Chapter 9
Supercentenarians and Semi-supercentenarians in France

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9.1 Introduction

The number of centenarians has increased considerably in industrialized countries. In France, it rose from about 200 in 1954, to more than 1,000 in 1970, and to 3,500 by 1990 (Labat and Dekneudt 1989). It then exceeded 8,000 at the end of the twentieth century (Robert-Bobée 2006) and according to INSEE's recent estimates, it reached 21,000 in 2016 and this number could rise to as much as 270,000 by 2070 (Blanpain and Buisson 2016).

Given the high level of mortality at very old ages, most centenarians do not survive very long. However, the greater the increase of centenarians in number, then the more likely it is that some of them will live to be 110 and thus become so-called supercentenarians, simply because we expect to observe more extreme values in larger populations. Recently, we have indeed witnessed the emergence and the gradual expansion of a new age group that used to be limited to extremely rare and often dubious cases of exceptional longevity. The most famous validated case is the French female supercentenarian Jeanne Calment, who was born in 1875 and died in 1997 at the age of 122.4 years; to this day, she is the verified oldest person who has ever lived (Robine and Allard 1999). The study of this recent phenomenon is important for two main reasons: (1) the emergence of a new age group is interesting in its own right; (2) the growing size of this very old age group should make it possible to

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measure with greater accuracy the age-trajectory of mortality after the age of 100, and hence, to inform our expectations about how the mortality curve unfolds at very old ages. A slowdown in the increase of human death rates at these ages has been observed frequently in human populations (Horiuchi and Coale 1990; Manton 1992; Horiuchi and Wilmoth 1998; Lynch and Brown 2001; Gampe 2010). Moreover, this phenomenon of mortality deceleration is consistent with various theoretical explanations (Beard 1959; Vaupel et al. 1979; Wachter and Finch 1997; Wilmoth and Horiuchi 1999; Steinsaltz and Wachter 2006; Mueller et al. 2011). Nevertheless, its validity has recently been challenged by those who assert that the Gompertz model is appropriate even at the very oldest ages (Gavrilov and Gavrilova 2011; Brouard 2012; Gavrilova and Gavrilov 2015).

The question of the trajectory of mortality at very old ages was in fact the main driver in the development of an *International Database on Longevity* (IDL), gathering as many verified cases of supercentenarians as possible in countries where the quality of vital records allows it. France has been a contributor since the beginning of the IDL project. Prior to the project, "true" cases of French supercentenarians had been identified by trackers of exceptionally long-lived individuals but not exhaustively, and meanwhile, the quality of the reporting of age at death in France's official vital statistics system diminishes abruptly with advancing age among the oldest old (Meslé and Vallin 2002). It is true that the wide-ranging IPSEN survey on centenarians was conducted in the early 1990s (Allard 1991; Allard et al. 1996), but we must recognize that the follow-up of birth cohorts included in the sample provided no more than a very limited number of deaths above age 105.

A first important step was undertaken by the IDL project with the publication of a first volume on supercentenarians (Maier et al. 2010), giving an overview of country-specific analyses including France (Meslé et al. 2010) and international comparisons of the first IDL data sets. Nevertheless, the final objective was not entirely reached, because of the small numbers of survivors at the most extreme ages of the human lifespan. In brief, we were not far from being able to measure life expectancy at age 110, but not yet close to estimate how the actual shape of the mortality curve unfolds beyond 110. Another issue also became ever clearer: even if we are becoming capable of producing more and more precise mortality indicators above age 110, an important gap will remain between the reasonably accurate data on younger centenarians (let us say those aged 100–105 years) and the increasingly accurate data on older centenarians aged above 110 from the continuation of our systematic validation work on supercentenarians. Consequently, the IDL project members decided to expand its research agenda by including a special investigation on deaths occurring between ages 105 and 110, the so-called semi-supercentenarians.

The present chapter is the French contribution to this new endeavor. Our study covers the continuing quest for the identification and the validation of new cases of supercentenarians, which have emerged within the past 10 years, and the special investigation dedicated to producing accurate measurements of mortality among semi-supercentenarians.

Similarly to Meslé and colleagues' work published in the 2010 volume on supercentenarians, we mobilize three different sources of data here, each one grasping reality from a different angle and with varying degrees of accuracy and coverage: death counts from the official vital statistics system, nominative transcripts from the *Répertoire national d'identification des personnes physiques* (RNIPP), and a "public" list of individual supercentenarians. We will discuss the validity of these sources and how we can make the most of their respective strengths for the purpose of mortality measurements, with the help of age validation procedures and the extinct generation method to estimate populations at risk.

We will first focus on the RNIPP, which stands out as a crucial source of data for the identification of supercentenarian and semi-supercentenarian deaths in France (Sect. 9.2). We will then describe our age validation procedures for each of these two categories of old-age deaths (Sect. 9.3), and provide a comparison between the RNIPP records and "public" lists of individual supercentenarians (Sect. 9.4). The much-awaited analytical result of this research is presented in Sect. 9.5, where we will calculate mortality indicators using vital statistics and RNIPP data to compare them within selected appropriate births cohorts. Closing remarks are offered in Sect. 9.6.

9.2 The RNIPP Data

Three sources of data can be used to enumerate semi- and supercentenarians in France: (1) the vital statistics system operated by the French National Institute of Statistics and Economic Studies (*Institut national de la statistique et des études économiques*, or INSEE), (2) the National Directory for the Identification of Natural Persons (*Répertoire national d'identification des personnes physiques*, or RNIPP), also administered by INSEE, and (3) public lists of long-lived individuals compiled from personal archives, local media coverage, and to some extent the IPSEN survey. Among these, the RNIPP stands out as the most reliable source (Meslé et al. 2010).

