Homo 75/1 (2024), 9–39
J. Comp. Hum. Biol.
Published EarlyAccess October 21, 2024, published online November 2024

Review Article

Breathing time: a longue-durée multidisciplinary study of respiratory illnesses and airborne diseases in Switzerland (16th–21st century CE)

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With 11 figures

Abstract: This research is the first of its kind to assess the impact of respiratory illnesses and airborne diseases (acronymized as "RIAD" hereafter) on Swiss mortality in the long run, between the 16th and the 21st century CE. It reviews historical, demographical, statistical, medical, and bioarchaeological, primary and secondary data originating from archive material or previously published specific analyses into the topic (n = 55). An innovative intersectional and multidisciplinary approach was developed in order to apprehend, collect, organize, and analyze data stemming from several different disciplinary fields. Through this approach, this research endeavors to answer the following questions: 1) what are the social and environmental factors guiding the risk or not of suffering from RIAD, 2) do these factors appear to be constant on a territorial scale and through time, 3) can the evolution of RIAD occurrences be correlated to the local history of a particular region? And 4) does a better understanding of RIAD dynamics in the past allow us to draw any useful lessons for their future sustainable management?

Accordingly, collected raw data were converted and normalized into crude mortality, natality, and RIAD mortality rates per thousand individuals and subsequently set within the demographic and epidemiological transition model. This model serves as a relevant reading grid for the understanding of the pathological and demographic evolutions that this study highlights. Indeed, this data compilation effort enabled to reconstruct crude birth and death rates for Switzerland from 1580 CE to the present day and to present the latter in graphical form. This graphical presentation is a breakthrough in the field of RIAD research in Switzerland and further enabled to assess internal data coherence and trend evolutions by means of joinpoint regression analysis.

Main results include the confirmation of the considerable impact of industrialization on the respiratory health of peri-alpine populations. They also underline the selective and versatile nature of the pressure exerted by respiratory diseases on specific socio-economic and demographic classes, whose composition has varied through time.

This research was impeded by the uneven quality of the available sources. Nonetheless, it still provides a robust outlook on the longue-durée evolution of respiratory health. The obtained results might thus be of interest to a wide array of scholars active in the study of respiratory diseases through time, but also clinicians and health policy makers, as this study highlights particular aspect of the current health situation, and the future worldwide challenges posed notably by global urbanization, with regard to respiratory health issues.

Future research could develop similar approaches in neighboring regions, or focus on specific types of RIAD, in order to contrast other local pathological signatures with the one presented in this manuscript.

Keywords: palaeopathology; palaeoepidemiology; palaeodemography; literature survey; historical archives; urbanism; industrialization

DOI: 10.1127/homo/2024/1797
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1 Introduction and background

The ensemble of diseases that can be regrouped into one umbrella category of “respiratory diseases and airborne illnesses” (acronymized as “RIAD” hereafter) represent a key component of human health and mortality. Such health issues can be roughly sorted into non-specific conditions (for instance (chronic) sinusitis, mastoiditis, otitis, chronic obstructive pulmonary disease (COPD), diffuse parenchymal lung disease (DPLD), pleurisy, asthma, and pneumonia) or specific manifestations (such as leprosy (Hansen’s disease), tuberculosis, smallpox, measles, scarlet fever, mumps, diphtheria, pertussis, rubella, varicella and croup). These conditions mainly fall into the following International Classification of Diseases (“ICD-11”) categories (WHO 2023): 1A00-1H0Z (Certain infectious or parasitic diseases), AA00–AC0Z (Diseases of the ear or mastoid process) and CA00-CA0Z (Upper respiratory tract disorders), CA20-CA2Z (Certain lower respiratory tract diseases), CA40-CA4Z (Lung infections), CA60-CA8Z (Lung diseases due to external agents) and CA00–CB7Z (Diseases of the respiratory system). Several of these conditions are listed amongst leading causes of illness and death worldwide. While RIAD may appear as a somewhat heterogeneous ensemble, it nevertheless constitutes this research’s primary response to the problem raised by C. Rosenberg (1989), regarding the ever-changing and shifting nature of medical classifications over time, as knowledge of a disease is refined or new links between symptoms and causative agents are discovered. Indeed, numerous studies have demonstrated the value of studying long-term evolutions of clustered groups of diseases which encompass diverse aetiologies, physiopathological courses and diagnoses; such as cardiovascular diseases (CVDs) for instance (Roth et al. 2015; Ritchey et al. 2020). These clustered analyses represent powerful tools to identify large-scale epidemiological trends and their links to specific socio-historical contexts (pandemics, urbanization and industrialization, wars, migration, medical developments, etc.). However, the development of a historically informed epidemiological perspective necessarily also requires a close understanding of how our predecessors might have apprehended a given pathological manifestation, and how they classified it. At the same time, such interdisciplinary work requires harmonization of definitions. For instance, medical diagnostic finesse cannot be replicated by the study of historical sources or human bone remains (cf. *infra*). The proposed study category of RIAD takes these limitations into account, as it provides an overarching classification of respiratory diseases that can be applied not only in the field of medicine (particularly in epidemiological research), but also in historical and bioarchaeological studies, and thus enables a comparison between these different disciplines.

In this sense, according to figures published by the Institute for Health Metrics and Evaluation (IHME) of the University of Washington in 2017 (IHME 2017), close to 7% of the world’s population suffers from RIAD (WHO 2017), while data published by the Forum of International Respiratory Societies in 2021, reveals that COPD alone, affects 200 million people and kills 3.2 million per year, while tuberculosis affects 10 million people and causes 1.4 million deaths per year. Finally, lower respiratory tract infections are responsible for more than 2.4 million deaths per year and remain a primary cause of child mortality (FIRS 2021). It is further to be noted that, as highlighted either by the One Health Concept of the World Health Organization (WHO 2017) or recent academic research into occupational lung diseases (Devinck & Rosental 2009; Rosental 2009; Sauler & Gulati 2012; Cullinan et al. 2017), respiratory health is not a mere medical indicator. Rather, it represents a complex notion, known to be tightly correlated to socio-economic, environmental, working, living and sanitary framework conditions (Barnouin & Sache 2011; Sauler & Gulati 2012; Cullinan et al. 2017; Yaussy et al. 2016; Yaussy 2019; Betsinger & DeWitte 2020). Understanding respiratory health thus means to apprehend the complex interplay of all these factors, in order to develop a comprehensive approach of their respective imprints on human communities, which in turn will allow to meaningfully and proactively manage ongoing and future health challenges (Lewis et al. 1995; Hays 2005, 2007; WHO 2005, 2021; Perrenoud 2012; Ferkol & Schraufnagel 2014; Lindahl & Grace 2015; Yaussy et al. 2016; Yaussy 2019; Betsinger & DeWitte 2020; Condrau 2020; Labaki & Han 2020; Vuilleumier 2020; Mackenbach 2021).

Accordingly, this study aims to develop an intersectional longue-durée and multidisciplinary assessment of RIAD in Switzerland between the 16th and the 21st century CE (note that all further dates, unless specified, refer to the Current Era (CE) as well). More precisely, this study endeavors to answer the following questions: 1) what are the social and environmental factors guiding the risk or not of suffering from RIAD, 2) do these factors appear to be constant at the scale of a territory and through time, and 3) can the evolution of the RIAD occurrences be correlated to the local history of a particular region? 4) does a better understanding of RIAD dynamics in the past allow us to draw any useful lessons for their future sustainable management?

As pointed out above and as previous research into similar topics have highlighted, to infer on past populations and their health dynamics proves to be an arduous, bias-laden exercise; regardless of the envisaged disciplinary approach (Bintlìjf & Sbonias 1999; Wheldon et al. 2013; Voutilainen et al. 2020). Indeed, both historians and ancient demographers will deplore the often fragmentary, discontinuous, chronologically disparate, non-inclusive, and non-exhaustive nature of the ancient source corpuses at their disposal. In sum, the bulk of historical sources often reflect population samples whose own statistical or even qualitative representativeness remains difficult to assess (Bintlìjf & Sbonias 1999; Wheldon et al. 2013; Voutilainen et al. 2020). Medical doctors and palaeopathologists, on their part, are confronted with the evolution of their disciplines and associated terminological shifts, with the lack of reliability and precision of ancient diagnoses and the continuous renewal of the viral-bacterial reservoir and related diseases, rendering a strict comparison of precise causes of death through time rather difficult (Fernández 2012; Gruber et al. 2012; Rühli et al. 2016; Grauer 2018). Finally, archaeologists and bioanthropologists face the problem of the scarcity and uneven chronospatial distribution of relevant ancient remains, as well as their variable state of conservation and taphonomic alteration (Paunier 2019; Vanmoerkerke 2020). Moreover, human bone specialists also see their potential analytical scope reduced due to the inherently limited diagnostic accuracy resulting from the study of dry bones, as well as by the osteological paradox; a theorem that questions the value of observing a given pathology in a skeletonized individual. This is due, on the one hand, to the fact that skeletal lesions are not easily imputable to a specific disease, especially in the case of respiratory diseases (Lee et al. 2024), and on the other hand, because certain individuals will die before even developing osteological lesion of a specific disease. Further, the presence of a given lesion is – in itself – not necessarily proof of the fatal course of a disease, nor does it inform on the potential presence of other lethal soft-tissue wounds (Wood et al. 1992; Siek 2013).

2 Material and methods

2.1 Study design

In an effort to avoid some of the said biases and interpretative pitfalls affecting the value of any analysis drawn from a heterogeneous corpus of historical, medical, or archaeological data, this article proposes an innovative, robust, feedback-generating, and integrative approach in response to this old problem. In order to analyze RIAD in the past, the following approach draws on a multidisciplinary and translocal analysis of a given region (Switzerland). It takes into consideration the fact that different RIAD cannot necessarily be clearly told apart by the diverse ancient datasets at our disposal (from dry human bones to past archives and medical studies). By grouping all RIAD together, however, they can be contrasted with other causes of death in a significant insight-providing manner. The proposed approach thus features three different procedures to bypass the exposed biases, all of which have been previously mobilized individually by various researchers, but never brought together in a holistic joint approach (Perrenoud & Sardet 1991; Wanner 2002; Schumacher & Oris 2011; Rosental 2017; Lunny et al. 2021).

Thus, representativeness, relative and absolute value issues of secular statistical and archival data are to be overcome by considering, on the one hand, a longue-durée plurifocal approach (16th–21st century) taking into account n = 5 localities (Geneva, Bern, Neuchâtel, Lausanne and Bière) and the modern Swiss nationwide statistical database (Swiss Federal Statistical Office (SFSO)). This enabled to compare, contextualize and generate feedback on the available data. On the other hand, by contrasting a total of six, partially overlapping, successive demographic and statistical series providing information on population dynamics within different demographic samples. The point here is to compile these data into comparable successive chronological series (in the form of standardized crude natality, mortality and RIAD mortality rates expressed per thousand individuals), and check their internal and external coherence, but also to apprehend their trend evolution. This approach provides data sets whose relative values concur in a statistically demonstrable way and whose values can be mathematically tested for significant trend changes. To solve the medical problem of the comparative value of old cause of death diagnoses, a diagnostic and classificatory scale modification is proposed. Since one cannot distinguish precisely – on an ancient documentary basis as well as on the palaeopathological level – between the main types of RIAD, these various conditions are combined into a single generic set, which groups all diseases affecting the respiratory tract, or whose primo-infection occurs within this interface. This categorization allows to distinguish and compare the incidence rate of RIAD with other distinct classes of causes of death (circulatory system failure, metabolic complications, accidents, etc.). Finally, it also partially solves the problem of palaeopathological diagnosis, since most osteological markers are non-specific in nature and may well be the result of several different RIAD.

RIAD constitute an intersectional record of great value for the understanding of past health dynamics (Fig. 1), and *a fortiori* present and future populations (Le Roy Ladurie 1973; Yaussy et al. 2016; Yaussy 2019; Perrenoud 1989, Perrenoud & Sardet 1991, Perrenoud 1993a; Rosental 2017). Hence, this article proposes to exemplify this record by applying the presented methodology to the study of the evolution of RIAD in Switzerland, between the 16th and the 21st century CE. These chronospatial limits stem from the fact that Switzerland represents a pertinent region wherein to study the evolutionary and transmission dynamics animating RIAD (Binz 1963; Eckert 1978; Perrenoud 1979, 2012). This is due to its central location within Europe, its mercantile links with neighboring regions and its situation on major passageways through the Alps. Further, Switzerland also displays a clear demographic transition, from a scarcely urbanized landscape to denser populated urban centers during the 18th century. Until then, most of the Swiss population resided in rather modest-sized agglomerations on the Swiss Plateau, nestled in between the Jura and Alpine reliefs (Fig. 2). This state of facts provides a convenient chronological cut-off point for the local onset of urbanization (Binz 1963; Eckert 1978; Perrenoud 1979, 2012).

In palaeopathological terms, focus was set on the identification of publications considering, exploring and describing specific anatomical regions and morphological alterations

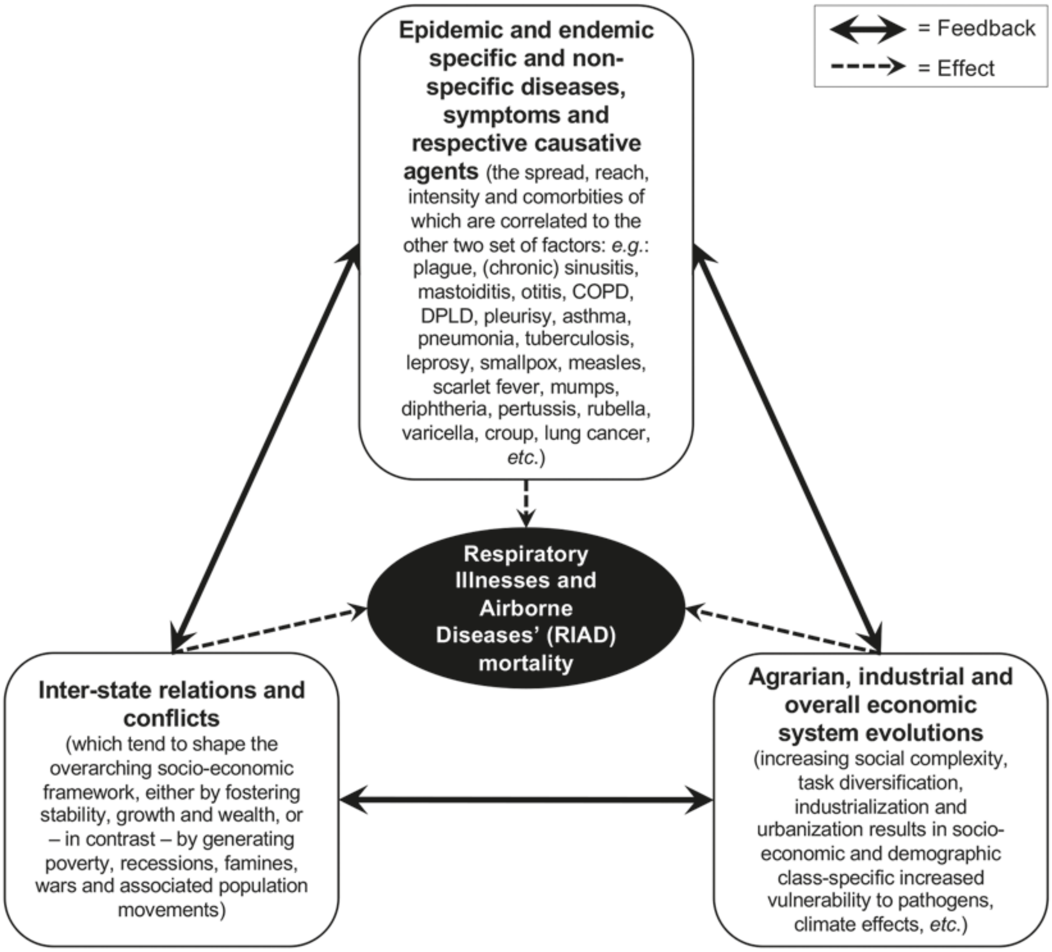


Fig. 1. Interpretative scheme showing the main effect and feedback interactions shaping the intersectionality of respiratory illnesses and airborne diseases (RIAD) considered within this study: 1) Epidemic and endemic specific and non-specific diseases, their symptoms and respective causative agents, 2) Inter-state relations and conflicts and 3) Agrarian, industrial and overall economic system evolutions. These three sets of factors interplay and eventually shape the respiratory pathological record of the communities under study across time and space. Indeed, the various diseases listed, whether of strictly respiratory nature or not, present certain comorbidities with the category of RIAD, and as such are themselves subject to wider constraints, dictated in particular by agrarian, industrial and overall economic system evolutions, as well as inter-state relations and conflicts. Figure by authors, based on data by Perrenoud (1989).

