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Health, frailty and disability after ninety: results of an observational study in France

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Running title: Health after ninety

Abstract (250 words)

Background: In spite of their increasing demographic weight, health characteristics of the oldest old remain poorly described in epidemiological studies.

Objective: To describe the health of people aged 70 years and over included in the SIPAF study, and to compare the prevalence of health indicators including successful aging, frailty, and disability and between three age groups including the oldest old.

Methods: The study population is composed of 2,350 retired people recruited between 2008 and 2010, of whom 512 are aged 90 and over (21.8%). A comprehensive geriatric assessment was performed at home by trained nurses. The prevalence of health and functional indicators, as well as the distribution of people among successful ageing, frailty, and disability, were described by age group (70-79, 80-89, 90+) and sex.

Results: Compared to their younger counterparts, people aged 90 years and over were more likely to experience functional limitations, sensory impairment, cognitive impairment, poor mood, and frailty. One third of the nonagenarians needed help in at least one basic activity of daily living and 25% met the frailty criteria. In contrast, the prevalence of most chronic diseases did not increase after ninety. Successful ageing concerned 9% of the oldest old. Women were less likely to experience successful ageing and more likely to be frail or dependent.

Conclusion: This study shows the diversity of health states in very old age and points out that one quarter of the people aged 90 and over said frail are likely to take advantage of preventive actions of disability.

Key words: Aged, 80 and over; Epidemiology; Frail elderly; Successful ageing.

Introduction

Thanks to medical and social advances, life expectancy has dramatically increased during the 20st century. Whereas the increase in life expectancy was initially due to the diminution of infant and child mortality, the increase in life expectancy is now related to the increasing longevity of old people. According to the central scenario established by the French Institute for Statistics and Economic Studies, the number of centenarians could reach 200,000 by 2060, in other words 13 times the current number. The quality of life at very old age has become an important issue. The joint action on healthy life years (JA: EHLEIS) [1] revealed that additional life years may be at the cost of some limitations. In France, life expectancy increased by 1.8 year for women and 1.6 year for men between 2005 and 2011. During the same period, disability-free life expectancy remained relatively stable (+0.3 years for women and +1.2 year for men) [2].

Epidemiological studies focusing on the oldest old are needed to improve our knowledge of the characteristics and needs of this increasing segment of population. Such studies exist, mainly in North European countries, United Kingdom (UK), and Japan. The UK was pioneer in the description of functioning in the oldest old [3-6]. The predominance of functional indicators in early studies was counterbalanced thereafter by the use of health indicators (physical and mental illnesses) [7, 8]. Some tried to classify the oldest old in homogeneous groups according to their health and/or functional status [9-11] and others to investigate the predictors of longevity [12-16]. In order to better understand the heterogeneity of situations in old age, Rowe and Kahn suggested to distinguish and value “successful ageing” ageing from ageing with disability or in poor health [17]. In Finland, Nosraty et al compared the prevalence of successful ageing according to different definitions [18], its predictive value with regard to longevity after 90 years [19], and its different components according to the oldest old themselves [20]. The concept of frailty, defined as a loss of resistance to stress,

exposing the subject to an increased risk of falls, loss of autonomy and death [21], is often considered as a state of pre-disability and can hence contribute to disentangle the heterogeneity of situations in the oldest old [22]. All these studies, as well as additional ones [23-35], are presented in a chronological overview of the literature about the health of the oldest old in Appendix.

In France, there is a paucity of information about the characteristics of the oldest old. Despite numerous sources of health information (national population-based surveys, epidemiological studies, analyses of data from the health insurance system), results concerning the oldest old are rarely displayed separately from results in the old age category [36]. The oldest old are often a minority in study samples, because this is a small age group compared to younger age groups, and because the oldest old are less likely to participate in epidemiological studies [37].

In this context, this study aimed to analyse the characteristics of a sample of 2,350 old people aged in France, among which 512 subjects were aged 90 and over. Using the information of a comprehensive geriatric assessment, the objective was to describe and compare the proportion of subjects meeting the criteria for successful aging, frailty, and disability among three age groups including the oldest old.

Methods

Study design and population

This work is part of a cross-sectional study carried out to characterize health and functional independence among people aged 70 and older (SIPAF study, French acronym for "Système d'Information sur la Perte d'Autonomie Fonctionnelle de la personne âgée"). Subjects were selected at random among the 2,100,000 recipients of a supplementary pension fund, AG2R La Mondiale (Paris, France). The randomization was centralized and performed by the

actuary of AG2R La Mondiale. Using information about the geographic area of residence, the sampling method was designed to ensure the inclusion of participants from all regions of France excluding overseas territories, in rural as well as in urban areas. The randomization was stratified by age group in order to include a larger proportion of oldest old than expected with a simple random drawing. As a result, people aged 90 years and over represented 21.8% of our study sample whereas they represented 5.7% of the population of France in 2009 (according to the National Institute of Statistical and Economic Information). After they had given their informed consent, participants were interviewed at home by trained nurses who collected information on health and functional abilities. The research protocol was approved by an independent ethics committee (permission n°060316).

