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Brief communication title: Can the palaeoepidemiology of rickets during the industrialisation period in France be studied through bioarchaeological grey literature and French medico-historical literature of the 18th-early 20th centuries? Preliminary examination of a complex topic.

Authors name and affiliations:

Antony COLOMBO ^{1,2*}, H el ene COQUEUGNIOT ^{2,3,4}, Olivier DUTOUR ^{2,3,5}

1 - Laboratorio di Antropologia fisica, Dipartimento di Scienze Biologiche, Geologiche ed Ambientali – BiGeA, Universit  di Bologna, Bologna, Italy

2 - Chaire d'Anthropologie biologique Paul Broca, EPHE-PSL University, Paris, France

3 - UMR 5199 PACEA, CNRS/University of Bordeaux/Ministry of Culture ; LabEx Sciences arch ologiques de Bordeaux, n  ANR-10-LABX-52, Pessac, France

4 - Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

5 - Department of Anthropology, Canada Social Science Centre, Western University, London, ON, Canada

***Corresponding author:** Dr Antony Colombo; *address:* Laboratorio di Antropologia fisica, Dipartimento di Scienze Biologiche, Geologiche ed Ambientali – BiGeA, Universit  di Bologna, via Francesco Selmi 3, 40126 Bologna, Italy.

Telephone number: +39 051 2088059; *e-mail address:* colomboantony@gmail.com

ORCID:

Antony Colombo – 0000-0002-8855-7502

H el ene Coqueugniot – 0000-0002-1844-4588

Olivier Dutour – 0000-0001-8134-788X

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Abstract:

Objective: This study explores whether data relating to rickets from the French medico-historical literature (FMHL) and bioarchaeological grey literature are useful in evaluating its epidemiology during the industrialisation of France. Unlike other European countries such as England, industrialization in France was a slow and continuous process with two phases: the first in 1830 to 1870 and the second in 1870 to 1914.

Materials and methods: A bibliographical analysis of 2800 FMHL sources from the 18th to the early 20th centuries and 50 archaeological excavation reports from the last 21 years was undertaken.

Results: The FMHL data is very heterogeneous and predominantly dates to the second phase of industrialisation. The bioarchaeological data is very incomplete and predominantly relates to the period before industrialisation. At the same time, knowledge improvement and institutional changes to protect children could explain more systematic registration of cases of rickets.

Conclusions: No solid conclusions can be made regarding the prevalence of rickets at present, however these data hold great potential.

Significance: In comparison to England, no systematic investigation of rickets prevalence during the period of industrialisation in France has been undertaken to date.

Limitations: The lack of archaeological excavations from this period and the limited paleopathological analysis of the sites excavated have contributed to our current lack of understanding regarding the impact of industrialization on the prevalence of rickets on the French population.

Suggestions for further work: The FMHL data needs to be homogenized and osteoarchaeological collections need to be restudied with a common protocol focusing on signs of vitamin D deficiency.

Introduction

Vitamin D deficiency is a metabolic disorder that can affect the mineralisation of osteoid tissue, leading to weakened bones, and bone deformities. Active rickets occurs when this deficiency happens during childhood, although severe deformities may be seen in adults (residual rickets) (Brickley and Mays, 2019). Vitamin D is produced inside the skin upon sunlight exposure, but to a lesser extent can also be provided by nutritional intake. Both are influenced by the environment (*e.g.* weather, food) and cultural habits (*e.g.* sedentism, clothing, food quality) for an optimal vitamin D rate (Brickley et al., 2014).

Today, rickets remains a public health issue, in developing countries but also in western countries, where it is often linked to immigration (Creo et al., 2017). Although rare in France, vitamin D deficiency and rickets did not disappear during the 20th century, and may be on the rise among infants and adolescents because of their increasing inactivity and poor dietary practices (Mallet, 2004, 2013).

The Industrial Revolution was a major cause of the increased prevalence of rickets in urbanised England (Lewis, 2002). However, England and France did not experience the same industrialisation (Lévy-Leboyer, 1968). The English Industrial Revolution began at the end of the 18th century, whereas in France industrialisation was a slow and more continuous process. It happened in two phases: the first one (1830-1870), with coal and textile industries, and the second one (1870-1914), with electricity, steel and chemical industries (Verley, 2003). Although the French economy was strong, the period of political instability from the Revolution in 1789 to at least 1870 (Figure 1) could have caused a later industrialisation in comparison to England (Roehl, 1976). This gradual transition may have been beneficial with less damaging effects on health (Weir, 1997) and air quality (*i.e.* smog) (Frioux, 2019) and better working conditions for children (Bensimon, 2020), than seen in more rapidly industrialising countries.

French archaeological sites dated from the industrial periods are missing from large bioarchaeological studies (*e.g.* Jankauskas and Grupe, 2018) and exhaustive reviews focused on rickets (*e.g.* Brickley and Ives, 2008). To our knowledge, no bioarchaeological studies from this period in France have been published in refereed journals. This lack prevents us understanding the rickets prevalence in France. Nevertheless, studies before and after industrialisation are available. Schattmann et al. (2016) studied a pre-industrial archaeological site in Douai (north of France) in which 50% of the children under 5 years old had rickets.

Before the 1960s, rickets was reported in 15-30% of hospitalised French children (Mallet, 2004).

Medico-historical literature has already been useful to document the palaeoepidemiology of rickets and to complement bioarchaeological data (*e.g.* Veselka et al., 2021). This article evaluates how French medico-historical literature (FMHL) and unpublished excavation reports can help in the investigation of the palaeoepidemiology of rickets during industrialisation in France.

Material and Methods

A bibliographical search was undertaken on the FMHL: medical books, dictionaries and doctoral theses, hospitals and administrative records, *etc.*, from 1750 to 1930 (before, during and after the French industrialisation) on *Gallica* (for italic French terminology, see Table 1). To date, 2800 references have been screened with automatic detection for the word “*rachitisme*” within the text, without assumptions about the most informative document type and not restricted to a specific region of France. Given the context of the word’s use, the document’s relevance for our study was evaluated.

