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The male–female health-survival paradox and sex differences in cohort life expectancy in Utah, Denmark, and Sweden 1850–1910

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ABSTRACT

Purpose: In Utah, the prevalence of unhealthy male risk behaviors are lower than in most other male populations, whereas women experience higher mortality risk because of higher fertility rates. Therefore, we hypothesize that the Utah sex differential in mortality would be small and less than in Sweden and Denmark.
Methods: Life tables from Utah, Denmark, and Sweden were used to calculate cohort life expectancies for men and women born in 1850–1910.
Results: The sex difference in cohort life expectancy was similar or larger in Utah when compared with Denmark and Sweden. The change over time in the sex differences in cohort life expectancy was approximately 2 years smaller for active Mormons in Utah than for other groups suggesting lifestyle as an important component for the overall change seen in cohort life expectancy. Sex differences in cohort life expectancy at the age of 50 years were similar for individuals actively affiliated with the Church of Jesus Christ of Latter-day Saints and for Denmark and Sweden.
Conclusions: The hypothesis that a smaller sex difference in cohort life expectancies in Utah would be detected in relation to Denmark and Sweden was not supported. In Utah, the male–female differences in life expectancy remain substantial pointing toward biological mechanisms or other unmeasured risk factors.

Introduction

The gender gap in survival has increased through the first three quarters of the 20th century in most Western countries [1–3], and today, the sex differential in mortality is in favor of women throughout the World [4]. The reasons that men die younger than women stem from constitutional—biological—genetic and external—environmental, behavioral, social, and cultural factors [5]. Several accepted biological mechanisms to explain these differences are based on hormonal, autoimmune, and genetic explanations [6]. For example, it has been suggested that estrogen could be protective because its effect on serum lipids and its likely protective influences on cardiovascular diseases in females [7]. The fact that males may experience a greater susceptibility to infections has led to the development of the immunocompetence hypothesis, which states that there are significant suppression effects of testosterone on immunity [8]. The X-chromosome hypothesis states that the lack of a second X-chromosome among males increases their mortality in relation to females [9].

Behavioral factors have also been proposed to explain female–male differences in mortality [3] with risk-taking behaviors occurring more frequently among men including cigarette smoking and alcohol consumption, both of which elevate their risk of several serious diseases where men are more adversely affected than women [10]. Cigarette smoking is thought to be the largest identifiable factor in explaining an increasing sex gap in mortality, but it is well known that cigarette smoking alone cannot explain the temporal sex difference in mortality. In particular, a sex difference in survival persists among never-smokers [11–13].

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In an effort to further consider the universality of the female advantage in survival, we introduce into the analysis a unique population, the state of Utah, which has the characteristics that suggest that it may have a smaller survival gender differential. Data regarding survival in Utah are derived from the Utah Population Database (UPDB). The UPDB is a comprehensive health research database containing linked demographic, medical, and genealogical data spanning the Utah population from the last two centuries [14]. The medical data held within UPDB is extensive but given the historic period under investigation that predates the establishment of vital record keeping, fertility and mortality data are drawn from vast genealogical records. The genealogical data on more than 1.6 million individuals comprise families who experienced demographic events (birth, marriage, and death) as migrants to frontier Utah and their descendants. Previous studies have used this in search for causes for cancer [15–18], effects of air pollutants on respiratory health [19], early life conditions influence on later mortality [20], risk for cardiovascular diseases [21] and asthma [22], and overall mortality patterns. The UPDB comprises data on families with and without an affiliation to the Church of Jesus Christ of Latter-day Saints. Active Mormons may experience survival benefits because they are more likely to abstain from alcohol and tobacco, they fast once a month, as well as participate in church and related social activities than other Utah residents [23]. An additional characteristic of this population is its historically high fertility rates [24,25], a feature that has been shown to adversely affect survival in this and other populations, primarily for women [26,27]. Such studies of specific religious groups have previously proven useful for understanding sex differentials in mortality [28–30].