Health assessment

Information was collected about self-rating of health, unintentional weight loss, chronic diseases, emotional status, cognitive impairment, functional abilities, sensory limitations, and physical activity.

Self-perceived health was assessed using the question "How is your health in general?". A complementary question was asked: "How is your health compared to people of the same age as you?". Participants were asked about unintentional weight loss (of 10% of body weight during the past 6 months). Chronic diseases were identified by reported diagnosis/symptoms/treatment during the last 12 months of 14 diseases, including asthma, allergies, diabetes, cataract, high blood pressure, heart attack, stroke/cerebral haemorrhage, chronic bronchitis/emphysema, arthrosis/(rheumatic) arthritis, osteoporosis, gastric or duodenal ulcer, malignant tumour, migraines/frequent headaches, and chronic anxiety/depression (list used by the European Commission to monitor population health). Emotional status was assessed with the self-rating of morale and the 15-item Geriatric

Depression Scale (GDS15) [38]. Cognitive impairment was defined as a Mini-Mental State Examination score of 26 or less [39].

Questions about sensory limitations dealt with the ability to see newspaper print clearly, the ability to see the face of someone 4 meters away clearly, and the ability to hear distinctly what is said in a conversation without difficulty, optionally with corrective devices (glasses, hearing devices). Participants were also asked whether they can walk up and down stairs without difficulty, and whether they can lift a bag weighing 5 kg without difficulty. The evaluation of activity limitations examined the five activities of daily living (ADL) included in the Katz index [40], i.e. bathing, dressing, toileting, transferring, continence and feeding, as well as instrumental activities of daily living (IADL) [41] such as food preparation, the ability to use a telephone, housework (light and heavy), shopping and the ability to manage one's finances.

The level of physical activity was assessed with the International Physical Activity Questionnaire (IPAQ) [42] and 3 levels of activity were distinguished (low, moderate and high) according to time spent walking and doing moderate (for instance, carrying light loads, leisure bicycle ride, tennis) and vigorous activity (for instance, carrying heavy loads, digging, lifting a pack of 6 bottles or speed bicycle) during the past 7 days.

Other information

In addition to age and gender, socio-demographic information included the marital status, education level (number of years at school), self-rating of economic situation, and social isolation. Social isolation was defined as having reduced contacts with family (less than once a month) or as the absence of anyone to confide in, which could give an advice in case of need or show affection.

Successful ageing

Successful ageing was defined according to the work of the Vitality 90+ study [18], as a good or fair self-perceived health in the absence of each of the following: dementia (defined as MMSE<20), vision or hearing impairment, disability in ADL, depression (GDS15>5 or low self-rated morale), and social isolation.

Frailty

Frailty was defined according to the construct derived from the Cardiovascular Health Study (CHS) [43]. Due to variations in health assessment between the SIPAF study and the CHS, some components of our operational measurement of the frailty differ from the original definition. In particular, measures of grip strength and slow walking speed were replaced by self-reported variables, as previously observed in other epidemiological settings [44, 45]. The five frailty components were defined as follows:

- Nutrition: unintentional weight loss or body mass index ≤18.5 kg/m^2;
- Energy: positive answer to the question "Compared to before, do you feel weak now?" or negative answer to the question "Do you have a lot of energy?";
- Physical activity: low level of activity according to the IPAQ questionnaire;
- Physical strength: difficulty lifting a bag weighing 5 kg;
- Mobility: difficulty walking up and down stairs.

Integrated approach

Participants were categorised into four groups, being:

- Successful ageing: people who met the criteria of successful ageing in the absence of frailty;
- Intermediate group: people who did not met the criteria of other groups;

- Frailty: people who met three of the five criteria of frailty, in the absence of disability in ADL;
- Disability: people who needed help in at least one ADL.

Statistical analyses

All the health indicators were described in terms of prevalence by age group (70-79 years, 80-89 years, 90 years and older) and sex in case of significant differences between men and women. The differences between age groups and between men and women were analysed using Chi-2 tests. The significance level was set at 5%. Statistical analyses were performed using the STATA v13.

Results

Characteristics of the study population

A total of 2,350 people agreed to participate in the study. A close relative, generally the spouse or the child, was present during the interview in 16.6% of the cases. The participation rate amounted to 18.9%. The main reasons for non-participation were the lack of interest in the study (28.3% of the non-participants), followed by a state of frailty (10.8%) and the refusal of a close relative (7.3%). Male sex and younger age positively influenced the participation, as well as living in low-populated areas and in departments where the population is aging or with a lower standard of living [46]. The study population included 863 participants aged 70 to 79 years, 975 participants aged 80 to 89 years, and 512 participants aged 90 years and over (21.8% of the study population). The oldest participant was aged 102 years. The proportion of women increased with age: there were 1.13 women for 1 man in the age interval 70-79, 1.51 in the age interval 80-89 years, and 2.16 after age 90 years.

Women were less likely to live in couple compared to men (4.6% versus 51.9%) and more likely to experience financial difficulties in very old age (11.8%). The oldest old had a lower level of education compared to younger generations. Social isolation (family and/or emotional) was reported by 29.6% of the individuals aged 90 and over (n=147). Characteristics of the participants are further described in the Table 1.