Bioarchaeological data can be found in a few published articles in regional archaeological journals but mainly in archaeological excavation reports (grey literature) written by osteoarchaeologists. The database *dolia* of the *Inrap* – French leader in rescue archaeology - contains references of both archaeological analysis and excavation reports. A keyword search was undertaken without restriction to a specific region, through the *thesaurus*: “*époque contemporaine*”, “*temps moderne, XVIII^e siècle*”, “*méthodologie, anthropologie*”, “*mort, nécropole, cimetière, cimetière paroissial, sépulture*”. This led to 209 results, narrowed down to 50 that were deemed potentially interesting, because human remains or related terms were mentioned in the abstract. From those with human remains, searches for “*rachitisme*” or related terms “*carence*”, “*vitamine D*”, “*maladie métabolique*”, “*rachitisme résiduel*” were automatically undertaken, regardless of the diverse diagnostic methods found in these reports.

Results

Much of the FMHL screened was not informative. Relevant data about rickets was identified in hospital, *sanatorium*, or day nursery reports, but above all, in the *rapports et procès-verbaux des délibérations des départements*. These reports give mortality, causes of death and health status of living *enfants de l’assistance publique* per year. Data about mortality (incorrectly) attributed to rickets (Tables S1 and S3), and rickets cases reported in the living population during the two phases of French Industrialisation (Tables S2 and S4), have been collected for 15 departments, mainly in the North and East of France (Figure 2). More data relating to the rickets epidemiology from the FMHL are available for the second phase of the industrialisation (82 documents against 27 for the first phase).

Most archaeological sites identified from *dolia* are in the North and East of France (Figure 3). The period before industrialisation is represented by 26 reports, compared with 14 for the first phase and 10 for the second phase (Table S5). However, only 23 of these 50 sites presented bioarchaeological data. Reports from four sites (one from the industrialisation period)

mention positive cases of rickets in children (active or healed) and five other (two from the industrialisation period) report cases of residual rickets in adults. These reports used different diagnostic criteria, and thus are not directly comparable.

Some statements can be highlighted after the compilation of data from both FMHL and excavation reports (in Supplementary Information). Data collected will not be interpreted at this stage of the study for the reasons below.

Discussion

Two preliminary statements can be made. The FMHL data is very variable and is more abundant for the second phase of French industrialisation. Data seems to have been more systematically recorded. On the contrary, excavation reports with data relevant to the rickets epidemiology predominantly relate to the period before industrialisation.

The FMHL gathers a different kind of data: quantified data (primary sources: *e.g.* hospital or administrative reports) and general comments (secondary sources: *e.g.* books, dictionaries). Primary sources could permit investigation of rickets prevalence through mortality records and its presence in the living population. It should be noted that while rickets was frequently listed as cause of death in the FMHL, rickets is no longer considered a terminal disease. Nevertheless, it is complicated to compare time periods. Data registration is sporadic in all of the French departments observed. Also, the populations (*i.e.* from hospital, governmental care, *sanatorium*, free medical consultations, day nursery) and age groups (mainly 0-2 and 0-12 years old) reported, and the socio-economic status examined in the various reports can be different. Moreover, data may concern a city, a group of cities, or a complete region without any distinction between rural and urban environments.

Even if variations in rickets prevalence could be observed over time, interpretation should consider that during the first phase of the French industrialisation, data confused rickets with other symptoms or diseases. Rickets was associated with “bone caries” - outdated term for infectious osteitis or osteomyelitis - (*e.g.* Charvet, 1860), tuberculosis (Armeuille and Parmentier, 1847; Lafargue, 1903; Perrochaud, 1877; Pihan-Dufeillay, 1863, 1865), and sometimes associated with weakness and syphilis (reports from the *Conseil Général de la Marne* and *Conseil général du Nord*). Indeed, once rickets had been identified by medical doctors in France prior to 1683 (Sigaud de la Fond, 1781), and for a long time afterwards, it was viewed as a stage of other diseases (often debated in the medical literature of the time). This included dwarfism (Sigaud de la Fond, 1781), tuberculosis (Jossic, 1856), criticised by Guérin (1839), congenital syphilis (Parrot, 1886), criticised by Assada (1886), or even scurvy, gout, and cancer (*Dictionnaire des sciences médicales*, 1820). Confusion regarding the definition of rickets can be demonstrated by non-effective treatments that persisted over time. These included mercury syrup, reconsidered in the 1830s (Ducluzeau, 1831), or plants like *Osmunda regalis*, massages and cold baths (*Dictionnaire des sciences médicales*, 1820). Treatments for rickets were also adapted to the discoveries and medical fashions such as electrotherapy (Pascalis, 1819) and vaccination (Comité central de vaccine, 1811, 1812). Vaccination was later considered to cause rickets (Comité central de vaccine, 1850, 1853) before being demonstrated to have no impact (Comité central de vaccine, 1877).

The role of vitamin D in rickets was understood in 1922 with its discovery. But in France, empirical observations by the scientists during the industrialisation period improved detection rates of rickets and introduced some useful treatments. Thus, by the second phase of industrialisation, rickets detection was far better. The physiopathological process of rickets was described by Broca (1852). Lack of sunlight was proposed as a cause of the disease in 1833 (Ducrotay de Blainville, 1833). However, sunlight was only accepted as a treatment in the late 19th century when it was compulsory for children to be sent to *sanatoria* on the coast (law of July 15, 1893) (Monod, 1897). Poor nutrition was often identified as a cause of rickets, but the only effective dietary treatment was cod liver oil. Its effectiveness was already reported in 1823 (Virey, 1823), but it was first introduced in France as a potential treatment for rickets in 1845 (Hogg, 1856) and was finally accepted as such after the 1850s (Bouchardat, 1853; Escallier, 1850; Hogg, 1856; Taufflieb, 1853). Despite this, cod liver oil was only used by the general public after the 1870s (Meurein, 1873). In addition, prevention against poor nutrition was institutionalised in 1892 with the establishment of the *goutte de lait* to bring quality food for poor infants (Variot, 1904).