Here, we hypothesize that the Utah male–female survival difference is among the lowest observed and smaller than that in Sweden and Denmark. This hypothesis is based on the fact that many residents in Utah are active in the Mormon Church, whose members have healthier life styles (e.g., proscription from alcohol and tobacco), especially relevant for men and elevated fertility and associated maternal mortality risks [24]. These behaviors were common among members of the Church during the early settlement years though not enforced until the 1860s [31] and institutionalized in 1906 with the Word of Wisdom [32,33]. We anticipate that the female longevity advantage would grow with time in Utah as their elevated fertility declined during the demographic transition. Denmark and Sweden serve as appropriate comparison countries because many descendants of both nations were widely represented among the early migrants to Utah and because these countries have high-quality cohort mortality data spanning the historic years (birth cohorts 1850–1910) in question. In the 1850s, Mormon converts began to emigrate from Denmark with the Swedish migration beginning somewhat later. Mulder [34] (p. 107), in his study of Scandinavian migration, reports that between 1850 and 1905, 22,653 “members of record” emigrated to Utah, with 56% Danish, about one-third Swedish, and 11% Norwegian.

Methodology

The population in Utah grew rapidly during the mid and late 19th century (Fig. 1*A*). The first pioneers arrived in 1847 and the population grew rapidly as a large number of migrants from the Midwest in the United States, Europe, and Canada entered the state during the next few decades [25]. Most native-born population in Utah during this time period had some association with the Church; however, both non-Mormons and inactive Mormons became an increasingly larger proportion of the population over time (Fig. 1). The early birth cohorts were largely the descendants of American, English, and Scandinavian founders. The birth cohorts selected for analysis comprised descendants from American and other nationalities (82.7%, with birth cohort-specific proportions ranging from 74.6% to 99.4%), Sweden (4.4%, ranging from 0.5% to 18.7%), and Denmark (12.8%, ranging from 0.01% to 6.7%) with each cohort having a larger proportion of Swedish and Danish descendants over time (Fig. 1*B*).

Utah cohort life tables were constructed from UPDB data. Individuals were required to be born in Utah between 1850 and 1910, link to a genealogical record because this signifies more complete information, and have a known death or follow-up date, yielding 339,945 individual records.

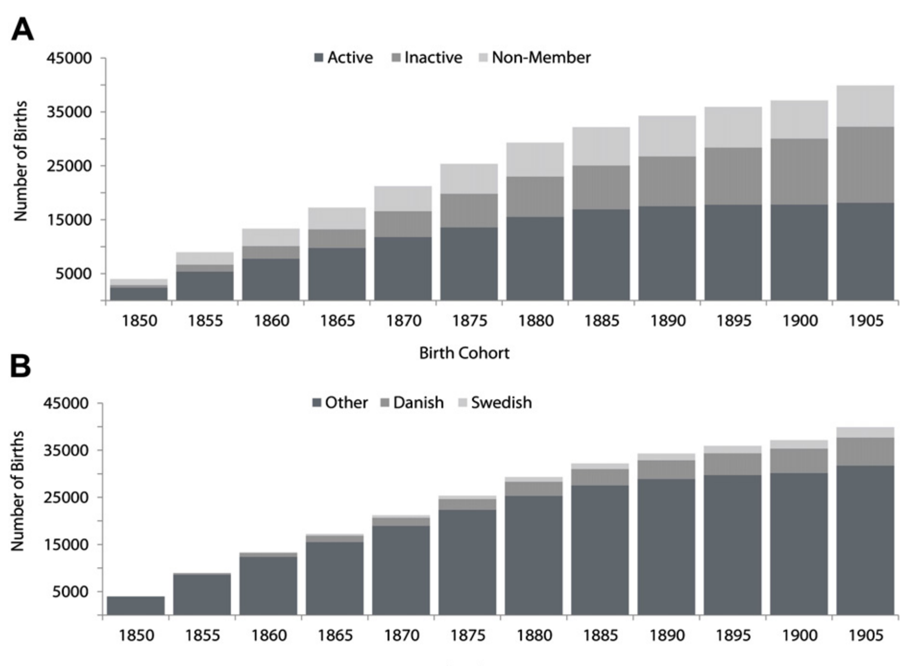

Fig. 1. Number of births for birth cohorts by status within the Church of Jesus Christ of Latter-day Saints (A) and nationality (B).

UPDB contains data on both Mormons and non-Mormons. Accordingly, pooled (all ages, all level of religious involvement) life tables were constructed by Church activity level: active, inactive, and those not connected to the Church. Religious affiliation is based on baptism and endowment dates reported on family history records. Individuals are typically baptized into the Church at the age of 8 years (later if they join as adults). Therefore, if an individual died before the age of 8 years, their mother's status within the Church was used as a proxy. Posthumous baptisms are not considered in this analysis. Individuals with an endowment date have pledged to live their lives in accordance with the doctrine of the Church and are considered active followers. Because endowments occur when an individual is an adult, for this analysis, active Mormons are defined as those with an endowment date before the age of 40 years. Individuals baptized but not endowed were considered as the inactive followers of the Church. Those lacking both a baptism and an endowment date were considered nonfollowers. This yielded 172,227 active Mormons, 95,183 inactive Mormons, and 72,535 individuals not associated with the Church.

