Introduction

Obesity can lead to several chronic illnesses. It is also associated with increased loneliness, decreased mental health, sickness absence and high healthcare costs. In various countries, high prevalence rates of obesity have been reported. While it has been shown that body weight gradually increases with age, it can drop among the oldest old (≥80) (e.g., Hajek et al.). In addition, several studies reported the prevalence rates of obesity among the oldest old. For example, a prevalence rate of 20.8% was reported in Saudi Arabia, 30.0% in Spain, 17.3% in Italy and 18.2% in Mexico. However, a systematic review, meta-analysis and meta-regression is lacking. The knowledge about the prevalence of obesity is of particular relevance because there is a continuing increase in the number of individuals aged ≥80 years. Furthermore, our current work may determine risk factors of obesity in this age bracket, which can assist in creating interventions. Moreover, such a work can identify gaps in our knowledge and can therefore guide future research.

Beyond that, conducting a meta-analysis can enable the pooling of studies. Compared with individual studies, this can assist in providing a more accurate oversight. In addition, a meta-regression can help to disentangle the influence of potentially important moderating factors (such as country or assessment of obesity).

Methods

This systematic review satisfied the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. Moreover, it has been registered in the International Prospective Register of Systematic Reviews (PROSPERO, under the registration number: CRD42020193890). Furthermore, a study protocol has been published.

Three electronic databases were searched in August 2021 (Medline, PsycINFO, CINAHL). The Medline search strategy is shown in Table 1. Two reviewers (AH, BK) evaluated the suitability using two steps (title/abstract screening and a subsequent full-text screening). In addition, a hand search was done. When opinions differed, discussions were used to resolve it. This procedure was also used when opinions differed in data extraction and evaluation of the study quality.

Inclusion criteria were as follows: observational studies (cross-sectional and longitudinal) investigating the prevalence of obesity among the oldest old (i.e., ≥80 years) and preferably (but not required) identifying its correlates; assessment of main variables with suitable tools; published in English or German language; and published in peer-reviewed, scientific journals. Studies were excluded when they solely examined samples with a specific disorder (e.g., individuals with mental disorders). Restrictions were not applied regarding time and location of the studies.
A pretest was conducted before our final eligibility criteria based on a sample of 100 titles/abstracts. Nevertheless, our eligibility criteria did not change.

One reviewer extracted the data (BK) with a second reviewer (AH) cross-checking it. Data extraction included study design, definition and operationalization of obesity, sample characteristics, analytical approach and main findings.

The well-established Joanna Briggs Institute (JBI) standardized critical appraisal instrument for prevalence studies was used for evaluating the quality of the studies. The score ranges from 0 to 9, with higher values corresponding to higher study quality (and less risk of bias). Two reviewers (AH, BK) independently evaluated the quality of the studies.

With regard to meta-analysis, random-effects models were used to pool proportions across studies. Random-effects models were used as we assumed heterogeneity across studies. In accordance with the existing recommendations, heterogeneity between studies was estimated using the $I^2$ statistic, with $I^2$ values of 25%−50% being considered as low, 50%−75% as moderate and ≥75% as high heterogeneity. To perform the meta-analysis, the well-established “metaprop” was used.

With regard to meta-regression, the “meta regress” implemented in Stata 16 command was used (random-effects, with restricted maximum likelihood; Knapp–Hartung adjustment for the standard errors were applied). As the coefficients in the meta-regressions are originally scaled as double arcsine values (instead of proportions), the effect sizes were first recalculated (according to Lipsey and Wilson).

Meta-regressions were performed to explore the sources of heterogeneity. As one study had an extraordinary high prevalence of obesity, it was included in sensitivity analysis. Moreover, we restricted the meta-analysis was restricted to studies using body mass index (BMI) ≥30 (objectively assessed) in further analysis. In addition, we restricted the meta-analysis was restricted to studies using BMI ≥30 (self-rated) in another analysis. Moreover, a funnel plot and the Egger test were used to identify publication bias ($P < 0.05$ suggests publication bias). Stata 16.1 (College Station, TX, USA) was used.

