Year: 2013

Secular trends in tuberculosis during the second epidemiological transition: a Swiss perspective

Holloway, Kara L ; Henneberg, Renata ; de Barros Lopes, Miguel ; Staub, Kaspar ; Link, Karl ; Rühli, Frank J ; Henneberg, Maciej

DOI: https://doi.org/10.4236/aa.2013.32011

Advances in Anthropology
2013. Vol.3, No.2, 78-90
Published Online May 2013 in SciRes (http://www.scirp.org/journal/aa)

DOI:10.4236/aa.2013.32011

Secular Trends in Tuberculosis during the Second Epidemiological Transition: A Swiss Perspective

Kara L. Holloway[1], Renata Henneberg[1], Miguel de Barros Lopes[2], Kaspar Staub[3], Karl Link[3], Frank Rühli[3], Maciej Henneberg[1]
[1]Biological Anthropology and Comparative Anatomy Research Unit, University of Adelaide, Adelaide, Australia
[2]Pharmacy and Medical Sciences, University of South Australia, Adelaide, Australia
[3]Centre for Evolutionary Medicine, Institute of Anatomy, University of Zürich, Zürich, Switzerland
Email: kara.holloway@adelaide.edu.au

Received January 17th, 2013; revised February 23rd, 2013; accepted March 1st, 2013

The second epidemiologic transition is defined as "the age of receding pandemics", wherein mortality declines, life expectancy increases, and population growth occurs. The major causes of death also shifted from predominantly acute infectious diseases to degenerative and "man-made" diseases (Omran, 1983). The aim of this study was to determine the timing of the transition in Zürich (Switzerland) and to investigate patterns of tuberculosis mortality during this period. This is one of the first studies to specifically investigate the timing of the second transition in Zürich, Switzerland. The data sources for this study were Swiss records of mortality from the Staatsarchiv (Canton Archives), Stadtarchiv (City Archives) and a published volume of State Statistics (Historische Statistik der Schweiz). The changes in mortality through time were addressed for all causes of death in the city of Zürich for the years 1893 to 1933 that is, the time including the second epidemiological transition. After 1933 the structure of the mortality data collection changed as the responsibility was transferred away from the canton archives. Mortality from tuberculosis was then examined in greater detail and compared with changes in living standards as well as population density occurring at the time.

Keywords: Tuberculosis; Second Epidemiological Transition; Switzerland

Introduction

An Overview of Tuberculosis

Tuberculosis is an ancient disease and has been one of the biggest causes of death among societies throughout history (Kaufmann & Britton, 2008). Tuberculosis occurs in individuals infected with a bacterium called Mycobacterium tuberculosis and who cannot control the organism effectively due to a lowered immunity (North & Jung, 2004). Tuberculosis is usually transmitted by inhalation of aerosols generated primarily by coughing (Cole, Eisenach, McMurray, & Jacobs Jr., 2005). However, ingestion of contaminated meat and dairy products is a route of infection for the related bacterium, Mycobacterium bovis, which predominantly infects cattle but can cause infection in humans (Waddington, 2004; Wilbur, Farnbach, Knudson, & Buikstra, 2008).

Mycobacterium tuberculosis does not always cause disease; in fact only approximately 10% of infected individuals suffer pathological signs and symptoms (Wilbur et al., 2008). A patient can even be asymptomatic and thus appear to be "cured" for long periods of time, yet may show signs and symptoms later in life. Since M. tuberculosis spreads mostly through the respiratory tract, the common pathological signs and symptoms include coughing, difficulty breathing, bloody sputum, weakness, lethargy, loss of appetite and weight, night sweats, pallor and chest pain (Dormandy, 1999; Wilbur et al., 2009). Tuberculosis can affect any part of the body and with time, the bacteria can disseminate from soft tissues of the lungs to the other parts of the body, including the bones (Wilbur et al., 2008).

In Europe, tuberculosis was likely responsible for 20% to 25% of all deaths during the 1500s (Stead, 2001). There are difficulties with this estimate, however, because relevant historical records can be absent, or incomplete and ambiguous on cause of death in the pre-modern era. For example, in many countries, physicians were hesitant to diagnose tuberculosis because of the social implications for the patient and instead recorded the cause of death as some other unspecified pulmonary disease (Johnston, 1995). The term "tuberculosis" also did not become widely used until the 1830s (Wilbur et al., 2008). A number of other names were given to pulmonary conditions presenting tuberculosis-like signs and symptoms including "consumption", "phthisis" and "the white plague", while diseases of other organs caused by M. tuberculosis were referred to as tabes mesenterica and "scrofula" or "King's evil" (Herzog, 1998; Miller & Thompson, 1992; S. Newsom, 2006; Smith, 1988). In addition, disease diagnosis prior to the 19th century did not have a high degree of certainty, and new systems of disease classification were introduced in the early 20th century (Dormandy, 1999; Rucker & Kearny, 1913). Improving accuracy in diagnostics and shifts in disease classification can cause problems in interpretation of the mortality and morbidity of tuberculosis through time as disease categories associated with tuberculosis can also include several other conditions. For example, "phthisis" may also include other pulmonary diseases with symptoms similar to pulmonary tuberculosis. However, the disease now known as tuberculosis has been reported in some ancient literature such as a Babylonian text written by the monarch Hammurabi between 1948 and 1905 BCE (Herzog, 1998; Kaufmann & Britton, 2008; S. Newsom, 2006; Steinberg, 1996). We investigated patterns in tuberculosis during the 19th and 20th centuries, many years after it was first described in these ancient writings. Thus, while some diagnoses are likely to be incorrect, the majority will not be. We considered the terms "tuberculosis", "consumption", "phthisis", "scrofula" and "King's Evil" as evidence of tuberculosis since these were the most commonly used terms during the time period under investigation (Burke, 2011).

Switzerland—Public Health, Demography and Economy

General Overview of Switzerland

Switzerland is a central European country comprised of 26 regions called "cantons". These cantons differ in size, population, language, geographical features, and extent of urbanization. The borders of Switzerland are irregular because they represent negotiations and agreements in the past (Steinberg, 1996). For example, the Canton of Basel was split into two half-cantons (Basel-Stadt and Basel-Land) after a disagreement between urban and rural areas in 1830 (Bouvier, Craig, Gossman, & Schorske, 1994; Steinberg, 1996). The Swiss government has been stable since 1848 (Butler, Pender, & Charnley, 2000; Steinberg, 1996), but each canton has its own constitution, executive, legislative and judiciary, laws and practices, flag, and coat of arms as well as a separate Parliament (Steinberg, 1996). Multiple religions are accepted in Switzerland and in the past the population was approximately equally divided between Protestant and Catholic. The country has been neutral since 1815, but still maintains an army (Remak, 1993). The country's economy, while highly specific (banks, watches, cheese, and chocolates), has been very successful. This success has been partly due to dependence on foreign workers, which reduces labor costs. These workers came from a variety of countries including France, Poland, Germany and Italy (Bouvier et al., 1994).

A Short History of Switzerland

At the end of the 1700s, Switzerland had no central government, no common treasury, troops, currency, judiciary or mark of sovereignty despite the long history of Confederation dating back to the 13th century (Bouvier et al., 1994; Remak, 1993). At the time, each canton was governed separately, though there was a larger Parliament for the country, which consisted of representatives from each canton. However, in 1798 major changes occurred when Napoleon invaded Switzerland from France (Remak, 1993). Following the invasion, Napoleon converted Switzerland into the Helvetic Republic, which united and centralized the cantons. Napoleon also granted freedom of speech, movement and religion to the country, and introduced a common currency, law code, and postage system (Remak, 1993). However, due to dissatisfaction with some of these changes among the populace, especially the loss of traditional rights of the individual cantons, Napoleon altered the Helvetic Republic with "The Act of Remediation" in 1803, which did not return the cantons to Swiss control but did reintroduce some traditional rights. Napoleon lost control of Switzerland in 1814 and in 1815 a Federal Treaty was signed. This reverted the country to pre-Napoleonic policies and provided regulations for political relationships between the cantons (Bouvier et al., 1994; Remak, 1993; Steinberg, 1996). France was also required to pay compensation for damages incurred during Napoleon's military campaigns, which supported Switzerland's economic development. The Treaty also introduced the concept of neutrality. While the Swiss citizenry was supportive of this, they did not support the Treaty's centralization of the country (Remak, 1993).