In an effort to make direct connections between Denmark and Sweden and Utah, life tables are estimated for Utah that take advantage of Danish and Swedish 19th century converts to the Church. The Utah portion of the analyses is restricted to the descendants from Denmark and Sweden who are present in UPDB, including Mormons and non-Mormons. The international migrants themselves who appear in the UPDB were excluded to avoid introducing a health migrant effect—their Utah-born progeny and subsequent descendants are the focus of the analysis.

Genealogical records of the descendants of Utah pioneers are linked to construct multigenerational pedigrees that represent a diverse population comprising both American and European converts to the Church and their descendants [25]. The largest proportion of European converts of the 19th century were from England and Wales [25]; however, a substantial proportion were native to Sweden and Denmark. To construct the life tables for Swedish and Danish descendants born in Utah, founders were identified by place of birth and both mother and father were required to be born in their respective countries. All descendants of founding couples meeting the aforementioned criteria were used to estimate life expectancies for each subpopulation. Utah natives who were descendants of Swedish and Danish founders numbered 39,427 and 13,320, respectively.

Life expectancies at birth and at the age of 50 years were constructed based on cohort life tables. An abridged cohort life table was constructed for 5-year periods beginning in 1850. All life table estimates were constructed using Mortpak for Windows version 4.1 [35]. Mortpak derives the life table values using the method by Greville [36], which assumes that age-specific death rates are log-linearly related to age. To complete the life table, ${}_nq_x$ values are extrapolated until no survivors remain by fitting a Makeham function through the last six ${}_nq_x/(1 - {}_nq_x)$ values available.

Cohort life table data for Denmark and Sweden in the period 1850–1910 was retrieved from the Human Mortality Database [37]. Both populations have a tradition for capturing high quality data on population counts and deaths (see documentation in the Human Mortality Database [37]). In Denmark, the National Statistical Office was found in 1850 and censuses were conducted nationwide approximately every 5 years [37]. In Sweden, each parish has kept a complete and continually updated register of its population for more than 300 years [37] and the quality of the data on population counts and deaths are of very high quality from 1861 onward [37]. For each subpopulation, cohort life expectancies at the age 0 and 50 years were calculated using the formula [38]:

$$e_x^0 = \frac{T_x}{l_x}$$

where $l_{(x)}$ is the number left alive at age x years and

$$T_x = \sum_{a=x}^{\infty} {}_nL_a$$

where ${}_nL_a$ are the person-years lived between ages a and n years, and T_x represents the total number of person-years lived by the cohort from age x years until all members of the cohort have died. The reasons for examining cohort life expectancies at age 50 years are two-fold: to avoid the direct mortality effects of childbearing in women and permit comparisons that are based on religious affiliations that are appropriately measured in adulthood. For the small sample populations (i.e., descendants by parental countries of origin), 95% confidence limits were calculated using the methods suggested by Andreev and Shkolnikov [39].

Results

The overall cohort life expectancy e_0 increased from 1850 to 1910 in Utah, Sweden, and Denmark for both sexes (Fig. 2*A*–*C*), and the sex differential in life expectancies was in favor of women for all populations. The early cohorts in Utah (i.e., born in 1850–1855) had higher cohort life expectancy than those born in 1860–1880 (Fig. 2*A*). For these early Utah cohorts, the sex difference in cohort life expectancy was small when compared with Sweden and Denmark (Fig. 2*D*). These lower Utah sex differentials disappeared