In a nutshell, the RNIPP was created in 1945 and initially consisted of paper listings that were kept at INSEE's regional offices. In the early 1970s, the listings of persons born after 1890 in metropolitan France (1900 for French overseas *départements*) were computerized and centralized by INSEE. The RNIPP is considered exhaustive by INSEE for cohorts born 1890 (1900 for overseas *départements*) and beyond, but incomplete for earlier birth cohorts. It covers all persons born in France, as well as persons born abroad and living in France who have requested a social security number (*numéro d'identification personnel*). For further details on the RNIPP, see Meslé et al. (2010, p. 126-127).

Access to the RNIPP is limited because it gathers data at the individual level and it includes nominative information that is deemed confidential. In 2004, our research group was granted permission by the *Commission nationale de l'information et des libertés* (CNIL) to access transcripts of individual records of the RNIPP. That same year, INSEE provided us with an RNIPP extract, namely a nominative list of 3,272 persons who died in France between 1988 and 2002 and were born between 1883 and 1897[1]. For each individual, we were given the following information: first and last names[2], sex, date and place of birth, date and place of death, and age at death. The age validation results presented below for alleged semi-supercentenarians is based on this list.

For the remaining results, we use four newer extracts of the RNIPP that INSEE provided us following an agreement concluded between INSEE and the French National Institute for Demographic Studies (*Institut national d'études démographiques*, or INED) in May 2014. The agreement states that exactly 1 month after both parties signed the agreement, INSEE will first provide INED with an RNIPP extract of all individuals born in France (metropolitan France, overseas *départements*, as well as Saint Barthélemy, Saint-Martin, and Saint-Pierre et Miquelon), for which the difference between their alleged years of death and birth is at least 105, and with the longest-term perspective allowed by the RNIPP. Then, every calendar year starting in 2015, INSEE will be providing INED with the same type of RNIPP extract, but the lists will then be limited to persons who have died in the last 2 years according to the RNIPP. Since May 2014, we therefore received new files in June 2014 (10,305 cases, including the 3,272 cases already received in 2004), April 2015 (1,681 cases), March 2016 (1,851 cases), and April 2017 (2,037 cases). The individual nominative information given with each of these extracts are: first and last (and maiden for females) names of the deceased, sex, date and place of birth, date and place of death, and the number of the birth and death certificates (if available). In the present study, we use the lists of names resulting from these four RNIPP extracts, which are partly overlapping. If we keep a single occurrence for each individual, the RNIPP list then totals 12,751 cases. We also have to discard all cases where the death occurred before the 105th birthday, and that results in a new total of 9,138 alleged semi-supercentenarians and supercentenarians. Moreover, we decided to limit our work to individuals who were born and died in metropolitan France and four overseas *départements* (Guadeloupe, Guyane, Martinique, and Réunion)[3]. Our total RNIPP universe therefore sums up to 9,100 individuals (8,284 females and 816 males).

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[1] INSEE provided us with all cases where the difference between alleged years of death and birth was 105 or greater. The data set therefore included some deaths of individuals that passed away at age 104, namely those who had not yet celebrated their 105th anniversary that year.

[2] For married females, both married and maiden names are provided.

[3] Mayotte is excluded because it was too recently established as an overseas *département*. Other French overseas territories of various statuses were also excluded since the quality of their civil registration system was still questionable at the beginning of the twentieth century. It should be noted, however, that until they became overseas *collectivités* in 2007, the small islands of Saint Martin and Saint Barthélemy were included as parts of Guadeloupe, while Saint-Pierre et Miquelon is excluded altogether despite having been an overseas *département* until 1985. To make things clear, among French overseas territories only those currently coded 971 (Guadeloupe), 972 (Martinique), 973 (Guyane) and 974 (Réunion) are included, while those coded 975 to 988 are excluded.

9.3 Age Validation of Supercentenarians and Semi-supercentenarians

We used the following age at death validation protocol to determine whether the alleged supercentenarians and semi-supercentenarians lived as long as implied by the RNIPP. The first part consists in verifying the accuracy of the information relative to the person's birth, namely his/her exact date of birth (i.e., year, month, and day of birth). This is achieved by referring to the person's birth certificate, available at the town hall of his/her birthplace or at the *département*'s archives. The accuracy of the person's exact date of death (i.e., year, month, and day of death) is also subject to a thorough verification and for that purpose, we use the death certificate from the town hall of the person's death commune. Then we compute the person's verified age at death from his/her dates of birth and death indicated on the birth and death records.

In the validation results presented below, we consider that a person's age at death has been correctly recorded in the RNIPP if the difference with the verified age is either null, or less than 4 days when the discrepancy is due entirely to a birthdate error. The rationale for allowing such errors in the birthdate is that the maximum delay to report a birth is set to 3 days in France, which can create some confusion over the date of the birth and the date of its registration.

9.3.1 Supercentenarians

The RNIPP extracts yielded a total (both sexes) of 231 alleged supercentenarians that were born and died in French *départements* (except Mayotte), and their death was between 1988 and 2016[4]. As Table 9.1a shows, we were able to find the birth and death certificate for all of these individuals, and the dates of birth and death recorded in the RNIPP were correct for the vast majority of them (213 or 92%). Out of the 18 erroneous cases, 12 were cases of disappearance (explained below), five had errors on their year of death, and one had the wrong year of birth. The results for females only are provided in Table 9.1b, with even greater scores overall for correct dates of birth and death (205 out of 216 or 95%). Tables 9.2a and 9.2b list the type of errors that were found.