therein (through different methodological approaches); all of which have been acknowledged as representing potential markers of RIAD:

– Macroscopically and endoscopically observable alterations to the morphology of the maxillary sinuses' walls resulting from chronic maxillary sinusitis (CMS), according to criteria established by Boocock et al. (1995a/b).
– Alterations (observable through endoscopy and µCT-scanner) affecting the structures composing the auditory canal as described (according to a presence/absence criterion) by Mays & Holst (2006) in the case of cholesteatoma of the external and middle ear, Floreanova et al. (2020) for assessing changes to the bony structures of the middle ear due to otitis media, and Dalby et al. (1993) for the assessment of otosclerosis and auditory ossicle fixation.
– Radiologically observable alterations to the morphology of the mastoid cells of Lenoir, as described by Purchase et al. (2019).
– Macroscopically observable alterations and osteological implications of leprosy detailed by Roberts in *The International Textbook of Leprosy* (2018) and further detailed by Andersen & Manchester (1992), Robbins et al. (2009) and Suzuki et al. (2012)
– Macroscopically observable alterations and osteological implications of tuberculosis on the cranium and postcranial skeleton, as described by Stones & Schoeman (2004), Singh & Dutta (2006), Ravikanth et al. (2017) and Müller (2013) and Dangvard Pedersen et al. (2019).
– Macroscopically observable inflammatory periosteal reaction on the ribs, subsequent to episodes of lower

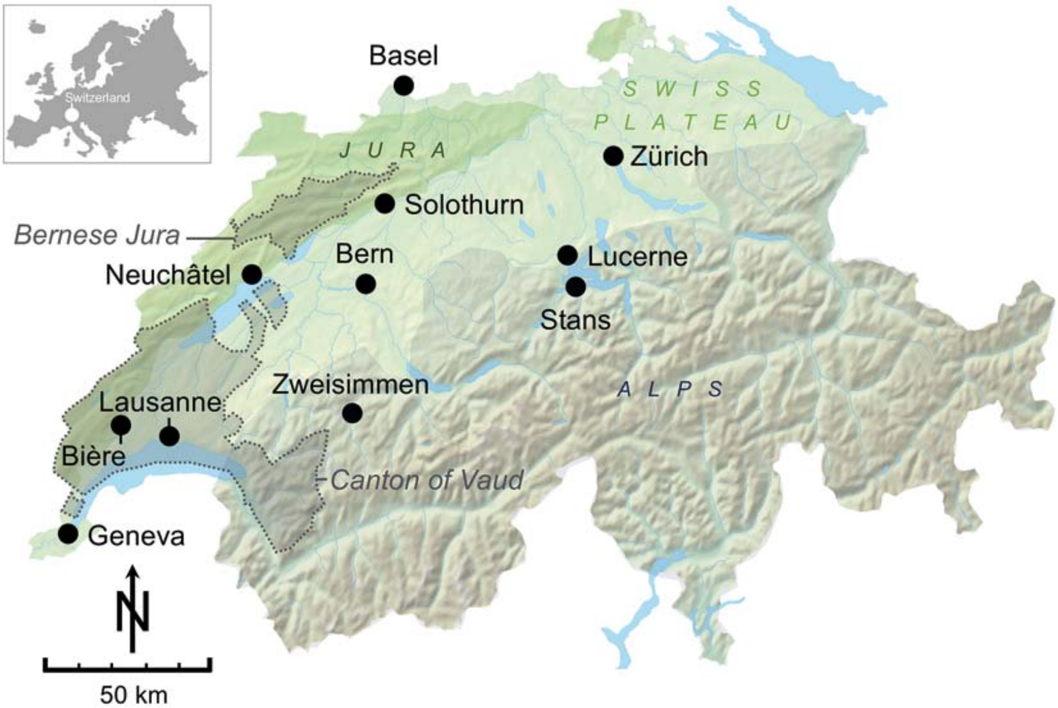


Fig. 2. Map of Switzerland showing main regions and places mentioned in text. Black dots: cities and villages, contoured shaded areas: regions, colored areas: main topographical environments of Switzerland. Figure by authors, based on a vector image by Swiss Federal Office of Topography (2022).

respiratory tract disease, as detailed by Davies-Barrett et al. (2019).

2.2 Corpus constitution procedure

The chronospatial and multidisciplinary focus of this study called for a certain degree of inventiveness in order to compile the literature body on which it draws. Therefore, this research sought to develop a historiographical overview by: 1) drawing on a selection of published and unpublished scholarly works obtained through various means, starting with library work, extended through associated Google Scholar queries and bibliographical screening of the retained works; 2) examining original archival material in order to check the information provided in the aforementioned scholarly literature, as well as complete it when the data was insufficient. While the resulting corpus may appear somewhat heteroclite in nature, the updated PRISMA guidelines for the reporting of systematic reviews were followed as closely as possible (Page et al. 2021), to ensure a certain degree of representativeness and repeatability to this study. It is noteworthy that adhering to the PRISMA guidelines could prove to be of great interest with regard to the comparability of future studies on the topic as well. In this sense, the present study corpus was constituted as follows (Fig. 3 and Supplementary Files: Tables 1–4):

1. Collection and analysis of secondary literature:
   – Firstly, scholarly publications (scientific journals, academic works, curatorial notes, books, electronic postings, etc.) which dealt with the issue of the evolution of RIAD, or the retained archival material, were identified. Their study aimed to understand, contextualize, and apprehend the said archival series and previous research published on the matter. This approach allowed to retain n = 12 relevant publications, out of a total of several hundred. This selection was based on the following criteria: topical relevance of the item with respect to the archival material, clarity of the primary data and results, and repeatability degree of the proposed analyses and interpretations. In parallel, trilingual (English, French and German) Google Scholar queries with the search terms presented in Table 1, in threefold association, without Boolean operators, were performed. In each query, the first n = 10 results provided by the default algorithm search parameters, were considered. This allowed to further integrate n = 9 publications into the corpus. To ensure result saturation, the bibliographies of the said publications, were also also checked, a step which allowed to retrieve n = 2 additional relevant publications.
   – Secondly, medical publications focusing on mortality trends over time in Switzerland, were identified.

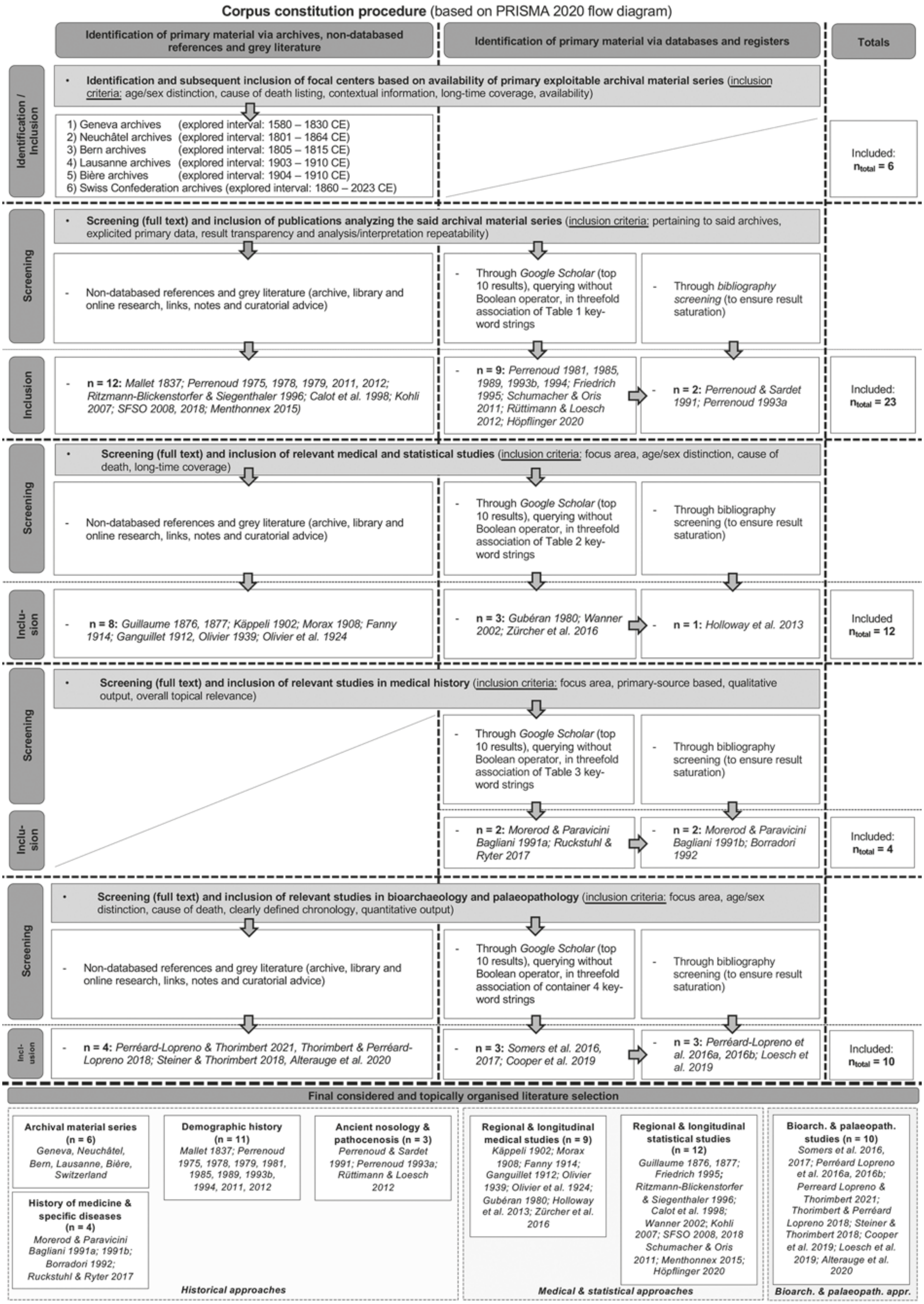


Fig. 3. Method of constitution and classification scheme of the literary corpus selected for the elaboration of the present article (according to the PRISMA 2020 flow diagram). Figure by authors.

For these writings, the following inclusion criteria were considered: age and sex discriminated data, documented causes of death within the reported time range and overall chronological span. This approach allowed for the inclusion of another n = 8 productions. This search was completed via Google Scholar queries with the keywords contained in Supplementary Files: Table 2. This allowed for the inclusion of n = 3 additional publications. Through bibliographical screening, n = 1 further publication could be included in the study.
- Thirdly, publications dealing with medical history in the region and chronology of interest were sought. After a preliminary archival and bibliographical survey, no such publications or grey literature could be identified. Therefore, Google Scholar queries were launched instead, using the keywords contained in Supplementary Files: Table 3, without Boulean operators. By selecting only publications strictly based on tangible historical material, focusing on the defined study area, and producing qualitative output of interest, n = 2 additional publications were included into the study. The screening of their respective bibliographies brought to light n = 2 additional relevant productions, which were also included in the study.
- Fourthly, published scientific productions or grey literature dealing with bioarchaeology and palaeopathology of the period and region of interest, were identified. In terms of non-referenced research, n = 4 such reports were identified. Relevancy criteria included the presentation of substantial demographic data and cause of death diagnoses. Contribution of significant quantitative data was also considered as a valid inclusion criterion. Subsequently, through Google Scholar queries with the series of keywords presented in Table 4, another n = 3 studies of interest could be identified. By studying their bibliography, n = 3 additional pertinent publications were discovered.

The retained n = 49 publications were then classified into n = 6 themes: 1) demographic history, 2) ancient nosology and pathocenosis, 3) history of medicine and specific diseases, 4) regional and longitudinal medical studies and 5) regional and longitudinal statistical studies as well as 6) bioarchaeological and palaeopathological studies). These n = 6 themes were then organized according to their methodological filiation: 1) historical approaches, 2) medical and statistical approaches, and 3) bioarchaeological and palaeopathological approaches. The latter distinction, albeit not necessarily evident to apprehend, appears repeatedly throughout the compiled literature corpus, which explains why it is mobilized as well in the frame of this study.

2. Collection and analysis of ancient sources (archives):
   - In order to verify the reliability of the information presented by the literature and to complete the demographic data obtained, an analysis of primary archives was also conducted. Adequate and exploitable historical sources were identified in n = 6 archival series (Fig. 4 and Supplementary Files: Tables 5–10): at federal level (through the Swiss Federal Statistical Office nationwide data compilation); and at local level in the archival material from the cities of Geneva (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121), Bern (BERNHIST 1700–2023), Neuchâtel (AECN 1801–1814/1816–1839/1841–1847/1850–1864, HSSO 2012; Guillaume 1876, 1877), Bern (BERNHIST 1700–2023), Lausanne (AVL 1903–1910, RC 063/002-00272; ACV 1904–1910. SB 267/53/3) and the village of Bière (ACV 1904–1910. SB 267/13/3). Inclusion and relevancy criteria included the existence of age and sex discriminating archives, an associated listing of causes of death, and a documented historical context of production. The chronological span and accessibility of the archives were also decisive criteria. The equivalent of several linear meters of ancient documents were either examined physically or numerically, including parish, civil and medical registers. Overall, this exploration was complicated by the fact that some of this material had not been exploited before, was scattered and / or degraded in nature, and not always readily comparable, especially for the Early Modern Era. However, it enabled to confirm the results of the identified literary studies. It also enabled to supplement these data, especially for the Modern Era (16^{th}–19^{th} century).