## Results

### Study overview

In Figure 1, a flow chart is displayed. In total, after removing duplicates, 4553 studies were screened (title/abstract screening). In this first step, the most common reason for exclusion was that the respective studies simply did not report the prevalence of obesity among the oldest old. In the second step (full-text screening), three different reasons for exclusion were identified. In sum, $n = 19$ studies were included in our present systematic review.

![Figure 1](image)

Data came from North America ($n = 6$, three studies from the USA, one study each from Mexico, Barbados and Canada), South America ($n = 1$ from Brazil), from Europe ($n = 8$, two studies each from Spain and Germany and one study each from Sweden, Finland, Italy and Switzerland), Asia ($n = 3$, two studies from China and one study from Saudi Arabia) and Africa ($n = 1$ from South Africa). Three studies used longitudinal data (one of these studies both used cross-sectional and longitudinal regressions), whereas the other 16 studies used cross-sectional data. The observation period in the longitudinal studies ranged from 10 months to 13 years. The majority of the studies used data from large, representative surveys (e.g., Vitality 90+ Study, which is representative for community-dwelling and institutionalized individuals aged ≥90 years in the city of Tampere, Finland). The sample size ranged from 101 to 95 477. With one exception (5.2%), the proportion of women mainly ranged from 40% to 70%. While the majority of the studies did not explicitly describe the mean age, it ranged from 84 to 92 years in the remaining studies. Only a few studies used self-reports of obesity (e.g., based on self-reported height and weight). Further details are shown in Table 2.

### Correlates of obesity

Only three studies examined the correlates of obesity among the oldest old. Two longitudinal studies found that the risk of obesity

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Table 1  Search strategy (Medline)

| # | Overweight |
|---|------------|
| #1 | Excess weight |
| #2 | Obesity* |
| #3 | Adipos* |
| #4 | #1 OR #2 OR #3 OR #4 |
| #5 | Oldest old |
| #6 | Octogenarian |
| #7 | Aged, 80 and over [MeSH Terms] |
| #8 | #6 OR #7 OR #8 |
| #9 | Octogenarian |
| #10 | Prevalence [Title/Abstract] |
| #11 | #5 AND #9 AND #10 |

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Table 2  Study overview and key findings

| Author           | Country     | Definition of overweight | Definition of obesity | Assessment of obesity | Study type               | Sample characteristics and target population | Sample size | Age | Females in total sample morbidity | Diabetes | Results: prevalence of overweight (if data are available: also stratified by sex) | Results: prevalence of obesity (if data are available: also stratified by sex) | Results: correlates |
|------------------|-------------|--------------------------|-----------------------|-----------------------|---------------------------|-----------------------------------------------|-------------|-----|-----------------------------------|----------|-----------------------------------------------------------------|-----------------------------------------------------------------|-------------------|
| Abolfotouh (2001) | Saudi Arabia | Not applicable           | Waist circumference ≥95 cm for women, ≥100 cm for men and/or waist-to-hip ratio ≥0.85 for women or ≥0.95 for men | Assessed during the interview | Cross-sectional | Population identified through primary healthcare centers Target population: Population of aged ≥65 years in the catchment areas of three primary healthcare centers in Abha (capital city of Asir province in south-western Arabia) | n = 101 | Age: | mean not specified, SD not specified, ≥85 | Females: 32% Not specified | Diabetes: not specified | Diabetes: not specified | Not reported |
| Andrade (2012)    | Brazil      | BMI 25–29.9              | BMI ≥30               | Assessed during the interview | Cross-sectional | Random sample of people aged ≥60 years Target population: Participants were from the Family Health Programme and from the Community Agents Health Programme in Vitória-ES (Brazil) | n = 195 | Age: | mean not specified, SD not specified, 80–96 | Females: 67.6% Not reported | Diabetes: not reported | Diabetes: not reported | 15.8% |
| Carter (2006)     | Barbados    | Not applicable           | BMI ≥30               | Assessed during the interview | Cross-sectional | Random sample of people aged ≥60 years Target population: older adults in urban Barbados | n = 137 | Age: | mean not specified, SD not specified, ≥85 | Females: 61.3% Not reported | Diabetes: not reported | Diabetes: not reported | Not investigated |
| Das (2005)        | USA         | BMI 25–29.9              | BMI ≥30               | Assessed during the interview | Cross-sectional | Veterans Target population: Veterans receiving outpatient care at Veterans Affairs medical facilities (representing all regions in the USA) | n = 165 938 | Age: | mean not specified, SD not specified, ≥80 | Females: 5.2% Not reported | Diabetes: not reported | Diabetes: not reported | 16.1% (women: 19.1%; men: 16.0%) |
| Faeh (2009)       | Switzerland | BMI ≥25                  | BMI ≥30               | Self-reported           | Cross-sectional | SOcio-Medical Indicators for the POPulation of Switzerland, Interkantonales GesundheitIndikatorenProjekt, Swiss Health Survey Target population: population-based surveys covering all language regions of Switzerland | Not specified Age: | mean 80, SD not specified, range not specified Females: 45% | Morbidities: not reported | Diabetes: not reported | Diabetes: not reported | 41.0%–47.5% |

