. As far as they do, the associations are probably indirect for the most part: for example, economic depression or war may lead to famine or bad working conditions during pregnancy and thus to more deliveries with low birth weight (and thus increasing suicide risk). Coincidentally, hard times lead to lower fertility, thus to smaller relative cohort size, and thus to better relative life chances (and thus decreasing suicide risk). To assess such indirect effects, which would potentially smooth out on a large scale, a finer time scale would be required – for example, yearly data intervals in period and age. However, these effects play no role in the results reported above.

Interpreting birth cohort effects relative to: psychopathology, behavior and the socio-cultural context

The mechanisms in suicide birth cohort effects must lie within the common dimensions of suicide behavior – psychopathology, coincident behavior and the socio-cultural context. This results in three working hypotheses, which should be explored in more detail.

Since most suicides are associated with mental disorders like major depression or schizophrenia, the first working hypothesis is that suicide birth cohort effects are directly associated with similar birth cohort effects in incidence of underlying psychiatric disorders. This hypothesis requires us not only to demonstrate coinciding birth cohort effects in underlying disorders, but it also shifts the focus of interpretation to the latter. Depression and schizophrenia represent the highest risk disorders.

A series of studies around 1990 examined the potential impact of birth cohort effects on the incidence of depression [25, 27, 29, 31, 33, 57]. While Wickramaratne et al. [57] reported an increase in risk of depression in male – but not in female – birth cohorts born after World War II in ECA (Epidemiological Catchment Area) survey data, Kessler et al. [27] found little sex-specific variation across cohorts in NCS (National Comorbidity Survey) data. Warshaw et al. [56] introduced an alternative interpretation of increasing depression rates by assuming age-period interaction effects – that is, period effects which enclose only a part of age groups, in this instance the younger age groups. This interpretation has received some support in recent years [26, 41]. Unfortunately, methodical problems appear to be insoluble due to lack of prospective population based data on depression. Moreover, the common retrospective data format entails underreporting of former events [15, 48], and, finally, recall bias could itself be a matter of birth cohort effects.

APC analyses in schizophrenia encountered less data-specific hurdles due to the availability of register data [11, 53, 54]. However, the challenge for schizophrenia research was different. APC analyses had to disentangle decreasing rates – in contrast to increasing rates as in depression. To sum up, the hypothesised parallel between birth cohort effects on suicide and, separately, on psychiatric diseases, turns out to be inconsistent.

The second working hypothesis focuses on the association between suicide birth cohort effects and suicidal behavior itself, i. e., the method used: shifts between more and less lethal methods might induce shifts in suicide rates [18]. Moreover, the use of suicide methods varies by sex. In Switzerland, over the last 125 years, the use of firearms has supplanted hanging as the principal method of suicide. There is no evidence that the increase in firearm suicides has involved birth cohort effects (unpublished results).

Another optional source of suicide birth cohort effects derives from abuse of alcohol and illicit drugs known to increase suicide risk at the individual level [7]. The causal relationship involves three main dimensions: firstly, suffering due to addiction [47], secondly, the comorbidity of addiction and depression [28] as well as other mental disorders, and, thirdly, the release of impulsive suicidal behavior under the influence of alcohol [3, 9] and other drugs. The first two factors have the most influence on birth cohort effects since it is known that addictive behavior is mostly determined at an early age and differs from birth cohort to birth cohort [16, 24, 44]. Besides, there are sex-specific distinctions: men consume alcohol and illicit drugs more frequently than women and also in larger dosages [10] so that addictive behavior is more frequent in men than in women. In Western Europe the use of alcohol and drugs probably increased during the 1960s and 1970s [2, 6] and then declined until the 1990s which parallels the intermediate increase of suicide birth cohort estimates in males born after World War II. Thus, the analogies between suicide birth cohort effects and addiction appear to be comprehensive. A comparison of changes in suicide birth cohort effects and alcoholism before World War II has yet to be done.

