


REVIEW

The prevalence and predictors of anxiety and depression in near-centenarians and centenarians: a systematic review

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ABSTRACT

Background: Current research on the psychological health of near-centenarians (95–99 years old) and centenarians remains limited. Existing studies have mainly characterized their physical, cognitive, and social health. Results on the anxiety and depression of near-centenarians and centenarians (more than 95 years old) have been mixed with some studies, finding higher rates of anxiety and depression among those older than 95 years and others reporting no difference in rates compared with younger age groups. This study aims to synthesize the existing literature on the prevalence and predictors of anxiety and depression in near-centenarians and centenarians.

Method: A systematic review was conducted using Ovid Medline, Embase, PsycINFO, CINAHL, SCOPUS, and the Cochrane database. Common and conflicting findings among the literature were examined.

Results: Thirty-eight studies met the inclusion criteria. Six studies examined the prevalence and predictors of anxiety, and 37 studies investigated the prevalence and predictors of depression. Five studies examined both anxiety and depression in the same sample. Prevalence data on anxiety and depression varied significantly, as did comparisons with rates in younger populations. Findings on predictors of anxiety and depression were contradictory.

Conclusion: There is a large degree of heterogeneity among studies of centenarians' psychological status. Findings conflict on the prevalence and predictors of anxiety and depression and rates compared with younger age groups. Variation in findings may result from the different inclusion criteria, sampling methods, and measurement tools. Better harmonization of centenarian study methodologies may improve consistency of findings to aid in developing clinical interventions.

Key words: aged, 80 and over, mental health, longevity, oldest old

Introduction

The number of near-centenarians (95–99 years old) and centenarians is rapidly expanding worldwide. For example, the number of centenarians has increased by 254% in Australia between 1995 to 2015 (Australian Bureau of Statistics, 2015), by 66% in the USA from 1980 to 2010 (Meyer, 2012), and by 56% in Europe in the past 5 years (Teixeira *et al.*, 2017). However, research into the psychological health of the oldest-old is limited.

Near-centenarians and centenarians (older than 95 years) can provide a model of successful ageing.

They are a heterogeneous population group and have demonstrated several characteristics to achieve exceptional longevity (Richmond *et al.*, 2012). Centenarians have been categorized into three types, based on their route to reaching extreme old age: survivors, delayers, and escapers (Evert *et al.*, 2003). Survivors are centenarians who have been diagnosed with a common age-associated disease before the age of 80 years; delayers are those diagnosed with a common age-associated disease between the age of 80 years and 100 years, and escapers are individuals who have reached the age of 100 years but have not been diagnosed with any age-associated disease. Exploring the physical, cognitive, social, and psychological resources associated with longer life and the variability in the health profile of population groups older than 95 years may provide critical insights into healthy brain ageing.

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The psychological health of those older than 95 years is a major predictor of longevity (Jopp *et al.*, 2016b). However, research on the mental health of this group has produced conflicting results, with some reporting lower rates of depression in centenarians than in the general population (Richmond *et al.*, 2011), while others (Scheetz *et al.*, 2012) reporting higher levels of depressive symptoms than octogenarians and sexagenarians. There have also been large variations in the estimates of the prevalence rates of anxiety: in Australia, 9.5% of centenarians reported anxiety symptoms (Richmond *et al.*, 2011), whereas in Portugal, the prevalence rate was almost five times higher (Ribeiro *et al.*, 2015).

This is the first systematic review to examine the prevalence and predictors of anxiety and depression in near-centenarians and centenarians across ethno-regional groups. A better understanding of the mental health of the oldest-old may help to guide interventional studies and ameliorate prevention of negative psychological health in this vulnerable population.

Method

The protocol for this review is registered in International prospective register of systematic reviews (CRD42018096606). This systematic review follows the guidelines by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher *et al.*, 2015).

Search strategy

This review systematically searched the literature across Medline, Embase, PsycINFO, CINAHL, SCOPUS, and the Cochrane Database of Systematic Reviews. The search was limited from 1990 to July 1, 2018. This cutoff was selected based on demographic statistics, as there were an estimated 96,000 centenarians in the world in 1990, which enabled researchers to study this population with significant sample sizes (United Nations, 2015). Language was limited to English, and the search was limited to humans. Search terms (Medical Subject Headings [MeSH] and keywords) used were “centenarian*,” “oldest-old,” “95 years old and over,” “aged 95+,” “longevity,” “mental health,” “anxiety,” and “depress*” (see Appendix 1 for full search strategy). The search strategy was adapted for each database in consultation with a research librarian. The MeSH term “longevity” and keywords “aged 95+” were omitted from the SCOPUS search strategy, as it resulted in a large number of irrelevant results. Reference lists of eligible articles and relevant reviews were examined to increase the scope of the review.

Study selection

Articles were screened using a two-stage process. Initially, articles were screened using the title and abstract, based on eligibility criteria. Pertinent articles were screened by examining the full-text. Inclusion criteria were papers that implemented community-based or population-based sampling, investigated a study population of near-centenarians (older than 95 years) and/or centenarians, and measured anxiety and/or depression. Studies were excluded if they were qualitative studies, dissertations, single-case reports, conference abstracts, book chapters, editorials, and letters or did not specify how the psychological health of the participants was measured. Review papers, although excluded, were screened to ensure no relevant literature was missed. Studies that did not conduct analyses specifically on persons aged 95 years and older, had a small sample size (fewer than 15 participants), used a clinical sample, or only examined personality traits, were excluded.

Quality assessment

One reviewer (A.C.) assessed the quality and bias of studies by using a modified version of the Newcastle-Ottawa Quality Assessment Scale used by Herzog *et al.* (2013) (see Appendix 2). The scale is adapted from the Newcastle-Ottawa Quality Assessment Scale for cohort studies and is specifically modified for observational studies. This scale assesses studies based on three major categories: the selection of the study sample, the comparability between different outcome groups, and the objectivity of measuring the outcome. The modified version of the Newcastle-Ottawa Quality Assessment Scale for observational studies is a commonly accepted tool and has been utilized in systematic reviews on the association between polypharmacy and dementia (Leelakanok and D’Cunha, 2018), the impact of neuropsychological and neuropathological deficits on functional health in older adults (Overdorp *et al.*, 2016), and the role of amyloid- β peptides as a mediator of the association between Alzheimer’s disease and affective disorders (Abbasowa and Heegaard, 2014).