2.3 Corpus overview

A glance at the retained literature corpus reveals that several historical, demographical, statistical, medical, bioarchaeolgical or palaeopathological studies on the evolution of health within historical population samples from Switzerland have been published since the early 20^{th} century. Yet, one also notes that these studies have mainly focused on the second half of the modern period (Ganguillet 1912; Eckert 1978; Gubéran 1980; Wanner 2002; Schumacher & Oris 2011; Holloway et al. 2013; Perrenoud 2012; Rüttimann & Loesch 2012; Perréard Lopreno et al. 2016a, 2016b; Zürcher et al. 2016; Somers et al. 2017; Thorimbert & Perréard Lopreno 2018; Cooper et al. 2019; Floris & Staub 2019; Loesch et al. 2019; Alterauge et al. 2020; Greub & Barras 2020; Perréard Lopreno & Thorimbert 2021). This is imputable to the fact that both the quality and quantity of known sources on the health state of medieval and early modern populations are relatively limited and scarce. Indeed, apart from a few targeted approaches focusing on Switzerland throughout the great epidemics that raged from the end of Antiquity to the beginning of the modern era, there has never been any specific, large-scale, multidisciplinary, and/or diachronic research undertaken on the topic of Swiss respiratory health

Corpus overview (main primary and secondary sources)

Geneva sources (*span: 1580 – 1880 CE*)

Main primary sources: demographics (mortality) and specific causes of death

- **Archives de l'État de Genève (AEG)**
1545. E.C. Morts, Suppl. 1. *Plague deaths*. Carnet d'aucuns morts de peste.
- **Archives de l'État de Genève (AEG)**
1549 – 1798. E. C. Morts n° 1 – 69. "Death book" of the City of Geneva (1549-1798). *Livre des morts de la Ville de Genève*, 69 registers
- **Archives de l'État de Genève (AEG)**
1560 – 1811. Santé E1. Mortality tables, Geneva (1560-1811). *Tableaux de la mortalité à Genève (1560-1811)*.
- **Archives de l'État de Genève (AEG)**
1615. PC. Supp-2036.1615. Register of the "*visitor of the deceased*". *Registre du "visiteurs des morts"*.
- **Archives de l'État de Genève (AEG)**
1798 – 1880. E.C. Genève décès, n° 1 – 83. City Council census of deaths in the City of Geneva (1798-1880). *Registre d'état civil des décès de la Ville de Genève*, 83 registers
- **Bibliothèque publique et universitaire de Genève (BPUG)**
1785. Ms Cramer 121. Extracts from the mortuary register until 1785. *Extraits des Registres mortuaires jusqu'en 1785.*

=> 333000 entries (age, sex, date and cause of death listed in 28552 cases)

Main secondary sources: demographics (specific rates and population structure

- **Mallet, E.**
1837. Recherches historiques et statistiques sur la population de Genève, son movement annuel et sa longévité, depuis le XVIe siècle jusqu'à nos jours (1549–1855). Paris: Paul Renouard, 172 pp.
- **Perrenoud, A.**
1978. La mortalité à Genève de 1625 à 1825. *Annales de démographie historique*, 1978 (1), pp. 209-233.
- **Perrenoud, A.**
1993a. Nosología y patocenosis: contribución al debate sobre las causas del descenso de la mortalidad. *Revista de Demografía Histórica–Journal of Iberoamerican Population Studies*, 11(3), pp. 89-150.

Overall Swiss sources (*span: 1860 – 2023 CE*)

Main secondary sources: demographics and specific causes of death

- **Gubéran, E.**
1980. Tendances de la mortalité en Suisse: 2. Maladies infectieuses 1876-1977. *Swiss Medical Weekly*, 110 (15), pp. 574-583.
- **Ritzmann-Blickenstorfer, H. & Siegenthaler, H.**
1996. *Statistique historique de la Suisse*. Zürich: Chronos.
- **Calot, G, Confesson, A., Sardon, J.-P., Baranzini, E., Cotter, S. & Wanner, P.**
1998. Deux siècles d'histoire démographique suisse: Album graphique de la période 1860-2050. Neuchâtel: Bundesamt für Statistik (BFS) / Office Fédéral de la Statistique (OFS), 240 pp.
- **Swiss Federal Statistical Office (SFSO)**
2008. Sterblichkeit nach Todesursachen in der Schweiz: 1998/2003. *Demos – Informationen aus der Demographie*, 3(2007), pp.1-84.
- **Swiss Federal Statistical Office (SFSO)**
2018. *Todesfälle in der Schweiz auf Rekordniveau: Die Spanische Grippe von 1918*. Bundesamt für Statistik (BFS) / Office Fédéral de la Statistique (OFS): Neuchâtel, 8 pp.
- **Höpflinger, F.**
2020. *Bevölkerungswandel Schweiz: Soziodemografische und familiendemografische Entwicklungen im Langzeitvergleich*. Stallikon: Käser Druck, 190 pp.

Bern sources (*span: 1805 – 1815 CE*)

Main primary sources: demographics (mortality) and specific causes of death

- **Online Historical, Geographical, and Social Database of the Canton of Bern (BERNHIST)**
1700–2023. *Relationale Datenbank mit Schlüsseldaten aus den Bereichen Bevölkerung, Wirtschaft, Umwelt, Politik für den Zeitraum von 1700 bis zur Gegenwart.* http://www.digibern.ch [online resource; consulted on 01.01.2021].

=> 4390 entries (age, sex, date and cause of death listed in 497 cases)

Main secondary sources: demographics (specific rates and population structure

- **Rüttiman, D. & Loesch, S.**
2011. Mortality and Morbidity in the City of Bern, Switzerland, 1805-1815 with Special Emphasis on Infant, Child and Maternal Deaths. *HOMO – Journal of Comparative Human Biology*, 63 (2012), pp. 50-66.

Lausanne sources *(span: 1401 – 1910 CE)*

Main primary sources: demographics (mortality) and specific causes of death

- **Archives de la ville de Lausanne (AVL)**
1903–1910. RC 063/002-00272. Register of burials in Lausanne – La Sallaz cemetery. *Inscriptions des personnes inhumées au cimetière de la Sallaz (1903 – 1910) – Indication de l'année, du mois et du jour du décès, du numéro de tombe, du nom, prénom habituel, de la profession, et de l'âge de la personne inhumée; format: Folio, 37 x 27 x 2 cm., 94 pp.* 1 volume, 2265 entries (1086 complete).
- **Archives cantonales vaudoises (ACV)**
1904–1910. SB 267/53/3. Register of deaths in Lausanne (1876 – 2004) – *Indication de l'année, du mois et du jour du décès, de la cause de décès, du nom, prénom habituel, de la profession, et de l'âge de la personne décédée*. 6 volumes, 3340 entries (3335 complete), 242 folios.

=> 5628 entries (age, sex, date and cause of death listed in 4421 cases)

Main secondary sources: demographics (specific rates and population structure

- **Morax, J.**
1908. La tuberculose à Lausanne. *Journal de statistique suisse*, pp. 195-204.
- **Olivier, E.**
1939. Médecine et santé dans le pays de Vaud au XVIIIe siècle (1675-1798). Lausanne: Édition de la Concorde.
- **Morerod, J.-D. & Paravicini Bagliani, A.**
1991a. Une liste des maladies de l'hôpital de Vevey, 1401-1416. *Revue historique vaudoise*, 99 (1991), pp. 79-99.
- **Morerod, J.-D. & Paravicini Bagliani, A.**
1991b. L'histoire de la santé dans le pays de Vaud au Moyen Age: un bilan. *Gesnerus: Swiss Journal of the History of Medicine and Sciences*, 48 (3-4), pp. 257-267.

Neuchâtel sources (*span: 1801 – 1864 CE*)

Main primary sources: demographics (mortality) and specific causes of death

- **Archives de l'État du Canton de Neuchâtel (AECN)**
1801–1814/1816–1839/1841–1847/1850–1864. Unknown original classification number (D.18b – Historische Statistik der Schweiz (HSSO)). *Tableau des naissances et des décès qui ont eu lieu dans la Principauté et Canton de Neuchâtel (1816–1847).*

=> 27007 entries (age, sex, date and cause of death listed in 14984 cases)

Main secondary sources: demographics (specific rates and population structure

- **Guillaume, L.**
1876. Recherches sur le movement de la population dans le canton de Neuchâtel de 1760 à 1875. *Journal de statistique suisse*, 1 (1876), pp. 31-47.
- **Guillaume, L.**
1877. Recherches sur la population dans le Canton de Neuchâtel de 1760 à 1875. *Journal de statistique suisse*, 1 (1877), pp. 149-172

Bière sources (*span: 1401 – 1910 CE*)

Main primary sources: demographics (mortality) and specific causes of death

- **Archives cantonales vaudoises (ACV)**
1904–1910. SB 267/13/3. Register of deaths in Bière (1876 – 1995) – *Indication de l'année, du mois et du jour du décès, de la cause de décès, du nom, prénom habituel, de la profession, et de l'âge de la personne décédée*. 2 volumes, 189 entries considered, 7 folios.

=> 189 entries (age, sex, date and cause of death)

Main secondary sources: demographics (specific rates and population structure

- **Olivier, E.**
1939. Médecine et santé dans le pays de Vaud au XVIIIe siècle (1675-1798). Lausanne: Édition de la Concorde.
- **Morerod, J.-D. & Paravicini Bagliani, A.**
1991a. Une liste des maladies de l'hôpital de Vevey, 1401-1416. *Revue historique vaudoise*, 99 (1991), pp. 79-99.
- **Morerod, J.-D. & Paravicini Bagliani, A.**
1991b. L'histoire de la santé dans le pays de Vaud au Moyen Age: un bilan. *Gesnerus: Swiss Journal of the History of Medicine and Sciences*, 48 (3-4), pp. 257-267.

Data management plan

- **Standardization:** rates per 1000 individuals, percentages, *etc.*
- **Organization:** according to variable(s) of interest (chronology, demographic variables, causes of death, labor specialization class (ISCO-09) and subsequent plotting using 1) Microsoft Excel, 2) Prism – GraphPad and 3) Joinpoint Trend Analysis Software

Fig. 4. Presentation of the main primary sources mobilized in this study alongside the main secondary sources commenting them. Figure by authors.

mobilizing the specific primary or secondary sources presented above (Binz 1963; Le Goff & Biraben 1969; Biraben 1975, 1976; Mckeown 1979; Aker & Cecil 1983; Morerod & Paravicini Bagliani 1991a, 1991b; Borradori 1992; Hays 2005, 2007; Betsinger & DeWitte 2020; Condrau 2020; Vuilleumier 2020; Mackenbach 2021; Hofstetter 2020, 2021); an aspect which this manuscript hopes to cover.

Consequently, in terms of historical demographic approaches, the present research's literature corpus retains a series of studies focusing on demographic trends in Geneva between the 16th and early 19th centuries (Mallet 1837; Perrenoud 1975, 1978, 1979, 1981; 1985, 1989, 1993b, 1994, 2011, 2012; Wanner 2002; Schumacher & Oris 2011). These studies analyze the mitigating factors of mortality as well as the dichotomy between "ordinary" and "crisis" mortality; all of which data is derived from demographic curves stemming from the analyses – by their respective authors – of the Geneva city council registers (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121; Perrenoud 1975, 1981; 1989, 1993b, 2012). The Geneva city council archives open on December 23, 1549. From 1549 to 1579, the data is relatively uneven from year to year, and some of them are missing altogether. Nevertheless, individual entries generally mention the name, domicile, and profession of the deceased. From 1580 onwards, record-keeping improved, and the data became more standardized, particularly with regard to age and cause of death. This information was moreover collected by a physician appointed specifically for the task, known as the "*visiteurs des morts*" or "visitor of the deceased". It was thus decided to consider the data from 1580 onwards. However, a significant hiatus concerns the plague epidemic of 1615–1616, during which a recordkeeping gap of n = 6 weeks, from January 20 to February 29, 1616, occurred. Finally, an original register from the early 17th century has been lost in the second half of the 20th century, but it so happens that this information could be reconstructed thanks to the work of E. Mallet on the said archival series (Mallet 1837). All in all, the Geneva city council archives include n = 153752 baptismal records and n = 38236 marriage records covering the period from 1550 to 1797, along with over 133,000 recorded deaths for the period 1580 to 1830. In addition to clarifying past crude mortality rates, these data also made it possible to address women and child mortality as well as nuptiality and fertility rates (Mallet 1837; Perrenoud 1979). Two articles (Perrenoud & Sardet 1991; Perrenoud 1993a), classifying causes of deaths as listed in the Geneva civil registers (years 1740–1759, 13803 death certificates, 1775–1784, n = 8332 death certificates, and 1800–1819, n = 14749 death certificates) were also considered. Their contents (n = 36884 death certificates), whenever possible (n = 28552 cases), were reorganized according to current medical nomenclature and generic categories (such as the ICD-11) (Barblan-Souvairan 1977; Perrenoud 1978; Perrenoud & Sardet 1991, Perrenoud 1993a; WHO 2023). A similar study on mortality and its main components in the city of Bern (between 1805 and 1815, n = 4390 death certificates, of which n = 497 are of usable quality) was also considered and reclassified in analog fashion (Rüttimann & Loesch 2012). The latter historical and demographic approach to mortality is based on the analysis of the Bernese burial register (BERNHIST 1700–2023); an archive providing information on the causes of death of individuals, their biological profile and civil identity, as well as on their profession (Rüttimann & Loesch 2012). Similarly, archive material and longitudinal studies into causes of death registered by the city council of Neuchâtel from 1801 to 1864 (n = 27007 recorded deaths, of which n = 14984 are of usable quality) (AECN 1801–1814/1816–1839/1841–1847/1850–1864; HSSO 2012; Guillaume 1876, 1877) and the Lausanne cemetery authority as well as the Lausanne city council in the early 20th century (1903–1910 and 1904–1910) were also surveyed (AVL 1903–1910. RC 063/002-00272, ACV 1904–1910. SB 267/53/3). The latter material and studies compile respectively n = 2288 death certificates (n = 1086 of which are complete) and n = 3340 death certificates (a total of n = 3335 of which inform on causes of death), and which were thus also included into this study. Lastly, archival material from the village of Bière, provides insight into demographic characteristics and causes of death within a small rural community in Western Switzerland from 1904 to 1910 (ACV 1904–1910. SB 267/13/3). This series keeps record of n = 189 deaths along with their causes. Ultimately, all presented primary and secondary sources were reorganized and normalized into comparable crude natality, mortality and RIAD mortality standardized curves per 1000 individuals. Inevitably, many of these datasets based on parish and local authorities' death registers are subject to several well-recognized and widely discussed biases (mostly preservation and representativity issues or of a semantic nature), which were amply examined by their respective authors and analysts. In the framework of this study, the inclusion of these data still seems justified, as they provide a relative appreciation of the death toll in several distinct localities during different times. The expressed figures may not be accurate in absolute terms, but as they are ridden by some of the same methodological biases (for example the "urban penalty"-demographic pitfall (Davenport 2020)), they appear compatible and should still offer an interesting comparative overview.

In terms of historical approaches centered on the apprehension of diseases during the medieval and modern periods, a thorough monograph devoted to leprosy on the territory of Vaud between the 13th and 17th centuries (Borradori 1992), as well as a series of historiographical studies on early healthcare and patient status in Vaud during the medieval period (Morerod & Paravicini Bagliani 1991a, 1991b), were considered. Further, the most recent and complete study on the institutional evolution of public health in Switzerland, between 1750 and the present time (Ruckstuhl & Ryter 2017), was also included into the literature corpus of the study. The limits and biases of such historical approaches have also been thoroughly addressed by their authors (mainly the contextually dependent nature and limited quantitative value of such insights), yet it still appeared useful to consider these literary data, as they offer a useful qualitative basis to contrast with or contextualize our quantitative data.

In terms of medical research addressing diseases affecting historical and subpresent populations in Switzerland, a thorough longitudinal study into the evolution of mortality according to crude and true incidence and prevalence rates of main infectious diseases published by E. Gubéran (Gubéran 1980) was considered. More local studies were also considered, such as the monitoring of tuberculosis in Bern by Zürcher et al. (Zürcher et al. 2016), in Lausanne by J. Morax (Morax 1908), in the Bernese Jura (Ganguillet 1912) or the whole of Switzerland (Käppeli 1902; Fanny 1914; Olivier 1939; Olivier et al. 1924). Moreover, the following statistical censuses – carried out by the Swiss Federal Statistical Office – were also integrated into the present study, as their standardized classification of causes of death enabled to extract the figures pertaining to RIAD mortality as well as that of other generic causes of death (Friedrich 1995; Ritzmann-Blickenstorfer & Siegenthaler 1996; Calot et al. 1998; Kohli 2007; SFSO 2008, 2018; Menthonnex 2015; Höpflinger 2020). The main limitation of this dataset is its chronological scope (1860 onwards), the evolution of medical knowledge, its comparative diagnostic value and associated terminological shifts. However, as previously explained, this analytical issue might be bypassed by considering larger generic disease categories.