(Continues)
Table 2  Continued

| Author          | Country | Definition of overweight | Definition of obesity | Assessment of obesity | Study type | Sample characteristics and target population | Sample size age females in total sample morbidity and diabetes | Results: prevalence of overweight (if data are available: also stratified by sex) | Results: prevalence (if data are available: also stratified by sex) | Results: correlates |
|-----------------|---------|--------------------------|-----------------------|-----------------------|------------|---------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------|----------------------------------------------------------------|-------------------|
| Flegal (1998)   | USA     | BMI 25.0–29.9            | BMI ≥30               | Assessed during the interview | Cross-sectional | National Health Examination Survey National Health and Nutrition Examination Surveys Target population: nationally-representative sample of the US civilian, non-institutionalized population | Not specified Age: mean not specified, SD not specified, ≥80 Females: not specified Morbidities: not reported Diabetes: not reported | 37.3% (women: 35.0%; men: 42.7%) | 12.6% (women: 15.1%; men: 8%) | Not investigated |
| Gutiérrez-Fisac (2004) | Spain | BMI 25–29.9 | BMI ≥30 or waist circumference >102 cm in men or >88 cm in women | Assessed during the interview | Cross-sectional | Representative non-institutionalized population (≥60 years) Target population: community-dwelling older adults in Spain | n = 628 Age: mean not specified, SD not specified, ≥80 Females: 55.6% Morbidities: not reported Diabetes: not reported | 42.8% BMI (women: 34.6%; men: 58.2%) | 25.8% BMI (women: 29.2%; men: 19.4%); 60.8% waist circumference (women: 72.1%; men: 39.6%) | Not investigated |
| Gutiérrez-Fisac (2013) | Spain | Not applicable | BMI ≥30 | Assessed during the interview | Cross-sectional | Representative non-institutionalized population, Study on Nutrition and Cardiovascular Risk in Spain Target population: community-dwelling older adults in Spain | n = 893 Age: mean not specified, SD not specified, ≥80 Females: 55.0% Morbidities: not reported Diabetes: not reported | Not reported | 30.0% (2008–2010) BMI (women: 31.6%; men: 28.2%); 60.1% (2008–2010) waist circumference (women: 69.6%; men: 48.9%) | Not investigated |
| Hajek (2015)    | Germany | BMI 25–29.99            | BMI ≥30               | Self-reported         | Cross-sectional and longitudinal (three waves, 18 months between waves) | German Study on Ageing, Cognition and Dementia in Primary Care Patients Target population: community-dwelling and institutionalized older adults in six large German cities (Bonn, Düsseldorf, Hamburg, Leipzig, Mannheim and Munich) | n = 1882 Age: mean ± SD, 84.0 ± 3.3, 79–97 Females: 65.8% Morbidities: not reported Diabetes: not reported | 40.0% | 13.7% | Odds of becoming obese increased with increasing age groups in women (e.g., 84–86 years compared with 70–80 years: OR: 0.22, 95% CI: 0.05–0.92). Moreover, the risk of... |
| Author                  | Country        | Definition of overweight | Definition of obesity | Assessment of obesity | Study type                                                                 | Sample characteristics and target population                                                                 | Sample size age females in total sample morbidity diabetes | Results: prevalence of overweight (if data are available: also stratified by sex) | Results: prevalence (if data are available: also stratified by sex) | Results: correlates                                                                 |
|------------------------|----------------|--------------------------|-----------------------|----------------------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Hajek (2020)           | Germany        | BMI 25–29.99             | BMI ≥30               | Self-reported        | Longitudinal (two waves, 10 months between waves)                          | Study on Needs, Health Service Use, Costs and Health-Related Quality of Life in a Large Sample of Oldest-Old Primary Care Patients (85+) | n = 783 Age: mean ± SD, 88.9 ± 2.9, 85–100 Females: 67.9% Morbidities: not reported Diabetes: not reported | 37.9% (women: 34.2%; men: 45.8%)                                                                 | 10.2% (women: 10.4%; men: 10.0%)                                                                      | Regarding random-effects logistic regression, age was negatively (OR: 0.77, 95% CI: 0.59–1.00) and the presence of chronic conditions (OR: 1.32, 95% CI: 1.11–1.57) was positively related to obesity |
| Jardim (2018)          | South Africa   | Not applicable           | High waist-to-hip ratio (>0.9 in men, >0.85 in women) | Assessed during the interview | Cross-sectional                                                              | Health and Aging in Africa: Longitudinal Studies of INDEPTH Communities Target population: adults in a subdistrict of Mpumalanga Province in rural South Africa | n = 549 Age: mean not specified, SD not specified, ≥80 Females: 46.4% Morbidities: not reported Diabetes: 12.2% | Not reported                                                                                   | 71.5%                                                                         | Not investigated                                                                 |
| Kaplan (2003)          | Canada         | BMI 25–29.9              | BMI ≥30               | Self-reported        | Cross-sectional                                                              | Canadian National Population Health Survey Target population: community-dwelling older adults living in Canada          | n = 580 Age: mean not specified, SD not specified, ≥680 Females: 26.8% Morbidities: not reported Diabetes: not reported | 26.8% (women: 26.8%; men: 26.7%)                                                                 | 5.3% (women: 5.6%; men: 5.0%)                                                                      | Not investigated                                                                 |