In 1831, the 1815 Treaty was effectively rejected (Steinberg, 1996). Religious schisms also arose, driven in part by issues of economic inequality: more urban, prosperous cantons were gradually converting to Protestantism while the poorer and rural cantons remained Catholic (Remak, 1993). This religious division had progressed slowly throughout the 1830's as Liberalism became increasingly popular in Switzerland and other neighboring European countries. This led to religion-based alliances between the Catholic cantons, and widespread unrest, with some unsuccessful attempts made by protestant Radical groups to overthrow the government in 1844 and 1845. In 1847, a Civil War erupted when seven Catholic cantons tried to establish a separate alliance, though it ended in less than a month with few casualties (Butler et al., 2000; Remak, 1993; Steinberg, 1996). After the war, unification between the cantons became favored, precluding the revolutionary uprisings, which plagued much of Europe, and a new constitution was drafted in 1848, which remains in use today. This new Constitution resolved the longstanding conflict between national centralization and traditional canton-based freedoms (Steinberg, 1996), by forbidding alliances between the cantons. It created a "bottom-up" system that allowed citizens to vote on all decisions by the government. Thus power rests with the people rather than a central authoritative group (Bouvier et al., 1994).

Industrialization and the Economy of Switzerland

Switzerland was one of the earliest industrialized countries in Europe, on a par with the United Kingdom, the United States, and France (Butler et al., 2000; Steinberg, 1996). By 1780, the entire region of eastern Switzerland was largely industrialized; producing exports such as milk products, silk textiles, cotton and mechanical parts (e.g. watches) (Steinberg, 1996). From 1880 to 1950 only the UK had a higher gross national product per head. However, several features distinguished industrialization in Switzerland from that experienced by other early industrializers: a slow rate of urbanization, high levels of economic specialization (e.g. high quality mechanical parts and textiles, see below), slow spread of railways, a strong dependence upon foreign labor, limited geochemical natural resources, such as coal, a high rate of international investment, a geographical concentration of economic activities in micro-units, and a very high level of industrialization (Butler et al., 2000; Steinberg, 1996). In fact, by 1850, Switzerland ranked fourth in the level of industrialization behind the United Kingdom, Belgium and the United States (Siegenthaler, 1972). Railway systems developed quickly in the mid 19th century in other early industrializers, but lagged in Switzerland, even in comparison to other aspects of economic growth. This was due to difficulty with the mountainous terrain, the absence of coal (industry and development was fueled largely with hydropower) the small size of Swiss cities, and lack of a strong, central government. Mountainous terrain was also an overall obstacle to economic development in Switzerland: 25.5% of the land is unproductive (e.g. High Alps), 30.3% is "forested", and only 38.3% is available for agriculture (Steinberg, 1996). Only 5.8% is considered surface area suitable for habitation and infrastructure. In a small country, this amounts to a very small area.

In complement to industrialization, Switzerland also maintained a vigorous agricultural economy. This economy was focused on specialized milk products, such as cheese and chocolate, which, together with tourism, watch making, and textile production, provided consistent income for rural areas throughout the 19th century. While the country maintained a high rate of importation for cereals, exports, particularly of luxury items, formed a critical component of the economy; only Belgium had a higher export rate. Switzerland's overwhelming economic focus on export and luxury items, like watches and embroidery, was due to the nation's dearth of raw materials, and high transport costs (Butler et al., 2000; Siegenthaler, 1972; Steinberg, 1996). Little economic centralization occurred; Swiss industrialists and canton governments were not supportive of large scale production and industrialization or the construction of factories (Steinberg, 1996). Instead, machines were installed in worker's home, allowing a continuation of cottage industry and piece production (Bouvier et al., 1994; Butler et al., 2000). This practice resulted in a much lower urban population density than was found in 19th and 20th century Britain or Germany (Steinberg, 1996). While exportation was expensive, Swiss goods remained competitive because of low labor costs: wages were 15% lower and hours 15% longer when compared with Germany (Steinberg, 1996). This advantage did not overcome all of Switzerland's disadvantages, however, translating into a heavy emphasis on economic specialization and high levels of skilled labor, high product quality, and involvement in international trade, open markets, and optimization of trade conditions (Butler et al., 2000).

Switzerland employed child labor throughout the 19th century, but also maintained a system of compulsory education. Children participated in industrial activities within the home, and thus were also able to attend school. Education of children between the ages of 6 and 16, both boys and girls, became compulsory in the 16th century (Bouvier et al., 1994; Steinberg, 1996). Economic assistance was provided to parents who could not afford schooling for their children (Steinberg, 1996). Much of Switzerland's economic success has been attributed to this emphasis on high quality, accessible education even in the face of rapid economic growth (Butler et al., 2000).

Living Conditions in Switzerland

Switzerland maintained a uniformly high standard of living in rural and urban areas during industrialization in comparison to other early industrializers. This was largely due to the use of white coal (hydropower) brought into the city from rural areas (rather than black) which produced less pollution, and also to low urban population density (Schoch, Staub, & Pfister, 2011; Steinberg, 1996). For instance, in 1900, only 6% of Swiss citizens lived in towns with a population of over 10,000. By 1910 this had only increased to 25%. In comparison, Great Britain had reached 25% by the 1840s. Zürich had a population of 28,000 during the late 1800s, though in-migration and incorporation of surrounding regions into Zürich due to economic difficulties in 1893 pushed this number up to 100,000 (Steinberg, 1996).

Economic hardships also affected Switzerland in the 19th century. Despite intensive agriculture, there were periodic food shortages in the 1810s, particularly in urban areas and this was associated with the internal conflict and fall of Napoleon's Empire in 1814 (Bouvier et al., 1994; Steinberg, 1996). Later, in 1845, Switzerland also experienced an epidemic of potato blight, which precipitated widespread poverty, increased levels of child labor, and famines during the 1850s (Butler et al., 2000). However, dietary and economic conditions improved during the 1880's, with increased consumption of animal protein as well as cheap grain (Schoch et al., 2011). With this influx of grain from cheap imports, local farmers decided to focus on milk products instead. Around this time (1870 to 1912), the public healthcare system was established and public sanitation (such as the introduction of sewerage systems, waste removal and public health education), immunization as well as housing/working conditions were further improved (Schoch et al., 2011). The public health system may have addressed factors such as water pollution, poor quality foods in the marketplace, disposal of animal waste from slaughterhouses, cemeteries, problems with leaky sewers and septic tanks, street cleaning, housing with inadequate ventilation or sunlight and harmful chemicals or working conditions in industry (Bourdelais, 2006). Major investments in the urban water supply and sewerage systems were completed during the last third of the 19th century in Switzerland (Condrau & Tanner, 2000). These methods were more effective in urban areas than in rural areas; likely because the former have a higher population density and these measures could be more effectively implemented in cities than in smaller, country towns. However, economic difficulties associated with a rise in the price of wheat and flour products due to poor harvests during 1880-1888 caused many farmers to become unemployed and forced many people to migrate from rural areas to cities in search of a new occupation (Graber, 1926; Schoch et al., 2011). However, while bread prices were rising substantially in other countries (especially in Europe) the Swiss Government established an association called the "Wheat Administration" on the 9th of January 1915 (Graber, 1926). The task of this association was to moderate the prices of wheat products in Switzerland, to control imports of these products into the country, maintain reserve stocks of cereals and to encourage the cultivation of home-grown wheat. Since this administration was in control of purchasing wheat, when prices increased during the 1880's, it became difficult to afford Swiss-grown wheat. The Wheat Administration was very successful during WWI and consequently, bread prices in Switzerland were tolerable for the consumer, unlike in other countries around the world.

The conflicts and economic disturbances that ravaged much of Europe through the 19th and 20th centuries had a moderate effect upon Switzerland's economy and living standards. Switzerland did not participate in WWI but did experience minor economic declines in part because the country maintained a standing army during the period. Numerous refugees from Russia, France and Germany were also admitted during the 1910s, resulting in additional economic declines because these individuals required housing and subsistence, thus reducing the amount of land and food available (Steinberg, 1996). Even during WWI, the standard of living in Switzerland did not decline, largely because of governmental attempts to control and prevent malnutrition; government subsidies ensured that milk products were highly accessible and a school lunch policy was instituted (Schoch et al., 2011). In addition, the Government also provided sufficient wheat for bread products through direct cost to the country during WWI (Graber, 1926). During the 1930s, Swiss manufacturing (watches and textiles) was severely affected by the Great Depression and in some areas, entire industries collapsed. Changes in currency exchange rates also severely affected Swiss profits and in north-eastern Switzerland, many towns relying upon single industries, became economically vulnerable (Steinberg, 1996).