For cases of disappearances, the date of death recorded in the RNIPP actually corresponds to the date of judgement of the person gone missing (all dates are relatively recent, with the earliest at 2002, see Table 9.2b). This practice results in incorrect ages at death and we have no way of knowing the true ages at death of these

[4] For the sake of consistency with the age validation process of semi-supercentenarians presented in the next section, we limit our work on supercentenarians to those who died in 1988 or later. This results in a single exclusion: one case of a supercentenarian who died in 1987.

Table 9.1a Age validation results for alleged supercentenarians who died in France (French *départements* only, excluding Mayotte) between 1988 and 2016, both sexes[a]

		Validation procedure			
		Birth and death certificates or other legal documents were found[b]		Dates of birth and death were validated	
Age at death (years)	Number of cases	Number of cases	In%	Number of cases	In %
110	133	133	100.0	127	95.5
111	48	48	100.0	45	93.8
112	28	28	100.0	27	96.4
113	11	11	100.0	7	63.6
114	5	5	100.0	4	80.0
115	1	1	100.0	1	100.0
116	2	2	100.0	1	50.0
117	1	1	100.0	0	0.0
122	2	2	100.0	1	50.0
Total	231	231	100.0	213	92.2

[a]The alleged supercentenarians were supposedly born between 1875 and 1906 in French *départements* (excluding Mayotte)
[b]If the death certificate does not exist because the person has gone missing, then a legal document confirming the person's disappearance was found

Table 9.1b Age validation results for alleged supercentenarians who died in France (French *départements* only, excluding Mayotte) between 1988 and 2016, females[a]

		Validation procedure			
Age at death (years)	Number of cases	Birth and death certificates or other legal documents were found[b]		Dates of birth and death were validated	
		Number of cases	In %	Number of cases	In %
110	121	121	100.0	120	99,2
111	46	46	100.0	44	95.7
112	28	28	100.0	27	96.4
113	10	10	100.0	7	70.0
114	5	5	100.0	4	80.0
115	1	1	100.0	1	100.0
116	2	2	100.0	1	50.0
117	1	1	100.0	0	0.0
122	2	2	100.0	1	50.0
Total	216	216	100.0	205	94.9

[a]The alleged supercentenarians were supposedly born between 1875 and 1906 in French *départements* (excluding Mayotte)
[b]If the death certificate does not exist because the person has gone missing, then a legal document confirming the person's disappearance was found

Table 9.2a Six errors found on the dates of birth and death of alleged supercentenarians who died in France (French *départements* only, excluding Mayotte) between 1988 and 2016, both sexes

	True year of:		Errors on the year of:		Age at death:	
Sex	Birth	Death	Birth	Death	Alleged	True
M	1877	1966	Ok	1990	113	89
F	1878	1982	Ok	1992	113	103
F	1878	1982	Ok	1992	114	104
F	1879	1974	Ok	1992	113	95
F	1890	1975	Ok	2013	122	84
F	1891	1994	1881	Ok	113	103

Table 9.2b Twelve cases of disappearance for which the date of the court decision was registered as the date of death, among alleged supercentenarians who died in France (French *départements* only, excluding Mayotte) between 1988 and 2016, both sexes

	Year of:			Age at death:	
Sex	Birth	Disappearance	Court decision	Alleged	True
F	1890	1973	2002	111	Unknown
M	1892	1963	2002	110	Unknown
F	1892	1965	2008	116	Unknown
M	1895	1943	2006	110	Unknown
F	1895	1963	2007	111	Unknown
M	1897	1945	2007	110	Unknown
F	1898	1979	2011	112	Body found in 1980
F	1898	1995	2015	117	Unknown
M	1899	1947	2009	110	Unknown
F	1899	1989	2009	110	Unknown
M	1903	1993	2015	111	Unknown
M	1904	n.d.	2014	110	Unknown

individuals[5]. The sex distribution is half and half (i.e., 6 cases each). For all males except one, their alleged age was 110, while alleged ages ranged from 110 to 117 for females. With regards to the five erroneous cases due to incorrect years of death, all were females but one, and the errors artificially lengthened these person's lifespans (once by 38 years, once by 24 years, once by 18 years, and twice by 10 years). All of them actually died between 1966 and 1982 and errors are probably due to manual data entry errors. The person with an incorrect birth year (1891 rather than 1881) is a female and her verified age at death in 1994 is 103 instead of 113. This is also a typical data entry error.

Among the 213 "true" supercentenarians, 20 (9.4%) were born and died in an overseas *département*. Compared to the 3% share of the overseas population in the total French population, such a high proportion of supercentenarians looks very

[5]Taking in account the long delay to obtain a judgement after a disappearance, it is quite improbable to have supercentenarians among them.

suspicious. Indeed, levels of mortality in the past used to be much higher in overseas *départements* than in metropolitan France, and this should have produced the reverse result. It is very likely, however, that until these territories got the full status of *département* (1946) the functioning of the civil registration system and its use by administrative services were not perfect. A thorough scientific validation of age thus seems required in cases born or died in overseas *départements*, with a more in-depth check of the actual correspondence between their official death and birth certificates, complemented by intermediate individual proofs of life. In upcoming Sects. 9.4 and 9.5, we chose to exclude Guadeloupe, Guyane, Martinique, and Réunion, as we have already done for all other French overseas territories. Our analyses will therefore rely on 193 cases of validated supercentenarians (including 185 females).