Data extraction

Data collected from articles included study design, sampling method, geographical region, demographic information (mean age, age range, and number of participants), measurement tool utilized and reported cutoff points, and relevant outcomes measured (anxiety or depression). To ensure reliability, 20 papers were initially reviewed by two independent reviewers (A.C. and Y.L.) for full-text screening to verify the eligibility criteria. There was good agreement with a Cohen’s kappa

coefficient of 0.773. Disagreements were solved by a third independent reviewer (F.H.). Remaining papers were examined by A.C. Figure 1 depicts the PRISMA flowchart of the study selection.

Results

Thirty-eight studies were included in this review (see Figure 1). Six studies examined anxiety, 37 studies analyzed depression, and 5 studies examined both. The characteristics of included studies are summarized in Tables 1 and 2.

Prevalence and predictors of anxiety

Only four of the six studies examining anxiety provided prevalence rates, and these were discrepant. Ribeiro *et al.* (2015) found that 45.4% of centenarians presented clinically significant anxiety symptoms in Portugal. Richmond *et al.* (2011) reported a low rate of 9.5% among centenarians in Australia, and Fässberg *et al.* (2013) found even fewer anxiety disorders among Swedish near-centenarians, with a prevalence rate of 5.9%. Based on the Kessler Psychological Distress Scale (K10) measures, Sachdev *et al.* (2013) reported that Australian centenarians scored 15.03 on average and 18.7% of the sample had a K10 score of ≥ 20 , which indicates clinical levels of anxiety and depressive symptoms.

The only study that compared anxiety symptoms in centenarians and other age groups and found no significant differences in anxiety symptoms between centenarians, the 75–85 years age group, and the 86–89 years age group was by Dello Buono *et al.* (1998).

Five studies examined the predictors of anxiety in centenarians. In Portugal, 48.8% of women reported clinically significant anxiety symptoms compared with 18.2% of men (Ribeiro *et al.*, 2015). However, both Australian studies (Richmond *et al.*, 2011; Sachdev *et al.*, 2013) found no significant sex differences. Key predictive factors of anxiety were negative subjective health perception, poor objective health status, income inadequacy, and loneliness (Ribeiro *et al.*, 2015). Only one study (Richmond *et al.*, 2011) did not find any significant associations between anxiety and physical, social, or cognitive functioning.

Prevalence and predictors of depression

Twenty of the 37 studies on depression provided prevalence rates of depression. The prevalence rates varied considerably across the literature: some studies indicated that depression is not common among centenarians. Clinically significant depressive symptoms were reported only by 13.5% of centenarians in Australia, as measured by the Hospital Anxiety and

Depression Scale (HADS) (Richmond *et al.*, 2011), and by 12.8% in Italy, as measured by the 30-item Geriatric Depression Scale (GDS-30) (Tafaro *et al.*, 2002). By contrast, around 20% of centenarians in the U.S.A. met the criteria for clinical depression (Jopp *et al.*, 2016b) and 29% of participants indicated depression based on the 15-item GDS in Mexico (Pedro *et al.*, 2017).

Of 14 studies that compared prevalence rates or depression scores between centenarians and other age groups, 7 reported higher depression scores or rates in centenarians than the younger age groups and 7 found no significant difference between age groups. For instance, the Umeå 85+ study suggested that the prevalence of depression in Swedish near-centenarians and centenarians was almost double than that in 85-year-olds (32.3% vs 16.8%) (Bergdahl *et al.*, 2005). However, Cohen-Mansfield *et al.* (2013) found no significant difference in depression score between the old (75–84 years), the old-old (85–94 years), and the oldest-old (older than 95 years).

Thirty-one of the 37 studies investigated variables associated with depression in centenarians. Depressive symptoms have been positively associated with poorer rates of physical health (Tafaro *et al.*, 2002), back and neck pain (Hartvigsen and Christensen, 2008), and frailty (Lau *et al.*, 2016; Ribeiro *et al.*, 2018). The effects of poor health on depressive symptoms may be mediated through subjective health, as a negative self-perception of one's health may lead to lower mental well-being (Jang *et al.*, 2004). Depressive symptoms are also positively correlated with high levels of care, such as assisted living or institutionalization (Kato *et al.*, 2016; Margrett *et al.*, 2010) and reported levels of neuroticism, vision impairment, and traumatic events (Margrett *et al.*, 2010; Oseland *et al.*, 2016; Toyoshima *et al.*, 2018).

Fewer depressive symptoms in centenarians have been associated with a positive attitude towards life (Kato *et al.*, 2016), better perception of economic resources (Garasky *et al.*, 2012), higher quality of life (Richmond *et al.*, 2011), and better functional health (Jopp *et al.*, 2016b).

In most studies, sex was not a significant predictor of depression prevalence (Bergdahl *et al.*, 2005; Pedro *et al.*, 2017; Richmond *et al.*, 2011). The correlation of depressive symptoms in centenarians with cognition is also controversial, with a negative correlation reported by Davey *et al.* (2013) but not by Margrett *et al.* (2010), even though the latter did find that poorer cognition was linked to depression in octogenarians.