The City of Zürich—An Overview of Sanitation and Hygiene

Zürich is a very wealthy city located in northeastern Switzerland, within the canton of Zürich. Economic growth associated with industrialization began in approximately 1827, and became focused on cotton textiles around 1857. Industrialization affected the city in several ways including an increase in population density, decrease in the level of sanitation and beginning of social stratification. However, these changes occurred to a lesser extent in Switzerland compared to other countries (Steinberg, 1996). The sanitation and hygiene situation in Zürich in the early 1800s was similar to the rest of Europe; in 1837, a British tourist published an article in a Swiss magazine describing the amount of filth in the streets of Zürich. He stated: "when it rained the streets turned into lagoons covered in half a foot of mud" (Lemann, 2008). Due to a lack of sewage systems in Zürich, human and animal waste and refuse drained into small alleyways between houses and then into the River Limmat, and water-borne diseases such as cholera (at the time the records did not state the type of cholera) frequently raged through the city. To correct this, major sewage reforms were instigated between 1866 and 1870, resulting in the regular removal of household refuse, introduction of simple sewerage systems for waste and rainwater, and a system of waste management based on composting and deposition in rural areas. This strategy seems to have been effective; in 1883, Zürich hosted a national exhibition that presented the city as one of the cleanest and healthiest in Europe. Furthermore, in the 1890s, Swiss authorities proposed the adoption of a mode of waste disposal currently popular in Britain—incineration—and in 1899, the citizens of Zürich allocated 1 million Swiss francs to construction of an incinerator in Zürich. This was to help control the city's waste in the future, since the current management would be unable to cope with an increasing population. This facility, finished in 1904, was the first in Switzerland and the fourth in mainland Europe. Products of this facility did not impact the health of individuals living in Zürich because it was built some distance from the city. Other effective, though smaller scale public health reforms included the use of sealed containers with sliding lids for storing unwanted household refuse. These were designed for the purpose in the early 1900s, quickly made mandatory for all households in Zürich, and eventually mass-produced throughout the country until plastic rubbish bags made them obsolete in the 1970s (Lemann, 2008).

Switzerland's Role in the Treatment of Tuberculosis

Switzerland played a substantial role in the 19th century declines in mortality from tuberculosis. The country's great number of sanatoria distributed through its alpine regions—and its neutrality, which facilitated migration to these centers—long encouraged individuals infected with tuberculosis to establish short or long term residence there. The main reason for the migrations were the reputation of Switzerland's sanatoria in aiding those with tuberculosis; many with the disease believed if they could travel to these establishments that they would be cured. These establishments were dedicated to the care of patient with active tuberculosis, and were built throughout the 1800s and 1900s to offer a "cure" for tuberculosis (Rucker & Kearny, 1913). Contemporary medical thinking about active disease held that the "open-air" climate found in the high mountainous areas of Switzerland was an effective cure for the disease (Warren, 2006). The sanatoria also encouraged rest, including sitting in the sun, and "satisfactory" exercise (Dormandy, 1999; Rucker & Kearny, 1913), and provided clean, hygienic environments for patients, as well as a substantial nutritional regime: up to seven meals a day, consisting largely of dairy products and cod-liver oil (Roberts & Buikstra, 2003; Warren, 2006). All of these treatment methods related to the bolstering of disease resistance among patients through aiding the immune system with proper nutrition and this allowed many to recover from active tuberculosis. Rucker & Kearny (1913) describe the success rates of sanatorium treatment of at least four weeks for tuberculosis patients from 1905 to 1911. For those with early stage tuberculosis, more than 95% improved, 3.2% were unimproved and only 0.1% died in the sanatoria. Of cases with more advanced tuberculosis, 85% were improved, 12% were unimproved and only 1.0% died in the sanatoria. Very advanced disease resulted in 62% improved, 34% unimproved and only 3% deaths in the sanatoria. During this period, in the 19th and early 20th centuries, estimates of the frequency of tuberculosis in Switzerland are rough, as only mortality from the disease was recorded. However, in 1928, a law (Anfrage des Stadtrates betr. Erlass von Vorschriften über die Whonungsinspektion) was passed that required the reporting of all cases of active disease. Importantly, this law also required treatment of all recorded individuals, not just those who could afford a stay in a sanatorium (Gesetzgebung: Zürich, 1928).

However, tuberculosis has re-emerged in many other countries around the globe in the past few decades, following the development of drug resistance and the HIV/AIDS epidemic (Corbett et al., 2003; World Health Organization, 2012). Currently, the WHO estimates that one-third of the world's population is infected and two million die from tuberculosis each year. Thus, it is important to study this ancient disease in order to help us combat the current problem of re-emerging and drug resistant tuberculosis.

Materials and Methods

Data Sources

Historical Records and State Statistics

Data employed in this study include vital records on mortality from both the Stadtarchiv ("city-archive" (Stadt Zürich, 2012)) and Staatsarchiv ("canton-archive" (Canton of Zürich, 2012)) in the city of Zürich. The Stadtarchiv held records for causes of death in Zürich city from 1893 (likely because this was when the original city and the surrounding regions were combined) to 1933, which included mortality attributed to tuberculosis. There were many records in this archive, and we examined:

- Statistik der Infektionskrankheiten (Statistics of Infectious Diseases);
- Tuberkulose (Tuberculosis): two volumes; 1912-1932 and 1932 to 1935;
- Tuberkulose Sterbefaelle (Tuberculosis mortality): five volumes; 1903-1905, 1905-1915, 1915-1920, 1920-1934 and 1929-1936.

The Staatsarchiv held information detailing the introduction of Anfrage des Stadtrates betr. Erlass von Vorschriften über die Wohnungsinspektion (the Law regarding the compulsory recording and treatment of tuberculosis). Data were also collected from a volume of primary historical statistics for Switzerland (State Statistics) titled "Historische Statistik der Schweiz" (Ritzmann-Blickenstorfer, 1996). Both the Staatsarchiv and State Statistics yielded information on mortality attributed to tuberculosis for thirteen cantons (i.e. Zürich, Berne, Lucerne, Uri, Schwyz, Obwalden, Nidwalden, Glarus, Zug, Fribourg, Solothurn, Basel-Stadt and Basel-Land) for 1876 to 1935. From the book of State Statistics, the relevant table was "D43. Todesfälle infolge Lungentuberkulose nach Kantonen 1876-1935" (Mortality due to pulmonary tuberculosis by Canton).

The State Statistics also provided data on population sizes for Zürich city (through censuses) and a number of cantons (i.e. Zürich, Berne, Lucerne, Uri, Schwyz, Obwalden, Nidwalden, Glarus, Zug, Fribourg, Solothurn, Basel-Stadt and Basel-Land) for the years 1888, 1900, 1910 and 1930. This was used to calculate the population density for those years with available data: 1888, 1900, 1910 and 1930 (Gwillim Law, 2009). Each canton was assigned an arbitrary category of population density: low (<40 people per km^2), medium (40 - 80), high (81 - 100) or very high (>101). These reflect relative predominance of rural and urban styles of living. Cantons with low population density were Uri (19.0 people per km^2) and Obwalden (34.0). Medium density included Nidwalden (49.7), Glarus (49.3), Schwyz (62.2) and Fribourg (79.4). High density cantons were Berne (101.7), Lucerne (107.0) and Zug (115.6). Finally, very high density cantons included Solothurn (141.5), Basel-Land (144.4), Zürich (273.2) and Basel-Stadt (3221.6). Since population density increased through time in all cantons, this designation was attributed based on the population density estimated for each at the beginning of observations in 1888. Due to political and economic stability, population densities in studied areas would remain comparatively steady in comparison to each other thus without changing the nature of low-density and high-density areas.

The state statistics also provided average newborn life expectancies for 1878 to 1991. The available data represent an average for the whole of Switzerland (Zürich canton and city specific data were not available) and were used to give an indication of living conditions for 1840 to 1933.

Data Analysis

Causes of death were grouped into four categories according to type of disease. These include infectious, "organ" (i.e. diseases of organ systems such as the renal and reproductive systems), degenerative, and "other" (e.g. accidents, poisoning). While we are aware that some of the diseases placed in the group "organ" may be the result of infectious processes, we could not be sure and consequently, we simply chose to remove them from our general overview in order to reduce biases. Diagnoses were used as reported and no attempt was made to re-interpret them. Although some terms changed around 1900 (e.g. "phthisis" to "tuberkulose" (Rucker & Kearny, 1913)), an attempt was made to keep the causes of death consistent over the time period by determining which diseases had changed in nomenclature and their corresponding new names. The percentage contributions of each of these four disease groups were calculated by dividing the total deaths from all diseases in that group by the total deaths from all groups.

Data from literature investigating or describing the second epidemiological transition in other countries were consulted to provide a comparison for the Swiss data. Tuberculosis mortality data were available for England and Wales (1860-1960), Japan (1925-1964), Chile (1915-1965), Sri Lanka (1939-1967), The Netherlands (1875-1992), Australia (1907-1990) and cities in the United States (Philadelphia (1870-1930), New York (1866-1965)). The countries used for comparisons were chosen due to the availability of data and because they represent a diverse set of conditions and degrees of urbanization. These comparisons are thus useful to determine the effects of different living conditions and social factors on tuberculosis mortality through time. Graphs of percentage mortality from infectious, organ, degenerative, and other diseases were produced from the data presented in publications describing tuberculosis mortality in the other countries stated above (Carter et al., 2011; Condran & Cheney, 1982; Lewis, Taylor, & Powles, 1998; Omran, 1983, 2005; Wolleswinkel-van den Bosch, Looman, Van Poppel, & Mackenbach, 1997). In some cases this was difficult, especially where the causes of death were grouped or not clearly described. In some cases, graphs from publications were not clear and these were reproduced in a different format to allow an estimation of the timing of the second epidemiological transition.

