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REVIEW

Screening mammography use in older women according to health status: a systematic review and meta-analysis

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Background: The extent to which screening mammography (SM) recommendations in older women incorporate life expectancy factors is not well established.

Objective: The objective of this review was to evaluate evidence on SM utilization in older women by life expectancy factors.

Data sources: We searched Medline, Embase and Web of Science from January 1991 to March 2016.

Study selection: We included studies examining SM utilization in women ages ≥65 years that measured life expectancy using comorbidity, functional limitations or health or prognostic status.

Data extraction and synthesis: ORs and 95% CIs were extracted and grouped by life expectancy category. Findings were aggregated into pooled ORs and 95% CIs and meta-analyzed by life expectancy category.

Main outcomes and measures: The primary outcome was SM utilization within the last 5 years. Life expectancy factors included number of comorbidities, Charlson Comorbidity Index (CCI), activities of daily living, instrumental activities of daily living, self-reported health status and 5-year prognostic indices.

Results: Of 2,606 potential titles, we identified 25 meeting the inclusion criteria (comorbidity: eight studies, functional status: 11 studies and health/prognostic status: 13 studies). Women with higher CCI scores had decreased SM utilization (pooled OR: 0.75, 95% CI: 0.67–0.85), but increased absolute number of comorbidities were weakly associated with increased SM utilization (pooled OR: 1.17, 95% CI: 1.00–1.36). Women with more functional limitations had lower SM use odds than women with no limitations (pooled OR: 0.72, 95% CI: 0.62–0.83). Screening utilization odds were lower among women with poor vs excellent health (pooled OR: 0.85, 95% CI: 0.74–0.96).

Conclusion: Greater CCI score, functional limitations and lower perceived health were associated with decreased SM use, whereas higher absolute number of comorbidities was associated with increased SM use. SM guidelines should consider these factors to improve assessments of potential benefits and harms in older women.

Keywords: screening mammography, comorbidity, functional limitations, health status, meta-analysis

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Introduction

More than 50% of new invasive breast cancer cases diagnosed each year in the US occur among older women – women ages 65 years or older.[1] The increasing life expectancy of women in the US and attendant rise in the absolute number of breast cancer cases in older women will likely lead to an increasing absolute number of

mammograms performed in the ≥65 age group.[2] In 2010, the United States Centers for Disease Control and Prevention estimated that older women reported the highest prevalence of mammography use within the past 2 years.[3] However, the US Preventive Services Task Force (USPSTF) currently does not recommend screening mammography (SM) in women ages 75 or older due to insufficient evidence.[4] Although older women have a higher risk of breast cancer and lower risk of false-positive mammography results than younger women, their shorter life expectancy decreases the potential benefits of screening.[4–6]

A recent review concluded that screening for breast cancer is most appropriate for women with a life expectancy of at least 10 years.[7] Because the full benefit of screening is only realized with reduction in mortality, numerous studies have accounted for life expectancy factors to better identify the margin of benefit a woman might expect from undergoing screening.[3,7–10] To date, comorbidity burden, functional status and self-reported heath are the strongest predictors of life expectancy.[11–14] However, the current guidelines for SM do not account for life expectancy factors other than chronological age.[4,15]

In light of the current demographic, epidemiologic and policy environment, it is important to understand the extent to which the current practice of SM is targeted to healthy older women and avoided in older women with limited life expectancy. In this review, we reported the results of a systematic review and meta-analysis of the literature of studies assessing mammography screening utilization rates of older women in relation to age, functional limitations and health status including but not limited to comorbidity. The main objective of this review was to outline the current practices that exist for SM utilization in older women and the association between screening and life expectancy factors in order to help guide future SM guidelines.

Methods

This systematic review and meta-analysis has a published protocol[16] and is registered with PROSPERO with the registration number CRD42016032661. A PRISMA checklist is included in Table S1. The study is covered under an institutional review board (IRB) with exempt status submitted and approved by the IRB of University of California, San Francisco.

Search strategy and selection criteria

We performed a systematic search of the literature using Medline (using PubMed interface), Embase and Web of Science (January 1, 1991–March 1, 2016) to identify relevant studies. "Breast neoplasms" was combined with the permutations, variations and abbreviations of the relevant Medical Subject Headings (MeSH) keywords and non-MeSH key terms for mammography, age, health status and comorbidity, including cardiovascular diseases, comorbidity, cognition disorders, diabetes mellitus, functional limitation, health status, myocardial infarction and stroke. Complete search strategies are provided in the "Supplementary materials" section.

The broad criteria for this review allowed for the evaluation of multiple study designs published in English. The inclusion criteria were as follows: i) women aged 65 years or older in the US, ii) assessment of women's comorbidity (either as a specific condition or as a summary score), functional impairments and/or health status and iii) an outcome measure that addresses recent SM utilization. Additional studies were obtained through citations of review articles or contacting breast cancer screening experts regarding any unpublished articles that may be suitable for inclusion in the systematic review. Case reports were excluded. Data were extracted from the full-text article.

Most, if not all, of the target population was Medicare beneficiaries, with SM covered based on policy changes implemented in 1991.[17] At that time, Medicare Part B medical insurance, for which most women become eligible when they turn 65 years, covered the full cost of annual mammography for all women aged 40 or older.[2,4] To account for this Medicare policy change, we excluded studies evaluating screening utilization prior to 1991.[17] Women eligible for Medicare ages 65–74 years are near the upper limit of the USPSTF primary SM guidelines (age 74 years), and USPSTF guidelines note that data are currently inconclusive to provide screening recommendations for women ages 75 or older.[18]

Quality assessment and data extraction

To evaluate the quality of included studies, we used the Newcastle–Ottawa Scale (NOS) and Cochrane Collaboration Risk of Bias (CCRB) tool[19,20] to evaluate observational studies and clinical trials, respectively. The NOS measures the methodological quality of observational studies, giving predefined criteria, some of which have to be further specified based on topic. We specified these criteria in a consensus meeting with the authors (Tables S2A and S2B) before assessing the studies.