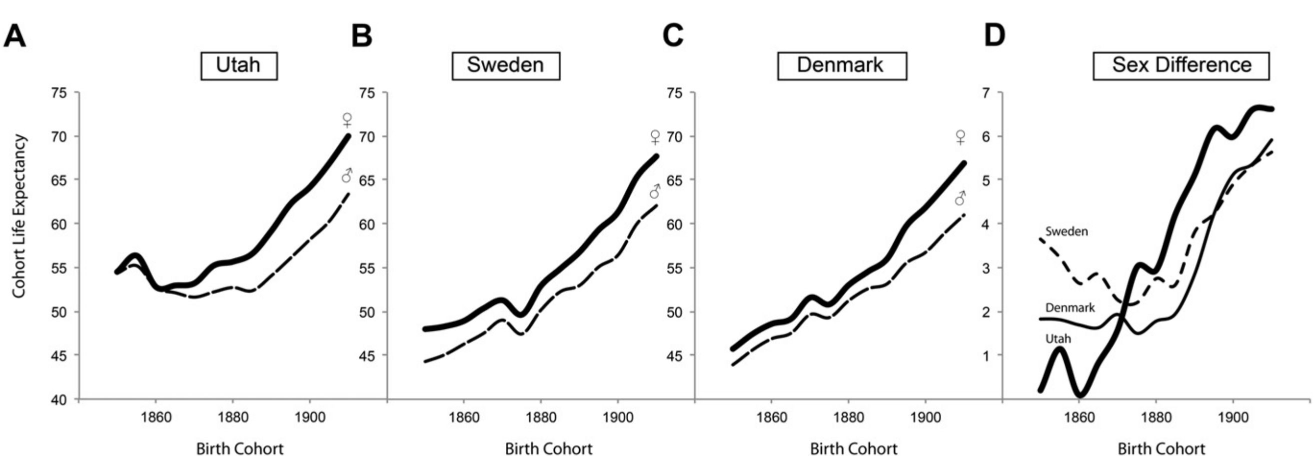

Fig. 2. Cohort life expectancy in Utah (A), Sweden (B), and Denmark (C) and the sex differences in each population (D).

for cohorts born around 1860. Subsequent to that, the birth cohorts of Utah had larger sex differentials in life expectancies than Sweden and Denmark (Fig. 2*D*).

The cohort life expectancy of Danish and Swedish descendants was generally lower, yet followed a similar trend to that of the rest of the general Utah population (Fig. 3*A* and *B*). There is more variation in cohort life expectancy of Swedish descendants compared with the Danish and general Utah population estimates; however, fluctuating estimates in the early cohorts may be due to small numbers. It is noteworthy that among Swedish descendants, there are selected historical periods where life expectancy is higher for males than females, suggestive of important environmental shocks that affect genders differently.

When further dividing the Utah population into subpopulations based on religious activity, we found that inactive individuals and those unaffiliated with the Church had the lowest cohort life expectancy at the age of 50 years for all cohorts and for both sexes (Fig. 4*A*). For men, active members of the Church had 2–4 years higher cohort life expectancy at the age of 50 years compared with men in the other two activity categories (Fig. 4*A*). Women actively participating in church activities had a generally higher cohort life expectancy at the age of 50 years when compared with the other two categories; however, these differences were smaller than those reported for men. Also, in 1865, inactive females had a slightly higher cohort life expectancy at the age of 50 years than active followers, and by 1905, women not affiliated with the Church had higher cohort life expectancy at the age of 50 years than individuals actively affiliated with the Church (Fig. 4*A*). The larger gender advantage of those less attached to the Church may reflect the higher mortality risks (past the age of 50 years when the effects continue to endure) associated with elevated fertility of active Mormons.

For Denmark and Sweden, the patterns were very similar with a smaller difference in cohort life expectancy at the age of 50 years for early cohorts and an increasing difference with consecutive cohorts (Fig. 4*B*). The sex difference in cohort life expectancy at the age of 50 years was very similar for active Mormons and for Denmark and Sweden (Fig. 4*C*). Both non-Mormons and inactive Mormons had a sex difference in cohort life expectancy at the age of 50 years that was 2–4 years higher than active Mormons (Fig. 4*C*). The change from 1850 to 1910 in the sex difference in cohort life expectancies was approximately 4 years for non-Mormons and inactive Mormons groups, and for active Mormons, the change was approximately 2 years (Fig. 4*C*).

Discussion

Based on unique data from the UPDB, we did not find consistent support for our initial hypothesis that the sex differential mortality would be smaller in Utah when compared with Denmark and Sweden. This hypothesis was motivated by our expectation that a lower prevalence of smoking and alcohol consumption among men in Utah and a larger burden of childbearing among women in Utah would narrow the difference in life expectancy. The sex difference in cohort life expectancy was larger in Utah except, importantly, during the early frontier settlement era (1850–1870) that was distinguished by a series of food shortages and hardships associated with migration and vagaries of establishing communities [24]. The smaller sex differences may also be the result of strong mortality selection leaving a more robust set of descendants where males have survival comparable with females.