Following established methods, the percentage of tuberculosis mortality was calculated by dividing tuberculosis mortality by total all-cause mortality. This was plotted for both Canton Zürich and the city of Zürich in order to observe trends and patterns over time, but also for comparison of the two. Tuberculosis mortality, expressed as a rate per 100,000 living individuals, was plotted against the calculated population densities for several Swiss cantons (Zürich, Lucerne, Uri, Schwyz and Berne) in order to determine any correlation between the two.

Results

Part One: The Timing of the Second Epidemiological Transition in Zürich City

The total number of recorded deaths for the causes in each disease group (i.e. infectious, organ, degenerative, and other) was expressed as a percentage of the total mortality for 1893 to 1933. This was plotted along with newborn life expectancy and is shown in **Figure 1**. The second epidemiological transition, defined by Omran (1983) as the time when degenerative diseases become more important than epidemic infectious diseases in terms of mortality, is clearly shown in **Figure 1**. This transition takes place in 1911, according to the intersection point of linear trend lines for degenerative and infectious diseases. The rate of increase of degenerative diseases was equal to the rate of decrease of infectious diseases; 0.0079 ± 0.0007 and 0.0078 ± 0.0007 per year, respectively. This transition is reflected in the increase in life expectancy; as individuals began living longer, they became more likely to develop degenerative diseases. The newborn life expectancy of males increased from 60.5 years in 1895 to 66.5 years in 1935. For females, the values increased from 62.2 years to 69.6 years over the same time period.

Part Two: Trends in Tuberculosis Mortality during the Second Epidemiological Transition in Zürich City and Zürich Canton

Mortality from tuberculosis, expressed here as a percentage of total mortality, was calculated for the canton of Zürich for 1840 to 1933 (Stadt Zürich, 2012) and Zürich city for a shorter period, 1893 to 1933 (Ritzmann-Blickenstorfer, 1996). The data are plotted in **Figure 2**, along with annotations of important historical dates for Switzerland, healthcare and tuberculosis treatment.

In the city of Zürich, the percentage of total mortality from tuberculosis decreased between 1893 and 1933. In the canton of Zürich there was a peak in tuberculosis mortality around 1890. This could be a result of economic difficulties involving the wheat market (as mentioned above) as well as migration,

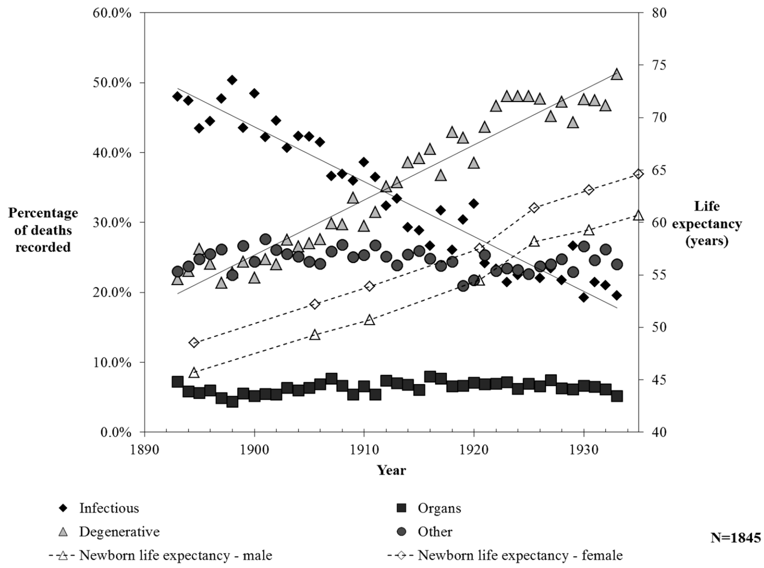

Figure 1.
Percentage mortality in the city of Zürich for infectious, organ, degenerative and other diseases, between 1893 and 1933. Newborn life expectancies for males and females are also plotted.

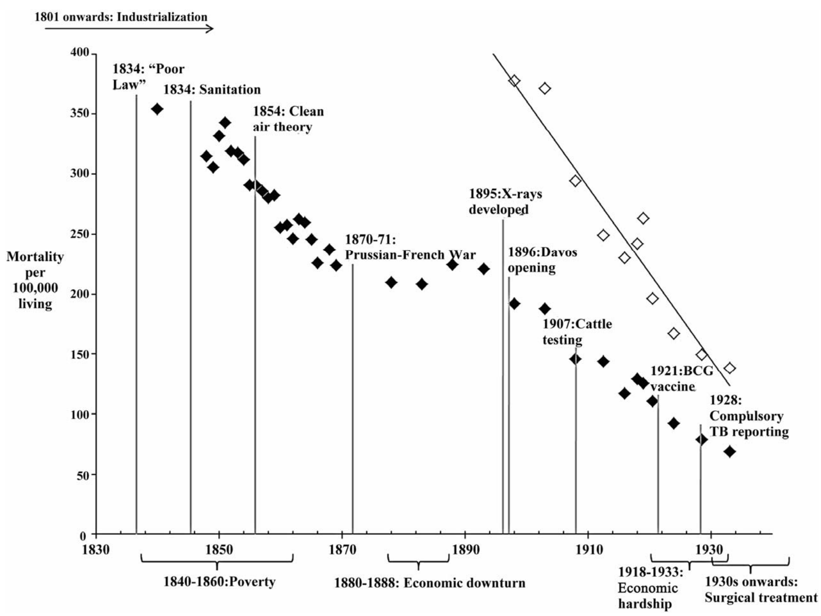

Figure 2.
Percentage of total mortality from tuberculosis in Canton Zürich (1840-1933) compared with Zürich city (1893-1933). Historical events are also shown.

resulting in lower nutritional value of the Swiss diet through rationing (Graber, 1926). The data for the city differed from the cantonal values in that the initial percentage was higher, likely due to the higher population density of the city (average 1485 people per km^2 between 1893 and 1933). Towards 1933, the percentage of total mortality from tuberculosis in the city began to approach the value for the entire canton. Finally, the decrease in tuberculosis mortality is more dramatic in the city than in the entire canton. This could reflect changes in living conditions as well as improved access to medical treatment and medical advances in the city, which would be greater in a higher population density area. In more crowded areas, before effective public health measures, there was a higher level of infectious diseases due to poor sanitation (waste products were left to decompose in the streets) as well as higher transmission rates due to population density. With the introduction of public health education and sanitation, these issues can be quickly and efficiently resolved. There is another interesting observation from **Figure 2**; the percentage of mortality from tuberculosis was decreasing even before medical advances related to tuberculosis care. This is potentially due to the improvements in living conditions and public health care in Switzerland rather than specific tuberculosis treatments. Additionally, tuberculosis mortality was also in decline in the city of Zürich before the second epidemiological transition occurred there, around 1911 (see **Figure 1**).

Part Three: Patterns of Tuberculosis in Other Swiss Cantons during the Second Epidemiological Transition and the Effect of Population Density

Population density (people/km^2) was plotted against the tuberculosis mortality rate per 100,000 living individuals (**Figure 3**) to determine whether correlations existed between these two variables in different cantons during the several years for which data were available: 1888, 1900, 1910, and 1930.

A positive relationship existed between population density and tuberculosis mortality in the earlier years, namely 1888 and 1900 (**Figure 3**). The mortality rate decreased through time, despite an increase in population density. The decrease in tuberculosis mortality is more dramatic in cantons with a higher population density than those with a lower population density. In those with lower density, the tuberculosis mortality rate in 1888 was 146 (per 100,000 living) but decreased to 90 by 1930. In cantons of very high population density, the tuberculosis mortality rate was 239 (per 100,000 living) in 1888 and decreased to 91 by 1930. Note that in 1930 the correlation between tuberculosis mortality and population density disappeared and both high and low density areas had the same tuberculosis mortality rates (approximately 90 per 100,000).

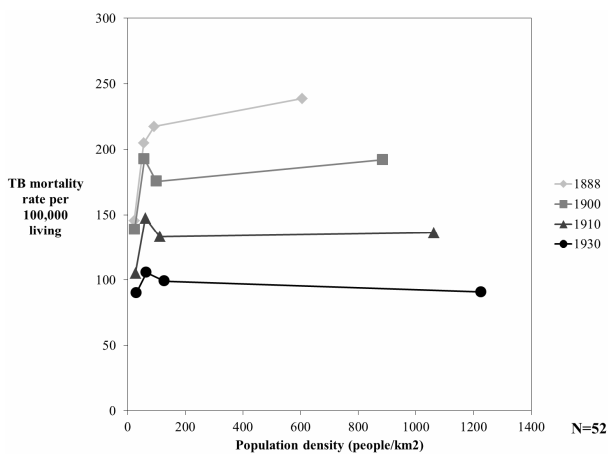

Figure 3.
Tuberculosis mortality rate per 100,000 living people compared with population density (logarithmic scale) in various Swiss cantons (1888-1930). Cantons include: Zürich, Berne, Lucerne, Uri, Schwyz, Obwalden, Nidwalden, Glarus, Zug, Fribourg, Solothurn, Basel-Stadt and Basel-Land.