Longitudinal studies have found that near-centenarians present more depressive symptoms over time (Ailshire *et al.*, 2011). This increase may not be a result of age *per se* but rather due to

Table 1. Key characteristics of included studies that measured the prevalence and predictors of anxiety in near-centenarians and centenarians

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Dello Buono <i>et al.</i> (1998), Italy	Cross-sectional Community-based sampling	Conducted at the participant's home or institution.	Participants from the Veneto region of Italy	Mean age = 101.1 years Range = 100+ years	38	Anxiety symptoms	LEIPAD BSI subscales from the PEQOL	When comparing centenarians with younger age groups (75 – 85 years and 86 – 99 years), there were no significant differences in anxiety scores. The prevalence of any anxiety disorder was 5.9% (n = 8). There was no significant association between suicidal feelings and anxiety disorders. The prevalence of clinically significant anxiety symptoms (GAI-SF ≥ 3) was 45.4% (n = 44). Two men (18.2%) and 42 women (48.8%) reported clinically significant anxiety symptoms. Loneliness, a higher number of medical conditions, income inadequacy, and a worse health perception were significant predictive factors of anxiety.
Fässberg <i>et al.</i> (2013), Sweden	Cross-sectional Population-based sampling	Two visits at the participant's home or institution.	Gothenburg 95+ Study	All participants were 97 years of age	269	Anxiety disorder ^a	DSM-III-R criteria	The prevalence of any anxiety disorder was 5.9% (n = 8). There was no significant association between suicidal feelings and anxiety disorders. The prevalence of clinically significant anxiety symptoms (GAI-SF ≥ 3) was 45.4% (n = 44). Two men (18.2%) and 42 women (48.8%) reported clinically significant anxiety symptoms. Loneliness, a higher number of medical conditions, income inadequacy, and a worse health perception were significant predictive factors of anxiety.
Ribeiro <i>et al.</i> (2015), Portugal	Cross-sectional Population-based sampling	Conducted at the participant's home, nursing home, or any other place of their convenience. Sometimes, a proxy was present.	Oporto Centenarian Study and Beira Interior Centenarian Study	Mean age = 101.1 years Range = 100 – 108 years	97	Anxiety symptoms	GAI-SF	The prevalence of clinically significant anxiety symptoms (GAI-SF ≥ 3) was 45.4% (n = 44). Two men (18.2%) and 42 women (48.8%) reported clinically significant anxiety symptoms. Loneliness, a higher number of medical conditions, income inadequacy, and a worse health perception were significant predictive factors of anxiety.
Richmond <i>et al.</i> (2012), Australia	Cross-sectional Community-based sampling	Conducted at the participant's place of residence. Almost all participants had a caregiver or next of kin present at the interview.	Five Australian states and territories	Men age = 101.0 years	188	Anxiety disorder	Self-report clinical diagnosis (validated by informant and medical records)	The prevalence of anxiety disorders was 3.3%. In terms of sex, 0% of men reported anxiety disorders and 4.1% of women reported anxiety disorders.

Table 1. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Richmond <i>et al.</i> (2011), Australia	Cross-sectional Community-based sampling	Conducted at the participant's place of residence. Almost all participants had a caregiver or next of kin present at the interview.	Five Australian states and territories	Mean age = 101.0 years	188	Anxiety symptoms	HADS	The prevalence of anxiety was 9.5% (n = 14). Centenarians had a mean HADS score of 3.25 for anxiety, which is considered normal for the general population. Anxiety was negatively associated with quality of life and positively associated with depression.
Sachdev <i>et al.</i> (2013), Australia	Cross-sectional Population-based sampling	Conducted at the participant's home and carried out in the presence of younger family members.	The Sydney Centenarian Study	Mean age = 97.4 years	200	Anxiety and depressive symptoms	K10	Centenarians had a mean K10 score of 15.03. No significant difference was found between sexes for the K10 scores.

Key: ^aAnxiety disorder = Generalized anxiety disorder or any phobic disorder; LEIPAD = Internationally Applicable Instrument; BSI = Basic Symptom Inventory; PEQOL = Profile of Elderly Quality of Life; DSM-III-R = Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised; GAI-SF = Geriatric Anxiety Inventory-Short Form, clinically significant anxiety symptoms ≥ 3 ; HADS = Hospital Anxiety and Depression Scale; K10 = Kessler Psychological Distress Scale, a score of ≥ 20 indicates clinically significant anxiety and depressive symptoms.

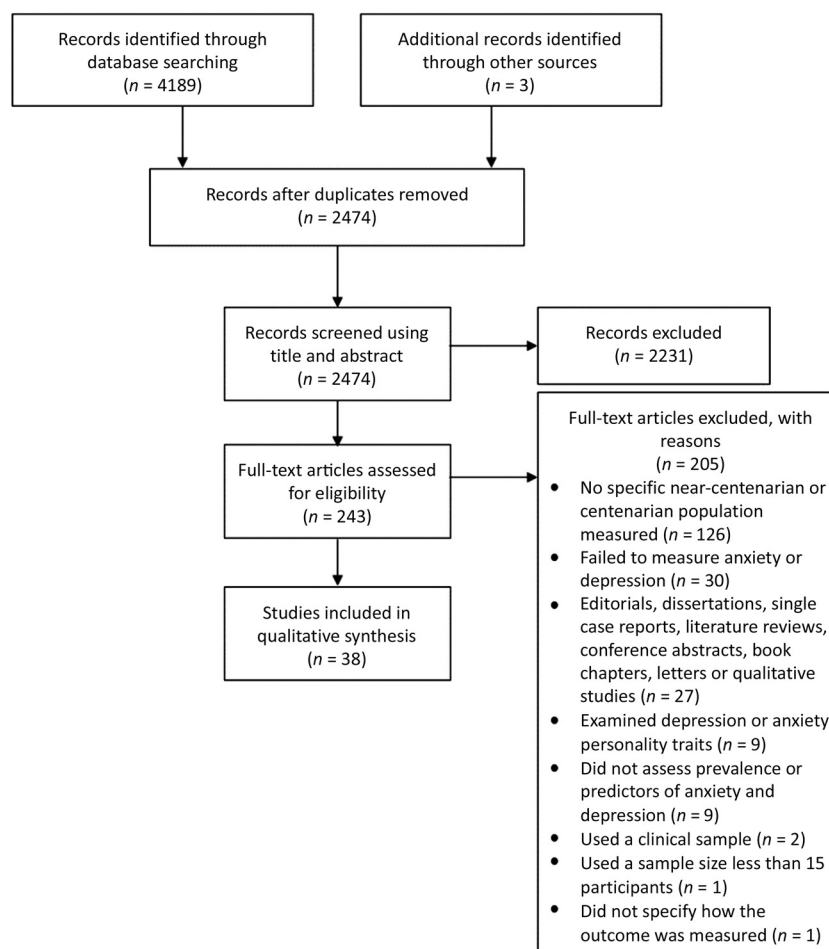


Figure 1. Flowchart of study selection using the inclusion and exclusion criteria.

the deteriorations in physical health and social and living situation. However, the study failed to account for selective attrition. Cohen-Mansfield *et al.* (2013) found that the decreases in psychological well-being over time occurred only when there were changes in physical health status or institutionalization.