9.3.2 Semi-supercentenarians

We now turn to the validation of alleged semi-supercentenarians that was conducted a few years ago using the 2004 RNIPP data extract. This was prior to the 2014 agreement between INED and INSEE (see Sect. 9.2) that resulted in the RNIPP data upon which the validation of alleged supercentenarians presented above rests. The validation period for alleged semi-supercentenarians is thus shorter and it covers years of death that range from 1988 to 2002. Out of the 3,272 persons included in the RNIPP data set at our disposal in 2004, all of whom had died in France between 1988 and 2002 and were born between 1883 and 1897, 2,031 had supposedly lived to ages 105–109, excluding those who died before their 105th birthday or after their 110th birthday, or were born outside French *départements*. Given the considerable size of this group, we had to limit the exhaustive check to the oldest individuals (alleged ages 107, 108, and 109), while half of cases at alleged age 106 and a third

Table 9.3a Age validation results for alleged semi-supercentenarians, cohorts supposedly born 1883–1897 and died 1988–2002 in France[a], both sexes

				Validation procedure			
Age at death (years)	Number of cases	Sample		Birth and death certificates or other legal documents were found[b]		Dates of birth and death were validated	
		Number of cases	Sampling fraction (%)	Number of cases	In %	Number of cases	In %
105	1,047	352	33.6	349	99.1	349	100.0
106	560	274	48.9	274	100.0	272	99.3
107	262	262	100.0	261	99.6	260	99.6
108	111	111	100.0	111	100.0	111	100.0
109	51	51	100.0	51	100.0	51	100.0
Total	2,031	1,050	51.7	1,046	99.6	1,043	99.7

[a]Metropolitan France and French overseas *départements* (excluding Mayotte)
[b]Excludes errors up to 3 days in the birthdate (8 cases)

of cases at alleged age 105 were checked. Table 9.3a shows the age-specific sampling fractions used for both sexes combined.

Among the 1,050 females and males in our sample, the birth and death certificates were found for nearly all of them (1,046 or 99.6%), and among the 1,046 checked cases the dates of birth and death recorded in the RNIPP were exact in 1,043 instances (99.7%). Only two of these three cases turned out to be false semi-supercentenarians. Indeed, the first one was allegedly born in 1884 and died in 1991 at age 106, but she was in fact born in 1894 and had thus died at true age 96. The second one had a 7-year error on her year of birth, which was supposedly 1891 but corrected to 1898, making her true age at death 100 in 1998, instead of 107. The last erroneous case is a woman born in 1895 for which we found a minor 10-day error on her date of death (she passed away on 8 Nov. 2001 instead of 29 Oct. 2001), but that left her age at death unchanged at 106. It should be noted that among these three erroneous cases, the one with a 10-year error on her year of birth was born and died outside metropolitan France, namely in Guadeloupe.

Table 9.3b displays the results limited to females (959 cases out of 1,050), which are highly similar to those presented in Table 9.3a for both sexes.

The high quality of RNIPP data was further confirmed by an additional age validation study of 100 cases (20 for each year of age from 105 to 109), randomly selected among the 10,305 cases from the 2014 RNIPP extract. No error was found either in the dates of birth or death among the 99 cases which could be validated (for the one remaining case, we were unable to find the birth and death certificates).

Nevertheless, it seems appropriate to apply the same conclusion as for supercentenarians and to exclude from this point forward all semi-supercentenarians born or died in overseas *départements*.

Table 9.3b Age validation results for alleged semi-supercentenarians, cohorts supposedly born 1883–1897 and died 1988–2002 in France[a], females

				Validation procedure			
		Sample		Birth and death certificates or other legal documents were found[b]		Dates of birth and death were validated	
Age at death (years)	Number of cases	Number of cases	Sampling fraction (%)	Number of cases	In %	Number of cases	In %
105	959	321	33.5	318	99.1	318	100.0
106	518	249	48.1	249	100.0	247	99.2
107	246	246	100.0	245	99.6	244	99.6
108	102	102	100.0	102	100.0	102	100.0
109	46	46	100.0	46	100.0	46	100.0
Total	1,871	964	51.5	960	99.6	957	99.7

[a]Metropolitan France and French overseas *départements* (excluding Mayotte)
[b]Excludes errors up to 3 days in the birthdate (8 cases)

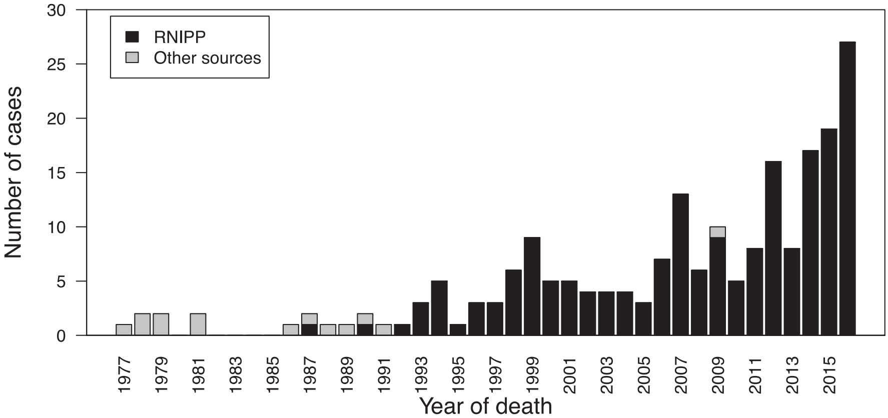

Fig. 9.1 Annual number of deaths of French supercentenarians included in the RNIPP and those that are known from other (public) sources but not found in the RNIPP, metropolitan France, 1977–2016, both sexes
Sources: RNIPP and https://fr.wikipedia.org/wiki/Liste_de_supercentenaires_français

9.4 RNIPP Data Comparison with Public Lists of French Supercentenarians

Besides official sources of information such as the RNIPP, that are subject to statistical confidentiality and for which permission by the CNIL must be obtained to grant data access, there are several public lists of individual supercentenarians in France. These public lists rely essentially on French communes' newsletters and information sites, local media coverage (e.g., press reports), research led by genealogical societies, and to a smaller extent the IPSEN survey. See, for instance, the Wikipedia list of French supercentenarians, available at https://fr.wikipedia.org/wiki/Liste_de_supercentenaires_français.