On the bioarchaeological and palaeopathological levels, a synthesis on the delicate question of the health state among Swiss skeletal populations between the end of the medieval and modern periods, proposed by Alterauge et al. (Alterauge et al. 2020), was integrated into our literature corpus. This work offers a very welcome global overview, as previous investigations displayed a more regional or problematic-driven focus, such as the investigation of skeletal collections stemming from early modern villages or city cemeteries as well as poorhouse graveyards. A certain number of these local studies (n = 9) were integrated into the present research body (Perréard Lopreno et al. 2016a, 2016b; Somer 2016, 2017; Perréard Lopreno & Thorimbert 2021; Thorimbert & Perréard Lopreno 2018; Steiner & Thorimbert 2018; Cooper et al. 2019; Loesch et al. 2019). The inevitable limit hampering both bioarchaeological and palaeopathological data is the state of preservation of human remains, the accuracy of skeletal lesion diagnosis, and the previously mentioned interpretative osteological paradox. In the case of the considered skeletal series however, both the state of preservation and the size of the samples allowed for basic information such as age and sex distribution as well as an overall palaeopathological appreciation to be carried out. Further, archaeological data enabled to contextualize these remains precisely enough for these insights to be mobilized within this study.

2.4 Analytical procedures

In terms of analytical procedures, the demographic and epidemiological transition model (Omran 2005; Harper & Armelagos 2010; Defo 2014; MacCracken & Philipps 2017; Holloway et al. 2013) was standardly mobilized as an analysis grid to apprehend the behaviors of RIAD through time and confront them with overarching demographic trends (Fig. 5). This approach required that – prior to plotting – all numerical data (namely crude mortality, natality and RIAD mortality rates), of either primary or secondary nature, extracted from the considered sources, be normalized to rates per 1000 individuals. Indeed, this step ensured maximal consistency between historical sources originating from sundry publications. The varying reporting frequency of the sources under study necessarily results in the consideration of different chronological intervals for the development of these rates. Still, this approach allows to reconstruct crude natality, mortality and RIAD mortality curves per thousand inhabitants in Switzerland, for most of the period comprised between 1580 and the present-day. For this step, the following softwares were used: Microsoft Excel and Prism – Graphpad. In order to check internal data coherence and consistency, but also to identify trend evolutions within the said rates, joinpoint regression analysis was carried out, so as to define the most significant slope breakpoints. For this step, the National Cancer Institute – Joinpoint Trend Analysis Software was mobilized (Kim et al. 2000; Weir et al. 2003; NCI 2022; Trinh et al. 2022) (Supplementary Files: Appendices 1, 2 & 3). Joinpoint regression analysis enables to determine the best fit line through data organized into chronological series. It systematically tests whether a multi-segmented line represents a significantly better fit then a straight or less-segmented line. In the following study, joinpoint regression analysis was used to characterize the evolution of annual crude natality, mortality and RIAD mortality rates per thousand inhabitants from 1580 till the present-day. The yielded line segments connect at spots called joinpoints. Each joinpoint denotes a statistically significant ($P = 0.05$) change in trend. The algorithm behind joinpoint regression analysis is an application of the Monte Carlo Permutation method, or in other words, a systematic search for the best fit line for every tested segment. The minimum and maximum number of such joinpoints is user-defined while the software calculates the permutation for the minimum number of joinpoints and checks whether more joinpoints are statistically significant and should thus be added to the model (all the way to the maximum user-defined joinpoint threshold) (Weir et al. 2003; NCI 2022; Trinh et al. 2022). A minimum of zero joinpoints (one line segment) and a maximum of five joinpoints (four-line segments) with parametric confidence intervals and Bayes information criterion 3 settings was considered for the presented case. Once the line segments were established, their statistical significance (and that of the obtained milestones and associated time series) was retested by means of Welch's unpaired *t*-tests (Fig. 6 and Supplementary Files: Appendix 4).

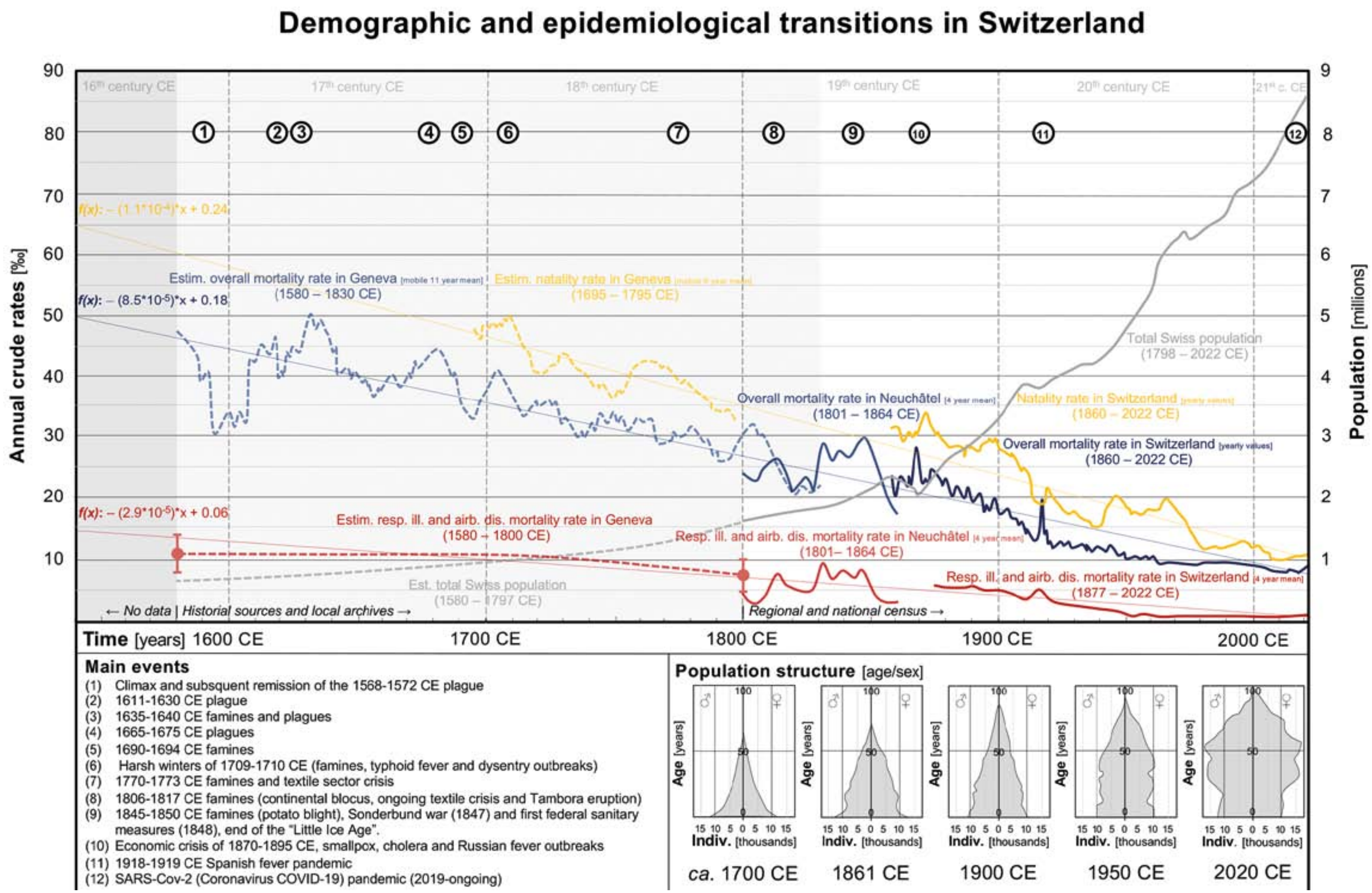


Fig. 5. Demographic and epidemiological transition in Switzerland (1580 to the present-day) in terms of crude natality, mortality and RIAD-induced mortality rates expressed in several year means and normalized to 1000 individuals. Yellow curves: Geneva (1695–1795) and Swiss (1860–2022) natality rates, blue curves: Geneva (1580–1830), Neuchâtel (1801–1864) and Swiss (1860–2022) mortality rates, red curves: Geneva (1580–1830), Neuchâtel (1801–1864) and Swiss (1877–2022) RIAD mortality rates. Figure by authors, based on data from Geneva (1580–1830), which are derived and adapted from the original analysis of primary sources (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121) and subsequent countings thereof published by Mallet (1837) and Perrenoud (1978, 1979, 1985, 1993a), Perrenoud & Sardet (1991), data from Neuchâtel (1801–1864) which are derived and adapted from the original analysis of primary sources and countings of AECN (1801–1814/1816–1839/1841–1847/1850–1864; HSSO.D.18b) by Guillaume (1876, 1877) as well as from the authors' analysis of the said archival series, data from Bern (1805–1815), which are derived and adapted from the original analysis of primary sources (BERNHIST 1700–2023), and subsequent countings thereof published by Rüttimann & Loesch (2012), data from Lausanne (1903–1910), which are derived and adapted from the original analysis of primary sources and countings thereof by Morax (1908), Olivier (1939) and Gubéran (1980), as well as from the authors' analysis of the corresponding archival series (ACV 1903–1910. RC 063/002-00272 and ACV 1904–1910. SB 267/53/3), data from Bière (1903–1910), which are derived from the authors' analysis of the corresponding archival series (ACV 1904–1910. SB 267/13/3), and overall Swiss data (1860–2022), which are derived from the original analysis of primary sources and subsequent countings thereof by the Swiss Federal Statistical Office, published in commented form by Gubéran (1980), Ritzmann-Blickenstorfer & Siegenthaler (1996); Calot et al. (1998); SFSO (2008, 2018), Menthonnex (2015) and Höpflinger (2020).

In structural terms, the results thus obtained were transposed into a unique, first-of-its-kind longue-durée comparative plot of the evolution of natality, mortality and RIAD mortality rates in Switzerland between 1580 and the present-day. As such, this state-of-the-art figure is commented hereafter in the form of a discursive presentation of the main evolutions of RIAD which can be drawn from the study of the selected literary corpus, within a contextual historical sketch of Switzerland during the considered chronological range.

3 Results and study contribution: shedding light on archival and historical data through the contextual input of the selected corpus

The following section presents the main results obtained through the study of the retained literary corpus. This approach mainly takes the form of a precise contextualization of the studied archival and historical data, which represents the first effort of its kind undertaken in the chronological and geographical range under consideration. More precisely, these results are presented hereafter in the form of a narrative and event-driven history of Switzerland, with a special focus on the dynamics of RIAD, from the 16th century till the present-day, based on the insights provided by their graphical summing-up (Fig. 5 (plotted raw data graph)) and subsequent statistical treatment (Fig. 6 (joinpoint regression analysis graph)).

3.1 The advent of a RIAD-dictated mortuary regime: mortality and its components in Switzerland from the 16th to the mid-19th century

The confederated Swiss cantons gained their independence and political recognition from the Holy Roman Germanic Empire just short of the 16th century; in 1499. Yet, the confederate organization remained fragmented, and the territory split between different power centers and their surrounding countryside. The 16th century also marks an internal division of the confederates, following the Protestant Reformation (Ducrey & Favez 2004; Nappey 2007; Head-König 2012; Würgler 2012; Bouquet 2021). In the absence of a centralizing political body, most population statistics – if and when they survived to date – were mainly drawn up at the parish level and only rarely at the town or transregional level (Binz 1963; Perrenoud 1979, 2011; Holloway et al. 2011; Holloway et al. 2013; Vitaux 2021). The fractional, scant, and partial nature of these records largely accounts for the difficulties in producing any reliable demographic estimates for the medieval period. Nevertheless, more precise observations can be drawn from the beginning of the modern period onwards, as the city archives and death statistics of Geneva, Neuchâtel or Bern, gradually become exploitable (Binz 1963; Perrenoud 1975, 1978, 1979, 2011).

Based on these sources, one learns that the dominant demographic regime from the end of the Middle Ages up to the 17th century (to the earliest) in peri-alpine Europe was characterized by crude birth and death rates peaking at extremely high levels before falling back to more ordinary levels, following the ebb and flow of epidemic waves, mainly of plague outbreaks (Bourdelais 1997, 2000; 2006; Omran 2005; Harper & Armelagos 2010; Perrenoud 1978, 1979, 2011; Vitaux 2021). As in-depth viro-bacterial dynamics were yet to be discovered, the humoral theory formed the backbone of most medical knowledge as late as the 17th century. Hence, most diseases, if noticed, were only recognized as such in their late stages. This state of knowledge resulted in the failure to apply preventive containment measures and often left scholars, institutions, and governments struggling to contain epidemic phenomena with coordinated actions (Perrenoud 1978, 1979, 2011; Borradori 1992). This absence of coordination further impeded the effectiveness of most locally enacted sanitary measures (Le Roy Ladurie 1973; Bourdelais 1997). It appears that only quarantine and forced isolation measures for people who suffered from leprosy, sometimes also applied in the case of plague, were of some use (Borradori 1992; Bourdelais 1997, 2006; Vitaux 2021). However, due to the inability of past populations to efficiently identify disease vectors and inhibit contamination chains, a pathological equilibrium established itself, centered on the plague, which drained the population reservoir at the expense of most other diseases (Perrenoud 1978, 1979, 2011; Kiple 1993; Bourdelais 1997; Mattmüller 2004; Dewitte et al. 2008; Kohn 2008; Mikhail 2008; Kacki 2016; Bramanti et al. 2021; Siuda & Sunde 2021; Vitaux 2021; Xhayet 2022). Further, while plague intensity decreased during the cooler winter months, it nonetheless swept away a non-negligible proportion of individuals weakened by other diseases, especially of a respiratory nature (Le Roy Ladurie 1973; Bourdelais 1997). In fact, under this regime (up until the mid-17th century), the share of deaths attributable to RIAD appears to have fluctuated as a function of plague intensity, accounting for ¼ up to over 1/3 of all registered deaths, with a crude mortality rate fluctuating roughly between 9 up to 15‰, according to estimates based on primary sources (local burial or parish registers) (Le Roy Ladurie 1973; Bourdelais 1997; Perrenoud 1978, 1979, 2011). Although substantial, the mortality share of RIAD is nonetheless subordinated to plague and its impressive mortality peaks, which must have played the lead role in terms of demographic regulation. Even if this regulating effort was carried out in association with other severe episodic afflictions such as famines and wars, and more consistently, infant mortality due to infectious diseases and childbirth complications (Le Roy Ladurie 1973; Bourdelais 1997, 2000, 2006; Perrenoud 1985, 1989, 1994; Lorenzetti & Perrenoud 1999; Hays 2005, 2007).