Despite the political instability in France (which could have delayed industrialisation), national laws could have helped to decrease the risk of developing rickets (Figure 1). The law of March 22, 1841, prohibited the employment of children under 8 years old (Pierrard, 1987; p. 55). The Jules Ferry laws (June 16, 1881; March 28, 1882) made school obligatory. Even though these laws were enacted, it does not mean that the laws were always followed.

Overall, a potential increase of rickets in the 19th century could result from greater understanding of the disease leading to its increased recognition. Better detection may also account for the increased evidence of rickets in the FMHL and must be considered in further studies.

The lack of bioarchaeological data about rickets during the French industrialisation could be related to the relative rarity of excavated sites dated to this period. Indeed, numerous cemeteries where individuals of this period were buried are still in use today. Although the royal orders of March 10, 1776, and December 16, 1843, and the imperial decree of June 12, 1804 led to moving cemeteries out of the cities (Lasserre, 1991) today they are located within city limits because of urban expansion.

Most of the sites with available bioarchaeological data report no cases of rickets or residual rickets. Only remarkable palaeopathological cases were mentioned in excavation reports along with the general health status based on the analysis of stress markers (*cribra orbitalia*, porotic hyperostosis, linear enamel hypoplasia) and dental health. Rickets and residual rickets were mentioned when obvious long bone deformities were visible. Other suggestive signs (Brickley and Ives, 2008; D'Ortenzio et al., 2018b) were not analysed except for the site in Rouen (Figure 3, n°43; Jimenez and Thomann, 2019) who reported the highest prevalence of rickets (see Table S5). Extreme prevalence between sites can be interpreted as a problem of methodology with a non-standardised protocol of study, leading to missed cases. Nevertheless, even with a meticulous palaeopathological investigation of rickets, fewer individuals probably died with active rickets than those who survived and died later, often in adulthood. Thus, any lesions will have been differentially remodelled, leaving a few cases of residual rickets (Brickley et al., 2017). In the future, it might be helpful to identify dental tissues

mineralisation defects (Colombo et al., 2019; D'Ortenzio et al., 2018a; D'Ortenzio et al., 2018b; Ogden et al., 2007).

Conclusion

FMHL, especially the *rapports des délibérations des départements*, can provide the data necessary to study the rickets palaeoepidemiology during the French industrialisation. Nevertheless, the literature is complex to use and interpret because of the general context in which it is reported. Advancement of medical knowledge, populations reported, the lack of data regarding their socio-economic status or living environment are factors to consider. These documents are available for the 96 departments of Metropolitan France and must be analysed in detail to allow a comprehensive palaeoepidemiological study.

The lack of focused research on rickets in the skeletal populations during the French industrialisation justifies the re-examination of large osteoarchaeological collections. A robust methodology for the diagnosis of vitamin D deficiency is needed, based on recent advances in palaeopathological diagnosis, considering the socio-economic groups, the degree of urbanisation and environmental factors (*e.g.* pollution, exposure to sunlight). A common protocol for diagnosing rickets in France skeletal remains via a targeted research project or during post-excavation analysis in rescue archaeology could achieve it. Finally, a comparison of both historical and skeletal data should be undertaken to achieve a more complete understanding of the palaeoepidemiology of rickets during French industrialisation. Only then could we search for a link between rickets and industrialisation in France as seen in England (Lewis, 2002).

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Table 1: Translation and definition of French terminology

French word / abbreviation (long form)	Definition / English translation
Material and Methods	
<i>Gallica (Gallica.bnf.fr)</i>	<i>Gallica</i> is the online open access digital library of the <i>BNF</i>
<i>BNF (Bibliothèque Nationale de France)</i>	French national library
<i>rachitisme</i>	rickets
<i>dolia (dolia.inrap.fr)</i>	Archives database of the <i>Inrap</i>
<i>Inrap (Institut national de recherches archéologiques preventives)</i>	National institute of research for rescue archeology
<i>époque contemporaine</i>	late modern period
<i>temps moderne</i>	early modern period
<i>XVIII^e siècle</i>	18 th century
<i>méthodologie</i>	methodology
<i>anthropologie</i>	anthropology
<i>mort</i>	death
<i>nécropole</i>	necropolis
<i>cimetière</i>	cemetery
<i>cimetière paroissial</i>	parish cemetery
<i>sépulture</i>	burial
<i>carence</i>	deficiency
<i>vitamine D</i>	vitamin D
<i>maladie métabolique</i>	metabolic disease
<i>rachitisme résiduel</i>	residual rickets
Results	
<i>rapports et procès-verbaux des délibérations des départements</i>	reports of the deliberations of the French departments
<i>département</i>	A “department” is an administrative division smaller than a region. Metropolitan France has 96 departments forming 12 regions.
<i>enfants de l’assistance publique</i>	children in governmental care
Discussion	
<i>goutte de lait</i>	Name of a French institution created after 1892 with the purpose of supplying infants with sterilised milk and good quality food, of offering free medical consultations to mothers and infants as well as providing education and hygiene advice to mothers.