Previous work by Meslé et al. (2010) singles out the RNIPP data as the most reliable source for enumerating supercentenarians in France. Figure 9.1 shows that the RNIPP records identify a growing number of supercentenarians. A total of 14 cases are missing according to public sources, but most of these deaths of supercentenarians not reported in the RNIPP occurred quite a while ago. If we limit ourselves to years of death beyond 1991, missing cases from the 193 RNIPP records are reduced to a single occurrence, which took place in 2009.

9.5 Cohort Probabilities of Death and Death Rates at Older Ages

In the present section, we take advantage of the validation work described above to investigate patterns and trends in probabilities of death and death rates at very old ages in France. Our first set of calculations is based on data from the national vital statistics system, which is the most commonly available source of mortality data in France. As stated earlier, it suffers, however, from data quality problems at advanced ages. Here, we take these data as they are published, making no corrections whatsoever. In a second step, we compute probabilities of death and death rates using both raw and verified data from the RNIPP. Finally, we take advantage of these various probabilities of death series obtained from vital statistics and from the verified RNIPP data to derive and compare curves of life expectancy at ages 100 and above.

Before moving forward, it should be noted that probabilities of death and death rates are two different concepts. In particular, their age trajectories differ (Thatcher et al. 1998, Figs. 2.1 and 2.2) and failing to distinguish between the two concepts could lead to inaccurate claims about the shape of the mortality curve at very old ages (see Ouellette and Bourbeau (2014), pages 7–11 for more details). We compute one-year cohort probabilities of death and death rates series starting at ages 100 and 105 for vital statistics and RNIPP, respectively. By definition, the probability of dying in the age interval $[x, x + 1)$, written q_x, for a given cohort, corresponds to the number of deaths to the cohort between ages x and $x + 1$ divided by the size of the cohort at exact age x (i.e., at the beginning of the age interval). For probabilities of dying calculated from vital statistics data, the denominator was obtained using the method of extinct generations (Vincent 1951). In the absence of migration, the outcome is the same as counting the exact number of survivors at the beginning of each age interval from a data set consisting of individual records, as it was done with the RNIPP data.

With regard to death rates, death counts are divided by the population's exposure to the risk of death. For a given cohort, the death rate in the age interval $[x, x + 1)$, written m_x, is equal to the number of deaths to the cohort between exact ages x and $x + 1$ divided by the number of person-years lived by the cohort in the same age interval. The outcome is a number of events per person-year. For the RNIPP data, the number of person-years lived were directly counted by adding the contribution of each individual in each age interval, thereby taking full advantage of the information on the exact date of birth and date of death of the semi- and supercentenarians. Given that female deaths account for more than 90 percent of all deaths of semi- and supercentenarians recorded in the RNIPP data set, the results shown below in most figures are for females only.

9.5.1 Vital Statistics Data for Ages 100 and Above

Figure 9.2 displays one-year probabilities of death, q_x, starting from age $x = 100$ for female cohorts born between 1883 and 1901, as well as for an earlier group of female cohorts born during the period 1868–1882. All these cohorts are extinct today and the vital statistics data allow us to follow each one starting from age 100 onward. More specifically, the calculations are based on the vital statistics data received from INSEE, where death counts are aggregated by sex, year of birth, year

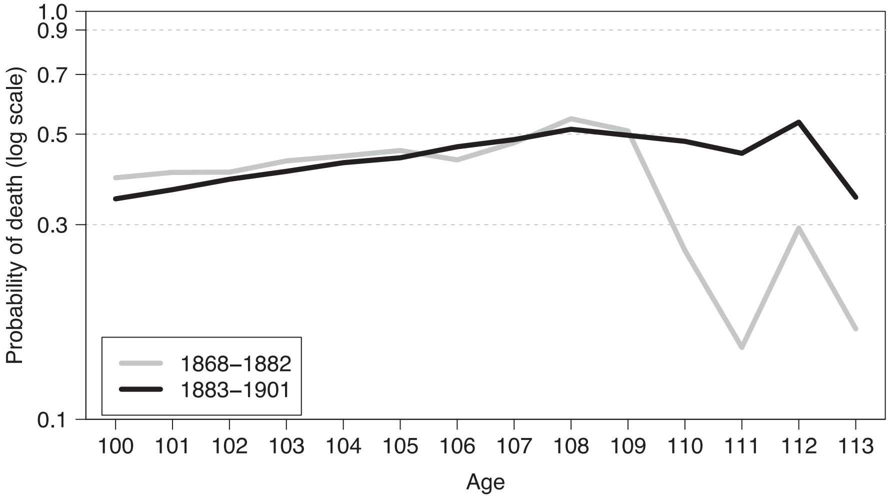

Fig. 9.2 Age-specific probabilities of death, q_x, for French female cohorts born 1868–1882 and 1883–1901 who died in metropolitan France
Note: The sizes of birth cohorts 1868–1882 and 1883–1901 at age 100 upon which the figure is based are $N = 10{,}829$ and $N = 45{,}684$, respectively
Source: Vital statistics

of death, and single years of age at death[6]. All deaths that occurred in metropolitan France are included here but we cannot distinguish between deaths of individuals born in France and deaths of individuals born abroad.