The third working hypothesis focuses on the social context, including both the socio-economic context and the social cohesion, in the Durkheim tradition. The impact of economic cycles and economic variables on suicide frequencies has been recognised for a long time and forms one of the empirical foundations of sociological theory [12]. Most variables representing social cohesion – for example, marriages and divorces, fertility, the proportion of illegitimate births – conform to economic cycles of varying periodicity [1]. One might also suggest an association with birth cohort effects [18]. However, the birth cohort effects shown in male and female suicide in Switzerland do not match with any known cyclical phenomena.

Similar limitations emerge whilst observing trends. Since we cannot objectively measure a trend in social cohesion or its duration, we are unable to relate its influence on suicide birth cohort effects. Major historical breaks like wars are possibly more revealing than trends. Durkheim suggested that wars distinctly enhance social cohesion [12], and in fact, a marked effect of World War I is obvious in Swiss male suicide period effects. Yet, there is no comparable response in cohort effects. Thus, social cohesion holds little promise as a separate, independent determinant of birth cohort effects in suicide.

To summarise the preliminary outcomes from our three working hypotheses: we could not find any noteworthy covariates of female suicide birth cohort effects, but in males the abuse of alcohol and illicit drugs merit further examination. Specifically:

- Birth cohort effects emerge in suicide as well as in abuse of alcohol and illicit drugs
- Coincidence of effects in post-war cohorts
- Coincidence of sex-specific differences
- Effects may occur directly or via comorbidity with depression and other mental disorders.

Methodological strengths and limitations

In comparing this study with previous work, the following strengths should be stressed. Firstly, the long time span analysed allows insights in long-term changes in birth cohort effects and their heterogeneity. Secondly, the study uses a complete APC model to disentangle period and cohort effects. Thirdly, the APC analysis assigns most biasing effects to period effects, so that birth cohort effects remain untainted. And, fourthly, the analysis relies on a simple and transparent procedure to identify a range of solutions for the definitive complete APC model – predetermined by the AP and the AC models – which works well if the age effects are strong (as they usually are in mortality data) and if the APC estimates include relevant curvilinear shapes besides (or instead of) linear trends.

This study shares the common limitations of APC analysis. On the one hand they are determined by the lack of definitive real models so that some ambiguity of the results cannot be excluded. On the other hand the APC effects represent formal time- and age-related dimensions, which are meaningless in themselves but provide helpful instruments to peruse the real world variables. Moreover, the analysis was constrained to main effects and leaves some space for more complex models, for example, non-linear models or models including interaction effects.

Underreporting of suicide in official statistics is a well-debated topic. In the 19th century, a considerable number of deaths were not certified by a physician so that we have to assume a time-dependent underreporting, specifically relevant during the last decades of the 19th century and the first decades of the 20th century. A detailed discussion of the historical data has been published by Jakob [23]. Accidents and undetermined violent deaths have been the most relevant targets for misclassification of suicide. In recent decades, the ratio of suicides vs. undetermined violent death has increased to 6:1, thus, limiting the relevance of systematic errors from this source.

Considering the underreporting of suicides in late 19th and early 20th century the decrease in male suicide rates since the end of 19th century looks even more impressive, whereas the upward trend in female suicides becomes less credible. How does underreporting affect the results of APC analyses? While age-specific bias are absorbed by age effects and period-specific bias by period effects, birth cohort specific biases are largely unknown. Underreporting is commonly an overall period effect.

Conclusion

In summary, birth cohort effects remain an intriguing topic in epidemiology of suicide. Many issues remain unresolved like the trend and cyclical mechanisms underlying birth cohort effects or the age when birth cohort effects typically emerge. Abuse of alcohol and illicit drugs emerge as a promising – cohort specific – risk factor which could account for sex-specific differences in suicide birth cohort estimates. Since birth cohort effects rise early but endure throughout life, a better understanding of these effects might open new doors in suicide prevention.

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