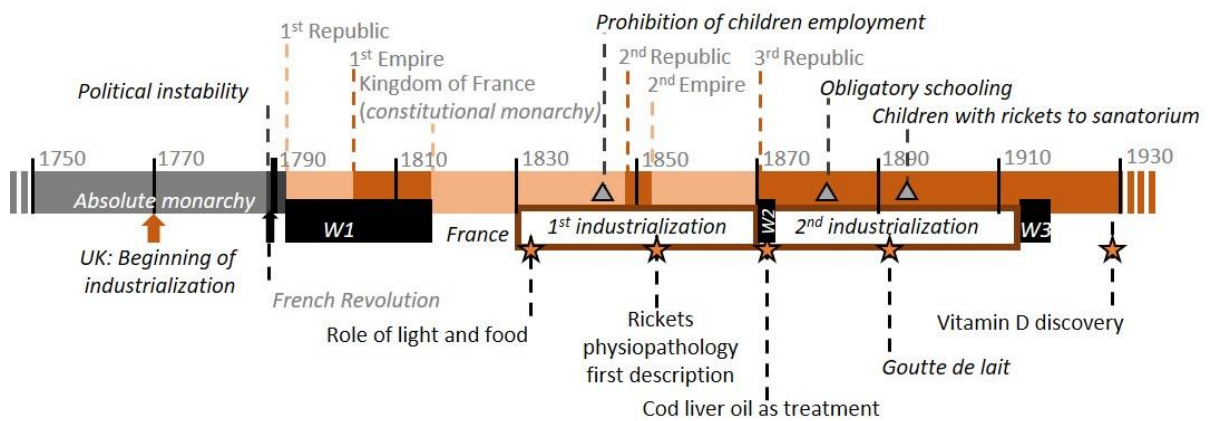


Figure 1: Historical timeline of industrialisation and rickets-related discoveries and innovations (W1: Napoleonic wars, W2: Franco-Prussian war, W3: 1st World War, grey triangles: laws protecting children, orange stars: discoveries and innovations related to rickets).

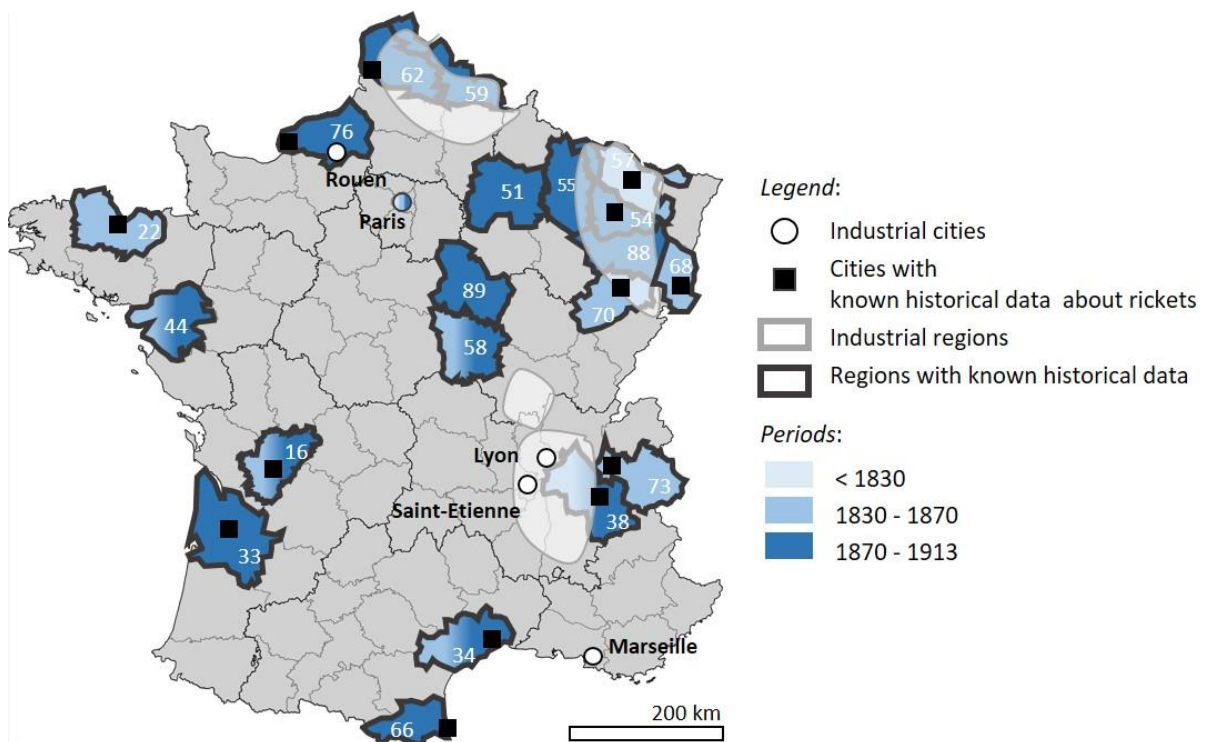


Figure 2: Map of the French departments for which data about rickets was collected from the French medico-historical literature of the 18th-20th centuries.