(Continues)
| Author          | Country | Definition of overweight | Definition of obesity | Assessment of obesity | Study type          | Sample characteristics and target population                                                                                                                                                                                                 | Sample size age females in total sample morbidity | Results: prevalence of overweight (if data are available: also stratified by sex) | Results: prevalence (if data are available: also stratified by sex) | Results: correlates |
|-----------------|---------|--------------------------|-----------------------|-----------------------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------|
| Lisko (2015)    | Finland | BMI 25–29.9              | BMI ≥30               | Assessed during the interview | Cross-sectional Vitality 90+ Study: community-dwelling and institutionalized individuals aged 90 in the city of Tampere, Finland  
(n = 569; Age: mean not specified, SD not specified, 90–91 females: 73.1%; Comorbidity: 70.4% (middle or high); Diabetes: not reported) | 33.7% (women: 33.9%; men: 33.3%) | 13.2% (women: 14.4%; men: 9.8%) | According to multinomial regression, obesity was significantly associated with a decreased likelihood of being able to perform a chair stand (OR: 0.27, 95% CI: 0.09–0.88), but not with physical functioning |
| Perissinotto (2002) | Italy   | Not applicable           | BMI ≥30               | Assessed during the interview | Cross-sectional Italian Longitudinal Study on Ageing: Target population: individuals in old age living in eight municipalities: Genoa, Seregno, Selvazzano-Rubano, Impruneta, Fermo, Naples, Casamassima and Catania  
(n = 670; Age: mean not specified, SD not specified, 0–84 females: 47.3%; Morbidities: not reported; Diabetes: not reported) | Not reported | 17.3% (women: 25.4%; men: 7.7%) | Not investigated                                                                                                            |
| Rivas-Marino (2015) | Mexico  | BMI 25–29.9              | BMI ≥30               | Assessed during the interview | Cross-sectional World Health Organization’s Study on global AGing and adult health: Target population: individuals aged ≥50 years in Mexico  
(n = 250; Age: mean not specified, SD not specified, ≥80 females: 60.1%; Morbidities: not reported; Diabetes: not reported) | 33.9% | 18.2% | Not investigated                                                                                                            |
| Samper-Ternent (2012) | USA     | BMI 25–29.99             | BMI ≥30               | Assessed during the interview | Cross-sectional Hispanic Established Population for the Epidemiological Study of the Elderly (H-EPESE), Health and Retirement Study (HRS): Target population: H-EPESE: community-dwelling Mexican Americans aged ≥85 years residing in Texas, New Mexico, Colorado, Arizona and California (USA)  
(n = 150; Age: mean 88.4, SD not specified, ≥85 females: 63.3%; Morbidities: not reported; Diabetes: NHW sample: 11.6%, MA sample: 27.4%) | 29.8% (women, NHW sample: 25.2%; MA sample: 29.5%; men, NHW sample: 35.9%, MA sample: 34.6%) | 10.8% (women, NHW sample: 8.8%; MA sample: 17.2%; men, NHW sample: 5.8%; MA sample: 20.2%) | Not investigated                                                                                                            |
| Author       | Country   | Definition of overweight | Definition of obesity | Assessment of obesity | Study type      | Sample characteristics and target population | Sample size age females in total sample morbidity | Results: prevalence of overweight (if data are available: also stratified by sex) | Results: prevalence (if data are available: also stratified by sex) | Results: correlates |
|--------------|-----------|--------------------------|-----------------------|-----------------------|------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|---------------------|
| Simonsson (2020) | Sweden    | Not applicable           | BMI ≥30               | Self-reported         | Cross-sectional  | Health on equal terms                         | Not reported                     | 9.8% (women: 11.5%; men: 8.6%)                     | Not investigated        |                     |
| Wang (2018)  | China     | BMI 24-27.9              | BMI ≥28               | Assessed during the interview | Longitudinal (six waves during 13 years) | Chinese Longitudinal Healthy Longevity Survey Target population: individuals aged ≥80 years in 631 counties and cities of 22 of China’s 31 provinces | n = 8026 Age: mean ± SD, 92.1 ± 7.4, ≥85 Females: 59.8% Morbidities: not reported Diabetes: not reported | 10.2% (men: 14.6%; women: 8.6%) | 4.4% (men: 6.9%; women: 2.6%) | Not investigated |
| Zhang (2008) | China     | BMI 25-29.99             | BMI ≥30               | Assessed during the interview | Cross-sectional  | Older rural Chinese Target population: individuals aged ≥60 years in the rural areas of Fuxin county, Liaoning province (China) | n = 591 Age: mean not specified, SD not specified, 80–99 Females: 51.3% Morbidities: not reported Diabetes: not reported | 8.1% (women: 10.2%; men: 5.9%) | 0.7% (women: 0.7%; men: 0.7%) | Not investigated |
Figure 2  Meta-analysis.