Studies were assessed for quality of selection (representativeness, selection of controls, ascertainment of exposure), comparability (adjustment for confounding) and outcome or exposure (assessment of outcome/exposure, length and adequacy of follow-up) independently by two authors (JD and TA). Measures of age, socioeconomic status (such as

race, education, income), health insurance and number of physician visits were identified as important confounders. Cohort and case–control studies could earn a maximum of 9 points, and cross-sectional and randomized clinical trials could earn a maximum of 10 points. Studies with scores of 6–8 points were considered to be of moderate-to-good study quality, and scores of ≥9 were deemed excellent. All studies were summarized irrespective of quality score.

A data extraction form was used to collect study characteristics, including type of study, number of participants, length of follow-up, exposure(s), outcome(s) and quality assessment. Exposures logged in this form were life expectancy factors, including comorbidity scales or specific diseases considered, functional limitation scales used and measures of health status. The primary outcome was SM utilization, defined as SM occurring within the last 1–5 years. We extracted ORs and corresponding 95% CIs from most studies, with some studies providing risk ratios or proportions of utilization. Quantitative results were extracted from text and tables, choosing preferably those adjusted for important confounders. Two authors (JD and TA) independently performed study quality assessment and data extraction. Discrepancies were discussed and resolved by the review team.

Qualitative synthesis and meta-analysis

We conducted a qualitative synthesis to describe the findings of included studies, explore associations of interest and examine the quality of the studies and robustness of the systematic review. Study findings were separated into the four exposure categories: comorbidity (measured using an absolute count, Charlson Comorbidity Index [CCI] and individual disease conditions), functional limitations (activities of daily living [ADLs], instrumental activities of daily living [IADLs]), health status and prognostic status. For each exposure, we aggregated study findings to perform meta-analyses assessing the overall magnitude of the association with recent SM utilization. Pooled ORs and corresponding 95% CIs were reported. Given the variation in measurement of exposures, we stratified our findings to address study heterogeneity. Heterogeneity was measured using I^2 values and Cochran's Q statistic. Pooled results were analyzed using random–effects models to control for heterogeneity.

We also performed sensitivity analyses to examine potential publication bias including jackknife analyses[21] and reported these findings in addition to the primary study findings and subgroup analyses.[22] We also performed meta-regression to understand how study traits contributed to heterogeneity of pooled effect estimates.[23,24] The meta-analysis results are

graphically displayed using forest plots.[22] All analyses were performed using STATA 13 (StataCorp LP, College Station, TX, USA).

Results

Study characteristics, including number of subjects, age range, years of data accrual, study design, assessment of outcome and assessment of exposure, are summarized in Table 1. We tabulated the full Newcastle–Ottawa findings of individual studies for descriptive purposes (Tables S2A and S2B). Full descriptive results by exposure type are found in Tables S3–S5.

Literature search

We identified 2,606 potentially relevant titles through PubMed, Embase and Web of Science (refer PRISMA flowchart in Figure 1). After excluding titles that did not report i) SM utilization and ii) comorbidity, health status and/or functional status and iii) original research that did not include (d) populations from the US, (e) SM utilization prior to 1991 and (f) results for women <65 years old, we identified 142 studies published between January 1, 1991, and March 31, 2016. After review of abstracts, we excluded 95 articles that did not meet the inclusion criteria. After reviewing 47 full-text articles,[17,25–70] 25 studies were included in the review, published between 1996 and 2016: there were ten cohort studies[29,31,32,39,40,42,56,63,64,68] and 15 cross-sectional studies.[17,27,33,36,37,44,46,51,52,59–62,65,69] No case–control studies were found, which is likely due to the highly common outcome of screening utilization. Characteristics of included studies are given in Table 1. Since three studies did not include ORs, only 22 of the 25 studies were included in the meta-analysis.

Quality assessment

All of the studies used a combination of surveys, Medicare insurance claims data and/or medical records to examine associations between the predictor(s) – comorbidity, functional status or health status – and the outcome, mammography utilization. Based on the quality assessment using the NOS (no clinical trials were included),[19] all studies were found to be of moderate to excellent quality, despite several studies using self-reported outcome assessment.

Estimates of the effect of the comorbidity on utilization of SM

A full list of comorbidities measured in each study can be found in Table S3A–C. Eight studies measured the association of comorbidity with SM utilization, with four studies using an unweighted number of comorbid