Discussion

Part One: The Timing of the Second Epidemiological Transition in Zürich City

When compared with data from other countries that industrialized in the 19th and early 20th centuries, and the cities within them, evidence here suggests that Switzerland and Zürich underwent the second transition early. For instance, in the earliest industrializers, the transition occurred during the 1920s in Great Britain (Omran, 2005), and before 1930 in major urban areas in the US, namely Philadelphia and New York (Condran & Cheney, 1982; Omran, 1983). In the Netherlands, for example, which experienced intensive industrialization in the 1860s and 1870s, cause of death and all-cause mortality data, covering the period from 1875 to 1992, suggest that the transition occurred there only in the 1930s (Wolleswinkel-van den Bosch et al., 1997). Other, later industrializing countries, including Nauru, Japan, Mexico, and Chile exhibited patterns of an epidemiological transition later, in 1955, 1951, 1957, and 1974, respectively (Carter et al., 2011; Omran, 1983, 2005). Evidence from Australia, for example, which industrialized mainly throughout the 20th century, seems to suggest that the transition occurred there in the 1920s; infectious disease mortality declined in the 1940s, stabilizing by 1950, and degenerative diseases, specifically cardiovascular disease and cancer, increased from 1920 on, only plateauing in 1940. Overall, the epidemiological transition in all of these other countries occurred later than in Switzerland.

The decrease in infectious disease mortality observed so early is attributable to several possible causes. Refrigeration, which would have reduced morbidity and mortality from gastrointestinal disease, is one possible cause. Refrigeration was under development in the early 1800s and was in widespread use in 1884 in the United States (Krasner-Khait, 2011); it likely became widespread in Switzerland at approximately the same time. The mortality rate from gastrointestinal diseases, many of which may be caused by an infectious agent (though not always), in Zürich city decreased substantially from 17% of all deaths in 1898 to 2% in 1914. This pattern suggests that the decline may be linked with improvements in food technologies, such as refrigeration. The decline would have substantially lowered mortality among children, the age group most affected by this type of disease, thus allowing more individuals within the population to reach adulthood. This theory is supported by the increase in life expectancy among newborns through time as shown in **Figure 1**.

Improvements in general sanitation also likely played a role in precipitating Switzerland's early transition. For instance, sewage control, which was introduced between 1866 and 1870 in Zürich, and the increased accessibility of potable running water in Zürich and other cities in the same time period, would have facilitated the epidemiological transition in Switzerland by further reducing mortality from water borne and many gastro-intestinal diseases. Similar structural changes were occurring in both England and Germany, but at a slightly later date. For instance, in England, a Public Health Act in 1875 required appropriate waterworks to be present and functional, while in Germany, all larger cities (i.e. more than 25,000 people) had efficient sewerage systems by the year 1900 (Vögele, 1998). These changes, lagging slightly behind those in Switzerland, are reflected in the decline of infectious diseases through time in these nations. For tuberculosis, these improvements in living conditions helped to increase the general immunity of the population and consequently decreased the number of people who developed active disease.

Importantly, Switzerland was a stable country during the time periods investigated, and unlike many other early and late industrializing countries, did not take part in any international wars in the mid-19th and early 20th centuries (and into the present day). Data from Switzerland also, unlike these other countries, show little evidence of poorer living conditions in highly populated cities compared with rural areas. In contrast, Great Britain, for example, experienced extensive damage to their urban, economic, and public health infrastructures during WWI and WWII. In WWII in particular, living conditions in urban areas dramatically deteriorated due to damage to buildings and homes, leading to overcrowding as well as rationing of food. This did not occur in Switzerland; living conditions remained stable throughout the wars. In Switzerland, many of the penalties associated with urban factories were avoided because individuals could work at home and were not subject to the poor conditions of living and working in large cities. This kept many native Swiss in their hometowns and encouraged some immigrants to move to these areas; thus helping to prevent cities becoming overcrowded. These factors, combined, seem to have contributed to a buffering of the epidemiological costs associated with industrialization and urbanization in Switzerland, and a comparatively earlier transition to a reduced regime of infectious disease and greater longevity among its citizens.

Part Two: Trends in Tuberculosis Mortality during the Second Epidemiological Transition in Zürich City as Well as the Entire Canton of Zürich

The 19th century witnessed several major shifts in mortality from tuberculosis in Zürich. Between 1840 and 1870, the percentage of total mortality from tuberculosis in the Canton of Zürich decreased substantially. This coincided with changes in health policies, including sanitary reforms and enactment of the "New Poor Law" (the "Old Poor Law" was introduced in the 16th century), which required the segregation of wealthy and poor individuals and encouraged those with the ability to work to find employment and support themselves (Wilson, 2005). The Newer Poor Law aimed at providing housing, clothing, food and education (for children) to the poor in return for several hours of labor per day in a workhouse (The National Archives, 2012). Separating these poorer individuals from those of higher socioeconomic status helped to reduce tuberculosis among the latter because they had less contact and opportunity for transmission of the disease with poor people with lower immunity due to a lower nutritional status. However, after the Prussian-French War (1870-1871), the percentage mortality due to tuberculosis increased, which may be attributed to the influx of a large number of both French troops and refugees, who were likely poorly nourished and stressed, into the canton near the end of the war. This trend persisted until approximately 1910, when the percentage decreased again in both the city and Canton of Zürich. This decline coincided with a number of important developments in tuberculosis prevention and control in Switzerland, including the discovery of X-rays in 1895 (these were later used as a method of diagnosing active pulmonary infection) (Herzog, 1998), and the initiation of testing cattle to control bovine tuberculosis around 1907 in many European countries (S. W. B. Newsom, 2006). These innovations were later followed by the first use of the Bacille Calmette Guerin (BCG) vaccine in 1921, which was the first—and only—vaccine to provide protection from tuberculosis, particularly in children (Herzog, 1998). Lastly, the 1928 Swiss law which required reporting and treatment of cases of tuberculosis (Gesetzgebung: Zürich, 1928), and the invention of surgical treatment for pulmonary tuberculosis in the 1930s (Herzog, 1998) likely contributed to the steady early 20th century decline in the disease in Switzerland and Zürich specifically. Interestingly, the years associated with the beginning of industrialization and economic hardship in Zürich (19th century), and thus potentially reduced overall health were not associated with increased mortality from tuberculosis.

The fact that tuberculosis mortality decreased before medical interventions in Zürich suggests that medical treatment and advances on their own may not be major causes of declines in mortality from tuberculosis in a given population. This finding is congruent with other scholarship on the second epidemiological transition, such as Omran (2005), which suggests that ecobiological changes, such as aspects of the environment, and the biology of hosts and pathogens, and socioeconomic, political and cultural changes, such as standards of living, hygiene and nutrition, exerted far more influence in precipitating the second transition than did medical intervention, such as surgery, drugs and vaccination. Likewise, our results suggest that in Switzerland, the second transition occurred before the implementation of major medical advances, such as chemical therapy/antibiotics and in the case of tuberculosis, before use of BCG vaccine. It seems that this early occurrence of the epidemiological transition is a result specific for Switzerland's combination of sanitation, local health care arrangements and living conditions. These latter ones included lack of overcrowded extensive urban agglomerations, working at home or in small establishments, relatively good food supply, and stable social relationships. This observation has important implications in the current global situation because there are a number of low-income countries struggling with the problem of multi-drug resistant bacteria (World Health Organization, 2012). Our findings suggest that clinical endeavors and public health initiatives in these contexts should emphasize improving overall health, general nutrition, and living standards, as much—if not more so—developing and providing new drugs and treatment regimens.

Tuberculosis, however, does defy easy categorization into the shifting patterns of mortality characteristic to the second transition. This is because it is an infectious condition, but also a chronic disease which, like degenerative diseases, often does not manifest symptoms for many years. As such, the picture of a decline in infectious disease mortality in Zürich and of tuberculosis specifically in the early 20th century is not straightforward; instead the data suggest a combination of infectious and non-infectious causes producing mortality through a chronic and long-lasting process. Tuberculosis does have an infectious origin, but active disease is a result of an individual's inability to control the disease. Mortality from the disease gives us information about a combination of the levels of transmission, nutritional status and level of public health, but it is very difficult to split these factors during corresponding interpretations. However, this information is useful for providing a general overview of the population's ability to resist other infectious agents and as this increases, the second epidemiological transition is observed.