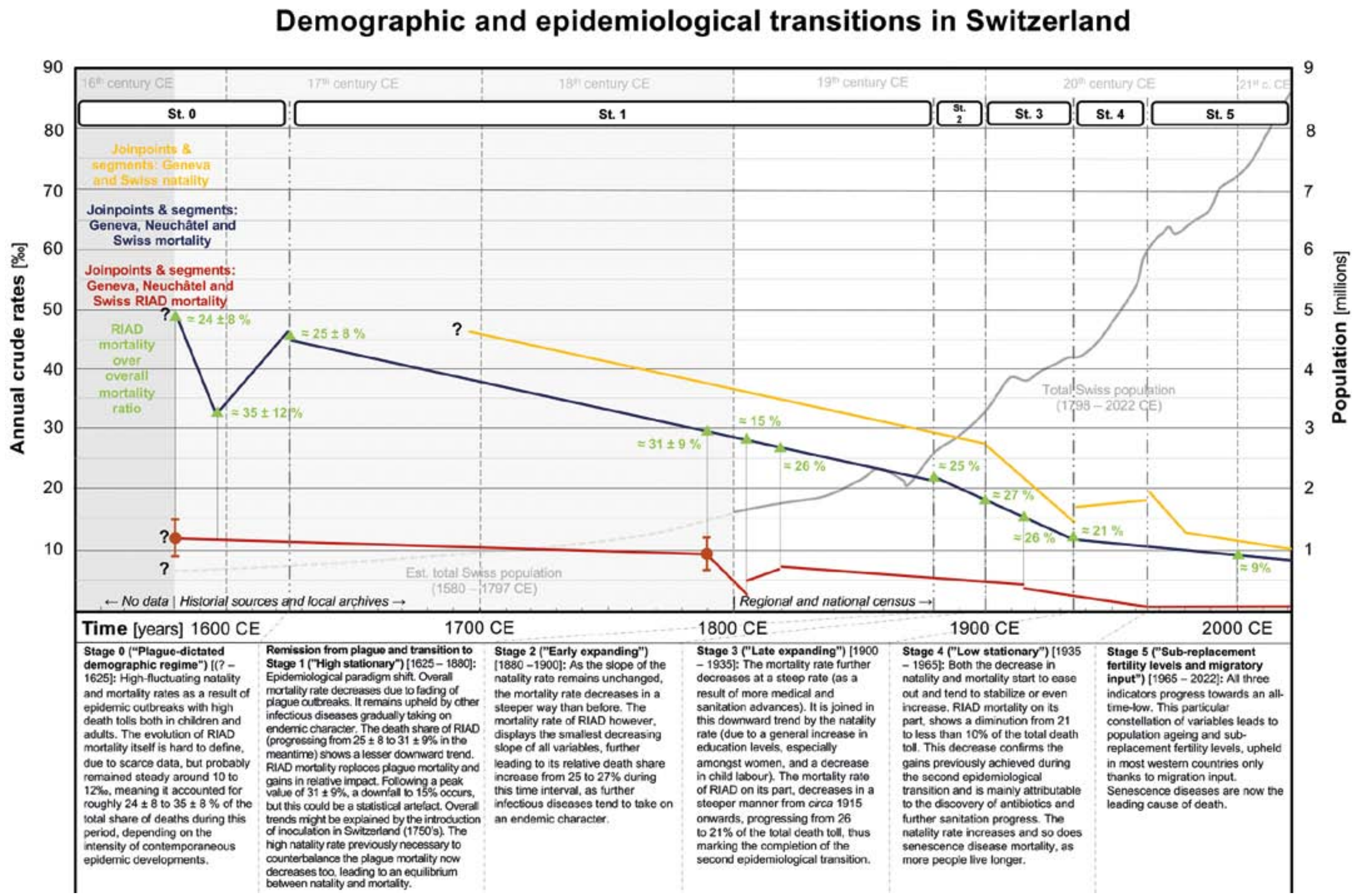


Fig. 6. Demographic and epidemiological transition in Switzerland (1580 to the present-day), in terms of crude natality, mortality and RIAD-induced mortality rates expressed in linear regressions, according to significant joinpoint regression determined segments. Yellow lines: Geneva (1695–1795) and Swiss (1860–2022) natality rates significant joinpoint regression determined segments, blue lines: Geneva (1580–1830), Neuchâtel (1801–1864) and Swiss (1860–2022) mortality rates significant joinpoint regression determined segments, red lines: Geneva (1580–1830), Neuchâtel (1801–1864) and Swiss (1877–2022) RIAD mortality rates significant joinpoint regression determined segments. Figure by authors, based on data from Geneva (1580–1830), which are derived and adapted from the original analysis of primary sources (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121) and subsequent countings thereof published by Mallet (1837) and Perrenoud (1978, 1979, 1985, 1993a), Perrenoud & Sardet (1991), data from Neuchâtel (1801–1864) which are derived and adapted from the original analysis of primary sources (AECN 1801–1814/1816–1839/1841–1847/1850–1864; HSSO.D.18b) and subsequent countings thereof published by Guillaume (1876, 1877) as well as from the authors' analysis of the said archival series, data from Bern (1805–1815), which are derived and adapted from the original analysis of primary sources (BERNHIST 1700–2023) and subsequent countings thereof published by Rüttimann & Loesch (2012), data from Lausanne (1904–1910), which are derived and adapted from the original analysis of primary sources and subsequent countings thereof published by Morax (1908), Olivier (1939) and Gubéran (1980), as well as from the authors' analysis of the corresponding archival series (AVL 1903–1910. RC 063/002-00272 and ACV 1904–1910. SB 267/53/3), data from Bière (1903–1910), which are derived from the authors' analysis of the corresponding archival series (ACV 1904–1910. SB 267/13/3), and overall Swiss data (1860–2022), which are derived from the original analysis of primary sources and subsequent countings thereof by the Swiss Federal Statistical Office, published in commented form by Gubéran (1980), Ritzmann-Blickenstorfer & Siegenthaler (1996); Calot et al. (1998); SFSO (2008, 2018), Menthonnex (2015) and Höpflinger (2020). All regressions calculated through Joinpoint Regression Analysis Software.

Bioanthropological and palaeopathological data on the period from the end of the Middle Ages up to the 17th century, remain relatively limited, as far as the Swiss case goes. Nevertheless, discoveries of several multiple burials from the 16th and early 17th century, have been interpreted as traces of epidemic mass graves (e.g., in Stans (NW) or Zweisimmen (BE)) (Somers et al. 2017). Furthermore, a diachronic synthesis by Alterauge et al. (Alterauge et al. 2020) highlights in particular the evolution of body size of the deceased over time. This indicator – alongside palaeopathological data and calculations of life expectancy over time – indicate a perceptible improvement in skeletal health between the end of the plague era and the onset of the subsequent plague remission regime (17th century onwards).

The 17th century opened with an economic recession following the plague outbreaks of 1562–1611/1612 and the Thirty Years War (1618–1648). At the end of these conflicts, Swiss producers saw their exports to the European market collapse. In addition, internal economic recovery was difficult, as cities had squandered a lot of resources on defensive devices. In response, several popular risings took place (Eckert 1978; Ducrey & Favez 2004; Nappey 2007; Head-König 2012; Würgler 2012; Bouquet 2021).

In epidemiological terms, the beginning of the 17th century is characterized by an overall weakening of the plague (although localized important outbursts did still occur) and by unfavorable transregional political, sanitary, and economic situations. These contributing factors, although leading to a decrease in overall mortality, also slowly brought upon a new pathological equilibrium, now centered on RIAD (mainly tuberculosis and severe infectious childhood diseases) as leading causes of death and demographic regulators (Le Roy Ladurie 1973; Omran 1983, 2005; Bourdelais 1997; 2006; Gubéran 1980; Perrenoud 1975, 1978, 1979, 2011, 2012; Harper & Armelagos 2010; Dewitte et al. 2008; Holloway et al. 2011; Holloway et al. 2013). During the bulk of this period, life expectancy reached roughly 27 years (in contrast to 20 to 25 years during the plague). Men's mortality remains significantly higher than women's at birth, while women's mortality is higher between the ages of 25 to 39 owing to the risks of motherhood (Fig. 7). These variables further fluctuated according to socio-economic rank or professional specialization as well as sex, as outlined by the study of the archival material from Geneva (Fig. 8) (Perrenoud 1975, 1978, 1979, 2011, 2012; Harper & Armelagos 2010; Dewitte et al. 2008; Holloway et al. 2011; Holloway et al. 2013). This state of fact has been linked to differential living, working and sanitary conditions according to the socio-economic rank of the individuals under consideration (Perrenoud 1975, 1978, 1979, 2011, 2012).

These new dynamics and pathological equilibrium play a key-role in the unfolding of the first phase of the demographic transition, which in the case of Switzerland, fits roughly into the course of the 18th century (Perrenoud 1985, 1989; Holloway et al. 2011). Indeed, in stark contrast to the 17th century, the beginning of the 18th century does represent a phase of relative prosperity, supported by a proto-industrialization effort, itself sustained by various technical and agricultural developments. Yet, not only demographic sources but also historical sources reveal that socio-economic fractures and ideological disputes remained acute during this phase and led to the religious and rebellion war in Toggenburg (1712), in the wake of the harsh winters of 1709–1710, as well as to uprisings in annexed territories such as Vaud (e.g.: Lausanne 1723). Towards the closing of the 18th century, following the onset of another transregional economic recession and several famines, the most disadvantaged classes took the streets again (e.g.: in Fribourg and Geneva, in 1781) (Ducrey & Favez 2004; Nappey 2007; Würgler 2012; Bouquet 2021).

In a strict demographic sense, the overall crude mortality rate of the 18th century further decreases, following the trend established during the 17th century, in the wake of the last important plague outbreaks in Switzerland. It remains partly upheld by other infectious diseases gradually taking on an endemic character. As such, crude birth and death rates gradually aligned around 40 and 30‰ during the 18th century. In this sense, rather than reflecting a significant and sudden economic prosperity episode, the demographic indicators under consideration rather highlight a slow, uneven progression, interspersed with phases of decline (Perrenoud 1978, 1979; Perrenoud 1993b). As the case of the Geneva parish registers illustrate, the mortality rate of individuals aged 0 to 1 for instance, progresses from 200‰ in 1725–1744, to 231‰ in 1770–1790, before falling back to 170‰ in 1800–1825, while the overall mortality tends to decrease at a lower rate than a century before (Perrenoud 1978, 1979, 2012). This combination of factors confers to the population structure histogram the typical appearance of a pyramid with over-hollowed flanks (Fig. 5) (Calot et al. 1998). Further, the mortality share attributable to RIAD during the 18th century remains considerable, since airborne infectious diseases alone (such as smallpox, scarlet fever, measles, diphtheria, and tuberculosis) are all listed as leading causes of death within the Geneva parish registers, especially amongst young people and the most deprived population subgroups (Perrenoud & Sardet 1991; Perrenoud 1993a, 1994, 2012). According to our joinpoint regression model, the proportion of deaths attributable to RIAD in the course of the 18th century raised to a tangibly higher level than before, to 31 ± 9% (the uncertainty margin renders natural RIAD mortality fluctuations estimates), hence overshooting their projected average impact during plague outbreaks (24 to 25 ± 8%). It appears that in the course of the 18th century, RIAD effectively shaped most fluctuations in the overall mortality rate (smallpox and tuberculosis in the lead) (Perrenoud & Sardet 1991; Perrenoud 1993a, 2012; Ritzmann-Blickenstorfer & Siegenthaler 1996; Holloway et al. 2011; Holloway et al. 2013; Ruckstuhl & Ryter 2017; Vuillemin 2019). Indeed, whilst smallpox imprints a periodicity of about 5 years on

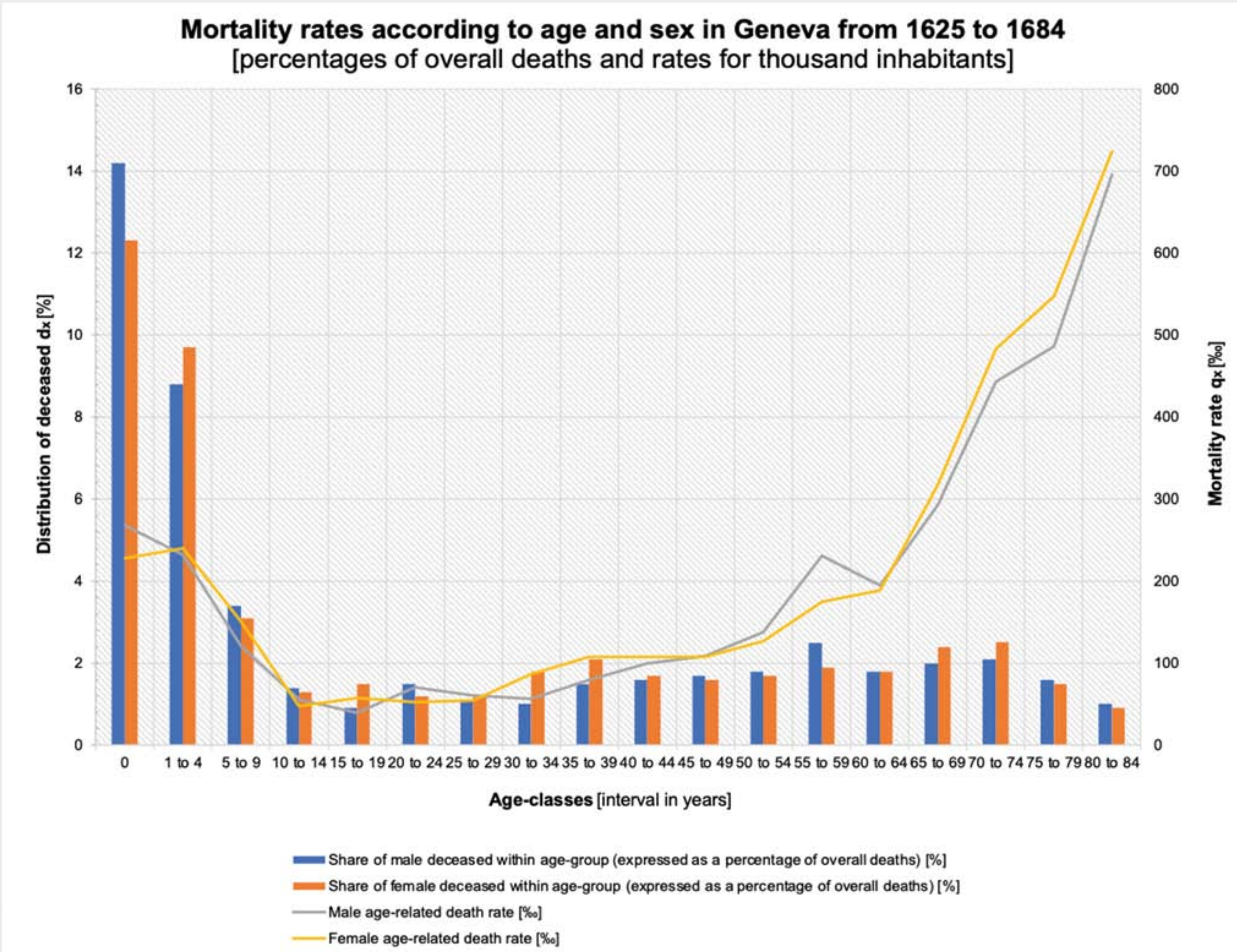
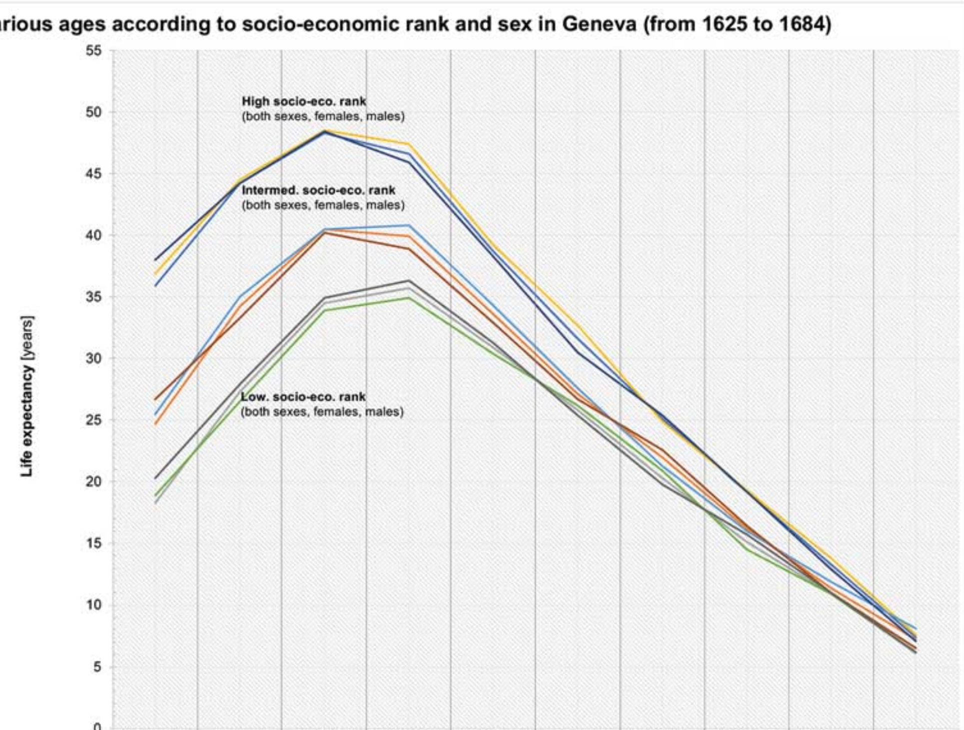


Fig. 7. Mortality rates according to age and sex in Geneva (1625–1684). Figure by authors, based on the original analysis of primary sources (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121) and subsequent countings thereof published by Mallet (1837), Perrenoud (1978, 1979, 1993a), Perrenoud & Sardet (1991).

the mortality curve, depending on the degree of immunity of a given population, tuberculosis presents with shorter cycles, striking regularly during winter and spring months (Perrenoud & Sardet 1991; Perrenoud 1993a). Such diachronic perspectives also highlight interesting health trends over longer time periods. Indeed, between 1730 and 1739, RIAD were responsible for the death of half of the male population of Geneva and only roughly 24% of women, but these figures evolved to 42% of men and 39% of women between 1775 till 1784 (Perrenoud 1981). These figures are thought to reflect the overall deterioration in health and living conditions, notably amongst the most vulnerable population layers (laborers, women, children, etc.), during the proto-industrialization phase (end of the 18th century) (Perrenoud 1981), as well as the pressure of working in difficult and unhealthy conditions extending to all population pools. Inequalities of the sort may well have been amplified by the introduction of new medical techniques, which were accessible only to affluent members of the population in their initial years of use (Perrenoud 1975, 2012).