Quality assessment

While 36 of the 38 centenarian studies on anxiety and depression obtained reasonable representations of the target populations and adequate sample sizes, 18 failed to report analyses comparing the characteristics of respondents and nonrespondents (Table 3). Most centenarian studies relied on self-report tools, which are susceptible to reporting bias, and few studies used clinicians to diagnose anxiety or depression, using a diagnostic manual such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) or International Classification of Diseases (ICD). Only some studies controlled for potential confounding factors such as sociodemographic characteristics when analyzing the predictors of anxiety and depression. When providing

prevalence rates for anxiety and depression between different age groups, significance tests were not always performed.

Discussion

We found significant heterogeneity in the literature on the psychological health of near-centenarians and centenarians. Even among the three studies that investigated the prevalence of anxiety symptoms in centenarians, large discrepancies existed. The percentage of centenarians with anxiety symptoms was more than four times higher in Portuguese centenarians (45.4%) compared with Australian centenarians (9.5%) and Swedish centenarians (5.9%) (Fässberg *et al.*, 2013; Ribeiro *et al.*, 2015; Richmond *et al.*, 2011). The largely varied results may have arisen from cross-cultural differences, as there appears to be generally high levels of anxiety and psychological suffering in Portuguese participants (Ribeiro *et al.*, 2015). For instance, the prevalence of anxiety symptoms measured by the 12-item General Health Questionnaire was 39.4%

Table 2. Key characteristics of included studies that measured the prevalence and predictors of depression in near-centenarians and centenarians

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE SAMPLE REPORTED)	SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Ailshire <i>et al.</i> (2011), USA	Longitudinal community-based sampling	Face-to-face interviews in the participant's home.	Health and Retirement Study	Range 96 – 100 years	225	Depressive symptoms	Brief version of the CESD, range 0-8, higher scores indicate greater depressive feelings, no cutoff score reported.	When comparing the baseline (before the age of 96 years) and follow-up results of individuals who reached 96 – 100 years of age, their mental health declined significantly over time, reporting higher depression scores at follow-up. At follow-up, there were no statistically significant sex, ethnicity, or education differences in CESD score.
Bergdahl <i>et al.</i> (2007), Sweden	Cross-sectional Population-based sampling	Conducted over two or three home visits in the participant's place of residence. Relatives and caregivers were sometimes present.	Northern Sweden	Range = 95 – 103 years	86	Depression	GDS-15 (screening), MADRS (evaluation), and DSM-IV criteria (diagnosis)	Near-centenarians and centenarians in urban municipalities had a higher prevalence of depression (32.3%) than participants in rural municipalities (14.6%) ($p=.042$).
Bergdahl <i>et al.</i> (2005), Sweden	Cross-sectional Population-based sampling	Conducted over two or three home visits in the participant's place of residence.	The Umeå 85+ study	Range = 95 – 103 years	65	Depression	GDS-15 (screening), MADRS (evaluation), and DSM-IV criteria (diagnosis)	When comparing between different age groups, the prevalence of depression among ≥ 95-year-olds was significantly higher than 85-year-olds (32.3% vs 16.8%, $p=.023$). There were no significant sex differences in the depression prevalence in the ≥ 95-year-old age group.

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	MEASUREMENT TOOL	OUTCOMES	RESULTS
Cheung and Lau (2016), Hong Kong	Cross-sectional Population-based sampling	Conducted in-home or center-based. At least one family member and/or social worker was present during the assessment.	Hong Kong Centenarian Study	Mean age = 97.7 years Range = 95 – 108	GDS-15, range 0 – 15, cutoff score >5.	Depressive symptoms	Nineteen participants (15.8%) had a GDS score of >5, whereas 101 participants (84.2%) had a GDS score of ≤5 and were considered ageing successfully. Significant associations between lower GDS and higher Successful Ageing Index scores, higher Mini-Mental State Examination scores, higher social activities, barriers to social activities, and higher optimism were found.
Christensen <i>et al.</i> (2013), Denmark	Cross-sectional Population-based sampling	In most cases, the interviews were conducted in the participant's home.	1915 Cohort Study	Mean age = 95.3 years	Modified version of the depression section from the Cambridge Mental Disorders Examination.	Depressive symptoms	When comparing depression symptomatology scores between individuals aged 95 years and individuals aged 93 years, there were no significant differences.
Cohen-Mansfield <i>et al.</i> (2013), Israel	Longitudinal Population-based sampling	Conducted in the participant's home.	Cross-sectional and Longitudinal Ageing Study	Mean age = 97.8 years Range = 95 – 108 years	CESD	Depressive symptoms	When comparing near-centenarians and centenarians with younger age groups (75 – 84 years and 85 – 94 years), there were no significant differences in CESD scores. Longitudinal results showed increased depressive symptoms over time.
Davey <i>et al.</i> (2013), USA	Cross-sectional Population-based sampling	Conducted in the participant's place of residence.	Phase 3 of the Georgia Centenarian Study	Range = 98 – 108 years	GDS-15	Depressive symptoms	Near-centenarians and centenarians who were part of the lower cognitive performance group were more likely to have a greater number of depressive symptoms than participants in the higher cognitive performance group (3.9 vs 2.9, $t_{(185)} = 2.555$, $p < .011$).