The sex difference in life expectancy of active followers of the Church was slightly higher than that of Denmark and Sweden, with the exception of the early and later cohorts. The studied cohorts would have been the most exposed to tobacco use. The apparent crossover in mortality by sex for active followers and the trajectories for Sweden and Denmark may be associated with the lower smoking rates among active members over time as well as the declining fertility rates. These findings also suggest that biological and possibly other unmeasured social and cultural factors related to health behaviors may have a major influence on the sex differential in life expectancy. The fact that descendants of Danish and Swedish immigrants to Utah had similar cohort life expectancies as the rest of the Utah population further suggests that factors leading to larger sex differences in Utah may be found in differences in the cultural and social setting in Denmark and Sweden. Variation in the sex differences by geography may be due to differences in the diffusion of risky behaviors, different economic and political contexts, cultural differences that influence dietary patterns in men and women, fertility preferences, and the interaction between environmental and genetic effects.

Biological factors could interact with environmental differences leading to variation in sex differences in life expectancy between

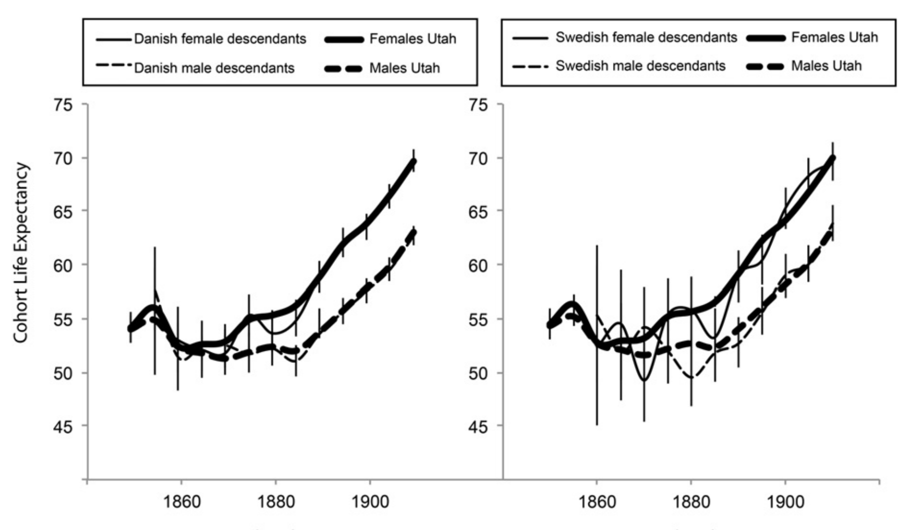

Fig. 3. Cohort life expectancy by sex for Danish descendants, Swedish descendants, and the Utah population. Vertical lines represent 95% confidence intervals.