Regarding the early 19th century, historical sources reveal that Napoleon Bonaparte's expansionist policy set the pace at the beginning of this period (through his annexation of Switzerland and continental blockade). Further, Napoleon's campaigns resulted in the transit of various armies through Switzerland, which, in addition to having to be fed, also carried their trail of infectious diseases (notably typhus). The eruption of the Tambora volcano in Indonesia (1815) and the simultaneous appearance of sunspots also induced catastrophic meteorological disruptions to crops and harvests (1816 being known as "the year without summer" throughout Europe). Switzerland – which was then entering its phase of industrial and demographic expansion (progressing from 1.8 million inhabitants in 1810 to 2.4 million inhabitants in



	At 0 years	At 1 year	At 5 years	At 10 years	At 20 years	At 30 years	At 40 years	At 50 years	At 60 years	At 70 years
Both sexes (stillbirths included): high socio-economic rank	35.9	44.2	48.3	46.6	38.7	31.6	25.1	19.2	13.3	7.4
Both sexes (stillbirths included): intermediary socio-economic rank	24.7	34.2	40.5	39.9	33.6	27.1	22	16.2	11.4	7.2
Both sexes (stillbirths included): low socio-economic rank	18.3	27.3	34.5	35.7	30.9	25.8	20.3	15.1	10.9	6.1
Males (stillbirths excluded): high socio-economic rank	36.9	44.5	48.5	47.4	39.2	32.7	24.9	19.3	13.8	7.6
Males (stillbirths excluded): intermediary socio-economic rank	25.5	35	40.5	40.8	34.3	27.6	21.3	16	11.9	8.1
Males (stillbirths excluded): low socio-economic rank	18.9	26.5	33.9	34.9	30.4	26.2	20.9	14.5	10.9	6.2
Females (stillbirths excluded): high socio-economic rank	38	44.2	48.4	45.9	38.3	30.5	25.4	19.2	12.9	7.1
Females (stillbirths excluded): intermediary socio-economic rank	26.7	33.3	40.2	38.9	32.9	26.7	22.6	16.4	11	6.5
Females (stillbirths excluded): low socio-economic rank	20.3	27.9	34.9	36.3	31.3	25.4	19.8	15.7	11	6.2

Fig. 8. Life expectancy at various ages according to socio-economic rank and sex in Geneva (1625–1684). Figure by authors, based on the original analysis of primary sources (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121) and subsequent countings thereof published by Mallet (1837), Perrenoud (1978, 1979, 1985), Perrenoud & Sardet (1991).

1850) – saw the famine on its territory aggravated by obligations imposed on farmers to cultivate certain species in priority as well as due to speculative stocking undertaken by retailers. Once again, famine and misery affected the poorest people first; many of them fled across the Atlantic (Calot et al. 1998; Ducrey & Favez 2004; Nappey 2007; Holloway et al. 2011; Würgler 2012; Höpflinger 2020; Bouquet 2021).

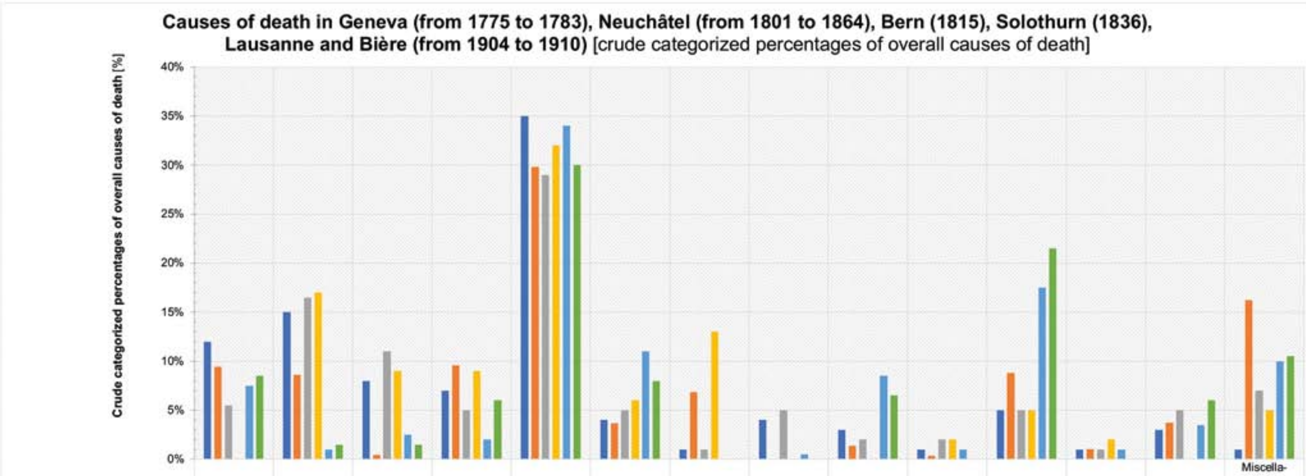
The demographic indicators under consideration, as well as our joinpoint regression model, mirror these trends, as the death toll of RIAD falls back to 15% at the transition between the 18th and 19th centuries, before peaking at roughly 26% during the beginning of the 19th century (Perrenoud & Sardet 1991; Perrenoud 1993a, 2012). Although this sudden trend shift might represent a statistical artifact (as it coincides with the end of the Geneva RIAD mortality graph and the onset of the Neuchâtel RIAD mortality curve), it could also well result from the troubled circumstances in the opening decades of the 19th century (Perrenoud 2017).

3.2 Paradoxes of the industrial age (1850s–1930s): an overall drop in mortality but a pronounced incidence of RIAD nonetheless

The period from 1850 onwards marks the advent of the second phase of the demographic transition, which effectively took place between 1880 and 1900 (Calot et al. 1998; Holloway et al. 2011; Menthonnex 2015). The overarching demographic trend reflects the medical improvements resulting from increased sharing of new knowledge and techniques (such as vaccination and surgery) (Bento & De Oliveira Fonseca 2013). It is also due to a quantitatively and qualitatively more stable food supply chain – which was brought about by new agricultural techniques – as well as through significant improvement in sanitary and living conditions (Gubéran 1980, Perrenoud 1978, 1979, 1993b, 2012; Calot et al. 1998; Menthonnex 2015). These evolutions, combined with a close to constant birth rate, bring about a gradual increase in life expectancy (from less than 30 years during much of the 18th century to 35 years in 1850 and beyond). This period marks the onset of a sharp population increase, drawing a relief in mortality pressure amongst young individuals and a lengthening of human life (Fig. 5) (Calot et al. 1998). The share of mortality attributable to RIAD, on the other hand, remains close to constant, progressing from roughly 26 to 25% of the total death toll between 1820 and 1880. These evolutions still remained subject to impressive mortality peaks, such as the one of the 1840–1850 famine and Sonderbund religious war, or during the long-lasting economic recession of 1870–1895 (Perrenoud 1978, 1979, 1993b, 2012). Following the establishment of a new Swiss federal state and constitution in 1848, social and public health progress was brought about by this new political entity. One of its main challenges was to even out social inequalities in the face of death; as age and sex adjusted mortality rates reported in Neuchâtel, Bern, and Lausanne, from the beginning of the 19th till the early 20th century, all still highlight the negative correlation linking an individual's age, sex and socio-economic ranking to his life expectancy, as well as to his odds to suffer or die from RIAD. All in all, RIAD constitute the primary cause of death in all considered places and subgroups (Fig. 9) (Petitpierre 1871; Perrenoud 1978, 1979, 1981; 2012; Ritzmann-Blickenstorfer & Siegenthaler 1996; Bagnoud 1998; Ducrey & Favez 2004; Nappey 2007; Holloway et al. 2011; Holloway et al. 2013; Würgler 2012; HSSO 2012; Rüttimann & Loesch 2012; Barrelet 2016; Somers et al. 2016; Zürcher et al. 2016; Höpflinger 2020; Bouquet 2021). This observation is further substantiated in comparison to other rapidly industrializing cities such as Basel (Switzerland), Hamburg and Bremen (Germany) (Ganguillet 1912; Fanny 1914; Hotz et al. 2016), Le Creusot (France), Herstal or Seraing (Belgium) (Bourdelais 2000; Eggerickx et al. 2018). Moreover, Swiss palaeopathological evidence from the Zürich and Bernese countryside and the Alpine region suggest that overall mortality, as well as crude prevalence of RIAD, do not appear to have been significantly lower in rural environments in comparison with urban settings (the "urban penalty"-phenomena), at least up to the early 19th century (Bertrand 1939; Head-König 2010; Holloway et al. 2013; Somers et al. 2017).

Socio-economically and technologically speaking, the second half of the 19th century further resulted in the complex interweaving of social, commercial, labor, and sanitary aspects. Indeed, the expansion of rail and road networks led to a substantial increase in goods, people and even more so, pathogen circulation. Agrarian trades declined from 54% to 31%, while the industry and service sectors progressed gradually, attracting more and more workers to insalubrious urban centers (Barbey et al. 1976). However, as working days lengthened and female and youth labor further increased (especially in the countryside), pauperization among the working and agricultural classes soared (notably after the recession of 1870–1895). At the same time, cities and their industrial fabric grew denser, bringing about their own set of environmental, sanitary and epidemiological issues, while hygiene measures and waste disposal techniques had been close to stagnating since several centuries. In this sense, several cholera outbreaks, the deadly smallpox epidemic accompanying the Franco-Prussian war of 1870 (Jorland 2011) and – to a lesser extent – the Russian flu of 1889–1890, all led to increased institutional hygiene investigations and measures, while working hours were limited to 11 hours a day over 6 days a week from 1877 onwards (Ducrey & Favez 2004; Nappey 2007; Holloway et al. 2013; Würgler 2012; Höpflinger 2020; Bouquet 2021).

In the light of the above, it is not surprising that both crude and true mortality and birth rates underwent a pronounced trend change during the second half of the 19th century, prefiguring the third phase of the demographic transition and the close of the second epidemiological transition (1900–1935) (Holloway et al. 2011). Indeed, in addition to industrial and technical developments, medical breakthroughs in the understanding of pathology, microbiology and hygiene seem to have raised awareness in the public and political spheres and prompted concrete health measures (Conrad et al. 1995; Brockliss & Jones 1997; Bynum et al. 2006; Holloway et al. 2011; Jackson 2011; Starobinski 2020; Vuilleumier 2020). In Switzerland, the first transregional measures to fight epidemics were implemented (1848), the federal law on epidemics was introduced (1886, updated in 1913 and 1970) and the Federal Office of Public Health (1893) as well as the Swiss Serum and Vaccine Institute (1898) were created. These developments all contributed to the regulation of the main mortality peaks, especially amongst young people (Ruckstuhl & Ryter 2017; Vuilleumier 2020). At the same time, they also fostered an increase in life expectancy (from 38 years in 1880 to 55 years at the dawn of the First World War) (Calot et al. 1998; SFSO 2008; Menthonnex 2015; Höpflinger 2020). The birth rate, because of the said awareness, but also due to an improved education, particularly amongst women, and a substantial increase in the chances of survival of the youngest individuals, also tended to decrease. Finally, some scholars also argue that climate, and in particular the warming at the end of the "Little Ice Age" (*circa* 1860), played an important role in the substantial demographic gains of this period (notably by selectively inhibiting deadly viro-bacterial activity) (Gubéran 1980; Perrenoud 1985, 1989, 1993b, 2012; Matthews & Briffa 2005; HSSO 2012; Rodriguez-Verdugo et al. 2020). In any case, the population structure histogram again reflects these changes well, as the flanks of the pyramid are now close to linear while the pyramid itself continues to raise (Fig. 5) (Calot et al. 1998). Yet, the difficult and often unsanitary living conditions combined with the deterioration of air and environmental quality resulting from massive industrialization tended to counterbalance the medical progress thus achieved, particularly amongst working-class populations (RC 063/002-00272 1903–1910; Gubéran 1980; HSSO 2012; Perrenoud 2012;