Table 1. Sociodemographic and health characteristics according to age and sex in the SIPAF study SIPAF (n=2,350)

Variable. N (%)	Age interval	Men (n=955)	Women (n=1393)
Living in couple	70-79 years	325 (80.3)	187 (40.9)
	80-89 years	277 (71.4)	102 (17.4)
	90 years and over	84 (51.9)	16 (4.6)
Low level of education[a]	70-79 years	58 (14.3)	50 (11.0)
	80-89 years	128 (33.4)	200 (34.3)
	90 years and over	69 (44.5)	181 (52.8)
Poor economic situation	70-79 years	18 (4.5)	26 (5.8)
	80-89 years	17 (4.4)	49 (8.5)
	90 years and over	6 (3.8)	40 (11.8)
Family isolation	70-79 years	71 (17.8)	77 (17.2)
	80-89 years	64 (16.8)	88 (15.3)
	90 years and over	30 (17.8)	55 (16.0)
Lack of emotional support	70-79 years	61 (15.2)	81 (18.0)
	80-89 years	60 (15.6)	95 (16.3)
	90 years and over	31 (19.4)	60 (17.8)
Visual impairment[b]	70-79 years	19 (4.8)	30 (6.6)
	80-89 years	34 (9.1)	62 (10.8)
	90 years and over	23 (14.3)	65 (20.0)
Hearing impairment[c]	70-79 years	148 (36.7)	106 (23.3)

	80-89 years	163 (42.3)	199 (34.1)
	90 years and over	100 (61.7)	189 (55.1)
Cognitive impairment[d]	70-79 years	42 (10.5)	32 (7.0)
	80-89 years	53 (14.0)	75 (13.2)
	90 years and over	34 (21.8)	90 (28.6)
Probable depression[f]	70-79 years	43 (10.7)	81 (17.8)
	80-89 years	56 (14.5)	148 (25.3)
	90 years and over	37 (23.3)	100 (29.4)
Low morale[g]	70-79 years	11 (6.7)	24 (7.1)
	80-89 years	18 (4.7)	40 (6.9)
	90 years and over	11 (4.0)	26 (5.7)

[a] ≤7 years at school

[b] Inability to read the newspaper or to see someone at 4 meters of distance

[c] Inability to follow a conversation with several people

[d] Mini Mental State Examination score < 20

[e] Need of help in at least one activity of daily living

[f] Geriatric Depression Scale 15 score >5

[h] Answer bad or very bad to the question: "How is your moral in general?"

Self-perceived health

When asked about their health, 48.0% of people aged 90 years and over (n=244) declared themselves in good health, 40.6% (n=206) consider their health fair, and 11.4% (n=58) perceived themselves in poor health (Figure 1.A). While the self-perceived health did not vary according to age, the relative health, meaning the rating of its own health compared to people of the same age, was better in the oldest old ($p<0.001$) (Figure 1.B). There was no significant difference between men and women.

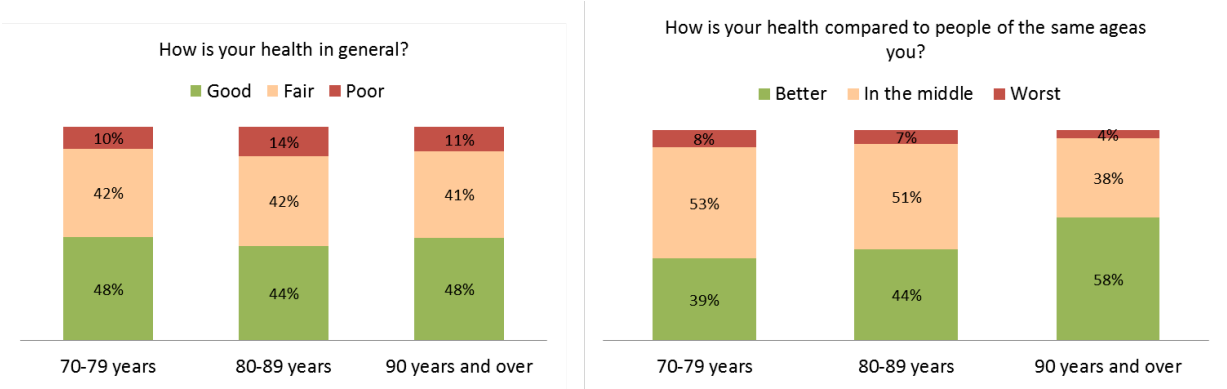

Figure 1. Self-perceived health (A) and self-rating of health compared to people of the same age (B) by age group in the SIPAF study (n=2,350)

Chronic diseases

Half of the participants included in SIPAF reported at least three chronic conditions, 51.2% in the age group 70-79 years (n=437), 54.7% in the age group 80-89 (n=527), and 45.5% in people aged 90 years and over (n=230) ($p<0.001$). After age 90 years, the main health problems were arthrosis/(rheumatic) arthritis, high blood pressure and chronic anxiety/depression (Figure 2). Their prevalence was higher in women compared to men (prevalence of arthrosis/(rheumatic) arthritis=76.3% versus 52.5%, $p<0.001$; prevalence of chronic anxiety/depression=20.9% versus 13.8%, $p=0.056$; prevalence of high blood pressure=47.3% versus 34.6%, $p=0.007$). Except for stroke, the prevalence of chronic diseases did not increase significantly with age. In the case of high blood pressure, diabetes and allergy, there was even a significant decrease in the prevalence with age.