| Study               | %       | ES (95% CI) | Weight |
|---------------------|---------|-------------|--------|
| Abolfotouh (2001)   | 20.79   | 13.36, 30.01 | 5.40   |
| Andrade (2012)      | 15.83   | 10.19, 22.98 | 5.61   |
| Carter (2006)       | 8.76    | 4.61, 14.80 | 6.06   |
| Das (2005)          | 16.12   | 15.95, 16.30 | 6.50   |
| Gutierrez-Fisac (2004) | 25.80 | 22.42, 29.41 | 6.26   |
| Gutierrez-Fisac (2013) | 29.94 | 26.94, 33.08 | 6.32   |
| Hajek (2015)        | 13.71   | 12.19, 15.35 | 6.45   |
| Hajek (2020)        | 10.22   | 8.18, 12.55 | 6.41   |
| Jardim (2018)       | 71.52   | 67.19, 75.57 | 6.17   |
| Lisko (2015)        | 13.18   | 10.51, 16.24 | 6.34   |
| Perissinotto (2002) | 17.31   | 14.52, 20.40 | 6.33   |
| Rivas-Marino (2015) | 18.00   | 13.44, 23.33 | 6.06   |
| Samper-Torrenti (2012) | 10.80 | 9.17, 12.86 | 6.44   |
| Simonsson (2020)    | 9.78    | 8.25, 11.48 | 6.45   |
| Wang (2018)         | 4.36    | 3.92, 4.83 | 6.50   |
| Zhang (2008)        | 0.68    | 0.19, 1.73 | 6.49   |
| Overall (I² = 99.69%, p = 0.00) | 17.76 | 13.29, 22.23 | 100.00 |

Figure 3  Meta-analysis (sensitivity analysis).