Table 1 Characteristics of studies identified in literature search

Source	Number of subjects	Age range, years	Accrual years	Study design	Assessment of comorbidity/functional status/health status	Assessment of mammography utilization	Outcome(s)
Ives et al[42]	2,175	65–79	1991–1992	Cohort (prospective)	Medicare claims	Medicare claims	≥1 screening in 2 years
Kiefe et al[44]	1,764	≥50	1995	Cross-sectional	Medical records review	Medical records review	≥1 screening within 2 years
Blustein et al[29]	2,352	≥75	1991–1992	Cohort (retrospective)	Self-reported	Medicare claims	≥1 screening within 2 years
Wright et al[69]	526	≥70	1992–1993	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Barr et al[27]	309	≥65	2000	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Scinto et al[63]	844	≥65	1990–1995	Cohort (prospective)	Self-reported, Medicare claims	Medicare claims	≥1 screening within 5 years
Caplan[33]	–	50–69 ≥70	1991–1992 1997–1998	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Heflin et al[37]	2,225	≥65	1992	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Harrison et al[36]	10,000	≥65	1993–1997	Cross-sectional	Medicare claims	Medicare claims	≥1 screening within 5 years
Schootman and Jeffe[62]	4,477	≥40	1996	Cross-sectional	Self-reported	Self-reported	≥1 screening within 1 year
Schonberg et al[59]	882	≥80	2000	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Walter et al[17]	3,988	≥70	2000–2001	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Bynum et al[31]	722,310	≥65	2000–2001	Cohort (retrospective)	Medicare claims	Medicare claims	≥1 screening within 2 years
Holt et al[39]	5,461	≥65	1998–2002	Cohort (retrospective)	Self-reported	Self-reported, Medicare claims	≥1 screening within 1 year
Thorpe et al[65]	3,655	≥65	1999–2001	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Mcbean and Yu[51]	99,438	≥65	1997–1998	Cross-sectional	Medicare claims	Medicare claims	≥1 screening within 2 years
Schonberg et al[61]	4,683	≥65	2005	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Williams et al[68]	4,222	≥65	2002–2004	Cohort (retrospective)	Validated measures	Self-reported	≥1 screening within 2 years
Mehta et al[52]	4,312	≥70	2002	Cross-sectional	Interview	Medicare claims	≥1 screening within 2 years
Caban et al[32]	4,610	≥65	2004–2005	Cohort (retrospective)	Self-reported	Self-reported	≥1 screening within 1 year
Reyes-Ortiz et al[56]	1,272	≥75	2004–2005	Cohort (retrospective)	Self-reported	Self-reported	≥1 screening within 2 years
Koya et al[46]	4,836	≥65	2002	Cross-sectional	Self-reported	Self-reported	≥1 screening within 1 year
Tan et al[64]	716,279	≥75	2006–2007	Cohort (retrospective)	Medical record, claims	Medicare claims	≥1 screening within 2 years
Schonberg et al[60]	2,266	≥75	2008, 2010	Cross-sectional	Self-reported	Self-reported	≥1 screening within 2 years
Hubbard et al[40]	49,775	≤65	2005–2010	Cohort (retrospective)	Medicare claims	Medicare claims	≥1 screening within 2 years

conditions' measure[32,37,59,71] and four studies using the CCI (Figure 2).[44,51,64,69] The pooled result showed no significant association between comorbidity and SM utilization (OR: 0.94, 95% CI: 0.80–1.10). However, when stratified by

comorbidity measurement, increased comorbidity measured using CCI was associated with decreased SM utilization (OR: 0.75, 95% CI: 0.67–0.85), while increased absolute number of comorbidities was weakly associated with
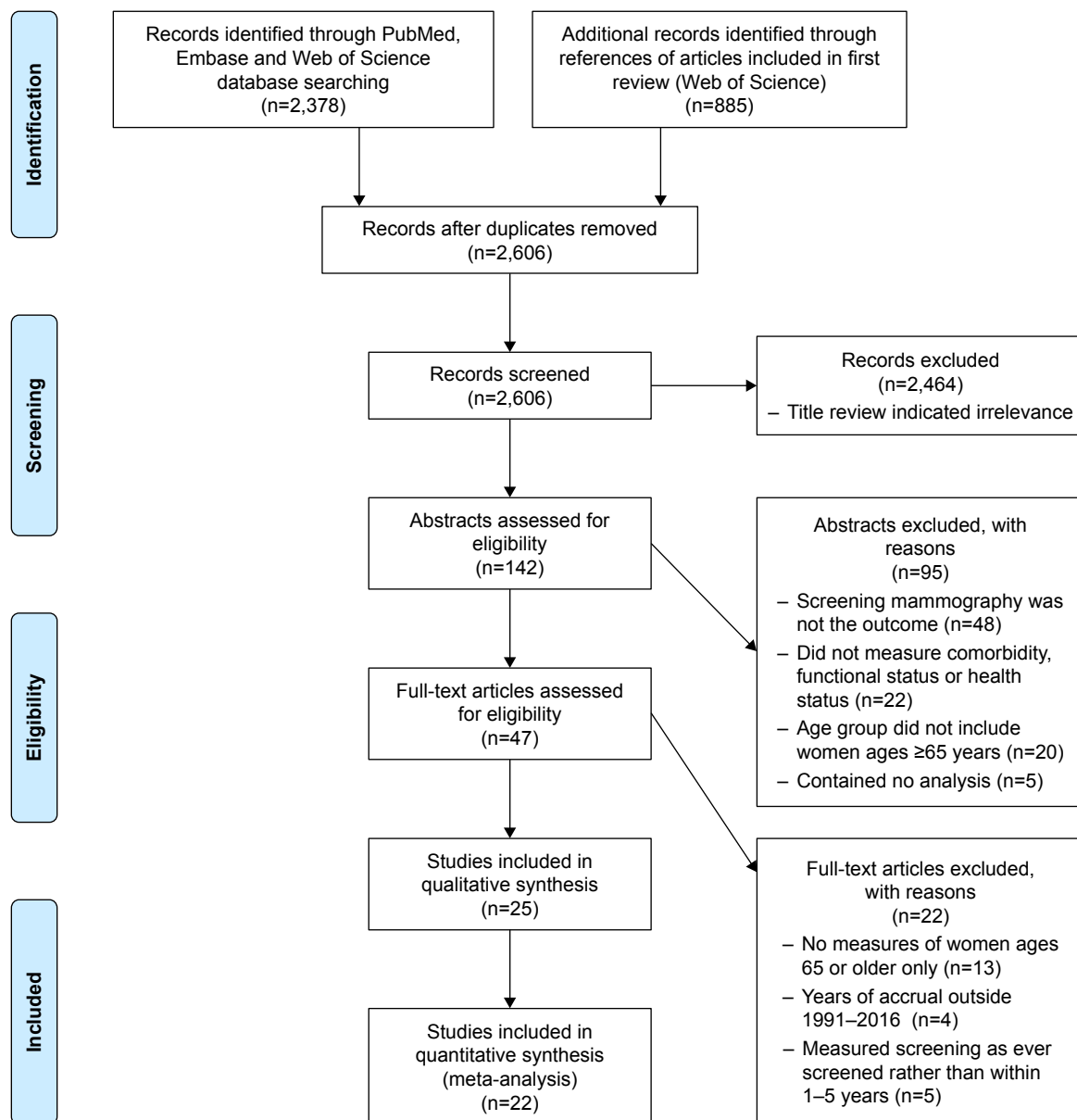
Figure 1 PRISMA flowchart of studies included.
Note: Copyright: © 2009 Moher et al. Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med* 6(7):e1000097. doi: 10.1371/journal.pmed1000097.