Part Three: Patterns of Tuberculosis in Other Swiss Cantons during the Second Epidemiological Transition and the Effect of Population Density

The results presented here suggest that tuberculosis mortality rates declined more rapidly in high population density cantons than in low-density cantons (from 1910 onwards), which may be due to progressive improvements in sanitation and changing strategies for handling tuberculosis patients which may be more effective in more crowded areas (as mentioned previously). However, high density areas also showed higher initial rates of tuberculosis mortality (during the years 1888 and 1900 specifically) likely due to poorer living conditions and increased human contact in these urban areas in comparison to low density rural areas.

These results further suggest that in 19th and 20th century Switzerland, living conditions exerted a substantial impact on mortality rates from tuberculosis, while medical interventions exerted less of an effect. Sanitation methods may have become effective in improving living conditions in high-density areas to make them comparable with lower density areas. The effect of good sanitation may result in a reduction of transmission of diseases because the population's immune systems are bombarded by infectious agents to a lesser extent than in the case of poor sanitation. With a lower level of infectious agents in the environment, accompanied by an increase in nutrition, the immune system of an individual will have a higher chance of controlling diseases. Additionally, outbreaks of specific diseases (e.g. cholera) will be less likely when there are fewer opportunities for the pathogens to be transmitted from one person to another. In the case of lower density areas, there are already fewer opportunities for the spread of pathogens. This has implications for developing nations, where a similar situation is currently present (poor living conditions, overcrowding and poor nutrition). Regions such as sub-Saharan Africa, South-East Asia and some countries in South America currently are considered high burden areas in terms of tuberculosis (World Health Organization, 2012). Consequently, improving the standard of living through sanitation (improving waste management and especially public health education) and reviewing and modifying how tuberculosis patients are handled could possibly be used to obtain the same effect as observed for Switzerland. Currently, many individuals are given antibiotic therapy for tuberculosis, but often do not finish the course of treatment (Tiemersma, van der Werf, Borgdorff, Williams, & Nagelkerke, 2011). This can be for a number of reasons including inability to obtain or afford the drugs, non-compliance (due to side effects) and lack of time to visit the clinic. However, there are obvious differences between modern developing nations and 19th and 20th century Switzerland including economical and geographical considerations. Thus it is impossible to predict the outcomes of improved sanitation, vaccination, and immunotherapy, but it should still be considered important to use all methods available to improve human health and combat a disease that has been a major cause of death for many years. In particular, sanitation and public health education have been very effective in reducing the mortality due to tuberculosis in Switzerland. Part of the gradual decline in tuberculosis mortality may be due to the country's attitude towards the disease. Many highly reputable sanatoria were built in Switzerland and people migrated from around the world to spend time in these establishments. Consequently, the Swiss population would have known about the disease and hygienic measures that aid in its treatment (Rucker & Kearny, 1913). Vaccination and drug therapy were introduced many years after the initial decline in tuberculosis, indicating that these are not necessary for the decline in tuberculosis mortality, though they do assist where implemented.

Limitations of the Study

There are several possible interpretive issues and limitations involved in analyses examining mortality and morbidity from tuberculosis in the second epidemiological transition. For instance, historical records, which are relied upon here, can be incomplete and biased through uneven distribution of ages or socioeconomic status (Doege, 1965; Rieder, Zwahlen, & Zimmermann, 1998). There may also be issues with the disease nomenclature, wherein certain diseases may be identified by several different cognates (e.g., phthisis) (Puranen, 1999). These issues may also lead to an inability to determine the actual cause of a disease in specific terms (i.e. the single disease which caused death) as well as whether an infectious agent was involved. In some cases, the nomenclature does not give us the opportunity to determine the cause of a disease as infectious or other. For this reason, we created the "organ" group to help remove this bias that would prevent us from giving an informative overview of the epidemiological transition in Switzerland. However, since the records employed here cover a time period after the modern nomenclature ("tuberculosis") had come into widespread use (1901 in Switzerland (Rucker & Kearny, 1913)), this issue likely did not substantially affect the results presented here. Difficulties with determining population size, and thus density, also present a possible limitation (see Antunes & Waldman, 1999), as both the population size and the geographical size of urban areas in Switzerland increased with urbanization throughout the mid to late 19th and 20th centuries. While the city of Zürich expanded substantially in 1893, the records employed begin at this time and thus it is unlikely to have affected the results presented here. Only data from the entire Canton of Zürich predate 1893 but no major increases in population size occurred across the whole canton before this time.

Another limitation is that much of the data employed here are derived from Zürich city only, and thus do not necessarily represent larger patterns within other cantons or Switzerland as a whole. This is however, also an advantage in that the death records are likely to be more complete as compared with an entire canton since the entire canton includes rural areas which may be overlooked during a census. Additionally, comparison of the results presented here with other literature regarding the second epidemiological transition showed that the trends observed in Switzerland are similar to what occurred in other countries, meaning our results can be extended to a wider area of Europe.

Comparison with the Literature

It is possible to compare evidence from Switzerland on tuberculosis mortality with that of numerous other nations for the period after 1870 because of the increased availability and completeness of data for this this period. Comparisons made between Switzerland and England or France, for instance, are useful because similar events (e.g. sanitation, improvements in public health) were occurring around the same time period at the same rate in these countries and therefore, any differences between them can be interpreted as being the result of differences in the country, such as culture and extent of urbanization and development. A comparison of Switzerland and Japan is also useful because the latter underwent urbanization later (at the end of the 19th century and early 20th century) and at a more rapid rate; thus the differences between the two countries can be used to give an indication of the impact of urbanization on tuberculosis mortality. In Switzerland, in 1901, tuberculosis mortality was 273 per 100,000 population for the entire country. Two countries, namely Hungary and France exhibited tuberculosis mortality rates above 300 per 100,000 in 1900 (**Figure 4**) (Johnston, 1995). Italy, Netherlands, Spain, United States, Denmark, England and Japan exhibited values closer to those of Switzerland, ranging between 160 and 199 per 100,000 (Gubéran, 1980; Johnston, 1995). Based on these comparisons, Switzerland has a higher tuberculosis mortality rate than many other countries in Europe (as well as the US). The reason for this could be a higher accuracy of historical records in Switzerland compared with other countries due to compulsory reporting of cases of tuberculosis. Another possibility is that Swiss cities did not grow in size until late in the 19th century. This is certainly true for Zürich; in 1893, the city expanded substantially and this would have had a major impact on the levels of overcrowding as immigrants had a larger area to migrate into. For cities such as London and Paris, their areas were defined earlier in the 19th century and thus public health and sanitation efforts were introduced into a well-known area.

Of these countries, mortality data for tuberculosis are also. available for several major cities (London, Paris and Tokyo). In 1900, tuberculosis mortality in Zürich city was 422 per 100,000 In Tokyo, it was 480 per 100,000 in 1900 (Johnston, 1995), and in London the tuberculosis mortality rate was estimated at 180 per 100,000 in 1891-1900 (Nathanson, 2007). Paris tuberculosis death rates were 173 per 100,000 (Preston & Walle, 1978). This comparison is useful because it shows that Zürich and Tokyo had similar, very high rates of tuberculosis mortality. London and Paris also had similar rates of mortality, but much lower than those of Zürich and Tokyo. Both Zürich and Tokyo had poor sanitation and hygiene around 1900, but Switzerland improved this situation at a faster rate than in Japan. This is because they both adopted different measures to help control tuberculosis. Switzerland initiated public health systems as well as sanitation and Japan used much cheaper methods of facilities (for the care of patients with tuberculosis) and public education (Johnston, 1995). The reason that both London and Paris have lower rates of tuberculosis mortality than either Zürich or Tokyo may be due to the fact the former had introduced Public Health Acts long before the latter did. England and Wales first introduced Public Health Acts in the 1840's (Szreter, 1988) and France in the 1850's (Preston & Walle, 1978). Thus, by 1900, both of these cities had improved living conditions when compared to Zürich and Tokyo, which did not introduce Public Health Acts until later, although Zürich introduced sewerage reforms earlier than Germany and England and Wales.

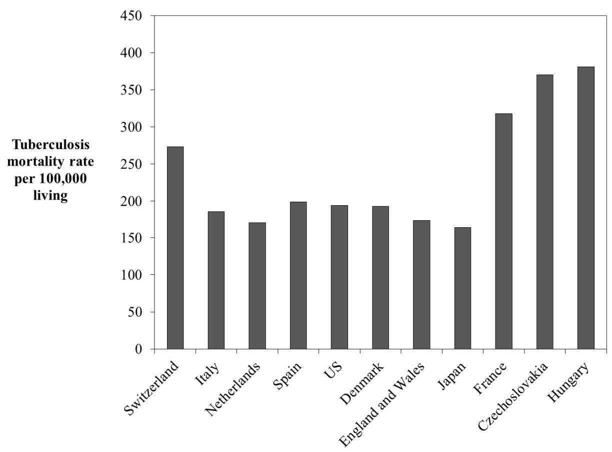

Figure 4.
Tuberculosis mortality rates per 100,000 living population for Switzerland and several other countries in the year 1900.