| Study               | %       | ES (95% CI) | Weight |
|---------------------|---------|-------------|--------|
| Abolfotouh (2001)   | 20.79   | 13.36, 30.01 | 5.62   |
| Andrade (2012)      | 15.83   | 10.19, 22.98 | 6.11   |
| Carter (2006)       | 8.76    | 4.61, 14.80 | 6.42   |
| Das (2005)          | 16.12   | 15.95, 16.30 | 6.97   |
| Gutierrez-Fisac (2004) | 25.80 | 22.42, 29.41 | 6.67   |
| Gutierrez-Fisac (2013) | 29.94 | 26.94, 33.08 | 6.74   |
| Hajek (2015)        | 13.71   | 12.19, 15.35 | 6.91   |
| Hajek (2020)        | 10.22   | 8.18, 12.55 | 6.86   |
| Lisko (2015)        | 13.18   | 10.51, 16.24 | 6.77   |
| Perissinotto (2002) | 17.31   | 14.52, 20.40 | 6.76   |
| Rivas-Marino (2015) | 18.00   | 13.44, 23.33 | 6.42   |
| Samper-Torrenti (2012) | 10.80 | 9.17, 12.86 | 6.90   |
| Simonsson (2020)    | 9.78    | 8.25, 11.48 | 6.91   |
| Wang (2018)         | 4.36    | 3.92, 4.83 | 6.97   |
| Zhang (2008)        | 0.68    | 0.19, 1.73 | 6.96   |
| Overall (I² = 99.66%, p = 0.00) | 14.20 | 9.94, 18.46 | 100.00 |
The estimated overall prevalence of obesity was 17.8% (95% CI: 13.3%–22.2%; Figure 2), with significant heterogeneity between studies ($I^2 = 99.7\%$, $P = 0.001$). When removing the study conducted by Jardim et al.,$^{27}$ (prevalence of obesity was 71.5%), the overall prevalence of obesity was 14.2% (95% CI: 9.9%–18.5%, Figure 3, $I^2 = 99.7\%$, $P = 0.001$). In further sensitivity analysis, we restricted the meta-analysis to the 10 studies using BMI ≥30 (objectively assessed) to quantify obesity (see Figure SS1). According to this analysis, the overall prevalence of obesity was 15.6% (95% CI: 9.6%–21.7%, $I^2 = 99.6\%$, $P < 0.001$). In another sensitivity analysis, we restricted the meta-analysis to the studies using BMI ≥30 (self-rated) to quantify obesity (see Figure SS2). According to this analysis, the overall prevalence of obesity was 11.3% (95% CI: 8.7%–13.9%, $I^2 = 85.4\%$, $P < 0.001$).

In addition, our meta-regression showed that prevalence of obesity was dependent on the assessment of obesity and the country (Table 3). The overall proportion of variance explained by these factors was 77.3%. According to the visual examination of the funnel plot (Figure 4) and the Egger test ($P = 0.02$), asymmetry of data has been suggested (implying publication bias).

However, as recently noted by Barker et al., the assumption of positive results being more often published is not necessarily true for proportional studies, as there is no clear definition or consensus about what a positive result in a meta-analysis of proportion is.$^{34}$ In our view, more plausible explanations for the absence of publications are that the studies had a small sample size or general poor quality.

### Quality assessment/risk of bias assessment

The quality assessment/risk of bias assessment is displayed in Table 4. The scores ranged from 5 to 9 (average score was 7.5, SD: 1.2) indicating a rather high quality (and a small risk of bias). The most frequent limitations were that the response rate was not reported (eight studies) and that studies did not clearly describe or discuss the assumptions of the statistical analysis chosen (10 studies).

## Discussion

The aim of our work was to identify the prevalence of obesity and to identify correlates of it among the oldest old. Furthermore, based on a meta-regression, potential sources of heterogeneity were identified. The pooled prevalence of obesity was 17.8% (95% CI: 13.3%–22.2%), and there was considerable heterogeneity between studies. In addition, there was evidence of a publication bias. Meta-regressions showed that some of the heterogeneity was explained by the types of measures of obesity and country of the respective sample.