Figure 9.2 reveals that for the latest group of birth cohorts born between 1883 and 1901, the q_x series seems reasonable, both in terms of level and trend, up to about age 108. After age 108, the series starts to decline slightly and becomes irregular. For the q_x series for the earlier group of cohorts born between 1868 and 1882, however, the declining trend and fluctuations are much more pronounced beyond age 108. This goes to show that the quality of vital statistics data has greatly improved over time in France even if some part of this apparent progress is due to the increase in the number of survivors at age 100. At the most advanced ages, the q_x's used to be largely underestimated, most probably due to age exaggeration problems. The underestimation may persist to some lesser extent past the age of 108 for the latest set of birth cohorts, and the RNIPP can be used to provide us with better information on this matter.

[6]Vital statistics routinely published by INSEE include death counts by single years of age up to 104, followed by an open age group starting at 105. Every year, INSEE kindly provides us with a special tabulation distinguishing death counts by single years of age until the observed maximum age at death.

9.5.2 RNIPP Data for Ages 105 and Above

We used the RNIPP data to compute age-specific probabilities of death beyond age 105 among semi- and supercentenarians, all of whom were born and died in metropolitan French *départements*. We decided to focus on female cohorts born during the period 1883–1901[7]: 1901 is the most recent extinct birth cohort as of 31 December 2016 while individuals born in 1883 reached age 105 in 1988, which correspond to the first year where we can consider that death registration above age 105 is complete in the RNIPP, as suggested by Fig. 9.3.

First, we used the original RNIPP data as they were provided to us by INSEE, that is without applying any correction emerging from our age validation work presented in Sect. 9.3. The second set of calculations uses only verified RNIPP data for ages 110 and above, for which an exhaustive check has been done (Table 9.1b). For ages 105–109, the check was not exhaustive but it has been demonstrated that errors are quite negligible (Table 9.3b) and original RNIPP data were used. Note that correcting for age-at-death errors among alleged supercentenarians could lead to differences in q_x values beyond age $x = 110$, as well as prior to that age because of possible changes in the remaining size of the birth cohorts at the beginning of each age intervals serving as denominator for q_x.

The results are illustrated in Fig. 9.4, along with the vital statistics q_x series from age 100 for birth cohorts 1883–1901 (from Fig. 9.2). Caution is advised when contrasting the latter with the two RNIPP q_x series because it includes the foreign-born

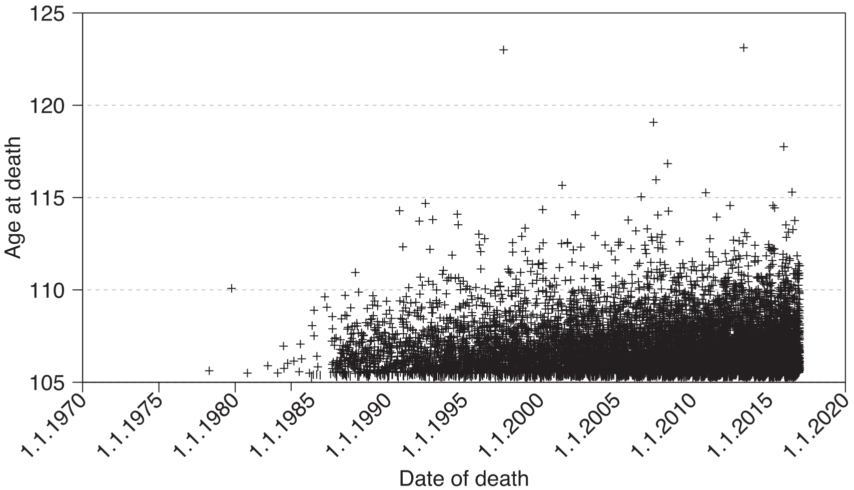

Fig. 9.3 Alleged age at death above age 105 by date of death in France
Source: RNIPP

[7]The group of birth cohorts 1883–1901 does not include the year 1875 during which Jeanne Calment was born.

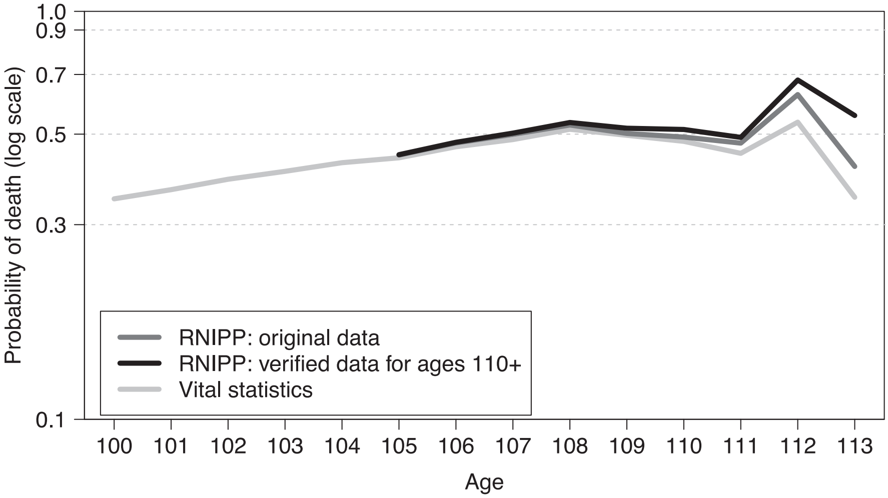

Fig. 9.4 Age-specific probabilities of death, q_x, calculated using two versions of the RNIPP data and the vital statistics data for French female cohorts born between 1883 and 1901 who died in metropolitan France
Note: The size of birth cohorts 1883–1901 at age 105 for the original and verified RNIPP data sets upon which the figure is based are $N = 3{,}492$ and $N = 3{,}485$, respectively. For vital statistics data, which includes deaths of individuals born abroad, the sizes are $N = 45{,}684$ at age 100 and $N = 3{,}959$ at age 105
Sources: RNIPP and vital statistics