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Dello Buono <i>et al.</i> (1998), Italy	See Table 1					Depression	LEIPAD BSI subscales from the PEQOL	When comparing centenarians with younger age groups (75 – 85 years and 86 – 99 years), there were no significant differences in depression scores.
Fässberg <i>et al.</i> (2013)	See Table 1					Depression	DSM-III-R Criteria for major depression DSM-IV Criteria specifically for minor depression	The prevalence of any depression was 8.2% (n = 22). The prevalence of major depression was 3.0% (n = 8) and the prevalence of minor depression was 5.2% (n = 14). Depression was associated with suicidal feelings.
Forsell <i>et al.</i> (1995), Sweden	Cross-sectional Community-based sampling	Most of the examinations took place in the participant's home; some also took place in a research center.	Stockholm	Range = 95+ years	60	Depression	MADRS Depression diagnosed using DSM-IV criteria A, B, and E (C and D were excluded) and the ICD-10	The prevalence of major depression defined by the DSM-IV was 7.9%. The prevalence of depression defined by the ICD-10 was 9.1%.
Garasky <i>et al.</i> (2012), USA	Cross-sectional Community-based sampling	Assessments only conducted on participants; no proxy reports included.	First wave of the Iowa Centenarian Study	Mean age = 101.6 years	152	Depressive symptoms	GDS-30	Less depressive symptoms in centenarians were associated with a better perception of their economic circumstances. Noninstitutionalized centenarians who believed they could not meet their future needs with their current resources reported greater depressive symptoms than centenarians who believed they could meet their future needs.
Hartvigsen and Christensen (2008), Denmark	Cross-sectional Population-based sampling	Residence-based interviews were conducted.	Danish 1905- Cohort study	All participants were 100 years of age	256	Depression	Modified version of the depression section from the Cambridge Mental Disorders Examination	A significant association was found between neck and back pain and higher depression scores among centenarians.

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Jang <i>et al.</i> (2004), USA	Cross-sectional Community-based sampling	Conducted in the participant's home, one-to-one.	Phase 1 of the Georgia Centenarian Study	Mean age = 100.7 years	72	Depressive symptoms	GDS-30	Centenarians had significantly higher depressive symptoms compared to the other age groups (60 – 69 years and 80 – 89 years). Health perceptions and depressive symptoms were less influenced by disability in the older age groups compared with the younger groups. Subjective health mediated the effects of disability and disease on depressive symptoms. There was a negative association between concentrations of the carotenoid lutein in the cerebellum and the GDS-15. When analyzing predictors of depression, social, functional, and psychological challenges failed to explain a significant proportion of the variance in depressive symptoms. Roughly 72% reported no or few depressive symptoms (GDS score 0 – 4). For clinical depression, the prevalence was 20% (GDS score of ≥ 8). Significant associations between depression and instrumental activities of daily living, support from relatives, and subjective health were found.
Johnson <i>et al.</i> (2013), USA	Cross-sectional Population-based sampling	Conducted in the participant's place of residence.	Phase 3 of the Georgia Centenarian Study	Mean age = 100.4 years	220	Depressive symptoms	GDS-15	
Jopp <i>et al.</i> (2016a), USA	Cross-sectional Population-based sampling	Conducted in the participant's place of residence over two sessions.	Fordham Centenarian Study	Mean age = 99.0 years Range = 95 – 107 years	75	Depressive symptoms	GDS-15	
Jopp <i>et al.</i> (2016b), USA	Cross-sectional Population-based sampling	Conducted in the participant's place of residence over two sessions.	Fordham Centenarian Study	Mean age = 99.3 years Range = 95 – 107 years	119	Depressive symptoms	GDS-15	

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Kato <i>et al.</i> (2016), USA	Cross-sectional community-based sampling	Conducted in the participant's place of residence.	Longevity Genes Study	Mean age = 100.1 years Range = 98 – 107 years	54	Depressive symptoms	GDS-15	Thirty-five participants (65%) had clinically significant depression (GDS score ≥ 5). Inverse associations were found between depressive symptoms, self-rated health, and positive attitude toward life. Centenarians under high levels of care illustrated greater depressive symptoms. Positive attitude toward life partially mediates the relationship between depressive symptoms and self-rated health.
Kiljunen <i>et al.</i> (1997), Finland	Cross-sectional community-based sampling	Conducted in the participant's place of residence.	The Vantaa 85+ Study	Range = 95+ years	22	Depressive symptoms	Zung DSI, range 20 – 80 years and 40 – 47 years indicates minimal to mild depressive illness, ≥ 48 years suggests clinical depression.	When comparing near-centenarians with younger age groups (85 – 89 years and 90 – 94 years), there were no significant differences in depression scores. No near-centenarians or centenarians (0%) had depression scores above the cutoff points of 40 and 48.
Lau <i>et al.</i> (2016), Hong Kong	Cross-sectional Population-based sampling	Conducted in home or center-based. At least one family member and/or social worker was present during the assessment.	Hong Kong Centenarian Study	Mean age = 97.6 years Range = 95 – 108 years	129	Depressive symptoms	GDS-14	Twenty-six participants (20.2%) of participants had a GDS score of >4 . A significant interaction effect was found between depression and frailty. Centenarians had a more negative frailty-subjective health relationship when they were more depressed.

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	MEASUREMENT TOOL	RESULTS
Margrett <i>et al.</i> (2010), USA	Cross-sectional based sampling	Conducted in the participant's place of residence.	Phase 3 of the Georgia Centenarian Study	Mean age = 99.8 years Range = 98 – 109 years	GDS-15	When comparing centenarians with octogenarians, there were no significant differences in depression scores. Cognition did not strongly predict depressive symptoms in centenarians. Residence in a nursing or personal care home and greater neuroticism were related to greater depressive symptoms in centenarians. In 2000 – 2002, 37% of ≥ 95-year-old participants reported a GDS score of ≥ 5, compared with 30.7% of participants in the 90-year-old group and 23.5% in the 85-year-old group. In 2005 – 2007, 39.2% of the ≥ 95-year-old participants reported a GDS score of ≥ 5, compared with 31.2% in the 90-year-old group and 20.7% in the 85-year-old group. In 2010 – 2012, 31.6% in the ≥ 95-year-old group reported a GDS score of ≥ 5, compared with 27.7% of the 90-year-old group and 25.0% of the 85-year-old group.
Nyqvist <i>et al.</i> (2017), Sweden	Three cross-sectional samples Population-based sampling	Conducted over two or three home visits in the participant's place of residence.	The Umeå 85+ study	Range = 95+ years	GDS-15	Depressive symptoms
				2000 – 2002 = 55 2005 – 2007 = 84 2010-2012 = 115		
O'Connor <i>et al.</i> (2016), USA	Cross-sectional, Community-based sampling	Conducted either at the participant's place of residence or in the research institute.	Center for Healthy Aging's Longevity Study	Range = 100+ years	CESD	When comparing centenarians with younger age groups (50 – 59, 60 – 69, 70 – 79, 80 – 89, and 90 – 99 years), there were significant differences in depression score (centenarians had higher scores than all age groups except the 50 – 59 years age group).