In comparing other work, there was considerable heterogeneity between studies. Markedly higher prevalence rates of obesity (i.e., ≥60%) were reported when the waist-to-hip ratio or waist circumference (instead of self-reported BMI) was measured to quantify obesity. Indeed, our sensitivity meta-analyses showed that a higher prevalence of obesity (15.6%) was identified when a cut-off of BMI ≥30 (objectively assessed) was used to quantify obesity compared with a prevalence of obesity of 11.3% when a cut-off of BMI ≥30 (self-rated) was used. Furthermore, and in accordance with previous studies examining younger age groups, we found particularly low prevalence rates of obesity in Asia (i.e., China), with 0.7%$^{32}$ and 4.4%.$^{33}$

In sum, the quality of the included studies was rather high. For example, most of the studies used data from samples with a high methodological quality. Common shortcomings include a missing description of the response rate and clarifying the model assumptions of the analytical approach.

Our current systematic review and meta-analysis revealed some gaps in our current knowledge. Our present work only identified very few studies analyzing the determinants of obesity among the oldest old. Thus, first, far more (longitudinal) studies are needed to identify the determinants of obesity in this age bracket. Second, more studies are required using valid tools such as professionally measured waist circumference or waist-to-hip ratio. Third, additional studies from areas neglected so far are required. Fourth, upcoming studies should clearly report the response rate as well as the underlying assumptions of the analytical approach used.

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### Table 3 Meta-regression analysis of factors affecting heterogeneity

| Variable | Coefficient (95% confidence interval) | $P$ value |
|----------|--------------------------------------|-----------|
| Assessment |                                       |           |
| Waist circumference (Reference: Body mass index) | 2.4 (0.1–4.7) | 0.04 |
| Waist-to-hip ratio | 4.7 (2.5–6.8) | <0.01 |
| Country |                                       |           |
| Barbados (Reference: China) | 1.4 (–0.9 to 3.7) | 0.17 |
| Brazil | 2.1 (–0.2 to 4.3) | 0.06 |
| Finland | 1.9 (–0.3 to 4.0) | 0.08 |
| Germany | 1.7 (–0.0 to 3.5) | 0.05 |
| Mexico | 2.2 (0.04 to 4.4) | 0.047 |
| Spain | 2.8 (1.0 to 4.6) | 0.01 |
| Sweden | 1.5 (–0.6 to 3.7) | 0.12 |
| USA | 1.9 (0.1 to 3.7) | 0.04 |
| Italy | 2.2 (0.03 to 4.3) | 0.048 |

Coefficients for Saudi Arabia and South Africa were omitted due to collinearity.

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Figure 4 Funnel plot.

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Meta-analysis and meta-regression

The estimated overall prevalence of obesity was 17.8% (95% CI: 13.3%–22.2%; Figure 2), with significant heterogeneity between studies ($I^2 = 99.7\%$, $P < 0.001$). When removing the study conducted by Jardim et al.$^{27}$ (prevalence of obesity was 71.5%), the overall prevalence of obesity was 14.2% (95% CI: 9.9%–18.5%, Figure 3, $I^2 = 99.7\%$, $P < 0.001$). In further sensitivity analysis, we restricted the meta-analysis to the 10 studies using BMI ≥30 (objectively assessed) to quantify obesity (see Figure SS1). According to this analysis, the overall prevalence of obesity was 15.6% (95% CI: 9.6%–21.7%, $I^2 = 99.6\%$, $P < 0.001$). In another sensitivity analysis, we restricted the meta-analysis to the studies using BMI ≥30 (self-rated) to quantify obesity (see Figure SS2). According to this analysis, the overall prevalence of obesity was 11.3% (95% CI: 8.7%–13.9%, $I^2 = 85.4\%$, $P < 0.001$).

In addition, our meta-regression showed that prevalence of obesity was dependent on the assessment of obesity and the country (Table 3). The overall proportion of variance explained by these factors was 77.3%. According to the visual examination of the funnel plot (Figure 4) and the Egger test ($P = 0.02$), asymmetry of data has been suggested (implying publication bias).

However, as recently noted by Barker et al., the assumption of positive results being more often published is not necessarily true for proportional studies, as there is no clear definition or consensus about what a positive result in a meta-analysis of proportion is.$^{34}$ In our view, more plausible explanations for the absence of publications are that the studies had a small sample size or general poor quality.