Over the 19th and 20th centuries, several major shifts were observed in tuberculosis mortality among developing nations undergoing the second transition. In most countries, tuberculosis mortality decreased through time in parallel with improvements in living conditions and sanitation. This is true for the US, where tuberculosis mortality declined in two stages: first during the first few years of the 20th century, and second between 1944 and 1950 (Doege, 1965). These two periods were associated with two different events; the introduction of sanitation and then later, specific drug therapy. Switzerland shows a decline equivalent to that in the US in the early 1900s, likely due to the same reasons of improving living conditions and public health campaigns. Data for the 1940's in Switzerland Gubéran (1980) reveal another similar trend to the US. During WWII, tuberculosis mortality rates remained stable, but later when the war had ended and streptomycin was introduced, the rate declined substantially. Declines in tuberculosis mortality have also been documented for Great Britain starting from the 1830's due to the introduction of a large number of Public Health Acts (Szreter, 1988). In contrast, data suggest that Japan experienced high mortality from tuberculosis starting around 1895 and 1900, and extending to after WWII (Johnston, 1995). Antibiotics and other medical interventions (e.g. surgery, other chemical agents) were introduced after the war and this was responsible for almost all of the decline in tuberculosis mortality in Japan. Rather than shifts in the disease nomenclature and diagnostic accuracy for tuberculosis, declines in tuberculosis mortality have also been described in low-income countries undergoing industrialization and the second transition later during the 20th century, such as Brazil, which witnessed major declines in mortality rates in São Paulo between 1945 and 1985 (Antunes & Waldman, 1999). However, in Brazil and other low-income nations, the transition was facilitated by medical interventions, such as antibiotics, as well as by improvements in living conditions and public health (Omran, 2005).

Changes in the age distribution of tuberculosis mortality have also been discussed for high-income nations undergoing industrialization and the second transition in the 19th and 20th centuries. For instance, Preston and Walle (1978) showed that in urban areas of France, such as Marseilles, Paris, and Lyon, tuberculosis mortality was highest in young adults (20 to 29 years) but changed to older age groups (30 to 39 years) through the 19th century (1816-1882). Doege (1965) showed that for the US this trend was also observed from 1900 to 1960 and not simply attributable due to an increase in life expectancy, but rather due to a change in the manifestation of tuberculosis across age groups. Tuberculosis was becoming a disease of the elderly and remained latent in younger individuals before reactivation later in life. Additionally, the average age of fatal tuberculosis increased in the US from 34.4 years in 1900 to 58.1 years in 1960 (Doege, 1965). While age information is not available for Zürich, life expectancy did increase in Switzerland over the time period 1893 to 1933 (**Figure 1**) while tuberculosis mortality decreased. Additionally, one study by Gubéran (1980) for Switzerland as a whole showed that older age groups were more commonly affected by tuberculosis through time for the studied period: 1875 to 1935. This may indicate that living conditions and health of children and young adults improved such that older individuals were far more affected by the disease due to lowered immunity in later life (Omran, 2005). This theory supports the other data presented here, suggesting that tuberculosis mortality decreases with improvement in living conditions.

Some studies have also found sex-based differences in tuberculosis mortality for some high-income industrializing countries undergoing the second transition. Data on sex in relation to tuberculosis mortality in Switzerland are largely unavailable, but Gubéran (1980) has demonstrated that for the country as a whole, females aged 15 to 29 years had a higher mortality rate than did their male peers between 1900 and 1960. Similar patterns have been found in the US and Japan (Doege, 1965; Johnston, 1995).

Several reasons for the decrease in tuberculosis mortality through time during the 19th and 20th centuries in many countries have been suggested. For instance, Miller and Thompson (1992) describe some criteria that assisted in the control and prevention of tuberculosis in Newcastle, Britain around the year 1907. These included compulsory notification of tuberculosis, sanatoria, building of hospitals and dispensaries, prevention of infection of the lungs and abdominal tract, education, and establishment of a national health authority. Other authors agree with these suggestions and describe them in relation to their own work on different countries. Preston and Walle (1978) reported that urban areas in France had poorer living conditions than the rest of the country as a whole. They additionally suggested that water supply, public health, and hygiene all must be controlled for a decrease in tuberculosis mortality to occur. This did occur in France during the late 19th and early 20th centuries. They highlighted that medicine, including vaccination, surgery and drug therapy, was not important in the decline of tuberculosis in France. This was also true for the US (Doege 1965) during the initial decline in the early 1900s. However, antibiotics were responsible for the secondary decline between 1944 and 1950. In São Paulo (Antunes & Waldman, 1999), the situation was slightly different, with tuberculosis mortality rates remainning high until after WWII. Reasons for the decline there included, besides the most important medication, preventative and therapeutic measures (such as public education, antibiotics, surgical interventions and a general increase in immunity through improvements in nutrition and living conditions), increased provision of health services (e.g. more clinics), and social changes (e.g. how the population interacted with one another, avoiding contact with others when they were contagious). However, recently the tuberculosis mortality rate has begun to increase again at an exponential rate, most likely alongside the growing HIV/AIDS problem in Brazil.

The situation in Japan (Johnston, 1995) is similar to what occurred in Brazil (Antunes & Waldman, 1999). Antibiotics to combat tuberculosis were not available until after 1950 but after that date were an important factor in the decline. Before this, the Japanese used facilities (such as sanatoria and specialist hospitals) and health education in order to combat the disease. While these measures are less expensive than social and economical changes, they are also less effective (Johnston, 1995). In Japan, transmission of the disease was mostly due to female industry workers returning to their homes in rural locations from urban areas and from migrating soldiers. Both of these groups were exposed to poor living conditions and thus were more likely to develop active tuberculosis. Finally, Szreter (1988) presents a series of arguments demonstrating that both improved nutrition and various public health measures were responsible for the historical decline in Great Britain. Szreter (1988) also mentions the numerous Public Health Acts in England and Wales that would have impacted living conditions. They also highlighted how nutrition is important, but so are a number of other factors including overcrowding, lack of sunlight, ventilation and occupational hazards (e.g. dust and smoke), all of which were common problems in the initial stages of industrialization.

In Switzerland, many of these factors did play some role in the decline of tuberculosis through time. Living conditions improved substantially during the second half of the 1800's, following the first sewerage reform in 1866. Public Health services were excellent (e.g. many hospitals, well-educated medical personnel) in Switzerland and contributed to the overall high quality of life in Swiss cities, which experienced few health disadvantages as observed in other countries. Industrialization did not affect Switzerland as negatively as other countries, due to some unique characteristics of the economy, such as the small number of factories and production centered within the home, and the slow growth of urban centers.

Conclusion

From these descriptions, it is clear that prior to chemical therapy and antibiotics, a series of factors were important in the decline of tuberculosis mortality through time. No single factor could be pointed out, but rather a combination of improved living conditions as well as public health changes was ultimately responsible for the decline in Switzerland. This is also true for other countries, but Switzerland is unique in that it was neutral during the years when conflict was common and has had a stable government since 1848. This allowed the second epidemiological transition to occur quickly and earlier than in other countries. This knowledge could be implemented in the high burden countries at present and consequently reduce mortality from tuberculosis in these areas, just as it occurred in Switzerland and other countries, many years ago. Many of these countries are currently undergoing the third epidemiological transition, characterized by an increase in the drug resistance of the tuberculosis bacterium. This limits the usefulness of medicine as a method of therapy. Instead, consideration of the ideas and practices employed by the Swiss and later, in other areas in Europe, may present another viable option for treatment, prevention, and ultimately reducing the global burden of tuberculosis.

Acknowledgements

Information derived from historical records was accessed at the StadtArchiv & Staatsarchiv (Zürich) and the staff at these organizations should be acknowledged for their assistance with locating the records of interest.

This research is supported by the Australian Postgraduate Award, Dorothy and Walter Duncan Trust Award, School of Medical Sciences Postgraduate Travel Award, Research Abroad Scholarship, Faculty of Health Sciences Postgraduate Travelling Fellowship, The University of Adelaide and the Mäxi Foundation Zürich.

REFERENCES

Antunes, J. L. F., & Waldman, E. A. (1999). *Tuberculosis in the twentieth century: Time-series mortality in São Paulo, Brazil, 1900-97* (pp. 463-476). Rio de Janeiro: Cadernos de Saúde Pública.

Bourdelais, P. (2006). *Epidemics laid low: A history of what happened in rich countries*. Baltimore: The Johns Hopkins University Press.