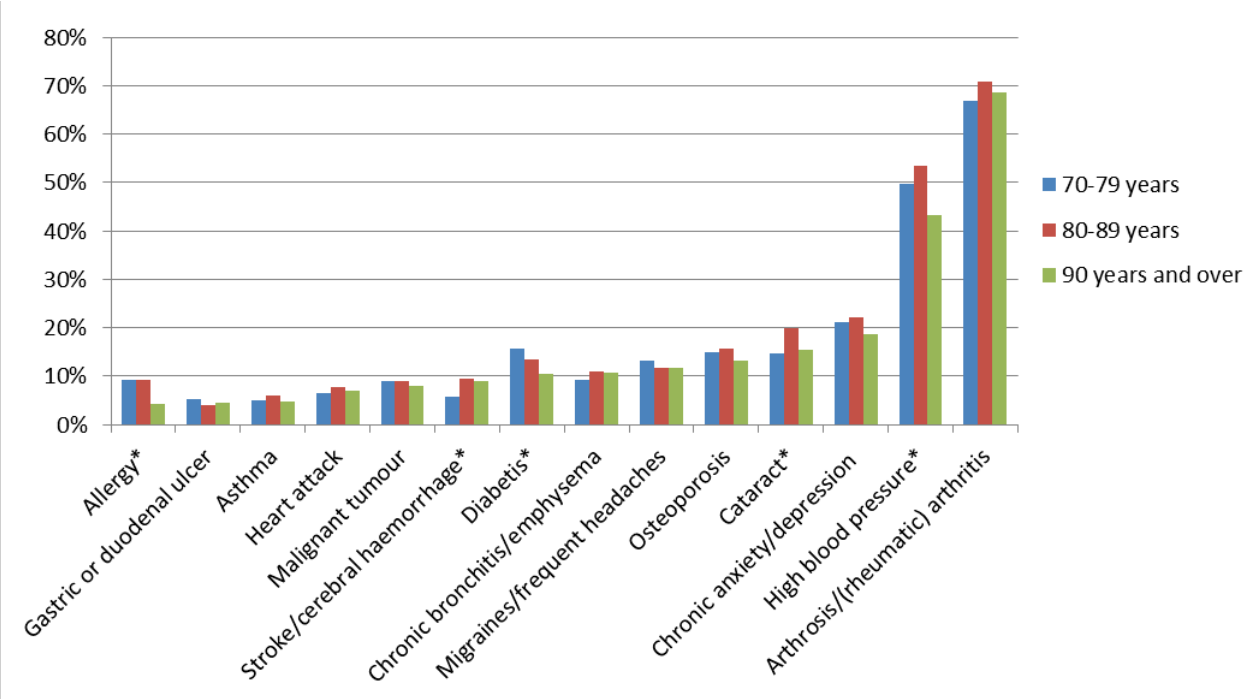

Figure 2. Prevalence of chronic diseases by age group in the SIPAF study (n=2,350)

* Significant difference between age groups ($p<0.05$)

Sensory impairment

The prevalence of visual and hearing impairment increased with age (Table 1). Hearing impairment, foremost, concerned 57.2% of the participants aged 90 years and over (n=289) versus 37.4% of people aged 80-89 years (n=362) and 29.6% of those aged 70-79 years (n=254) ($p <0.001$). Though hearing impairment was more reported in men of younger age intervals, there was no significant difference between men and women regarding sensory impairment after age 90 years.

Cognitive and mood disorders

The prevalence of cognitive and mood disorders also increased with age. Indeed, 26.3% of the participants aged 90 years and over (n=124) had a MMSE≤26 versus 13.5% of the participants (n=128) in age interval 80-90 years, and 8.7% of the participants (n=74) in age

interval 70-79 years (p<0.001). Though few people reported a low morale (7.0% of the oldest old), the results of the GDS15 indicated a probable depression in many more people (27.5% of the oldest old). There was no difference in the prevalence of cognitive and mood disorders between men and women after age 90 years.

Disability

The proportion of subjects needing help in ADL increased with age, from 5.5% (n=47) between 70 and 79 years, 14.1% (n=137) between 80 and 89 years, and up to 33.0% (n=167) after age 90 years (p<0.001). Bathing and dressing were the leading causes of difficulty (31.7% and 21.0% respectively). After age 90 years, 67.9% (n=343) of the participants needed help in IADL, versus only 15.7% (n=135) of participants aged 70-79 years. IADL causing the most difficulties were heavy housework and shopping (67.4% and 62.9% respectively). Men had less disability than women, and the gap widened with age (Figure 3); 37.8% (n=62) of the men were still independent versus 27.9% (n=96) of women after age 90 years (p=0.008).