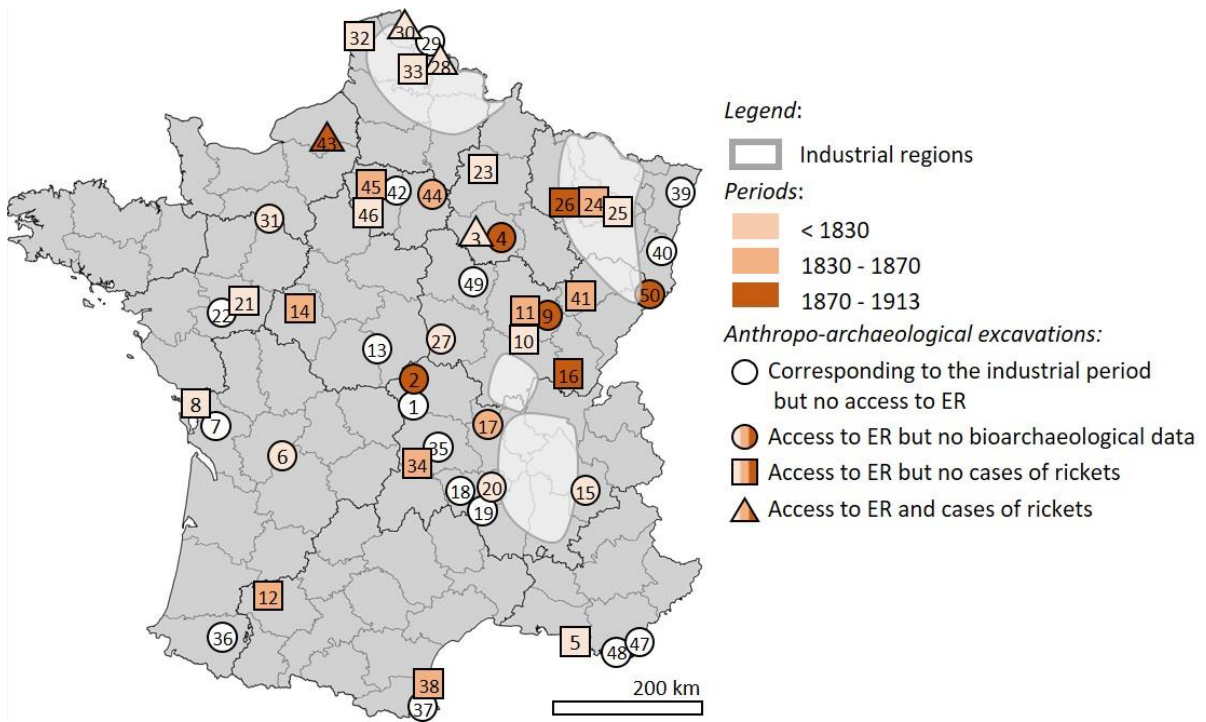


Figure 3: Map of the archaeological sites corresponding to the periods of industrialisation in France (numbers corresponds to cities, see Table 5).

SUPPLEMENTARY INFORMATION

Brief communication title: Can the palaeoepidemiology of rickets during the industrialisation period in France be studied through bioarchaeological grey literature and French medico-historical literature of the 18th-early 20th centuries? Preliminary examination of a complex topic.

Authors name and affiliations:

Antony COLOMBO ^{1,2*}, H  l  ne COQUEUGNIOT ^{2,3,4}, Olivier DUTOUR ^{2,3,5}

1 - Laboratorio di Antropologia fisica, Dipartimento di Scienze Biologiche, Geologiche ed Ambientali – BiGeA, Universit   di Bologna, Bologna, Italy

2 - Chaire d'Anthropologie biologique Paul Broca, EPHE-PSL University, Paris, France

3 - UMR 5199 PACEA, CNRS/University of Bordeaux/Ministry of Culture ; LabEx Sciences arch  ologiques de Bordeaux, n   ANR-10-LABX-52, Pessac, France

4 - Department of Human Evolution, Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

5 - Department of Anthropology, Canada Social Science Centre, Western University, London, ON, Canada

***Corresponding author:** Dr Antony Colombo; *address:* Laboratorio di Antropologia fisica, Dipartimento di Scienze Biologiche, Geologiche ed Ambientali – BiGeA, Universit   di Bologna, Via Francesco Selmi, 3, 40126 Bologna, Italy.

Telephone number: +39 051 2088059; *e-mail address:* colomboantony@gmail.com

Keywords: Vitamin D deficiency, bibliographical analysis, archaeological excavation reports, France.

As explained in the main manuscript, the data exported from the French medico-historical literature (FMHL) is not homogeneous enough for analysis and ideally needs to explore the 96 French departments. Also, the lack of data from the bioarchaeological side prevents us doing a proper palaeoepidemiological study of rickets during the period of industrialisation in France. This given, some statements can be highlighted after the compilation of data from both FMHL and excavation reports in the tables S1 to S5 below. We will not interpret them at this stage of the study. It should be noted that while rickets was frequently listed as cause of death in the historical documents, rickets is no longer considered a terminal disease.

FMHL: Before the French Industrialisation

Before industrialisation, rickets is erroneously reported to be the cause of death for 20% of children (Portal, 1797). But in Paris, between 1820 and 1825, only 0.54% of childhood deaths in hospital were attributed to rickets (Table S1).

FMHL: First Phase of the French Industrialisation

During the first phase of French industrialisation, results are very variable. For example, in Isère, between 1851 and 1871, 0% of individuals had rickets reported as their cause of death, compared to 2.1% in Metz (Moselle), in 1864 (Table S1). Both are located in industrialised regions (Figure 2).

Among living children, in 1856 in Nièvre, rickets was said to affect all population classes (Conseil Général de la Nièvre, 1856), however results differ highly between departments. In Charente in 1856, 30.8% of the observed population had rickets whereas the same year in Hérault, it was 0.66% of the children in governmental care (Table S2). Both regions are located in a less industrialised part of France (Figure 2) and a sunny part of the country.

FMHL: Second Phase of the French Industrialisation

During the second phase of French industrialisation, results are also variable (Table S3). For instance, between 1882 and 1898 in Vosges, 0% to 1.46% of the children who died between birth and 2 years had cause of death reported as rickets. Between 1881 and 1891, in Lille (main city in the department Nord), it ranged from 0.23% to 0.88%; and 1.05% to 2.05% in Nièvre. These departments and this city are located in or close to industrialised regions (Figure 2).

During this phase, in an industrialised area of France, rickets in living children could be as high as 17.5% in Nancy's hospital in 1899 (Meurthe-et-Moselle), whereas in Le Havre (Seine-Maritime) in 1884, it was only 1.66% (Table S4).

Excavation reports:

Positive cases of rickets in children (active or healed) were reported for four sites. Before industrialisation, the prevalence of rickets is 8.4% in Troyes, 14.3% in Armentières and 50% in Douai. During industrialisation, in Rouen, it is 46.7% (Table S5).

Five sites present cases of residual rickets in adults with prevalence ranging from 6.01% in Lunéville to 14.3% in Beaune before industrialisation and from 0.45% in Nancy to 25% in Rouen during industrialisation (Table S5). Reims, Lunéville and Nancy are cities in the same industrial region. Analysis of skeletal populations dating to before or during industrialisation identified no cases of rickets in children, but some cases of residual rickets in adults. These individuals were from different socio-economic classes.

Table S1: Data from the French medico-historical literature about mortality attributed to rickets through the first phase of French industrialisation (Ref: references; R: rickets, BC: bone caries (*i.e* osteitis or osteomyelitis), T: tuberculosis; Pop.: population type, GC: governmental care, H: hospital, FM: free medical consultation; BI: before industrialisation; age is expressed in years, Child.: children; n: number of, m: mean, sd: standard deviation, min: minimum, max: maximum, † are expressed per year except for ‡ for which it is for the whole period, mortality and rate is expressed as a percentage, rate is the number of deaths due to the disease to the total number of deaths).