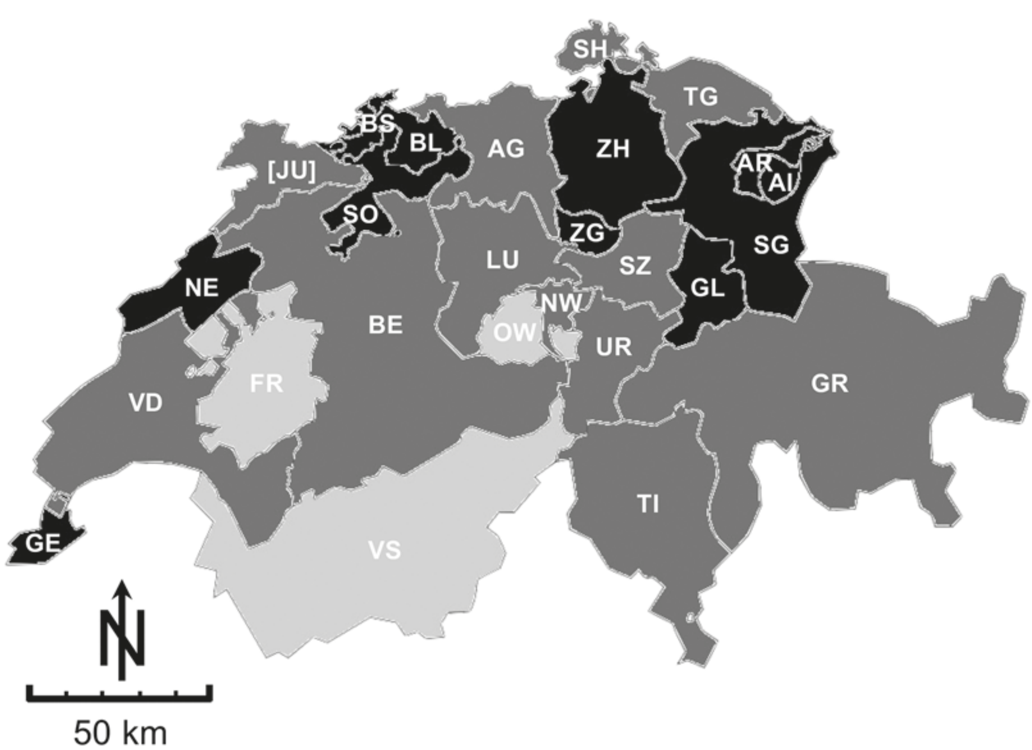
	Stillbirths and neonatal complications	Epilepsy, tetanus, (child-) seizures and convulsions	Metabolic diseases	Frailty and senility	Respiratory illnesses and airborne diseases	Gastro-intestinal diseases	Fevers	Parasite-borne diseases	Cancers and ulcers	Urogenital diseases	Cardio-vascular diseases	Childbed deaths	Violent deaths, accidents and suicides	Miscella-neous (infections of unknown origin, central nervous system diseases, unclassifiable diseases, etc.)
Geneva [1775 – 1783]	12.00%	15.00%	8.00%	7.00%	35.00%	4.00%	1.00%	4.00%	3.00%	1.00%	5.00%	1.00%	3.00%	1.00%
Neuchâtel [1801 – 1864]	9.42%	8.62%	0.45%	9.61%	29.81%	3.69%	6.84%	0.00%	1.36%	0.38%	8.82%	1.02%	3.73%	16.25%
Bern [1815]	5.50%	16.50%	11.00%	5.00%	29.00%	5.00%	1.00%	5.00%	2.00%	2.00%	5.00%	1.00%	5.00%	7.00%
Solothurn [1836]		17.00%	9.00%	9.00%	32.00%	6.00%	13.00%		0.00%	2.00%	5.00%	2.00%	0.00%	5.00%
Lausanne [1904 – 1905 – 1910]	7.50%	1.00%	2.50%	2.00%	34.00%	11.00%		0.50%	8.50%	1.00%	17.50%	1.00%	3.50%	10.00%
Bière [1904 – 1910]	8.50%	1.50%	1.50%	6.00%	30.00%	8.00%			6.50%		21.50%		6.00%	10.50%

Fig. 9. Causes of death in Geneva (1775–1783), Bern (1815), Neuchâtel (1816–1819), Solothurn (1836), Lausanne (1904, 1905 and 1910) and Bière (1904–1910), expressed in relative percentages of overall causes of death. Figure by authors, based on the original analysis of primary sources from Geneva (AEG 1545. E. C. Morts. Suppl. 1, AEG 1560–1811. Santé E1, AEG 1615. PC. Supp-2036.1615, AEG 1798–1880. E.C. Genève décès; BPUG 1785. Ms Cramer 121), Neuchâtel (AECN 1801–1814/1816–1839/1841–1847/1850–1864, HSSO D.18b), Bern (BERNHIST 1700–2023), Lausanne (AVL 1903–1910. RC 063/002-00272 and ACV 1904–1910. SB 267/53/3), and Bière (ACV 1904–1910. SB 267/13/3) and subsequent countings thereof published by Mallet (1837); Guillaume (1876, 1877); Petitpierre (1871), Perrenoud (1978, 1979, 1993a); Perrenoud & Sardet (1991); Rüttimann & Lösch (2012).

Illi & Heller 2014; Floris & Staub 2019; Vuilleumier 2020; Bouquet 2021). In this respect, a form of Swiss "paradox" emerged. Indeed, while Europe's socio-economic elites travelled to expensive and luxurious Alpine sanatoriums to be treated for various forms of chronic and acute respiratory diseases (since the second half of the 19th century), a large part of the Swiss population simply could still not afford any form of analogous treatment. Thus, local mortality levels from tuberculosis remained high; even beyond the gradual opening up of this type of facility to less affluent population segments of the population in the late 19th century (Bagnoud 1998; Corti 2012; Ritzmann 2017).

This led to a rather counter-intuitive situation, as overall mortality began to decline significantly from the late 19th century onwards, while the death toll due to RIAD remained fairly high, following a much less pronounced downward gradient (Gubéran 1980; Perrenoud 2012; Ruckstuhl & Ryter 2017). Accordingly, RIAD mortality peaked at 27% of the total death toll at the transition from the 19th to the 20th century. Hence, analyses of medical studies carried out in Lucerne (Käppeli 1902), Lausanne (Morax 1908; RC 063/002-00272 1903–1910), western and eastern Switzerland (Fanny 1914; Olivier 1939; Olivier et al. 1924) and in the Bernese Jura (Ganguillet 1912) at this time, all highlight – on the one hand – the massive impact of RIAD, and mainly tuberculosis, in industrialized and urbanized cantons *versus* rural and agricultural cantons (as opposed to the situation just a century earlier) (Fig. 10). Such studies also show – on the other hand – the way in which tuberculosis still remains most lethal amongst women and children, as well as amongst the underprivileged and least specialized working-class members (Käppeli 1902; Fanny 1914; RC 063/002-00272 1903–1910). As such, it is important to acknowledge the fact that this upward trend in the prevalence of RIAD did not affect all encompassed diseases, nor all demographic or socio-economic classes in the same way (Gubéran 1980; Kohli 2007; HSSO 2012; Perrenoud 2012; Illi & Heller 2014; Ruckstuhl & Ryter 2017; Vuilleumier 2020). For example, diseases that had once been particularly deadly amongst young people (diphtheria, scarlet fever, pertussis, measles, and smallpox) tended to significantly lose intensity in the final quarter of the 19th century (Gubéran 1980; HSSO 2012). This is mainly due to a considerable improvement in nutrition availability following the industrial revolution (in turn resulting in an increased resistance against infections in children). In contrast, crude

Tuberculosis mortality rates per 10'000 inhabitants in Switzerland (1881 – 1900)



Mostly industrialized cantons [Basel-Stadt (BS) | Geneva (GE) | St. Gallen (SG) | Zug (ZG) | Zürich (ZH) | Appenzell A.-Rh. (AR) | Basel-Landschaft (BL) | Neuchâtel (NE) | Solothurn (SO) | Glarus (GL) | Appenzell I.-Rh. (AI)]

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1881-1890): ***30.8***

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1891-1900): ***28.6***

Mixed economy cantons [Schaffhausen (SH | Thurgau (TG | Luzern (LU | Nidwalden (NW | Bern (BE) * | Aargau (AG) | Schwyz (SZ) | Ticino (TI) | Vaud (VD) | Grisons (GR) | Uri (UR)]

* Including Jura (JU), independent from Bern from 1979 onwards

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1881-1890): ***23.9***

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1891-1900): ***24.1***

Mostly agricultural cantons [Obwalden (OW) | Fribourg (FR) | Valais (VS)]

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1881-1890): ***16.8***

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1891-1900): ***18.4***

Switzerland

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1881-1890): ***26.3***

– Mean crude tuberculosis mortality rate per 10'000 inhabitants (1891-1900): ***25.7***

Fig. 10. Map of Switzerland showing cantonal crude tuberculosis mortality rates per 10,000 inhabitants between 1881–1890 and 1891–1900. Figure by authors, based on data compiled in Swiss nationwide censuses, published in commented form by Käppeli (1902), Morax (1908), Ganguillet (1912) and Fanny (1914).

and true mortality rates of tuberculosis and pneumonia did not decline in any significant manner until the beginning of the 20th century (Gubéran 1980; HSSO 2012; Holloway et al. 2013; Perrenoud 2012; Ruckstuhl & Ryter 2017). Finally, analyses of archival and historical data also reveal that influenza had been in constant raise since the end of the 19th century, before it eventually culminated in the Spanish flu pandemic of 1918–1919 (SFSO 2018) (Fig. 11). On a Swiss scale, it is estimated that about 22 000 people (13 000 men and 9 000 women) died within a few months. Cities seemed more affected than the countryside, and young men between 20 and 40 were the hardest hit by this pandemic (Gubéran 1980; Kohli 2007; HSSO 2012; Perrenoud 2012; Ruckstuhl & Ryter 2017; SFSO 2018; Vuilleumier 2020).

3.3 From 1945 to the present-day: towards the end of RIAD-dictated mortality? Or rather a shift of mortality from the young to the old?

Following this culmination in 1918, RIAD impact on mortality seemed to ease out, as the second epidemiological transition – defined as the time when degenerative diseases show a higher occurrence rate than epidemic infectious diseases in terms of mortality – completely unfolded (Fig. 11) (Omran 1983; 2005; Kohli 2007; Harper & Armelagos 2010; Holloway et al. 2013).

While the interwar period was marked by a social and economic situation that remained tense and worsened after the 1930s worldwide recession and the Second World War, by contrast, the period *post*-Second World War marked a phase of increasing prosperity (Bouquet 2021). Initially fueled by the discoveries of antibiotics and further medical progress, this new socio-economic framework also brought about its own set of epidemiological evolutions, such as the Hong-Kong flu or COVID-19 pandemics and the drastic sanitary measures deployed to fight them (Vuilleumier 2020).

In demographic terms, the entry into the fourth phase of the transition model took place during the years 1935 to 1965 (Calot et al. 1998; Menthonnex 2015; Höpflinger 2020). The overall downward trend observed during the previous phase – in both birth and death rates – begins to slowly stabilize or even increase in the case of natality. The population structure histogram loses its pyramidal shape and stretches even further (Fig. 5) (Calot et al. 1998; Kohli 2007; Menthonnex 2015; Höpflinger 2020). It is during this phase that the mortality pressure shifts definitively from youth to older ages, as infectious diseases gradually give way to senescence pathologies; thus, confirming the vital gains achieved during the second epidemiological transition. This evolution is tightly linked to the dynamics of RIAD during this period (Kohli 2007; Holloway et al. 2013), as the latter progressed from 21% of total causes of deaths in 1935 to less than 10% from 1965 onwards, as highlighted by modern Swiss federal medical statistics (Gubéran 1980; Calot et al. 1998; Kohli 2007; HSSO 2012; Menthonnex 2015; Höpflinger 2020). According to E. Gubéran (1980), this decrease was essentially the result of a continuous rise in living standards as well as of new medical breakthroughs, accompanied by a better nutrition. In addition, the decrease in birth rate – and its voluntary regulation – enabled agricultural productivity to keep up with the pace of population growth. Furthermore, the substantial gains in working and living conditions, as well as the tangible increase in sanitary conditions and in the general education level, made the prevention of diseases a matter of concern to everyone, and no longer the sole prerogative of the sick themselves, or of health institutions. Medical knowledge actively contributed to the reduction of RIAD mortality through the discovery of antibiotics, including sulphonamide antibiotics (developed as early as 1935) and penicillin (1943–1945), which are effective against pneumonia, otitis, and mastoiditis, as well as streptomycin (1946–1948) and isoniazid (1953), which both target tuberculosis. The newly established control over the mortality of the latter disease can be considered as one of the most important medical advances in the past century (Gubéran 1980).

Lastly, demographic researchers tend to distinguish a fifth and final phase of demographic evolution in which the global course of mortality is no longer dictated by RIAD. In the Swiss case, this final phase began in the final third of the 20th century and is characterized by birth and death rates stabilized at low levels, while the fertility rate is now below the threshold of population replacement (at least as far as the native population is concerned) (Calot et al. 1998; Kohli 2007; Menthonnex 2015; Höpflinger 2020). This constellation of factors tends to inhibit indigenous population growth. Hence, it is from this phase onwards that migratory movements ensured the bulk of population renewal. The age and sex histogram thus now resembles a more or less compressed bell, depending on the fertility rate of the population under consideration and its migratory balance. The dome-shaped crown – rather than a pyramid-shape – reflects the higher age reached by a substantial part of the population (as the average life expectancy at birth now reaches beyond 80 years) (Fig. 4). This generalized population aging is also reflected in the proportional distribution of causes of death. As compiled data analyses show, mortality is now no longer rhythmed by RIAD or infectious diseases' evolution, but rather by illnesses resulting essentially from human senescence (cardiovascular diseases, cancer, circulatory problems, etc.) (Fig. 11) (Calot et al. 1998; Kohli 2007; Menthonnex 2015; Höpflinger 2020; Holloway et al. 2013). Furthermore, RIAD themselves, after having constituted for a long time a latent threat to young individuals and the underprivileged classes, now constitute more of a threat amongst the older classes of populations or amongst immigrants (Calot et al. 1998; Kohli 2007; Menthonnex 2015; Höpflinger 2020; Holloway et al. 2013).

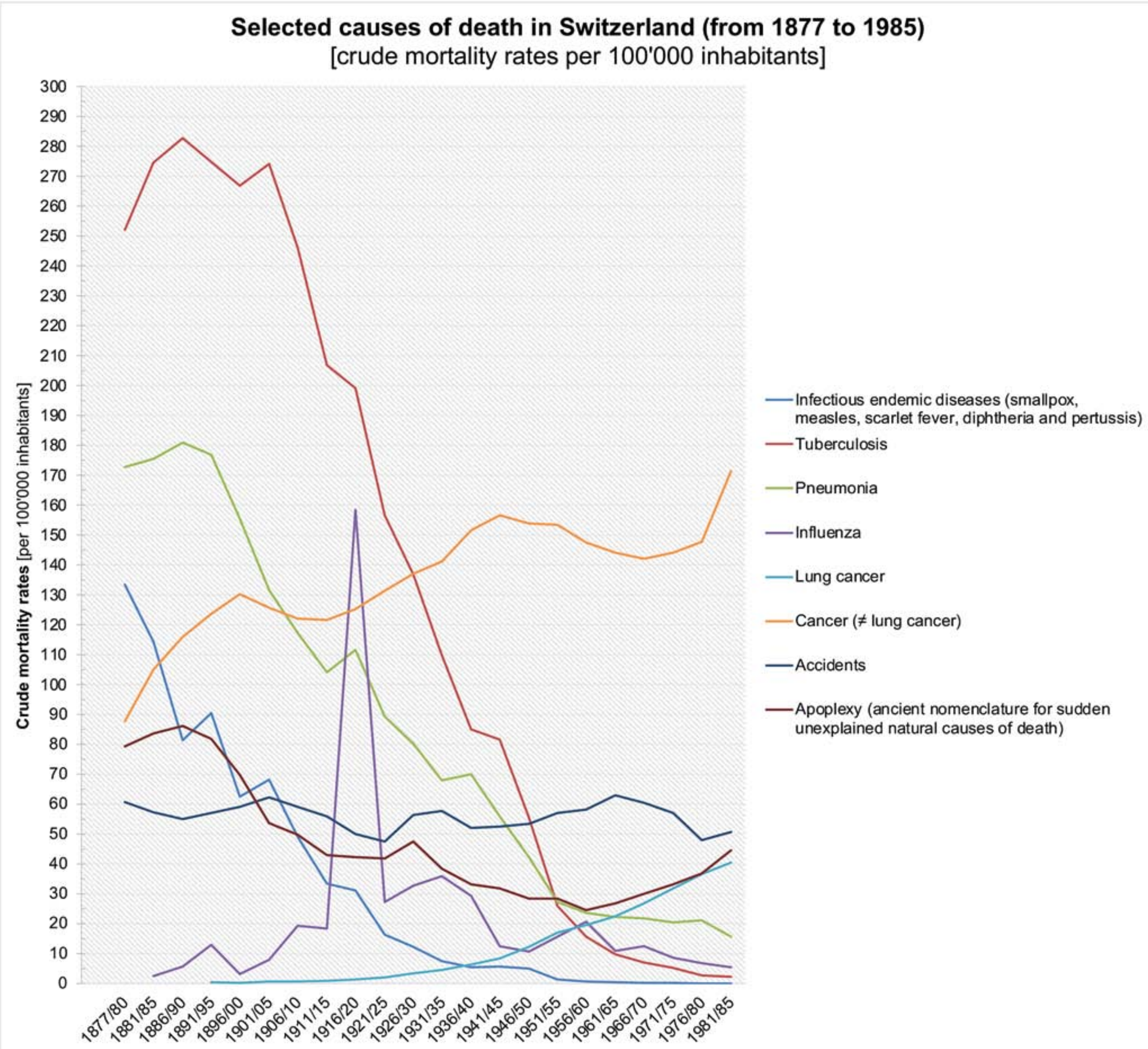


Fig. 11. Selected causes of deaths in Switzerland (1877–1985), based on data which are derived from the original analysis of primary sources and subsequent countings thereof by the Swiss Federal Statistical Office, reorganized into respective crude mortality rates expressed per 100,000 inhabitants. Exclusion of other causes of death was based on data availability, quality and relevance. Figure by authors, based on data by SFSO (1985); HSSO (2012).