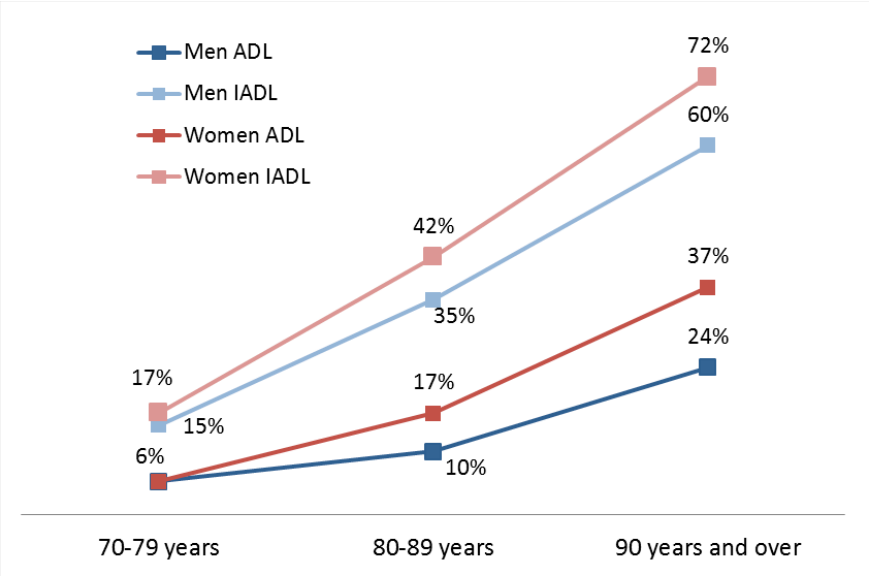

Figure 3. Proportion of people who needed help in ADL and IADL in the SIPAF study (n=2,350)

ADL = bathing, dressing, toileting, transferring, continence and feeding

IADL = food preparation, ability use a telephone, housework (light and heavy), shopping and ability to manage one's finances

Frailty

The prevalence of the different frailty criteria is described by age group and sex in Table 2. The frail phenotype concerned 25.3% of people aged 90 and over (n=125), versus 18.4% of people 80-89 years (n=183), and 9.5% of people aged 70-79 years (n=80) (p<0.001). Women were more likely to be frail compared to men in all age groups. After 90 years of age, 30.2% of the women (n=102) were frail versus 14.7% of the men (n=23) (p<0.001), with significant differences in the prevalence of criteria dealing with physical activity, strength and mobility.

Table 2. Prevalence of the different frailty criteria by age group and sex in the SIPAF study (n=2,350)

Variable, N (%)	Age interval	Men (n=955)	Women (n=1395)
Weight loss and/or thinness[a]	70-79 years	32 (7,9)	26 (5,7)
	80-89 years	33 (8,6)	57 (9,8)
	90 years and over	15 (9,3)	48 (14,2)
Fatigue[b*]	70-79 years	149 (37,1)	192 (42,2)
	80-89 years	191 (49,6)	303 (52,2)
	90 years and over	92 (57,9)	216 (63,7)
Low level of physical activity[c*]	70-79 years	94 (23,3)	126 (27,9)
	80-89 years	118 (30,8)	275 (47,6)
	90 years and over	81 (50,6)	236 (69,6)
Lack of physical strength[d*]	70-79 years	26 (6,5)	108 (23,8)
	80-89 years	68 (17,8)	308 (53,9)
	90 years and over	55 (34,4)	252 (75,5)

	70-79 years	64 (16,0)	83 (18,4)
Reduced mobility[e*]	80-89 years	99 (25,9)	202 (34,8)
	90 years and over	56 (35,2)	181 (53,6)

[a] Unintentional weight loss of at least 10% in 6 months and/or body mass index ≤ 18.5 kg/m²

[b] Positive answer to the question "Do you feel weak now?" or negative answer to the question "Do you have a lot of energy?"

[c] Low level of activity according to the IPAQ questionnaire

[d] Difficulty lifting a bag weighing 5 kg

[e] Difficulty walking up and down stairs

* Significant difference between men and women ($p<0.05$)

Integrated approach

According to the health, psychological and social indicators previously described, we estimated the prevalence of successful ageing to 9.1% (n=46) among people aged 90 and over, 22.8% (n=221) among people aged 80-89 years, and 38.7% (n=332) among those aged 70-79 years. The Figure 4 shows the distribution of the prevalence of successful ageing, frailty and disability according to age and sex. If men and women had close profiles in age group 70-79 years, differences were more pronounced in the oldest old, where women were less likely to experience successful ageing and more likely to be frail or disabled.