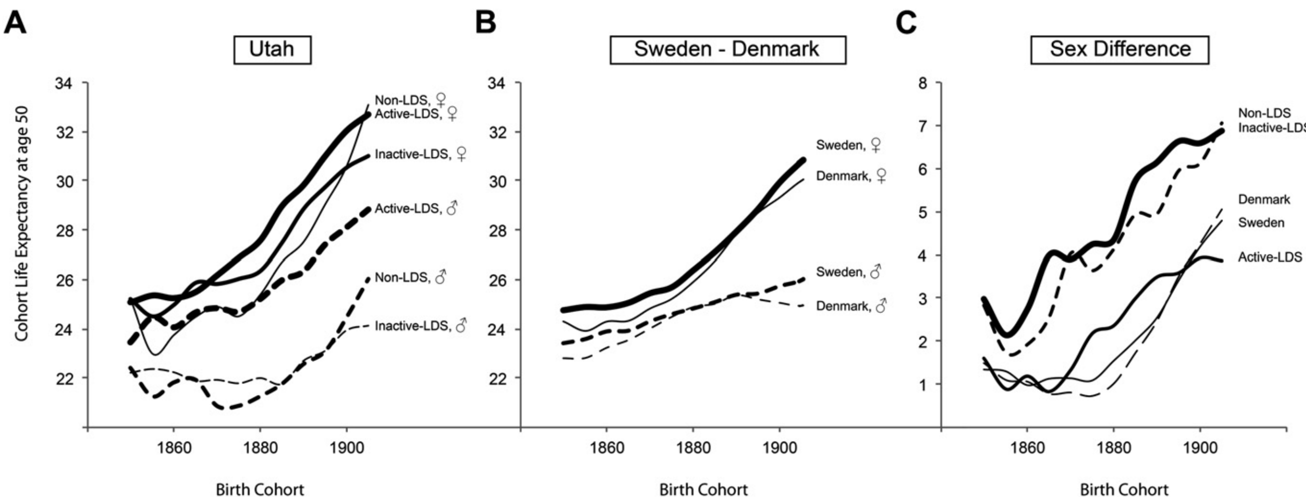

Fig. 4. Cohort life expectancy at the age of 50 years by sex and status within the Church of Jesus Christ of Latter-day Saints for Utah (A) and Sweden and Denmark (B) and the sex differences in each group (C).

regions. Although we failed to find a smaller overall cohort life expectancy in Utah, we do find that behaviors may likely play a major role in explaining the change in the sex differential seen in cohort life expectancy in Utah. The increasing sex difference in cohort life expectancy from 1850 to 1910 was approximately 2 years smaller for active Mormons than for non-Mormons or inactive Mormons, suggesting behavioral factors as an important component for the overall change. Proscriptions related to alcohol and tobacco use among active Mormons was possibly reflected in the observed higher cohort life expectancies for both sexes. This effect varied by sex where non-Mormons, inactive Mormons, and Mormon women were more similar in their cohort life expectancies at the age of 50 years than comparable men, with Mormon men having a much larger benefit compared with other men in Utah.

Interestingly, the sex differential in cohort life expectancy in Utah increased with consecutive cohorts from 1850 to 1910 in favor of women. This is well in line with the findings that there remains a sex difference in survival among never-smokers [11,12,40], given that smoking is thought to be the most important lifestyle factor underlying the sex differential in mortality. The findings warrant future research aimed at explaining gender differences by the cause of death.

In concordance with studies addressing the “healthy immigrant effect” [41,42], we find higher cohort life expectancies of Swedish and Danish immigrants in Utah when compared with that of their native countries. The finding that the sex differential in cohort life expectancy is smallest in Utah during the frontier era (i.e., persons born in 1850–1870) in relation to persons born at the same time in Sweden and Denmark suggests that special factors act on these generations of 19th century pioneers on sex differentials in mortality and life expectancy. These differences point to the potential mortality selection forces that create the health migrant effect.

The observation that all three religious groups were more similar for women than men suggests that the limited consumption of alcohol and tobacco among women will serve to limit differences in life expectancies (i.e., active Mormon women are more like non-Mormon women with respect to alcohol and tobacco use, a situation not reflected among men). This observation corresponds well with the suggestion that smoking is a principal factor behind the observed change in the pattern of sex mortality differences in the United States [13,40] and that smoking became increasingly socially acceptable among women in the United States from approximately the 1920s [43]. It is worth noting that generally Mormon women have more favorable life expectancies, but these advantages may be attenuated because of their higher (and for many years, risky) fertility.

We are aware of some limitations in the present study. The assumption that active Mormons have a healthy lifestyle and that this is the cause behind the differences observed in cohort life expectancies in this study may not be true universally and not the case at the individual level. However, when data are lacking on lifestyle at the individual level and a strong association with a healthy lifestyle is present in a specific group, it is a reasonable assumption. The association between religious activity and healthy lifestyle is supported by a 1980 study in Utah, which found that about 40% of non-Mormons were regular smokers, whereas 10% of the Mormon population did [21]. Also, studies at the individual level have found that the major reason for the lower risk of cancer between Mormons and non-Mormons is smoking for men and smoking and reproductive behaviors for women, further supporting the link between religious activity and lifestyle behaviors [15].

In conclusion, we did not universally confirm our initial hypothesis of smaller sex differences in cohort life expectancy in Utah when compared with Denmark and Sweden as sex differential in cohort life expectancy overall and irrespectively of specific religious groups was higher in Utah. Our study suggests that proscriptions related to tobacco and alcohol consumption may have been an important factor for the changes seen in sex differentials in cohort life expectancies. However, our results suggest that lifestyle factors alone were not sufficient to explain the total differences found in life expectancies for consecutive birth cohorts in Utah which proposes that other factors such as biological, gene–environment interaction, or unmeasured/unrecognized factors should be searched for.

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