female population, while the RNIPP data focuses exclusively on the native population. Despite this, the three curves practically overlap up to age 108, suggesting that the vital statistics is as reliable as RNIPP up to that age for cohorts born during the period 1883–1901. After age 108, however, the three curves start diverging. Probabilities of death derived from vital statistics data, which are known to be of poorer quality compared to the RNIPP data, show the lowest values and those calculated from the verified RNIPP data have the highest values. Such hierarchy between the curves was expected since age misstatement, especially when due to age overstatement, biases mortality estimates downwards at the most advanced ages (Preston et al. 1999). Probabilities of death beyond age 108 derived from the original set of RNIPP data fall between the two other curves, but they remain closer to the values obtained from verified RNIPP data.

So far in our analyses, we have focused solely on age-specific probabilities of death. Figure 9.5 presents these probabilities, together with age-specific death rates, m_x, according to the RNIPP verified data set[8]. As expected given the definition of q_x

[8] Recall that in the denominator of these death rates, the number of person-years lived were directly counted by adding the contribution of each individual. Calculations based on an aggregated version of the RNIPP data (by single years of age, death and birth) and resting on the assumption that deaths are distributed uniformly within each age interval leads to almost identical results (not shown here but available on request from nadine.ouellette@umontreal.ca)

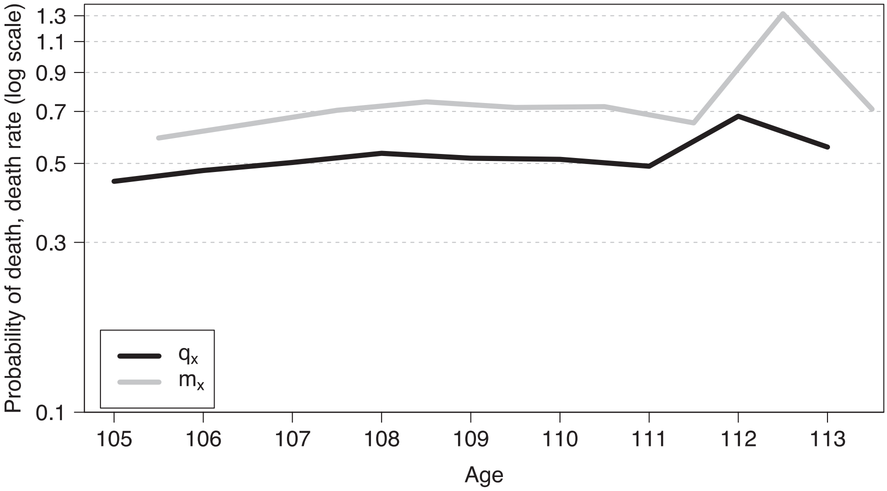

Fig. 9.5 Age-specific probabilities of death, q_x, and death rates, m_x, calculated using the verified RNIPP data for French female cohorts born between 1883 and 1901, metropolitan France
Note: The size of birth cohorts 1883–1901 at age 105 upon which the figure is based is $N = 3{,}485$
Source: RNIPP

and m_x, the figure shows clearly that the two series differ in terms of level, with lower q_x values at every age x compared to m_x values. The hierarchy comes indeed from the fact that in the absence of migration, the remaining size of birth cohorts at exact age x, serving as denominator in the calculation of q_x values, is greater (or equal) to the person-years lived in the given age interval, used in turn in the denominator of m_x values (see the details provided at the onset of Sect. 9.5). Although a definitive assessment of the age-trajectory of mortality falls beyond the scope of the present work because of the strongly decreasing number of survivors, the observed levels of mortality after age 105 displayed in Fig. 9.5 for French supercentenarians appear supportive of a force of mortality (or instantaneous death rate) at a constant level of 0.7 between age 108 and 111, corresponding to a 50% constant annual probability of death, suggested by previous scholars (Robine et al. 2005; Gampe 2010).

9.5.3 Life Expectancies After Age 100

We now use the q_x series discussed above to derive values of life expectancy at the oldest ages with standard life table techniques. For female cohorts born between 1883–1901, life expectancy at age 100 given by vital statistics is 1.57 years (Fig. 9.6). At age 105, when the verified RNIPP data becomes available, we obtain a barely higher value of female expectation of life from vital statistics (1.36 vs. 1.34 years). Afterwards, however, life expectancy values tend to diverge increasingly with age according to the two sources of data. At age 113, the vital statistics