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Osland <i>et al.</i> (2016), USA	Cross-sectional Community-based sampling	Participants were interviewed alone.	Oklahoma Centenarian Club	Mean age = 101.0 years	154	Depressive symptoms	GDS-10	A positive association was found between traumatic life events and depressive symptoms. Depressive symptoms were a significant predictor of traumatic life events, with a R^2 of .26. A positive association was found between depressive symptoms and traumatic life events that occurred in the later half of life.
Pedro <i>et al.</i> (2017), Mexico	Cross-sectional Community-based sampling	Conducted in the participant's home, sometimes in the presence of a caregiver.	Mexico City	Mean age = 101.82 years	393	Depressive symptoms	GDS-15	The prevalence of depression was 29% (n = 116) when using a GDS score ≥ 6 . The mean GDS score was 4, and no difference was found when comparing sexes.
Poon <i>et al.</i> (1992), USA	Cross-sectional Community-based sampling	Conducted in the participant's home, one-to-one.	Phase 1 of the Georgia Centenarian Study	Range = 100+ years	165	Depressive symptoms	GDS-30	The presence of depression was negatively associated with Instrumental Activities of Daily Living.
Ribeiro <i>et al.</i> (2018), Portugal	Cross-sectional Population-based sampling	Conducted at the participant's home, nursing home, or other place of convenience. Proxy sometimes present.	Oporto Centenarian Study and Beira Interior Centenarian Study	Mean age = 101.0 years Range = 100 – 105 years	91	Depressive symptoms	PGDS-14	Depression prevalence was 35.2% in Portuguese centenarians. Compared with prefrail centenarians, those who were frail had a higher risk of depression (OR = 3.92; 95% CI 1.48, 10.4).
Richmond <i>et al.</i> (2012), Australia	See Table 1					Depression	Self-report clinical diagnosis (validated by informant and medical records)	The prevalence of depression was 18.3% in the total sample. In terms of sex, 18.2% of men reported depression and 18.3% of women reported depression.

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Richmond <i>et al.</i> (2011), Australia	See Table 1					Depression	HADS	Twenty participants (13.5%) reported depressive symptoms. Centenarians had a mean HADS score of 4.05 for depression. Quality of life was negatively associated with depression.
Sachdev <i>et al.</i> (2013), Australia	See Table 1							
Scheetz <i>et al.</i> (2012), USA	Cross-sectional Community-based sampling	Conducted at the participant's home, one-to-one.	Phase 1 of the Georgia Centenarian Study	Mean age = 100.7 years Range = 99 – 110 years	137	Depressive symptoms	GDS-30	Centenarians scored significantly higher on the GDS-30 than octogenarians and sexagenarians. Differences were also identified between age groups in three GDS subscales: cognitive impairment, hopelessness, and the withdrawal-apathy-vigor subscale.
Selim <i>et al.</i> (2005), USA	Cross-sectional Community-based sampling	Health questionnaire mailed to the participant's home.	Large Health Survey of Veteran Enrollees	Range = 100 – 112 years	93	Depression	Clinical diagnosis	The depression prevalence was 21%. There were no significant differences between the 85–99 year and 100+ year age groups in depression prevalence.
Tafaro <i>et al.</i> (2002), Italy	Cross-sectional Community-based sampling	Conducted at the participant's place of residence.	Centenarians in Rome	Mean age = 101.8 years	157	Depressive symptoms	GDS-30	The depression prevalence was 12.8% (GDS score > 15). The GDS scores reported by centenarians were related to the number of chronic diseases, self-dependency, and the limitations of social relationships. The presence of depressive symptoms was not related to survival.

Table 2. Continued

AUTHOR, YEAR, AND COUNTRY	STUDY DESIGN AND SAMPLING METHOD	ASSESSMENT OF POPULATION	STUDY/AREA	AGE (MEAN/RANGE REPORTED)	SAMPLE SIZE (N)	OUTCOMES	MEASUREMENT TOOL	RESULTS
Tedone <i>et al.</i> (2014), Italy	Cross-sectional Community-based sampling	Conducted by trained multidisciplinary staff.	Northern Italy	Range = 100 – 109 years	88	Depression	Clinical diagnosis (validated by clinical documentation)	The depression prevalence was 10.3% among supercentenarians (105 – 109 years) and 33.9% among centenarians (100 – 104 years). Depressive symptoms were significantly associated with objective and subjective vision. When centenarians had social support, they indicated lower rates of depressive symptoms. However, greater depressive symptoms were found when individuals had low levels of visual function, even if they felt supported socially.
Toyoshima <i>et al.</i> (2018), USA	Cross-sectional Population-based sampling	Conducted at the participant's place of residence.	Phase 3 of the Georgia Centenarian Study	Range = 98 – 101 years	106	Depressive symptoms	GDS-15	GDS mean scores did not significantly differ between age groups or sexes. In the 95+ years age group, 32% had depression.
von Heideken Wagert <i>et al.</i> (2006), Sweden	Cross-sectional Population-based sampling	Conducted over 2 or 3 home visits in the participant's place of residence.	The Umeå 85+ study	Range = 95+ years	72	Depressive symptoms	GDS-15, MADRS and OBS.	The depression prevalence in the ≥ 95-year-old group was 25%, compared with 16% in the 85-year-old group and 29% in the 90-year-old group.
von Heideken Wagert <i>et al.</i> (2005), Sweden	Cross-sectional Population-based sampling	Conducted over 2 or 3 home visits in the participant's place of residence.	The Umeå 85+ study	Range = 95+ years	40	Depressive symptoms	GDS-15, MADRS, and OBS.	41 centenarians responded to the GDS and all scored less than 10. There was no significant difference between gender and urban or rural living area in relation to GDS score.
Yang (2013), Taiwan	Cross-sectional Community-based sampling	Conducted at the participant's chosen venue, usually at their home. Proxy sometimes present.	Taiwan Centenarian Study	Mean age = 102.5 years Range = 100 – 110 years	100	Depressive symptoms	Geriatric Depression Scale	