increased SM utilization (OR: 1.17, 95% CI: 1.00–1.36). Meta-regression results indicated that studies measuring comorbidity using CCI showed significantly lower SM utilization (pooled OR: 0.64, 95% CI: 0.50–0.82). Jackknife analyses showed that removal of McBean et al's study and the 2004 Schonberg et al's study, the two studies with the most extreme results, from CCI and absolute number of comorbidities groups, respectively, led to insignificant decreases in study heterogeneity and no marked change in the summary estimates.

In addition, nine studies measured individual comorbid conditions and their association with SM utilization

(Table S3C).[29,32,38,42,44,52,56,60,65] Physical conditions measured included hypertension, diabetes, lung disease, cancer, arthritis, myocardial infarction, stroke, heart disease and hip fracture. Mental conditions measured included cognitive impairment, Alzheimer's disease, depression and psychological distress. In pooled analyses, individual comorbid conditions were not significantly associated with SM utilization (OR: 0.97, 95% CI: 0.89–1.06; Figure S1). When stratified by type of condition, neither physical conditions (OR: 1.03, 95% CI: 0.93–1.14) nor mental conditions (OR: 0.85, 95% CI: 0.72–1.01) were significantly associated with SM utilization.
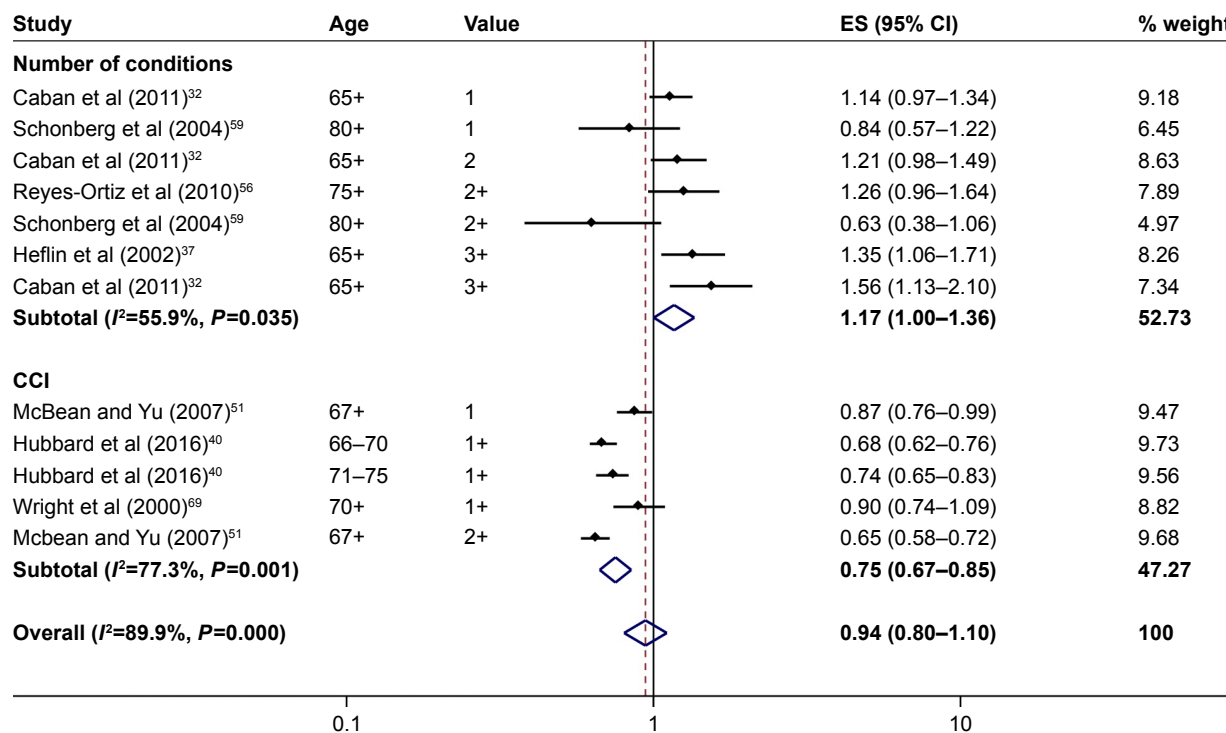
Study	Age	Value	ES (95% CI)	% weight
Number of conditions				
Caban et al (2011)[32]	65+	1	1.14 (0.97–1.34)	9.18
Schonberg et al (2004)[59]	80+	1	0.84 (0.57–1.22)	6.45
Caban et al (2011)[32]	65+	2	1.21 (0.98–1.49)	8.63
Reyes-Ortiz et al (2010)[56]	75+	2+	1.26 (0.96–1.64)	7.89
Schonberg et al (2004)[59]	80+	2+	0.63 (0.38–1.06)	4.97
Heflin et al (2002)[37]	65+	3+	1.35 (1.06–1.71)	8.26
Caban et al (2011)[32]	65+	3+	1.56 (1.13–2.10)	7.34
Subtotal (*I*²=55.9%, *P*=0.035)			**1.17 (1.00–1.36)**	**52.73**
CCI				
McBean and Yu (2007)[51]	67+	1	0.87 (0.76–0.99)	9.47
Hubbard et al (2016)[40]	66–70	1+	0.68 (0.62–0.76)	9.73
Hubbard et al (2016)[40]	71–75	1+	0.74 (0.65–0.83)	9.56
Wright et al (2000)[69]	70+	1+	0.90 (0.74–1.09)	8.82
Mcbean and Yu (2007)[51]	67+	2+	0.65 (0.58–0.72)	9.68
Subtotal (*I*²=77.3%, *P*=0.001)			**0.75 (0.67–0.85)**	**47.27**
Overall (*I*²=89.9%, *P*=0.000)			**0.94 (0.80–1.10)**	**100**

Figure 2 Forest plot of effect of comorbidity on SM utilization by study and measure type.
Note: Weights are from random-effects analysis.
Abbreviations: SM, screening mammography; ES, effect size; CCI, Charlson Comorbidity Index.