Ref	Department	Cities	Diseases	Pop.	Period (n years)	Age	Mortality %†		n death with disease†		Rate %†	
							m (sd)	[min-max]	m (sd)	[min-max]	m (sd)	[min-max]
[1]	34- Hérault	Montpellier, Béziers, Lodève, Saint-Pons	R	GC	1853 ^a		-		0			
[2]	38- Isère	Grenoble	R, BC	H	1851-1871 (6)	< 20	14.38 (2.82)	[10.16-17.65]	-	0	-	0.00
[3]	44- Loire-Atlantique	Nantes	T, R	H	1862-1864 (2)	[0-5]	-	-	-	[11-16]	-	[1.30-2.11]
						[0-15]	-	-	-	[14-26]	-	[1.40-2.85]
[4]	57- Moselle	Metz	R	FM	1864	[0-10]	-	0.77	-	8	-	2.08
[5]	58- Nièvre		R	GC	1856 ^b	-	-	-	-	-	-	-
[6]	59- Nord	Lille	R	H	1844-1852	[0-5]	-	-	-	148‡	-	1.59‡
[7]	68- Haut-Rhin		R	FM	1856	Child.	-	26.64	-	2	-	0.49
[8]	75- Paris		R	H	BI / 1820-1825	[0-12]	-	-	-	123‡		0.54‡
				H	1861-1864 (4)	Child.	14.78 (5.51)	[10.75 - 22.92]	5.00 (4.16)	[0-10]	0.49 (0.39)	[0.00 - 0.94]

[1] Conseil Général de l'Hérault (1857, 1882, 1889, 1890, 1891, 1892, 1895, 1897), [2] Charvet (1854, 1860, 1861, 1864, 1867, 1875), [3] Pihan-Duffeillay (1863, 1865), [4] Paté (1865), [5] Conseil Général de la Nièvre (1856, 1874, 1882, 1885, 1886, 1888, 1906), [6] Pierrard (1975), [7] Conseil Général du Haut-Rhin (1857), [8] Administration Générale de l'Assistance Publique à Paris (1867a, b, 1868, 1870)

^a no case of rickets observed during this year

^b rickets affects all low socio-economical classes

Table S2: Data from the French medico-historical literature about rickets in the living population through the first phase of French industrialisation (Ref.: references; R: rickets, BC: bone caries (*i.e* osteitis or osteomyelitis), T: tuberculosis; Pop.: population type, H: hospital, GC: governmental care, DN: day nursery, FM: free medical consultation; GP: general population; age is expressed in years, Child.: children; n: number of, ind.: individuals, min: minimum, max: maximum, rate is expressed as a percentage).

Ref.	Department	Cities	Diseases	Pop.	Period (n years)	Age	n ind. observed	n cases	[min-max] rate %
[1]	16- Charente		R	H	1856	-	68	21	30.88
[2]	34- Hérault	Montpellier, Béziers, Lodève, Saint-Pons	R	GC	1856	[0-12]	303	2	0.66
[3]	38- Isère	Grenoble	R, BC	H	1851-1871 (6)	< 20	[283-374]	[1-4]	[0.27-1.18]
[4]	68- Haut-Rhin		R	FM	1856	Child.	1535	36	2.35
[5]		Mulhouse	R	GC	1869	Child.	325000	30524	9.39
[6]	70- Haute-Saône	Luxeuil-les-Bains	R	H	1845-1850	< 20	883	7	0.79
[7]	73- Savoie	Aix en Savoie	R	H	1845	-	106	2	1.89
[8]	75- Paris	Paris 3e	R, T	FM	1847	-	945	7	0.74
[9]		Paris 9e	R	H	1837-1846	20	4810	11	0.23
				GP		20	3337	4	0.12
[10]				DN	1846-1867	Child.	3332	1	0.03
[11]				H	1861-1864 (4)	Child.	[4629-8450]	[5-62]	[0.06-1.33]

[1] Jossic (1856), [2] Conseil Général de l'Hérault (1857, 1890, 1891, 1910), [3] Charvet (1854, 1860, 1861, 1864, 1867, 1875), [4] Conseil Général du Haut-Rhin (1857), [5] Le Hir (1872), [6] Chapelain (1851), [7] Guiland (1846), [8] Armeuille and Parmentier (1847), [9] Ministère de l'Intérieur (1850), [10] Béluze (1911), [11] Administration Générale de l'Assistance Publique à Paris (1867a, b, 1868, 1870)

Table S3: Data from the French medico-historical literature about mortality attributed to rickets through the second phase of French industrialisation (Ref: references; R: rickets, T: tuberculosis, F: frailty, S: syphilis, W: weakness; Pop.: population type, GC: governmental care, H: hospital; age expressed in years, Child.: children; n: number of, m: mean, sd: standard deviation, min: minimum, max: maximum, † are expressed per year except for ‡ for which it is for the whole period).