Key: CESD = Center for Epidemiological Studies Depression Scale; GDS-15 = Geriatric Depression Scale Short Version, 15 items; MADRS = Montgomery Åsberg Depression Rating Scale; DSM-III-R = Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Revised; DSM-IV = Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition; LEIPAD = Internationally Applicable Instrument; BSI = Basic Symptom Inventory; PEQOL = Profile of Elderly Quality of Life; GDS-30 = Geriatric Depression Scale Long Version, 30 items; Zung DSI = Zung Depression Status Inventory; GDS-14 = Chinese Version of the Geriatric Depression Scale, 14 items; HADS = Hospital Anxiety and Depression Scale; OBS = Organic Brain Syndrome Scale.

Table 3. Critical appraisal of included studies using an adapted Newcastle-Ottawa scale for cross-sectional and longitudinal studies

AUTHOR	SELECTION		COMPARABILITY		OUTCOME		TOTAL SCORE (OUT OF 8)
	REPRESENTATIVENESS OF THE SAMPLE	SAMPLE SIZE	NON-RESPONDENTS	BASED ON DESIGN AND ANALYSIS	ASSESSMENT OF OUTCOME	STATISTICAL TEST	
	Ailshire <i>et al.</i> (2011)	+	+		+	+	
Bergdahl <i>et al.</i> (2007)	+	+	+	+	++	+	7
Bergdahl <i>et al.</i> (2005)	+	+	+	+	++	+	7
Cheung and Lau (2016)	+	+	+		+	+	5
Christensen <i>et al.</i> (2013)	+	+		+	++	+	6
Cohen-Mansfield <i>et al.</i> (2013)	+	+		++	+	+	6
Davey <i>et al.</i> (2013)	+	+		++	+	+	6
Dello Buono <i>et al.</i> (1998)	+	+		++	+	+	6
Fässberg <i>et al.</i> (2013)	+	+	+	+	++	+	7
Forsell <i>et al.</i> (1995)	+	+		++	++	+	7
Garasky <i>et al.</i> (2012)	+	+		+	+	+	5
Hartvigsen and Christensen (2008)	+	+		+	++	+	6
Jang <i>et al.</i> (2004)	+	+	+	++	+	+	7
Johnson <i>et al.</i> (2013)	+	+		+	+	+	5
Jopp <i>et al.</i> (2016a)	+	+	+	+	+	+	6
Jopp <i>et al.</i> (2016b)	+	+	+	+	+	+	6
Kato <i>et al.</i> (2016)	+	+	+	+	+	+	6
Kiljunen <i>et al.</i> (1997)	+		+	++	++	+	7
Lau <i>et al.</i> (2016)	+	+	+	++	+	+	7
Margrett <i>et al.</i> (2010)	+	+		++	+	+	6
Nyqvist <i>et al.</i> (2017)	+	+	+	+	+		5
O'Connor <i>et al.</i> (2016)	+	+		+	+	+	5
Oseland <i>et al.</i> (2016)	+	+		+	+	+	5
Pedro <i>et al.</i> (2017)	+	+	+		+	+	5
Poon <i>et al.</i> (1992)	+	+	+	+	+	+	6
Ribeiro <i>et al.</i> (2018)	+	+		++	+	+	6
Ribeiro <i>et al.</i> (2015)	+	+		++	+	+	6
Richmond <i>et al.</i> (2012)	+	+		+	++		5
Richmond <i>et al.</i> (2011)	+	+		+	+	+	5
Sachdev <i>et al.</i> (2013)	+	+	+		+	+	5
Scheetz <i>et al.</i> (2012)	+	+	+	+	+	+	6
Selim <i>et al.</i> (2005)		+	+	+	+	+	5
Tafaro <i>et al.</i> (2002)	+	+		+	+	+	5
Tedone <i>et al.</i> (2014)	+	+		+	+	+	5
Toyoshima <i>et al.</i> (2018)	+	+		++	+	+	6
von Heideken	+	+	+	+	++	+	7
Wagert <i>et al.</i> (2006)							
von Heideken	+	+	+	+	++		6
Wagert <i>et al.</i> (2005)							
Yang (2013)	+	+		+	+	+	5

in Portuguese participants aged 55 years and over (Ribeiro *et al.*, 2011), which is higher than other estimates on this age group, which ranged from 1.2% to 14% internationally based on other assessment tools (Bryant *et al.*, 2008). The variation in anxiety prevalence rates might also be due to

methodological differences, as Ribeiro *et al.* (2015) utilized the Anxiety Inventory – Short Form (GAI-SF), whereas Richmond *et al.* (2011) used the HADS and Fässberg *et al.* (2013) employed the DSM, Third Edition, Revised (DSM-III-R), or due to the use of different sampling strategies.

Most studies on near-centenarians and centenarians reported that poorer physical health is associated with higher levels of depressive symptoms (Hartvigsen and Christensen, 2008; Jang *et al.*, 2004; Tafaro *et al.*, 2002; Toyoshima *et al.*, 2018). Poorer physical health can circumscribe social interactions and physical activity, which may reduce mental well-being (Jang *et al.*, 2004). In addition, better functional health appeared to be generally correlated with fewer depressive symptoms (Jopp *et al.*, 2016b; Poon *et al.*, 1992; Tafaro *et al.*, 2002). Higher levels of function and mobility allow the oldest-old to have greater autonomy over their lives, which is important for good psychological health and a greater sense of control (Vallerand *et al.*, 1989). A positive attitude toward life is associated with lower levels of depression in extreme old age (Kato *et al.*, 2016), more positive coping strategies, greater psychological resilience, and an improved ability for the oldest-old to compensate for declines in physical health (Reichstadt *et al.*, 2007).