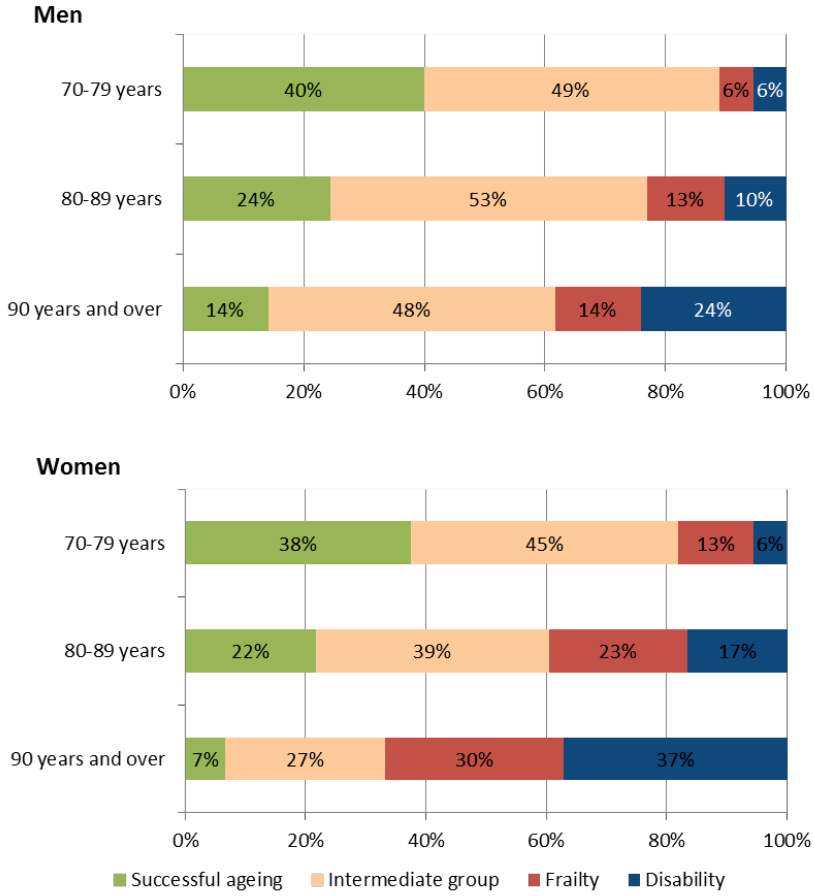

Figure 4. Distribution of people between successful ageing, frailty and disability by age groups, in men and women in the SIPAF study (n=2,350)

Discussion

Main findings

Considering together different indicators of health in old age, this study shows that 9% of the nonagenarians meet the criteria of successful aging, defined by ageing in relatively good physical and mental health, surrounded and without sensory or functional limitations, versus 39% of the septuagenarians. Though the prevalence of chronic diseases was relatively stable between septuagenarians and nonagenarians, there was a marked increase in the prevalence of

functional limitations, sensory impairment, cognitive impairment, poor mood, and frailty with age. As a result, about one third of the nonagenarians were dependent of other people for at least one ADL, and one quarter of people aged 90 years and over were considered frail.

Health

Regarding chronic health problems, we found joint and cardiovascular disease (high blood pressure) to the forefront of health problems reported by the oldest old, in agreement with previous studies [14, 31, 47]. The relative stability of the prevalence of chronic diseases between age groups observed in this study may be partly explained by a selection effect. Indeed, subjects with chronic illnesses were more likely to die before the age of 90 years, resulting in the relative health of the "survivors". This selection effect was previously suggested by Motta et al [11], by comparing the health of two populations of different age: in one hand, the 602 centenarians included in the IMUSCE study (*The Italian Multicenter Study on Centenarians*, 2005) [11] and on the other hand, the 5,632 participants included in the ILSA study (*The Italian Longitudinal Study on Aging*, 1997) aged between 65 and 84 years. The comparison of the two populations showed the lower prevalence of Parkinson's disease, high blood pressure, diabetes and thyroid disease in the older cohort. However, the prevalence of cognitive impairment was higher among the older cohort. Using similar definitions, our estimate of cognitive impairment in nonagenarians was lower than estimates from the PAQUID study, a French study on cognitive ageing (26% versus 35%) [14]. People included in the PAQUID study were recruited free of dementia at baseline and followed up for more than 20 years, whereas the SIPAF study had a cross-sectional design where one can expect the lower participation of people with cognitive impairment. Nonetheless, estimates of self-perceived health were comparable between the two studies (48% of the nonagenarians in SIPAF versus 42% of the nonagenarians in PAQUID perceived themselves in good health).

Disability

Our results confirm the extent of the need for assistance in activities of daily living. The methodological closeness of our study with the Canadian Community Health Survey (CCHS) - Healthy Aging [35] allows comparisons of prevalence of disability between the two studies. Among the 28,406 participants aged 50-104 years, 1,120 were aged 90 years and over. Among them, 26% reported a need of help in at least one ADL and 74% in at least one IADL. Our estimates are relatively close in value for ADL (33%) and IADL (68%), but also regarding the evolution of disability with age, with a marked increase after 80 years. Indeed, Guay et al. showed an exponential increase in difficulties in ADL with age. In line with previous studies [5, 48], the most problematic ADLs were those using the upper part of the body and requiring balance, i.e. bathing, dressing, and sleeping, and the most problematic IADLs were cleaning, shopping and dining.

Frailty

Frailty has raised growing interest in gerontology but few data are available in the oldest old. A study about the prevalence and the factors associated with frailty among 273 subjects aged 86 years reported that one participant in five was frail [22]. Based on a systematic review of the literature, Shamliyan et al [49] estimated the prevalence of the frail phenotype to 14% in people aged 65 years and over, and to 26% in people over 85 years. Our estimates are remarkably close to these figures, since we found that the prevalence of frailty was 17% in our whole study sample and 25% after age 90 years. Before the onset of disability, the screening and management of frailty offer opportunities to prevent or delay health complications and dependency [50]. After the detection of frailty, the main areas for improvement are the proper management of chronic diseases, the reduction of sarcopenia

through exercise and the establishment of a hyper-protein and high calorie diet, the prevention of fractures via vitamin D supplementation, and the reduction of polypharmacy.