Ref	Department	Cities	Diseases	Pop.	Period (n years)	Age	Mortality % †		n death with Diseases†		Rate % †	
							m (sd)	[min-max]	m (sd)	[min-max]	m (sd)	[min-max]
[1]	16- Charente	Angoulême & around	R	GC	1884-1892 (3)	[0-12]	4.91 (0.71)	[4.04-5.71]	2.00 (1.00)	[1-3]	5.01 (1.95)	[2.94-6.82]
[2]	22- Côtes-d'Armor	Saint-Brieuc	R	GC	1874-1904 (3)	[0-12]	5.55 (3.19)	[2.57-8.91]	-	1	-	5.26
[3]	33- Gironde	Bordeaux	R	H	1882	Child.?	-	-	-	12	-	0.72
[4]	34- Hérault	Montpellier, Béziers, Lodève, Saint-Pons	R	GC	1881-1896 (7)	[0-2]	5.76 (3.29)	[1.19-10.02]	2.43 (1.62)	[1-5]	6.89 (3.23)	[1.79-20.00]
		Montpellier	R		1890	[0-2]	-	7.14	-	1	-	33.33
[5]	44- Loire-Atlantique	Ancenis	R	GC	1884	[0-2]	-	1.90	-	1	-	0.98
		Nantes	R		1879	[0-2]	-	-	-	3	-	0.09
[6]	51- Marne	Châlons, Reims, Epernay, Vitry, Sainte-Ménéhould	R, T, F, S	GC	1891-1901 (11) ^a	[0-2]	10.88 (1.75)	[8.34 - 13.61]	11.73 (3.72)	[7-19]	7.34 (2.27)	[4.49 - 11.61]
			R		1909-1913 (2)	[0-2]	-	0.51	-	1	-	[6.67-12.5]
[7]	54- Meurthe-et-Moselle	Nancy	R	H ^b H ^c	1900	[0-12]	-	-	-	9 19	-	20.45 43.18
[8]	55- Meuse		R	GC	1881	[0-12]	-	-	-	16	-	40.00
[9]	58- Nièvre		R	GC	1873-1882 (2)	[0-12]	-	[3.74-6.15]	-	[0-1]	-	[0-3.45]
					1884-1905 (4)	[0-2]	9.37 (4.84)	[6.44-16.61]	4.25 (1.5)	[3-6]	1.50 (0.45)	[1.05-2.05]
[10]	59- Nord	Lille	R	GC	1872-1882 (5) ^d	[0-12]	4.98 (1.21)	[4.02-6.69]	3 (2.35)	[1-6]	5.09 (3.02)	[2.04-8.70]
			R		1881-1991 (6) ^d	[0-2]	9.91 (1.18)	[8.78-12.15]	3 (1)	[1-4]	0.55 (0.21)	[0.23-0.88]
			R, W, S, T	GC	1888-1889 (2)	[0-2]	-	[10.31-10.98]	-	[34-37]	-	[5.05-5.65]

	Haubourdin	R		1887	[0-2]	-	10.77	-	0	-	0.00
	Dunkerque	R		1889	[0-2]	-	13.33	-	2	-	33.33
	Dunkerque to Wormhoudt	R		1889		-	12.86	-	2	-	5.56
[11]	88- Vosges	R	GC	1882-1898 (10)	[0-2]	10.24 (1.41)	[7.40-12.39]	1.11 (1.05)	[0-3]	0.58 (0.54)	[0-1.46]
[12]	89- Yonne	R	GC	1901-1902 (2)	[0-2]	12,81	[9.95-12.81]	-	[1-1]	0.39	[0.39-0.54]
				1905-1912 (3)	[0- 12]	-	-	-	0	-	0.00

[1] Conseil Général de la Charente (1885, 1889, 1893), **[2]** Conseil Général des Côtes-d'Armor (1881, 1905), **[3]** du Castel (1882), **[4]** Conseil Général de l'Hérault (1857, 1882, 1889, 1890, 1891, 1892, 1895, 1897), **[5]** Conseil Général de la Loire-Atlantique (1880, 1885), **[6]** Conseil Général de la Marne (1892, 1893, 1894, 1895, 1896, 1897, 1898, 1900, 1901, 1902, 1910, 1914), **[7]** Spillman (1900), **[8]** Conseil Général de la Meuse (1882), **[9]** Conseil Général de la Nièvre (1856, 1874, 1882, 1885, 1886, 1888, 1906), **[10]** Conseil Général du Nord (1873, 1874, 1876, 1879, 1882, 1883a, b, 1884, 1885, 1887, 1888, 1889, 1890, 1892), **[11]** Vosges (1883, 1886, 1887, 1888, 1889, 1890, 1893, 1897, 1898, 1899), **[12]** Conseil Général de l'Yonne (1902, 1903, 1906, 1907, 1913)

^a in 1893, children sent to the *sanatorium* of Saint-Pol-sur-Mer

^b individuals before autopsies

^c same individuals after autopsies

^d in 1881, children sent to the *sanatorium* of Berck-sur-Mer

Table S4: Data from the French medico-historical literature about rickets in the living population during the second phase of the French industrialisation (Ref.: references; R: rickets, T: tuberculosis; Pop.: population type, H: hospital, GC: governmental care, DN: day nursery, S: *sanatorium*, FM: free medical consultation;; age is expressed in years, Child.: children; n: number of, ind.: individuals, min: minimum, max: maximum, rate is expressed as a percentage).

Ref.	Department	Cities	Diseases	Pop.	Period (n years)	Age	n ind. observed	n cases	[min-max] rate %
[1]	34- Hérault	Montpellier, Béziers, Lodève, Saint-Pons	R	GC	1889-1890 (2)	[0-12]	[102-104]	[1-3]	[0.001-0.003]
		Montpellier	R	DN	1909	[0-2]	140	22	15.71
[2]	54- Meurthe-et-Moselle	Nancy	R	H	1899	[0-12]	583	100	17.15
[3]	59- Nord	Haubourdin	R	GC	1887	[0-2]	130	1	0.77
		Saint-Pol-sur-Mer	R, T	S	1891	[0-2]	4943	80	1.62
[4]	62- Pas-de-Calais	Berck-sur-Mer	R, T	S	>1870	[2-12]	-	102	-
[5]	66- Pyrénées-Orientales	Banyuls-sur-Mer	R, T	S	1888-1901	[2-16]	-	1277	-
[6]	75- Paris		R	H	1897	[0-3]	314	106	33.76
[7]	76- Seine-Maritime	Le Havre	R	FM	1884	[0-12]	[1800-1808]	[14-34]	[0.77-1.89]
[8]	88- Vosges		R	GC	1882	[0-12]	-	-	1.66
[9]	89- Yonne		R	GC	1898-1912 (5)	[0-12]	[594-1498]	[2-8]	[0.14-0.71]

[1] Conseil Général de l'Hérault (1857, 1890, 1891, 1910), [2] Spillman (1900), [3] Conseil Général du Nord (1888, 1892), [4] Perrochaud (1877), [5] Lafargue (1903), [6] Béluze (1897), [7] Gibert (1888), [8] Conseil Général des Vosges (1883), [9] Conseil Général de l'Yonne (1899, 1900, 1906, 1907, 1913)

Table S5: Bioarchaeological data of rickets prevalence from the archaeological excavations reports during French industrialisation (map numbers are observable on Figure 3; BI: before industrialisation, 1I: first industrialisation, 2I second industrialisation, c.: century(ies); SES: socioeconomic status, n: number of individuals, %: prevalence of rickets or sequels of rickets, bold numbers highlight prevalence and number of cases of rickets or residual rickets >0).