Estimates of the effect of functional status on utilization of SM

Ten studies measured the effect of functional limitations on SM utilization (Figure 3), with three studies measuring functional limitations in multiple ways. Five studies measured ADLs,[29,33,42,62,63] five studies measured IADLs[32,37,42,56,59] and three studies used a scale incorporating both IADLs and ADLs.[32,59,69] Overall, functional limitations were associated with decreased SM utilization (pooled OR: 0.72, 95% CI: 0.62–0.83). Of the five studies measuring ADLs, three calculated ORs, showing a significant pooled effect of higher number of ADLs on decreased SM utilization (pooled OR: 0.55, 95% CI: 0.35–0.85) in Figure 3. Two studies reported chi-square results comparing SM utilization by ADL status (yes/no), with both studies showing a significant difference in screening utilization among women experiencing ADL limitations compared to women with no ADL limitations.[33,63]

Among the four studies measuring IADLs, the pooled result showed that higher numbers of IADLs were associated with decreased SM utilization (pooled OR: 0.79, 95% CI: 0.64–0.98). Three studies measuring IADL limitations in conjunction with ADL limitations found inverse associations.[32,59,69] Pooled results indicated that ADL limitations or IADL dependency led to decreased SM utilization (pooled OR: 0.72, 95% CI: 0.57–0.91).

In jackknife analyses, removal of Schootman et al long-term ADLs and long-term IADLs and Caban et al findings led to study heterogeneity in ADL (*P*=0.674), IADL (*P*=0.106) and ADL/IADL (*P*=0.683) groups, respectively, being no longer statistically significant. However, the pooled estimate still had significant study heterogeneity and did not change appreciably despite removal of these studies (*P*=0.003). Meta-regression analyses found no significant predictors of study heterogeneity.

Estimates of the effect of health status, life expectancy or prognosis on utilization of SM

Nine studies measured the association of health status on screening utilization, with eight studies measuring perceived general health[29,32,39,46,60,61,69] and two studies measuring health status using the Short Form-12 (SF-12) survey (Table S5).[17,27] The pooled result shown in Figure 4 demonstrated that lower perceived health was associated with lower SM utilization (pooled OR: 0.80, 95% CI: 0.69–0.93). Jackknife analyses showed no significant decrease in study heterogeneity, and meta-regression analyses did not find significant predictors of study heterogeneity.

Five studies measured prognostic index or life expectancy measures against utilization of SM (Table S4).[31,46,60,63,68]