4 Discussion

The study of RIAD in Switzerland developed in the present manuscript highlights the significant impact of human communities' relations, development, industrialization and living standards on respiratory health (Morax 1908; Olivier et al. 1924; Gubéran 1980; Perrenoud & Sardet 1991; Perrenoud 1993a; Holloway et al. 2013; Vuilleumier 2020), in line with the theoretical concepts of both "pathocenosis" and "microbial union" put forward by Grmek (1969) and Le Roy Ladurie (1973) respectively. As such, this observation constitutes an extremely up-to-date and timely concern as more and more humans are transitioning into often overcrowded, polluted, poorly sanitized, densely urbanized, and heavily industrialized landscapes (Es'andah 1976; Smith 2014; Lerch et al. 2017; Betsinger & DeWitte 2020; Kuddus et al. 2020). Indeed, the presented data compilation of the Swiss case exemplifies how infectious diseases – notably of respiratory type – in partial conjunction with episodic recessions, wars, and famines of all sorts, have consistently formed one of the main driving causes of mortality in peri-alpine communities at least since Antiquity, since all these factors are interdependent and directly affect both the pathocenotic balance and the microbial union within a given region (Grmek 1969; Le Roy Ladurie 1973; Ducrey & Favez 2004; Nappey 2007; Würgler 2012; Bouquet 2021; Hofstetter 2020, 2021). The present study, as well as previous investigations into the circumstances linking these various factors through time, reveal correlations between the lethality rate of diseases and particular socio-economic and demographic factors (Perrenoud 1975, 1978, 1979; Holloway et al. 2013; Roberts 2018, 2019, 2020; Vuilleumier 2020). Hence, one is provided with a renewed appreciation of the direct and adverse impact of industrialization, urbanization, globalization and conflict on the immuno-parasite equilibrium. Further, times of epidemic mortality precisely reflect the versatility and fragility of this equilibrium (Gonzalez et al. 2010). Moreover, this study shows that a global decrease in mortality does not necessarily mean an analogous evolution in RIAD mortality, as the case of the end of the 19th century and the beginning of the 20th century exemplify. During this period, overall mortality decreased much faster than that associated with RIAD, which resulted in the increase of their relative death toll share. This observation challenges estimates made in recent years, according to which urbanization might not have had that massive of a negative impact on mortality after all (Bandyopadhyay & Green 2017; Davenport 2020, 2021). While this may be true from the point of view of overall mortality (i.e. of all combined causes of death), estimated death counts from RIAD still seem to reflect the combined adverse effects of urbanization and industrialization on human health. The reasons underlying this state of fact are evidently numerous, but the Swiss case provides an interesting overview of some of these complex causalities and correlations which shape a given pathological landscape, wherein biological, socio-economic, demographic and medical factors intersect. Indeed, as Gonzalez et al. (2010) underline, disease interactions take essentially three forms: 1) antagonism: specific diseases find themselves hindered from spreading and overpowered by another, more "adapted" or "efficient" type of pathology, 2) synergy: a scenario wherein "*one disease facilitates the introduction or development of another disease*" (Gonzalez et al. 2010, p. 239) or 3) independence, which characterizes an environment in which diseases evolve without directly affecting each other. It might well be that – throughout the period under study in Switzerland – the shifting overarching framework conditions resulted in the occurrence of the first two types of disease interactions. For example, antagonism-type interactions have been suggested as having existed between plague, smallpox and measles; the latter two striking more strongly in the absence of major plague epidemics. Similar considerations have been proposed in the case of tuberculosis and leprosy, where the increased spreading of tuberculosis in the 17th century has been interpreted as being partially responsible for the concomitant decline in leprosy infections. More globally, the favoring of one disease over another, can in turn be seen as a consequence of the deregulation of the pathocenotic and microbial union, triggered by deep-reaching changes in human activity and communities' organization (Perrenoud 1993a; Gonzalez et al. 2010).

One also consistently observes – given that such stratified data is available – that RIAD tend to take on an endemic character and to thrive amongst the young, poor or working-classes in priority (Le Roy Ladurie 1973; Perrenoud 1975, 1978, 1979; Holloway et al. 2013; Rosental 2017; Vuilleumier 2020; Piret & Boivin 2021). In other words, the most fragile individuals (due to chronic undernourishment or exhaustion) and those most exposed to pathogens (due to unsanitary living or working environments), represent the demography most at risk, regardless of acute crisis settings or not (Gubéran 1980). This used to be the case in Switzerland as late as the beginning of the 20th century, and it would further take up until the middle of this same century to gradually fade out. Indeed, at this point in time, the stabilizing of the food supply chain, substantial improvements of living and hygiene conditions and medical innovations managed to establish a form of balanced control over RIAD. Hence, after centuries of exertion, infectious diseases finally gave way to other illnesses, especially senescence pathologies, in the rankings of causes of death. This highlights the importance of RIAD as a driving force behind the epidemiological and demographic transitions (Gubéran 1980; Holloway et al. 2013).

However, the current epidemiological situation should under no circumstances be seen as unassailable. It remains delicate to maintain and requires active input. Therefore, the conclusion drawn by E. Gubéran in his report on infectious diseases in Switzerland more than 40 years ago is still most relevant to this day: "[…] *the lesson drawn from the victories over* [infectious diseases] *is that action on the environment, lifestyle and diet must take precedence over advances in medical technology and treatment* […]." (Gubéran 1980: 580–581). Indeed, as illustrated for instance by the recent COVID-19 pandemic, in Switzerland and elsewhere, the versatility of the viro-bacterial and population immunity equilibrium and the adverse effects of globalization, industrialization, urbanization, conflicts and poor living standards on this unstable balance, are all key elements to be kept in mind at any given time (Grmek 1969; Le Roy Ladurie 1973; Gonzalez et al. 2010; Perrenoud 1993a; Brown & Leggat 2016; Rosental 2017; Patel et al. 2020a, 2020b; Rodriguez-Verdugo et al. 2020; Bickley 2021; UN 2023). In parallel, the versatility of this equilibrium is also illustrated in the rapid ability of some COVID-19 strains to bypass vaccine coverage. Also, likewise to all other RIAD through time, COVID-19 highlights the selective nature of such respiratory conditions targeting in priority the most fragile and vulnerable individuals. This observation is valid from a health state perspective, as COVID-19 struck largely amongst the elderly and those suffering from certain comorbid conditions (in the case of Western societies at least). It also resonates in a socio-economic perspective, as the disease hit the most marginalized, physically exhausted and deprived members of society most) (Kantamneni 2020; Khakee 2020; Patel et al. 2020a, 2020b; Lee et al. 2021; Tillmann et al. 2021). Accordingly, if one assumes that it is impossible to "de-hierarchize", "de-globalize" and "de-urbanize" our current world in any significant manner on the short run, this is tantamount to affirming that there will inevitably be other similar global pandemics in the future, whose lethality may be much higher and less selective than COVID-19 since, as stated by L. Shaw-Taylor: "*Experts*, […], *have always known that the world remained vulnerable to novel pathogens or new more lethal strains of old pathogens, but most of the world's governments were both woefully underprepared and either unable or unwilling to start making adequate preparations* […]." (Shaw-Taylor 2020: 16). In this sense, this article, might well serve as a timely reminder of the importance of monitoring and fighting infectious illnesses and RIAD, notably by properly funding public health agencies in charge and competent in this matter (Ventola 2015; Brown & Leggat 2016; Kantamneni 2020; Khakee 2020; Bickley 2021; Piret & Boivin 2021; Lobinska et al. 2022). This process should also help in addressing RIAD and associated public health issues at their root, rather than tediously duct-tape social fractures and flawed civil mechanisms later on (Graeber 2018). Further, it also demonstrates the need to critically re-evaluate – in the light of meaningful bioarchaeological, palaeopathological, historical and medical data – the very serious challenges posed by the massive industrialization and urbanization processes to come throughout the world in the next decades (Es'andah 1976; Smith 2014; Roberts 2018, 2019, 2020; Betsinger & DeWitte 2020; Kuddus et al. 2020; Piret & Boivin 2021; Zou et al. 2022).

5 Conclusions

This intersectional and multidisciplinary review approach – exemplified through a case-study focusing on respiratory health amongst Swiss populations between the 16th and 21st centuries – enabled to identify and circumvent some of the key methodological issues hampering this type of *a posteriori* investigation. The consideration and comparison of several demographic and statistical datasets allowed to test their internal consistency and statistical value, before mobilizing them as interpretative foundations. The main problem of the value of old medical diagnoses was apprehended by developing a broader classification system (i.e. the meta-category of RIAD) that encompasses all conditions targeting the respiratory tract (or contaminating the body through it). This approach allowed us to reduce the impact of terminological shifts in the medical jargon and misdiagnoses in past times. This classification system proved its soundness for the case of respiratory diseases, but it also seems to be transposable to any other generic disease categories. As such, this method firmly prepares the ground for a more systematic confrontation of historical insights, medical data and palaeopathological results. Indeed, the diagnostic precision of ancient bone analysis rarely allows for a clear and unique determination of the cause of death. Rather, it will yield a differential diagnosis exposing possible conditions responsible for the observable osteological lesions; an approach which is compatible with the previously proposed broader classification of medical conditions.

In sum, it is now possible to answer the research questions exposed in the introduction. Thus, to question 1) what are the social and environmental factors guiding the risk or not of suffering from RIAD, the answer seems to be the following. Age and socio-economic status appear to be paramount in the risk of developing respiratory diseases, i.e., younger individuals and those at the lower end of the socio-economic scale are at greatest risk. In environmental terms, this review points to a differentiation in the health status of rural and urban populations from the 19th century onwards, with a significantly higher prevalence of RIAD in urban settings. To question 2) do these factors appear to be constant across a territory and over time, this research answers in the negative. Large-scale climate change (e.g., the "Little Ice Age") or industrialization and associated urbanization appear to have had harmful effects on the respiratory health of the Swiss population. To question 3) can the evolution of RIAD occurrences be correlated to the local history of a particular region, this research suggests that it can. Indeed, the graphical presentation of the evolution of birth, death and RIAD mortality rates between the 16th century and the present era can be quite easily interpreted in the light of the overarching local and trans-regional historical contexts. Finally, to question 4) whether a better understanding of RIAD dynamics in the past can provide useful lessons for their sustainable management in the near future, the answer of this paper is affirmative as well. The presented research details the major ins and outs of the evolution of RIAD at the Swiss scale and its broader implications in settings other than Switzerland.

In other words, the presented results are not only of interest for historians of medicine, but they also provide useful insights for clinicians and health policy makers who wish to understand, manage, and prevent RIAD epidemics as of now or in the future. Lastly, this study also provides a contextual basis for palaeopathologists who aim to undertake an in-depth study of the osteological markers of RIAD in Switzerland through time. In addition to providing contextual data upon which to anchor the interpretation of such lesions in archaeological contexts, this work also led to identifying some of the major difficulties that limit the elaboration of longitudinal studies focusing on RIAD. Such difficulties include notably the lack of reliable ancient data, the scarcity of rural primary sources, the evolution of medical understanding and nomenclature, the osteological paradox bias, the osteological imperative to consider all illnesses and diseases affecting the respiratory tract (or infecting the body through it) in a conglomerate manner, etc. Nevertheless, this study represents a useful addition to the scientific corpus addressing the effects of RIAD on human communities and their development and offers some practical solutions to circumnavigate the difficulties inherent to the diachronic study of respiratory health.

In terms of future research perspectives, it would be of interest to develop similar approaches in neighboring regions or focus more precisely on specific types of respiratory diseases, in order to contrast other local or given pathological signatures with the one presented in this manuscript.

Acknowledgements: The authors are most grateful to Dr. S. Flohr, Dr. M. Krayenbühl, Dr. V. Magnin, Prof. Dr. Márquez-Grant, Prof. Dr. J.-D. Morerod, Dr. Dr. A. Mudry, Dr. Dir. L. Pernet, Dr. V. Varlet, Dr. C. Abegg, Drs. G. & D. Hofstetter, I. Achouche, A. Brandt-dit-Siméon, V. Carraux and D. Kreitmann for their insightful comments and support.

Funding, conflict of interest and authors' statements: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. TH compiled the data forming the backbone of this study. TH drafted the article; NM supervised the research. NM, AF and SG corrected and expanded the manuscript (modifications to introduction, analyses and main text). The authors have no conflict of interest whatsoever to disclose. All data on which this publication is based are available upon justified request to the authors and involved partner institutions.

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Manuscript received: February 9, 2024
Revisions requested: June 12, 2024
Revised version received: July 18, 2024
Manuscript accepted: July 22, 2024

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Supplementary files: Tables 1–10 and Appendices 1–4	
The supplementary files contain tables summarizing the key-word strings used to constitute the literary corpus of the present study and a list of the medical terms mobilized in the different archives (Geneva, Neuchâtel, Bern, Lausanne and Bière), which were consulted to assess the evolution of RIAD through time. Further to be found in appendix format are summaries of the different statistical operations performed on the retrieved corpus (linear and joinpoint regression analysis as well as Welch's unpaired *t*-tests).	
Tables 1–4.	Summary of key-word strings used in literary corpus constitution.
Table 5.	Medical terms – Geneva archives (1740–1759) (as listed in Perrenoud 1993a)
Table 6.	Medical terms – Geneva archives (1800–1819) (as listed in Perrenoud 1993a)
Table 7.	Medical terms – Neuchâtel archives (1801–1864) (as listed in AECN 1801–1814/1816–1839/1841–1847/1850–1864, HSSO D.18b)
Table 8.	Medical terms – Bern archives (1815) (as listed in Rüttimann & Loesch 2012; BERNHIST 1700–2023)
Table 9.	Medical terms – Lausanne archives (1904, 1905 and 1910) (as listed in ACV 1904–1910. SB 267/53/3)
Table 10.	Medical terms – Bière archives (1904–1910) (as listed in ACV 1904–1910. SB 267/13/3)
Appendix 1.1.	Overall analyses graphical summing-up.
Appendices 2.1–2.7.	Linear regressions of aggregated crude natality, mortality and RIAD mortality rates (GE – NE – CH).
Appendices 3.1–3.3.	Joinpoint regression analysis (0 to 5 joinpoints, parametric method CI, BIC3)
Appendices 4.1–4.6.	Welch's unpaired *t*-test results.