Our findings are consistent with a previous review on depression in the elderly (Djernes, 2006), which reported that somatic illness and functional impairment were significant predictors of depression. However, Djernes (2006) studied populations aged 60 years and over, whereas our systematic review analyzed only near-centenarians and centenarians, and thus, comparisons should be treated with care.

It remains unclear how prevalent depression is in centenarians, with worldwide estimates ranging from 0.0% to 65.0% (Kato *et al.*, 2016; Kiljunen *et al.*, 1997). Possible reasons for the substantial variation in prevalence rates of depression are differences in methodologies and cutoff points, sampling strategies, age ranges, inclusion and exclusion criteria, and different health conditions of the populations examined. Fifteen measurement tools were used across the centenarian studies in this review to investigate depression: the GDS-30, GDS-15, GDS-14, Portuguese version of the Geriatric Depression Scale (PGDS-14), GDS-10, Center for Epidemiological Studies Depression Scale (CES-D), Hospital Anxiety and Depression Scale (HADS), Zung Depression Status Inventory (Zung DSI), K10 Psychological Distress tool, Montgomery Åsberg Depression Rating Scale (MADRS), Basic Symptom Inventory (BSI), Internationally Applicable Instrument (LEIPAD), Organic Brain Syndrome Scale (OBS), the Cambridge Mental Disorders examination, and the DSM-IV criteria, with each specifying different criteria to define depression. Furthermore, some of the measurement tools such as the K10 Psychological Distress tool may overestimate the prevalence of depression, as several items in the questionnaire focus on symptoms related to fatigue, which although prevalent in centenarians, do not necessarily indicate depression.

Few studies have been conducted on the best measures to assess depression in near-centenarians and centenarians. A review by Balsamo *et al.* (2018) suggested that the GDS-30 is the most effective self-report instrument in assessing depression in the oldest-old compared with other existing tools such as the CES-D, because it contains items specifically tailored to geriatric participants. However, most self-report tools fail to differentiate pseudodementia from depression and unipolar depressive symptoms from bipolar disorder symptoms (Balsamo *et al.*, 2018). Although gold-standard clinical diagnoses using the DSM or ICD criteria are preferred and can be considered the most accurate measures of assessing depression, there is limited feasibility in large population studies, as significant labor and resources are required.

There are many limitations with the current literature on the psychological health of centenarians, in particular the methodological challenges of investigating the oldest-old population. Many studies are susceptible to the healthy volunteer effect, as centenarians who participate must be able to complete the rigorous assessment process. These participants are less likely to suffer from dementia or mild cognitive impairment, which reduces the generalizability of the findings. Owing to the cross-sectional design, it is difficult to distinguish whether comparisons made between centenarians and other age groups are due to cohort effects or age differences. Centenarian studies' inclusion and exclusion criteria differ. For example, the Sydney Centenarian Study includes all individuals who are aged 95 years or above in seven local government areas in Sydney, whereas the Georgia Centenarian Study includes only those aged 98 years or older. Some studies also have the tendency to report mean scores on anxiety or depression scales without any interpretation of their significance. Finally, most measurement tools used to assess anxiety and depression are self-report, which are susceptible to reporting bias. More recent centenarian studies (Sachdev *et al.*, 2013) synthesize self- and informant-reported data, which improve the reliability of the results.

This review is limited by the exclusion of studies that examined broader concepts of psychological health such as positive affect, life satisfaction, and personality traits and by the restriction to English-language publications. A strength of this review is our use of multiple databases and the rigorous search strategy to capture all apposite centenarian research on anxiety and depression.

Personality traits and clinical syndromes may overlap, but they differ in that clinical syndromes generally have symptoms of greater severity and are associated with more disability or distress, and personality traits are usually lifelong. While we concede

that most studies reported scale scores with or without threshold cut points and that measures of disability, distress, and longitudinal course are absent, the use of high-threshold cut scores on scales (Cheung and Lau, 2016; Kiljunen *et al.*, 1997) and clinical diagnoses using established criteria (Bergdahl *et al.*, 2007; Fässberg *et al.*, 2013) add weight to their being clinical syndromes.

We identified a substantial gap in the literature concerning the psychological health of centenarians. Fewer studies reported rates of anxiety compared with depression, and very few studies explored both anxiety and depression in the same centenarian sample. Only five specifically examined the prevalence or predictors of anxiety.

This review has significant implications for future research. Centenarian researchers should address the methodological points covered previously. Multiple facets of psychological health, such as apathy, as well as positive affect and life satisfaction, should be examined in addition to anxiety and depression (Cheng *et al.*, 2019). Future studies should also investigate the relationship between depression and the number of medications, specifically psychotropic medications, levels of physical activity (Martin *et al.*, 2012), levels of mental and cognitive activity, and perceptions of economic resources (Garasky *et al.*, 2012). As this review found that many centenarian studies utilize different measurement tools, cutoff points, and inclusion and exclusion criteria, future research should be directed toward the establishment of an international consortium to harmonize variables across studies, for example, as performed by the International Centenarian Consortium – dementia (Brodaty *et al.*, 2016). Use of similar criteria to measure anxiety and depression would facilitate cross-cultural comparisons. The role of biomarkers for depression (Strawbridge *et al.*, 2017) is yet to be explored in this very old population. Identification of prevalence rates and contributing variables to psychological morbidity in the oldest-old can assist clinicians in planning services to ameliorate these distressing symptoms.

Conflict of interest declaration

H.B. is on the advisory board of Nutricia Australia.

Description of authors' roles

A.C., Y.L., F.H. and H.B. contributed to the design of the review. A.C., Y.L. and F.H. reviewed the studies for inclusion and exclusion. A.C. completed data extraction and undertook the quality assessment of studies. All authors assisted in editing and writing the paper.

Supplementary material

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