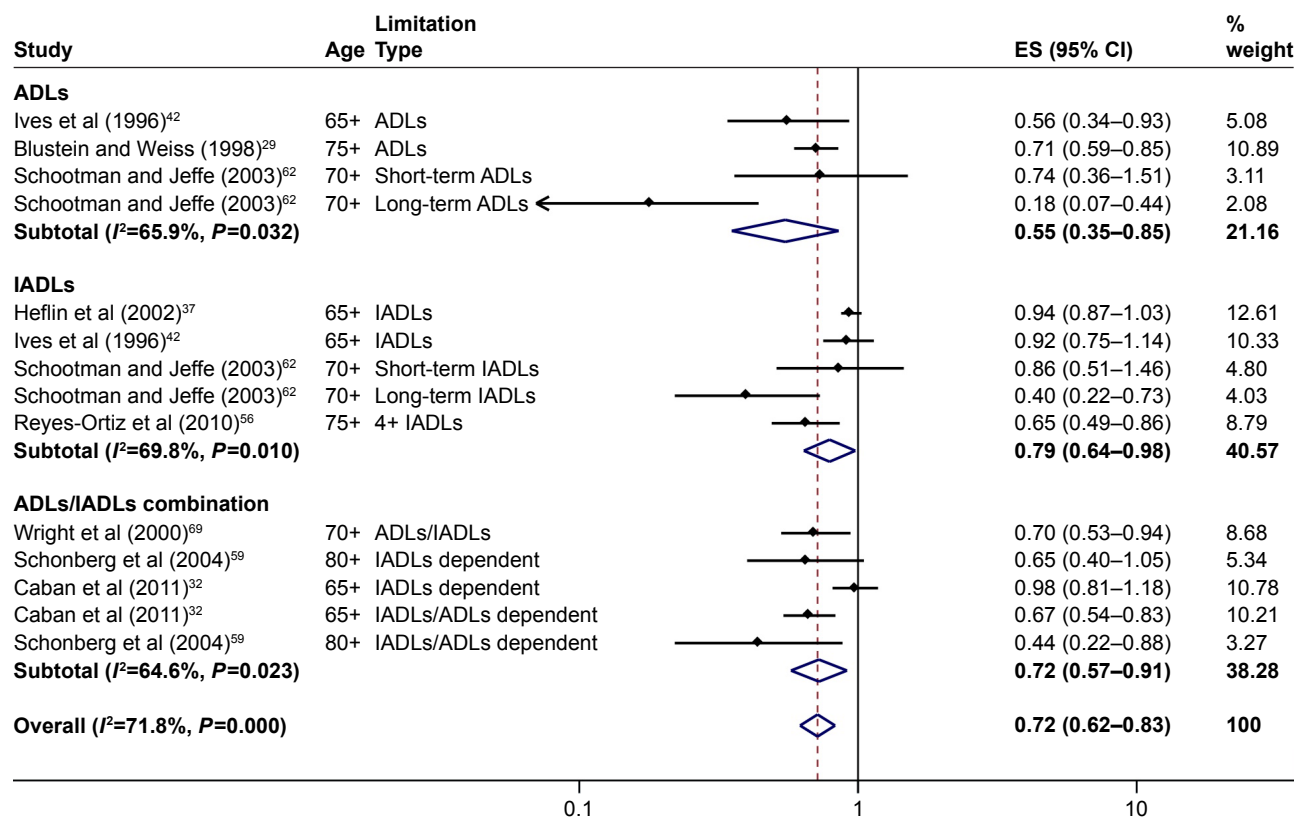| Study	Age	Limitation Type	ES (95% CI)	% weight
ADLs				
Ives et al (1996)[42]	65+	ADLs	0.56 (0.34–0.93)	5.08
Blustein and Weiss (1998)[29]	75+	ADLs	0.71 (0.59–0.85)	10.89
Schootman and Jeffe (2003)[62]	70+	Short-term ADLs	0.74 (0.36–1.51)	3.11
Schootman and Jeffe (2003)[62]	70+	Long-term ADLs	0.18 (0.07–0.44)	2.08
Subtotal (*I²*=65.9%, *P*=0.032)			**0.55 (0.35–0.85)**	**21.16**
IADLs				
Heflin et al (2002)[37]	65+	IADLs	0.94 (0.87–1.03)	12.61
Ives et al (1996)[42]	65+	IADLs	0.92 (0.75–1.14)	10.33
Schootman and Jeffe (2003)[62]	70+	Short-term IADLs	0.86 (0.51–1.46)	4.80
Schootman and Jeffe (2003)[62]	70+	Long-term IADLs	0.40 (0.22–0.73)	4.03
Reyes-Ortiz et al (2010)[56]	75+	4+ IADLs	0.65 (0.49–0.86)	8.79
Subtotal (*I²*=69.8%, *P*=0.010)			**0.79 (0.64–0.98)**	**40.57**
ADLs/IADLs combination				
Wright et al (2000)[69]	70+	ADLs/IADLs	0.70 (0.53–0.94)	8.68
Schonberg et al (2004)[59]	80+	IADLs dependent	0.65 (0.40–1.05)	5.34
Caban et al (2011)[32]	65+	IADLs dependent	0.98 (0.81–1.18)	10.78
Caban et al (2011)[32]	65+	IADLs/ADLs dependent	0.67 (0.54–0.83)	10.21
Schonberg et al (2004)[59]	80+	IADLs/ADLs dependent	0.44 (0.22–0.88)	3.27
Subtotal (*I²*=64.6%, *P*=0.023)			**0.72 (0.57–0.91)**	**38.28**
Overall (*I²*=71.8%, *P*=0.000)			**0.72 (0.62–0.83)**	**100**

Figure 3 Forest plot of effect of functional limitations on SM utilization by study and measure type.
Note: Weights are from random-effects analysis.
Abbreviations: SM, screening mammography; ES, effect size; ADLs, activities of daily living; IADLs, instrumental activities of daily living.

The pooled effect of the three studies shown in Figure 4 measuring life expectancy using regression showed a nonsignificant inverse association between life expectancy index score and SM utilization (pooled OR: 0.73, 95% CI: 0.53–1.00).

Discussion

Meta-analysis of the studies addressing life expectancy factors and SM utilization revealed that older American women with higher numbers of functional limitations, higher CCI score and lower perceived health are less likely to undergo routine SM. Prognostic indices, absolute number of comorbidities and specific disease conditions were not significantly associated with SM utilization. These observational studies provide a means to understanding how different measures of life expectancy affect SM utilization.

While increased CCI score was associated with a decrease in SM, the absolute number of comorbidities showed a conflicting, weak positive association with SM utilization. It is possible that having more comorbid conditions increased women's contact with their health care provider, leading to a greater likelihood of using preventive care.[32,37] Conversely, one study measuring CCI showed no indication that physicians had advocated for cancer screening in the population

of individuals with diabetes.[51] Other studies noted that there is little time in the primary care clinic to estimate each individual's candidacy for screening, especially older patients with multiple medical problems, which might lead physicians to screen everyone to avoid confusion with recommendations or medicolegal consequences.[17,37,59] The conflicting results show that more studies need to be conducted to determine who should receive SM and how comorbidity burden should factor into a provider's assessment of who is eligible for SM.