Successful ageing

The definition of successful aging varies substantially depending on the study, resulting in a wide range of prevalence, from less than 1% to over 90% [51]. The definition used in this study is based on previous findings from the 90+ Vitality study [19]. Because their work highlighted the extremely low proportion of old people free from any physical, psychological and social problems, we used a more realistic approach to successful ageing, allowing the presence of chronic diseases [52]. Nevertheless, our estimates should be considered with caution as they may vary with the choice of the definition. Of note, 11 women and 3 men classified frail also met the criteria for successful ageing, which can seem paradoxical. These cases probably show the limits of these health indicators. However, one cannot exclude that some people experience silent physical decline while they are still satisfied with their health, independent, surrounded by relatives, etc. Whether a classification bias or a reality, these cases remained very rare.

Differences between genders

Whether for mood, disability or frailty, women reported more impairments than men in our study. This difference is common in the literature [14, 23, 30, 48]. Whereas women live longer, European data show that they live longer with health problems compared to men [53]. Besides potential biological effects, the sex-differences could be of socio-economic nature [54]. Furthermore, our data were self-declared and we cannot exclude a reporting bias, where women may be more likely to be aware of and to report health problems than men [55].

Strength and limitations

The main strength of this study is the large number of people aged 90 years and over (n=512). For comparison, the French sample of SHARE (*Survey on Health, Ageing and Retirement in Europe*) only included 5% of people aged 85 years and over, i.e. 278 individuals in the analysis published by Sirven et al [56]. Another strength is the use of multiple health indicators – self-perceived health, medical conditions, functional indicators – rarely considered together in other studies. Despite the use of validated tools (MMSE, GDS15, etc.) and the presence of a close relative in 16.6% of the cases, we cannot exclude a possible measurement bias due to the declarative nature of our data, especially in the oldest old were the prevalence of cognitive impairment is higher.

The representativeness of our study population, composed of a random sample of recipients of a supplementary pension fund, can be challenged. Nevertheless, the representation of a variety of situations was ensured by the recruitment of people throughout France (excluding overseas territories), in rural and urban areas, from a source population of 2.1 million people.

Finally, the interpretation of the differences between age groups must take into account a possible cohort effect. The dates of birth of our study population ranged between 1906 and 1939, and it is likely that participants experienced relatively different situations in terms of living conditions (especially in the war years), organization of the system health, medical knowledge and preventive policies, including vaccination.

Conclusion

This study shows the heterogeneity of health states in very old age. In 1987, Rowe and Kahn stated that gerontological research should not neglect the substantial heterogeneity within age groups by focusing on average tendencies within such groups [17]. Indeed, we observed than

9% of the nonagenarians met the criteria for successful ageing, while 33% required help in ADL and 25% were in a pre-disability stage where they could benefit from preventive actions.

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Appendix. Main characteristics of the observational studies about disability and health in the oldest old

Author, year, country [reference]	Study design	Population	Main topic
O'Connor, 1989, UK [3]	Cross-sectional	N=132 nonagenarians	Mental and physical functioning in nonagenarians
McGuee, 1998, UK [4]	Cross-sectional	N=13,009 individuals aged ≥65 years, including 1,188 individuals aged ≥85 years	Prevalence of disability by age and gender
Andersen-Randberg, 2001, Denmark [47]	Cross-sectional analysis of the data from the Longitudinal Study of Danish Centenarians (LSDC)	N=207 Danish centenarians	Prevalence of disability and chronic diseases in centenarians
Jagger, 2001, UK [5]	Prospective cohort	N=1,344 patients registered in one large UK general practice, aged ≥75 years, and free from disability in ADL at baseline	Detailed description of the onset of disability
Von Strauss, 2003, Sweden [23]	Community-based cohort	N=1,848 individuals aged ≥77 years	Disability in men and women
Motta, 2004, Italy [11]	Cross-sectional	N=602 centenarians from the Italian Multicenter Studies on Centenarians (IMUSCE)	Groups of centenarians individuals depending on their psychophysical status and autonomy
Gondo, 2006, Japan [10]	Cross-sectional analysis of baseline data from a prospective cohort	N=304 centenarians living in Tokyo	Functional phenotypes in centenarians
Marengoni, 2008, Sweden [7]	Cross-sectional	N=1,099 individuals aged 77 to 100 years	Prevalence of chronic diseases and multimorbidity in the elderly population
Dupre, 2008, China [12]	Prospective cohort	N=13,297 individuals aged between 85 and 105 years	Predictors of Longevity
Xie, 2008, UK [6]	Retrospective analysis of a population-based cohort study in England and Wales + survival analysis	N=958 individuals aged ≥90 years	Characteristics and survival of the oldest old
Ferrer, 2008, Spain	Prospective cohort	N=176 nonagenarians	Predictive items of