City - excavation name	Dates	Dep.	Number on map	SES	n	n adults (with residual rickets)	%	n non-adults (with rickets)	%	Reference
Troyes	< 1776	10	3		400	293 (0)	0.00	107 (9)	8.41	Roms et al. (2011)
La Ciotat	1710 - 1831	13	5		400	315 (0)	0.00	95 (0)	0.00	Richier et al. (2011)
Edon	< 1828	16	6		-					Montigny et al. (2018)
Tonnay	18 th c.	17	7		x					<i>dolia</i>
La Rochelle	18 th c.	17	8		28	25 (0)	0.00	3 (0)	0.00	Nibodeau et al. (2010)
Beaune	< 1791	21	10		14	7 (1)	14.29	7 (0)	0.00	Alix and Latron (2016)
Issoudun	< 1707	36	13		x					<i>dolia</i>
Grenoble	< 1793	38	15		-					Colardelle (1999)
Yssingaux	< 1787	43	20		-					Delhopital et al. (2016)
Angers	< 1830	49	21		73	61 (0)	0.00	12 (0)	0.00	Gallien et al. (2014)
Reims	1791 - 1832	51	23	low	70	52 (1)	1.92	18 (0)	0.00	Bonnabel et al. (2011)
Lunéville	< 1819	54	25	high?	37	33 (2)	6.06	4 (0)	0.00	Prévot et al. (2013)
Parigny-les-Vaux	18 th c.	58	27		-					Guicheteau (2018)
Douai	< 1776	59	28		48*	-		48 (24)	50.00	(2016)
Armentières	< 1798	59	30		9	2 (0)	0.00	7 (1)	14.29	Cercy and Oudry (2006)
Alençon	< 1793	61	31		-					Chevet et al. (2018)
Boulogne-sur-Mer	< 1806	62	32		50	36 (0)	0.00	14 (0)	0.00	Cercy et al. (2013)
Lens	< 1778	62	33		4	4 (0)	0.00	0 (0)	0.00	Lançon (2005)
Pau	< 1792	64	36		x					<i>dolia</i>
Taxo-d'Avall	18 th c.	66	37		x					<i>dolia</i>
Bergheim	18 th c.	67	40		x					<i>dolia</i>
Paris 3e arr.	18 th c.	75	42		x					<i>dolia</i>
Cernay-la-Ville	< 1825	78	46		16	11 (0)	0.00	5 (0)	0.00	Warmé et al. (2018)
Toulon <i>Porte royale</i>	1709 - 1830	83	47		x					<i>dolia</i>
Toulon <i>Saint Roch</i>	< 1829	83	48		x					<i>dolia</i>

	Tonnerre	< 1777	89	49		x					Maurel et al. (2011)
1 st Phase of Industrialisation	Sainte-Thérènce	18 th - 19 th c.	03	1		x					<i>dolia</i>
	Dijon	1785 - 1841	21	11	low	865	711 (0)	0.00	154 (0)	0.00	Chopelain et al. (2015)
	Valence-sur-Baïse	< 1854	32	12		29	28 (0)	0.00	1 (0)	0.00	Paya et al. (2018)
	Tours	19 th c.	37	14	low?	27	23 (0)	0.00	4 (0)	0.00	Fouillet et al. (2018)
	Roanne	< 1864	42	17		-					Bocquet et al. (2006)
	Bouchemaine	< 1838	49	22		x					<i>dolia</i>
	Nancy	< 1842	54	24	middle	307	222 (1)	0.45	85 (0)	0.00	Dohr et al. (2012)
	Egliseneuve-d'Entraigues	< 1859	63	34		10	8 (0)	0.00	2 (0)	0.00	Parent and Tomson (2013)
	Plauzat	18 th - 19 th c.	63	35		x					<i>dolia</i>
	Claira	19 th c.	66	38		3	2 (0)	0.00	1 (0)	0.00	Vanderhaegen et al. (2017)
	Soufflenheim	1830 - 1874	67	39		x					<i>dolia</i>
	Jouarre	< 1865	77	44		-					Mecquenem et al. (2005)
	Mareil-Marly	< 1862	78	45		11	6 (0)	0.00	5 (0)	0.00	Karst and Kepper (2018)
2 nd Phase of Industrialisation	Urçay	18 th - 20 th c.	03	2		-					Arnaud et al. (2015)
	Rouilly-Saint-Loup	18 th - 20 th c.	10	4		-					Guicheteau et al. (2016)
	Fontaine-les-Dijon	< 1889	21	9		-					Viscusi (2018)
	Sainte-Hymetière	18 th - 20 th c.	39	16	high?	29	19 (0)	0.00	10 (0)	0.00	Billoin et al. (2010)
	Beaumont	< 1899	43	18		x					<i>dolia</i>
	Saint-Arcons-de-Barges	< 1930	43	19		x					<i>dolia</i>
	Pagny-la-Blanche-Côte	18 th - 20 th c.	55	26		13	3 (0)		10 (0)	0.00	Bernard et al. (2014)
	Croix	1799 - 1879	59	29		x					<i>dolia</i>
	Rouen	1780 - 1883	76	43		19	4 (1)	25.00	15 (7)	46.67	Jimenez and Thomann (2019)
Montreux-Château	< 1914	90	50		-					(Viscusi Simonin (2012))	

*individuals between [0-5] years old

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