Studies consistently indicated that greater numbers of functional limitations decreased SM utilization.[29,32,37,42,56,59,62,69] Studies using scales incorporating ADL limitations (ie, needing help with activities such as showering, dressing, getting in and out of bed/chairs, etc.) showed particular pronounced effects,[29,42,62] which one study suggested could indicate that access factors, such as fewer resources and social supports to facilitate travel to mammography facilities, may lead to lower utilization rates.[29] It is therefore possible that women with ADL limitations may need more support to receive mammography utilization. Another study indicated that the strong association found between ADL and IADL (ie, needing help with everyday household chores, shopping and overall getting
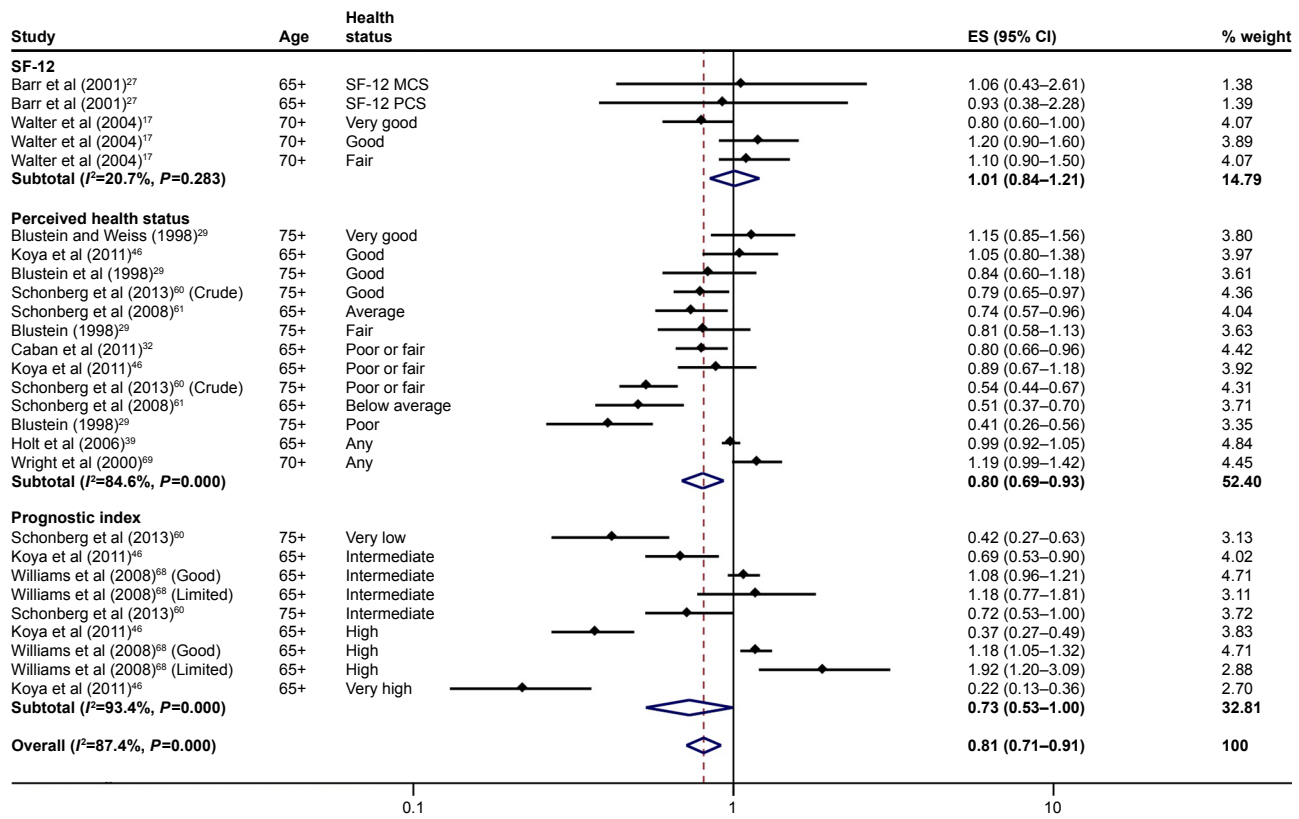
Study	Age	Health status	ES (95% CI)	% weight
SF-12				
Barr et al (2001)[27]	65+	SF-12 MCS	1.06 (0.43–2.61)	1.38
Barr et al (2001)[27]	65+	SF-12 PCS	0.93 (0.38–2.28)	1.39
Walter et al (2004)[17]	70+	Very good	0.80 (0.60–1.00)	4.07
Walter et al (2004)[17]	70+	Good	1.20 (0.90–1.60)	3.89
Walter et al (2004)[17]	70+	Fair	1.10 (0.90–1.50)	4.07
Subtotal (I^2=20.7%, P=0.283)			1.01 (0.84–1.21)	14.79
Perceived health status				
Blustein and Weiss (1998)[29]	75+	Very good	1.15 (0.85–1.56)	3.80
Koya et al (2011)[46]	65+	Good	1.05 (0.80–1.38)	3.97
Blustein et al (1998)[29]	75+	Good	0.84 (0.60–1.18)	3.61
Schonberg et al (2013)[60] (Crude)	75+	Good	0.79 (0.65–0.97)	4.36
Schonberg et al (2008)[61]	65+	Average	0.74 (0.57–0.96)	4.04
Blustein (1998)[29]	75+	Fair	0.81 (0.58–1.13)	3.63
Caban et al (2011)[32]	65+	Poor or fair	0.80 (0.66–0.96)	4.42
Koya et al (2011)[46]	65+	Poor or fair	0.89 (0.67–1.18)	3.92
Schonberg et al (2013)[60] (Crude)	75+	Poor or fair	0.54 (0.44–0.67)	4.31
Schonberg et al (2008)[61]	65+	Below average	0.51 (0.37–0.70)	3.71
Blustein (1998)[29]	75+	Poor	0.41 (0.26–0.56)	3.35
Holt et al (2006)[39]	65+	Any	0.99 (0.92–1.05)	4.84
Wright et al (2000)[69]	70+	Any	1.19 (0.99–1.42)	4.45
Subtotal (I^2=84.6%, P=0.000)			0.80 (0.69–0.93)	52.40
Prognostic index				
Schonberg et al (2013)[60]	75+	Very low	0.42 (0.27–0.63)	3.13
Koya et al (2011)[46]	65+	Intermediate	0.69 (0.53–0.90)	4.02
Williams et al (2008)[68] (Good)	65+	Intermediate	1.08 (0.96–1.21)	4.71
Williams et al (2008)[68] (Limited)	65+	Intermediate	1.18 (0.77–1.81)	3.11
Schonberg et al (2013)[60]	75+	Intermediate	0.72 (0.53–1.00)	3.72
Koya et al (2011)[46]	65+	High	0.37 (0.27–0.49)	3.83
Williams et al (2008)[68] (Good)	65+	High	1.18 (1.05–1.32)	4.71
Williams et al (2008)[68] (Limited)	65+	High	1.92 (1.20–3.09)	2.88
Koya et al (2011)[46]	65+	Very high	0.22 (0.13–0.36)	2.70
Subtotal (I^2=93.4%, P=0.000)			0.73 (0.53–1.00)	32.81
Overall (I^2=87.4%, P=0.000)			0.81 (0.71–0.91)	100