Quality assessment/risk of bias assessment

The quality assessment/risk of bias assessment is displayed in Table 4. The scores ranged from 5 to 9 (average score was 7.5, SD: 1.2) indicating a rather high quality (and a small risk of bias). The most frequent limitations were that the response rate was not reported (eight studies) and that studies did not clearly describe or discuss the assumptions of the statistical analysis chosen (10 studies).

Discussion

The aim of our work was to identify the prevalence of obesity and to identify correlates of it among the oldest old. Furthermore, based on a meta-regression, potential sources of heterogeneity were identified. The pooled prevalence of obesity was 17.8% (95% CI: 13.3%–22.2%), and there was considerable heterogeneity between studies. In addition, there was evidence of a publication bias. Meta-regressions showed that some of the heterogeneity was explained by the types of measures of obesity and country of the respective sample.

In comparing other work, there was considerable heterogeneity between studies. Markedly higher prevalence rates of obesity (i.e., ≥60%) were reported when the waist-to-hip ratio or waist circumference (instead of self-reported BMI) was measured to quantify obesity. Indeed, our sensitivity meta-analyses showed that a higher prevalence of obesity (15.6%) was identified when a cut-off of BMI ≥30 (objectively assessed) was used to quantify obesity compared with a prevalence of obesity of 11.3% when a cut-off of BMI ≥30 (self-rated) was used. Furthermore, and in accordance with previous studies examining younger age groups, we found particularly low prevalence rates of obesity in Asia (i.e., China), with 0.7%$^{32}$ and 4.4%.$^{33}$

In sum, the quality of the included studies was rather high. For example, most of the studies used data from samples with a high methodological quality. Common shortcomings include a missing description of the response rate and clarifying the model assumptions of the analytical approach.

Our current systematic review and meta-analysis revealed some gaps in our current knowledge. Our present work only identified very few studies analyzing the determinants of obesity among the oldest old. Thus, first, far more (longitudinal) studies are needed to identify the determinants of obesity in this age bracket. Second, more studies are required using valid tools such as professionally measured waist circumference or waist-to-hip ratio. Third, additional studies from areas neglected so far are required. Fourth, upcoming studies should clearly report the response rate as well as the underlying assumptions of the analytical approach used.
Some strengths and limitations of our current work are worth noting. To our knowledge, this is the first systematic review synthesizing the prevalence and correlates of obesity among individuals aged ≥ 80 years. Furthermore, the key steps were performed independently by two reviewers. Moreover, an additional hand search was conducted. Beyond that, a meta-analysis was performed. Compared with individual studies, such a meta-analysis can provide more power to estimate accurate prevalence rates of obesity (by including a large population based on several countries). In addition, a meta-regression was performed, which helped to identify the impact of moderating variables. As we exclusively included studies published in peer-reviewed literature, suitable studies may be excluded (e.g., gray literature). However, this ensures a certain quality of the included studies.

In conclusion, obesity remains a key challenge among the oldest old. Future research in this age bracket is urgently required in regions mostly neglected thus far (e.g., South America, Africa or Asia). Moreover, studies based on longitudinal data are required to clarify the determinants of obesity among the oldest old. Furthermore, studies based on objectively recorded obesity (e.g., waist circumference) are also required.

It should also be acknowledged that the prevalence of obesity can drop among the oldest old.6 Thus, the risk of sarcopenia caused by unintentional weight loss is quite high. Future research in this area is needed to get a more comprehensive picture of obesity among the oldest old.

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Disclosure statement

The authors declare no conflict of interest.

Author contributions

The study concept was developed by AH, BK and H-HK. The manuscript was drafted by AH and critically revised by BK and H-HK. The search strategy was developed by AH and H-HK. Study selection, data extraction and quality assessment were performed by AH and BK, with H-HK as a third party in case of disagreements. Meta-analysis and meta-regressions were performed by AH, with critical assessment by BK and H-HK. All authors have approved the final version of the manuscript.

Data availability statement

Not applicable

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher’s website:

Figure S1 Meta-analysis for studies with BMI ≥30 (objectively assessed) to quantify obesity

Figure S2 Meta-analysis for studies with BMI ≥30 (self-rated) to quantify obesity

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