Author, year, country [reference]	Study design	Population	Main topic
[13]			functional decline and 2-year mortality
Engberg, 2008, Denmark [24]	Cross-sectional analysis of the data of two prospective cohorts: "The Longitudinal Study of Danish Centenarians (LSDC)" and "The Danish 1905 Cohort Survey"	N=207 centenarians in the LDSC (born in 1895); N=225 centenarians in "The Danish 1905 Cohort Survey" (born in 1905)	Prevalence of disability in centenarians born ten years apart
Collerton, 2009, UK [8]	Cross sectional analysis of baseline data from 'The Newcastle 85+ study"	N=1,042 individuals born in 1921 and registered with the participating general practices	Health and disease in 85 year olds
Berlau, 2009, USA [25]	Cross-sectional analysis of baseline data from "The 90+ Study"	N=697 individuals aged ≥90 years	Prevalence of disability by age and gender
Nogueira, 2009, Brazil [26]	Cross-sectional population-based study	N=129 individuals aged between 80 and 96 years	Determinant factors of functional status among the oldest old
Freeman, 2010, Japan [27]	Comparative cross-sectional study	N=56 centenarians and 104 younger control subjects	Functional abilities and characteristics of centenarians
Arai, 2010, Japan [28]	Prospective cohort "The Tokyo Oldest Old Survey on Total Health (TOOTH)"	N=1152 randomly selected inhabitants of Tokyo aged ≥85 years	Strategies for data collection in the oldest old
Zhao, 2010, UK [29]	Retrospective analysis of the data from the "Cambridge City over-75s" cohort	N=321 individuals aged ≥85 years deceased after one year of follow-up	Modifications of health status during the year preceding death
Robine, 2010, France [57]	Demographic	Five low mortality countries, Denmark, France, Japan, Switzerland, and Sweden, part of the 5-Country Oldest Old Project (5-COOP).	Levels of mortality selection among the nonagenarians and centenarians
Jacobs, 2011, Israël [58]	Cross-sectional analysis of the data from the Jerusalem Longitudinal cohort study + survival analysis	N= 840 community dwelling people aged 85 years	Frailty, cognitive impairment and mortality among the oldest old
Kingston, 2012, UK	Cross-sectional analysis of	N= 839 individuals aged ≥85 years	Hierarchical ADL

Author, year, country [reference]	Study design	Population	Main topic
[48]	baseline data from 'The Newcastle 85+ study"		
Robine, 2012, France [16]	Ecological study of the relation between centenarian rate and climate characteristics	47 prefectures in Japan	Environmental predictors of longevity
Nosraty, 2012, Finland [18]	Cross-sectional analysis of the baseline data from "The Vitality 90+ Study"	N=1283 individuals aged ≥90 years	Definition and prevalence of successful ageing
Berlau, 2012, USA [30]	Prospective cohort "The 90+ Study"	N=216 individuals aged ≥90 years free of disability at baseline	Risk factors for onset of disability in the oldest old
Wu, 2012, China [31]	Cross-sectional	N=870 individuals aged between 90 and 108 years	Relationships between medical conditions, medical diagnosis and disability in nonagenarians and centenarians
Ferrer, 2013, Spain [22]	Cross-sectional	N=273 community-dwelling individuals aged 86 years included in a randomized-controlled trial	Frailty in the oldest old
Andersen-Randberg, 2013, Denmark [32]	Cross-sectional	N=207 Danish centenarians	Cardiovascular diseases in centenarians
Edjolo, 2013, France [14]	Prospective cohort "PAQUID"	N=2578 individuals aged ≥70 years at baseline and followed-up for at least 20 years	Predictors of longevity
van Houwelingen, 2013, Netherlands [33]	Prospective cohort "The Leiden 85-plus study"	N=597 individuals aged 85 years at baseline	Disability transitions in the oldest old
Cevenini , 2013, Italy [9]	Prospective cohort of sib-ships	N=1,160 Italian siblings aged ≥90 years	Classification of the oldest old according to their health status
Christensen, 2013, Denmark [34]	Comparison of two Danish cohorts born 10 years apart	N= 2,262 individuals aged 93 years in the first cohort (born in 1905); N=1,584 individuals aged 95 years in the second cohort (born in 1915)	Physical and cognitive functioning of people older than 90 years
Tiainen, 2013, Finland [15]	9-year follow-up of the "The Vitality 90+ study"	N=171 men and 717 women aged ≥90 years at baseline	Predictors of mortality in men and women aged 90

Author, year, country [reference]	Study design	Population	Main topic
			and older
Guay, 2014, Canada [35]	Cross-sectional	N=28,406 noninstitutionalized Canadians aged between 50 and 104 years	Description of disability by age
Nosraty, 2015, Finland [19]	Cross-sectional analysis of the data from " The Vitality 90+ Study" + survival follow-up	N=1,370 individuals aged ≥90 years	Successful ageing and longevity after age 90 years
Nosraty, 2015, Finland [20]	Life-story interviews conducted in the context of "The Vitality 90+Study"	N=45 community-dwelling nonagenarians (25 women and 20 men)	Successful ageing according to nonagenarians