0.1   1   10

Figure 4 Forest plot of effect of health status and prognostic score on SM utilization by study and measure type.
Note: Weights are from random-effects analysis.
Abbreviations: SM, screening mammography; ES, effect size; SF-12, Short Form-12; PCS, physical component summary score; MCS, mental component summary score.

around) dependence and mammography screening might be indicative of providers considering life expectancy when referring women to SM.[69] However, the fact that the finding did not occur across other measured preventive screenings makes this theory questionable and requires further investigation.

Poorer self-rated health was also found to be associated with decreased screening utilization, despite some conflicting findings. In one study, pain and discomfort, a potential indicator of poorer health, was a common reason why women might decide not to screen.[32] Conversely, a study done by Walter et al showed that older women with poorer health status, measured using the Medical Outcomes Study 12-item Short Form Physical Summary Scale (SF-12), did not avoid screening. Although Walter et al did not have mortality follow-up information on the sample, there is strong evidence that life expectancy is limited in women with worst health status measured by the SF-12.[17]

Pooled analysis of prognostic index scores found no significant association with SM utilization, even though some individual studies had significant findings. Koya et al found mammography use significantly associated with 4-year mortality risk and not age alone, attributing their finding to including age, comorbidity and functional status in their measurement

of mortality risk.[46] They hypothesized that the association means clinicians are skilled at identifying predictors of life expectancy in older individuals.[46] However, findings from other included studies seem to contradict this theory.[60,68]

Findings from these studies show that functional limitations and comorbidities when measured using the CCI are associated with decreased SM utilization, while absolute number of comorbidities was weakly associated with increased screening utilization. When discussing SM with older women, providers should ask questions or consult medical records to learn more about these life expectancy factors to better assess the potential benefit older women might receive from undergoing SM. Decision aids have been developed in breast cancer screening to measure key comorbidity and functional measures, though none have been widely implemented.[72,73] While more research is necessary to further understand the importance of life expectancy in measuring harms and benefits of SM, these findings indicate that providers may be weighing more than just age when discussing continuing SM with an older woman. Further assessment of current clinical recommendations and determination of eligibility for SM could lead to more accurately tailored screening referrals.

Strengths and limitations of studies and analysis

Our systematic review/meta-analysis had key strengths, such as incorporating searches from three major research publication databases ensuring full capture of the literature on life expectancy factors and SM utilization in older women. The use of quality assessment tools allowed us to quantitatively rate the quality of the studies included in our analyses. In addition, the use of stratification to clearly review the life expectancy factors ensured a limited degree of study heterogeneity when measuring our various exposures and SM utilization. Our study also was able to leverage meta-regression in sensitivity analyses to learn more about how different study features contributed to heterogeneity found in pooled results from meta-analyses.

Our review also had several limitations. The 20-year timespan of systematic review could lead to varied results due to secular trends, but examining the study results by year does not indicate that a trend exists. While this might account for some variation in the results, the lack of significant changes in screening mammography guidelines or public outreach within this older age group make any difference in effects due to secular trends minimal. Of the 25 studies included in our analysis, 17 relied on self-reported information for measurement of the exposure, while 16 relied on self-reported information to measure SM utilization. This raises concerns about recall bias, particularly when citing screening utilization within the last 2–5 years. Furthermore, self-reported health status is not a precise measurement of an individual's health, as it uses a Likert scale to assess health at the instance of interview, which might not represent an individual's overall health outside the clinical environment. Studies that ascertained screening utilization through insurance claims[29,31,36,39,40,42,51,52,63,64] were unable to distinguish between mammograms undertaken for screening and diagnostic purposes. However, it is reasonable from a clinical perspective to assume that the majority were screening procedures, since diagnostic procedures are performed only when a woman presents with symptoms of breast cancer.[29,51,52] The inability to distinguish the two types of mammography might lead to the measured population being slightly sicker than the normal SM population, which would lead to an overestimate of association.

More than half of the studies included were cross-sectional by design, which restricts the ability to ensure temporality of the exposure/outcome relationship. Despite this concern, all but two studies were of moderate to excellent study quality based on our cross-sectional study-specific quality assessment using the Newcastle–Ottawa Survey.

Conclusion

Studies have shown that the primary determinant of screening with mammography, regardless of age, is a physician's recommendation.[59,74–76] It is therefore critical that the guidelines be updated to reflect the importance of characteristics such as the presence of severe functional dependencies in ADLs and severe comorbidity as caused by conditions such as end-stage renal disease and severe dementia in concert with clinical judgment to estimate an individual's potential risks and benefits from screening rather than basing screening decisions on age alone. This systematic review and meta-analysis shows that consideration of functional status and comorbidity might be occurring in practice but still needs to be further weighed in SM recommendations, and targeted interventions are needed to facilitate precision cancer screening.

Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

JD and DB contributed toward concept and design. JD, TA and DB were involved in review and quality assessment of literature. JD, TA, IA, TO, RAH and DB performed analysis and interpretation of the data. JD, TA, IA, TO, RAH and DB carried out drafting of manuscript. JD, TA, IA, TO, RAH and DB contributed toward critical revision of the manuscript for important intellectual content. JD, IA and DB performed statistical analysis. DB obtained funding. JD, TA, IA, TO, RAH and DB agree to be accountable for all aspects of the work. All authors contributed to data analysis, drafting and revising

the article, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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