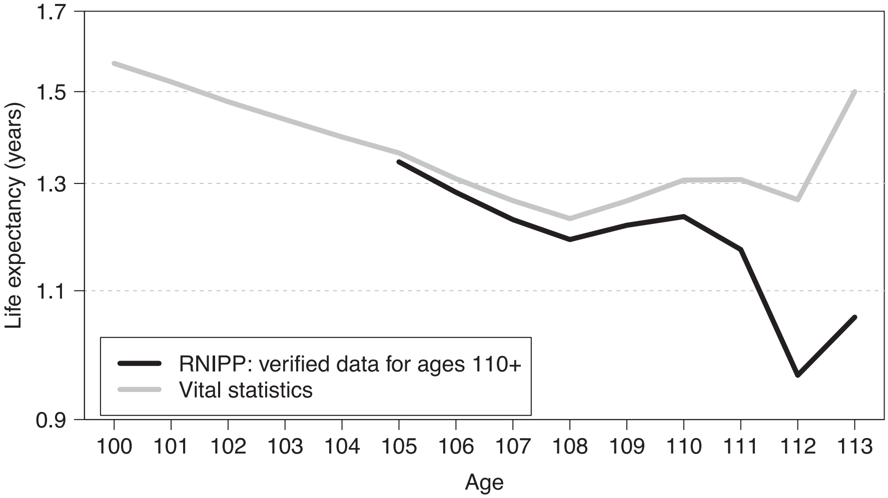

Fig. 9.6 Life expectancy by age above 100, according to vital statistics and according to verified RNIPP data for ages 110+ for French female cohorts born between 1883 and 1901 who died in metropolitan France
Note: The remaining size of birth cohorts 1883–1901 at age 105 for the verified RNIPP data upon which the figure is based is $N = 3{,}485$. For vital statistics data, which includes deaths of individuals born abroad, the sizes are $N = 45{,}684$ at age 100 and $N = 3{,}959$ at age 105
Sources: RNIPP and vital statistics

result appears to be quite exaggerated (1.50 years, compared to 1.23 if using verified RNIPP data), obviously due to the growing number of false cases of supercentenarians with age included in vital statistics. Perhaps more surprising is the sudden reversal of life expectancy values from vital statistics toward an unexpected increasing trend after age 108. The downward trend in the more trustworthy RNIPP life expectancy values also comes to a halt, but only temporarily between ages 108 and 110. Is this unexplainable bump at 109–111 years due to some undetected problem with the RNIPP data or is it attributable to random variation? The only way to know is to wait for additional years' worth of data. On the bright side, the vital statistics trend for life expectancy from age 100 to age 104 appears credible as it is in a perfect agreement with the life expectancy at 105, given by RNIPP data. Clearly, it would have been desirable to have the RNIPP data for ages 103 and 104 at hand. Such data could have been sufficient to demonstrate that vital statistics are probably reflecting the truth until these ages.

9.6 Conclusion

Although the evidence presented here illustrates the accuracy of mortality indicators given by vital statistics data for rather advanced ages (until around the age of 108 and 103–104 for probabilities of death and life expectancy calculations, respectively), these data cannot be used to assess the shape of the age-trajectory of mortality at the highest ages because they include growing shares of false supercentenarians or even semi-supercentenarians with advancing age. As for "public" lists of individual supercentenarians, they are inappropriate too because in addition to possible exhaustiveness concerns, there is a risk of selection bias due to the fact that data collected using press reports, notably, tend to favor extreme ages. On the other hand, thanks to their high quality, RNIPP data offer much firmer grounds to derive the level and age pattern of mortality at very old ages. The exhaustive validation of all deaths registered at the alleged ages of 110+ revealed that for cohorts born between 1883 and 1901 (all these cohorts are extinct today), errors are only few and easily explainable (either cases of disappearance when persons have gone missing or manual data entry errors), at least when dealing with individuals who were born and died in France. All corrections were effortless to make. Furthermore, for semi-supercentenarians, individual age at death validation conducted on a very large sample showed that errors are extremely rare, indicating that RNIPP data can be used without any verification until at least age 108. However, a first analysis of these RNIPP data indicates that the number of "verified" supercentenarians from overseas French *départements* is dubious. Most likely, in these territories, the age validation protocol would require more than the sole existence of a birth certificate corresponding to the death certificate. As for reported cases of exceptional longevity, these apparently more ordinary cases may actually require intermediate proofs of life between their birth and death. For this reason, we limited our mortality analyses to individuals that were born and died in metropolitan France.

Our study also reveals that while the quality of vital statistics remains quite deficient at very old ages, there has been a significant improvement over time. We see clearly the improvement when comparing curves of annual probabilities of death at ages 100 and above for two successive groups of birth cohorts (1868–1882 and 1883–1901). This finding provides hope that we will be able to get more and more accurate mortality trends at progressively older ages from a very accessible source of data in France. There is likely a long waiting time, however, for a conclusion about the shape of the mortality curve at very old age. Even the most accurate French data source today, namely the RNIPP, is not yet suitable to address this matter. But with the RNIPP, the ambition to reach a conclusion in a near future is not totally unrealistic, especially thanks to the rapidly-growing expected number of centenarians, semi-supercentenarians, and supercentenarians in coming decades. Furthermore, according to INSEE the RNIPP records are considered exhaustive only for cohorts born since 1890, meaning that the RNIPP covers all persons that died at age 110 since 2000 only, at age 111 since 2001 only, etc. Study of French supercentenarians has bright prospects in the next few years.

The probabilities of death calculated using RNIPP data for female birth cohorts born between 1883 and 1901 in Metropolitan France appear to level-off at 0.5 between ages 108 and 111, a finding in accordance with earlier studies (Robine et al. 2005; Gampe 2010). After age 111, however, data becomes too scarce to assess the trend. Also, we obtain a quite low life expectancy value of 1.2 years at age 108.

A practical conclusion is thus to recognize the usefulness of pursuing the gathering and validation of data in the following two directions: below age 105 to improve the link between the RNIPP and vital statistics mortality data series, and above age 110 to increase as much as possible the number of observations at the most advanced ages.

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