Bouvier, N., Craig, G. A., Gossman, L., & Schorske, C. E. (1994). *Geneva, Zurich, Basel: History, culture and national identity*. Princeton, NJ: Princeton University Press.

Burke, S. D. A. (2011). Tuberculosis: Past and present. *Reviews in Anthropology, 40,* 27-52.

Butler, M., Pender, M., & Charnley, J. (Eds.) (2000). *The making of modern Switzerland, 1848-1998*. London: Macmillan Press Ltd.

Canton of Zürich (2012). Staatsarchiv. URL (last checked 7 September 2012).
http://www.staatsarchiv.zh.ch/internet/justiz_inneres/sta/de/home.html

Carter, K., Soakai, T. S., Taylor, R., Gadabu, I., Rao, C., Thoma, K., & Lopez, A. D. (2011). Mortality trends and the epidemiological transition in Nauru. *Asia Pacific Journal of Public Health, 23,* 10-23.

Cole, S. T., Eisenach, K. D., McMurray, D. N., & Jacobs Jr., W. R. (Eds.) (2005). *Tuberculosis and the tubercle bacillus*. Washington DC: ASM Press.

Condran, G. A., & Cheney, R. A. (1982). Mortality trends in Philadelphia: Age- and cause-specific death rates 1870-1930. *Demography, 19,* 97-123.

Condrau, F., & Tanner, J. (2000). Working-class experiences, cholera and public health reform in nineteenth-century Switzerland. In S. Sheard, & H. Power (Eds.), *Body and city: Histories of urban public health* (pp. 109-122). Farnham: Ashgate Publishing Ltd.

Corbett, E. L., Watt, C. J., Walker, N., Maher, D., Williams, B. G., Raviglione, M. C., & Dye, C. (2003). The growing burden of tuberculosis: Global trends and interactions with the HIV epidemic. *Archives of Internal Medicine, 163,* 1009-1021.

Doege, T. C. (1965). Tuberculosis mortality in the United States, 1900 to 1960. *Journal of the American Medical Association, 192,* 1045-1048.

Dormandy, T. (1999). *The white death: A history of tuberculosis*. London: The Hambledon Press.

Gesetzgebung: Zürich (1928). *Request of the City Council: Adoption of rules on housing inspection*. Zürich

Graber, P. (1926). *Concerning the wheat monopoly in Switzerland* (Vol. 3). Geneva: French University Press.

Gubéran, E. (1980). Mortality trends in Switzerland 2. Infectious Diseases 1876-1977. *Swiss Medicine Weekly, 110,* 574-588.

Gwillim Law (2009). Switzerland cantons. URL (last checked February 2011). http://www.statoids.com/uch.html

Herzog, H. (1998). History of tuberculosis. *Respiration, 65,* 5-15.

Johnston, W. (1995). *The modern epidemic: A history of tuberculosis in Japan*. Cambridge, MA: Harvard University Press.

Kaufmann, S. H. E., & Britton, W. J. (Eds.) (2008). *Handbook of tuberculosis: Immunology and cell biology*. Weinheim: Wiley-VCH.

Krasner-Khait, B. (2011). History magazine—The impact of refrigeration. URL (last checked 21 January 2011).
http://www.history-magazine.com/refrig.html

Lemann, M. F. (2008). *Waste management*. Bern: Peter Lang.

Lewis, M., Taylor, R., & Powles, J. (1998). The Australian mortality decline: All-cause mortality 1788-1990. *Australian and New Zealand Journal of Public Health, 22,* 27-36.

Miller, F. J., & Thompson, M. D. (1992). Decline and fall of the tubercle bacillus: The Newcastle story 1882-1988. *Archives of Disease in Childhood, 67,* 251-255.

Nathanson, C. A. (2007). *Disease prevention as social change: The state, society, and public health in the United States, France, Great Britain, and Canada*. New York: Russell Sage Foundation.

Newsom, S. W. B. (2006). The history of infection control: Tuberculosis: Part two—Finding the cause and trying to eliminate it. *British Journal of Infection Control, 7,* 8-11.

Newsom, S. (2006). The history of infection control: Tuberculosis, part one: Defining a disease and its social consequences. *British Journal of Infection Control, 7,* 14-17.

North, R. J., & Jung, Y. J. (2004). Immunity to tuberculosis. *Annual Review of Immunology, 22,* 599-623.

Omran, A. R. (1983). The epidemiologic transition theory. A preliminary update. *Journal of Tropical Pediatrics, 29,* 305-316.

Omran, A. R. (2005). The epidemiologic transition: A theory of the epidemiology of population change. *Milbank Quarterly, 83,* 731-757.

Preston, S. H., & Walle, E. van de (1978). French mortality in the nineteenth century. *Population Studies, 32,* 275-297.

Puranen, B. (1999). Tuberculosis and the decline of mortality in Sweden. In R. Schofield, D. Reher, & A. Bideau (Eds.), *The decline of mortality in Europe* (pp. 97-117). New York: Oxford University Press.

Remak, J. (1993). *A very civil war: The Swiss Sonderbund War of 1847*. Boulder, CO: Westview Press, Inc.

Rieder, H. L., Zwahlen, M., & Zimmermann, H. (1998). Mortality from respiratory tuberculosis in Switzerland. *Sozial- und Präventivmedizin/ Social and Preventive Medicine, 43,* 162-166.

Ritzmann-Blickenstorfer, H. (1996). *Historische statistik der Schweiz [Historical Statistics of Switzerland]*. Zürich: Chronos Verlag.

Roberts, C. A., & Buikstra, J. (2003). *The Bioarchaeology of tuberculosis: A global view on a reemerging disease*. Gainesville, FL: University Press of Florida.

Rucker, W. C., & Kearny, R. A. (1913). Tuberculosis in Switzerland: Results of the campaign against the disease. *Public Health Reports (1896-1970), 28,* 2815-2829.

Schoch, T., Staub, K., & Pfister, C. (2011). Social inequality and the biological standard of living: An anthropometric analysis of Swiss conscription data, 1875-1950. *Economics and Human Biology,* in Print.

Siegenthaler, J. K. (1972). A scale analysis of nineteenth-century industrialization. *Explorations in Economic History, 10,* 75-107.

Smith, F. B. (1988). *The retreat of tuberculosis 1850-1950*. New York: Croom Helm Ltd.

Stadt, Z. (2012). Stadtarchiv—Stadt Zürich. URL (last checked 7 September 2012).
http://www.stadt-zuerich.ch/content/prd/de/index/stadtarchiv.html

Stead, W. W. (2001). Variation in vulnerability to tuberculosis in America today: Random, or legacies of different ancestral epidemics? *International Journal of Tuberculosis and Lung Disease, 5,* 807-814.

Steinberg, J. (1996). *Why Switzerland?* (2nd ed.). Cambridge: Cambridge University Press.

Szreter, S. (1988). The importance of social intervention in Britain's mortality decline c. 1850-1914: A re-interpretation of the role of public health. *The Society for the Social History of Medicine, 1,* 1-38.

The National Archives. (2012). 1834 Poor Law. URL (last checked 7 September 2012).
http://www.nationalarchives.gov.uk/education/lesson08.htm

Tiemersma, E. W., van der Werf, M. J., Borgdorff, M. W., Williams, B. G., & Nagelkerke, N. J. D. (2011). Natural history of tuberculosis: Duration and fatality of untreated pulmonary tuberculosis in HIV negative patients: A systematic review. *PloS ONE, 6(4),* e17601.

Vögele, J. (1998). *Urban mortality change in England and Germany, 1870-1913*. Liverpool: Liverpool University Press.

Waddington, K. (2004). To stamp out "So Terrible a Malady": Bovine tuberculosis and tuberculin testing in Britain, 1890-1939. *Medical History, 48,* 29-48.

Warren, P. (2006). The evolution of the sanatorium: The first half-century, 1854-1904. *Canadian Bulletin of Medical History, 23,* 457-476.

Wilbur, A. K., Bouwman, A. S., Stone, A. C., Roberts, C. A., Pfister, L. A., Buikstra, J. E., & Brown, T. A. (2009). Deficiencies and challenges in the study of ancient tuberculosis DNA. *Journal of Archaeological Science, 36,* 1990-1997.

Wilbur, A. K., Farnbach, A. W., Knudson, K. J., & Buikstra, J. E. (2008). Diet, tuberculosis, and the paleopathological record. *Current Anthropology, 49,* 963-991.

Wilson, L. G. (2005). Commentary: Medicine, population, and tuberculosis. *International Journal of Epidemiology, 34,* 521-524.

Wolleswinkel-van den Bosch, J. H., Looman, C. W., Van Poppel, F. W., & Mackenbach, J. P. (1997). Cause-specific mortality trends in The Netherlands, 1875-1992: A formal analysis of the epidemiologic transition. *International Journal of Epidemiology, 26,* 772-781.

World Health Organization (2012). WHO tuberculosis. http://www.who.int/topics/tuberculosis/en

