

Table 3. Descriptive summary of quality, performance indicators, and case detection rates (Cont'd)

Author, year, country,	Study design MMAT quality score	Description of intervention (study objective, target population, screening test, MSU type, time period of study)	Sample (number of clients screened or exams, demographics)	Reported cancer screening performance indicators	Cancer detection rate/1,000 exams
Garas et al. (1994), Greece (73)	Quantitative descriptive MMAT: 100%	Target: 42, 411 women ages 40-64 in the Iliia and Messinia counties, southern Greece Test: film MMG; MSU type: 1 van (multimodal, also provided Pap tests, results unreported) Period: 4 years; organized program	22,258 clients screened	Screening coverage rate = 52.5%; Abnormal call rate: 5.3% (n = 1169); biopsy rate: 0.8% (n = 176) (recommended), 0.7% (n = 158) performed, loss to follow-up: 11% Detected cases: n = 69; test PPV: 7.4%; biopsy PPV: 47.1% Proportion DCIS: 4.3%; stage I (< 2cm): 51.5%	3.1
Dershaw et al. (1992), USA (55)	Quantitative descriptive MMAT: 75%	Target: women age ≥ 35 in New York state Test: film MMG (Pap tests also offered, results not reported by study) MSU type: 1 van, 2 semi-mobile MMG units Period: 1988-1991 (3 years); opportunistic screen	22,540 exams	Abnormal call rate: 11.2% (n = 2515); biopsy recommended rate: 0.6% (n = 288); biopsy performed rate Detected cases: n = 50; test PPV: 2.0%; biopsy PPV (recommended): 17.3%; biopsy PPV (performed): 21% Operational measures: 25 exams offered daily, Costs (USD 1992): average cost per test = \$65; startup costs \$360,000;	2.2
McCoy et al. (1992), USA (36)	Quantitative descriptive MMAT: 50%	Target: women age ≥ 40 in Florida (socioeconomically disadvantaged) Test: film MMG (Pap tests also offered, results not reported by study); MSU type: 1 van Period: 1987-1991 (4 years); opportunistic screen	12,456 clients screened; First-screen: 72%	Abnormal call rate: 21.3% (n = 2,660) Detected cases: n = 90, test PPV: 4.0% ^a Proportion of cases DCIS: 10% (years 1987-89), 24% (years 1990-91)	6.6 (prevalent rate) 5.5 (overall rate) ^a
Tabar and Gad (1981), Sweden (22)	RCT MMAT: 100%	Target: 47,000 women age ≥ 40 Ostergotland county, Sweden; MSU type: 1 van Test: film MMG; control: no screening (22,000 women in Kopparberg county) Period: 1977-1980 (3 years); organized program	34,187 clients screened	Screening coverage rate among intervention group: 84.3% Abnormal call rate: 4.8% (n = 1655); biopsy rate: 0.1% (n = 362) Detected cases: n = 235; Test PPV: 14.2% ^a ; biopsy PPV: 64.9% ^a	6.9 ^a
Strax (1973), USA (23)	RCT MMAT: 50%	Target: 31,000 women age 40-64 participating in the Health Insurance Plan (HIP) in New York City Test: film MMG and CBE; MSU type: 1 van control group: no screening (31,000 women randomly matched on age, through HIP program) Period: 1963-1969 (7 years); organized program	20,211 clients screened	Intervention group: screening coverage rate: 66% Detected cases: n = 296; detection rate per 1,000 PYs: 2.72 70% of cases were without axillary nodal involvement Comparison group: Detected cases: n = 284; detection rate per 1,000 PYs: 1.86 45% of cases were without axillary nodal involvement	2.3

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Lorenzi et al. (2016), Brazil (21)	Quantitative descriptive MMAT: 75%	Objective: To evaluate the efficiency of the careHPV test in detecting high-risk HPV in women with no precursor lesions and evaluate performance as a primary screening method Target: women ages 18-85 residing in 4 states of South-East and Central-West Brazil Cotesting: CareHPV + Pap-liquid based cytology (Pap-LBC) MSU type: 1 van Period: 03-12/2012 (8 mos.); opportunistic screen	3,068 clients screened; Median age (range) = 47 (18-85)	Test positive for HR-HPV: 10.0% (n = 307) Abnormal cytology: total 4.3% (n = 132); [ASC/AGC-US: n = 66, ASC/AGC-H: n = 13, LSIL: n = 38, HSIL: n = 15]; HR-HPV positivity among cytology samples: 8.2% of normal samples, 39.4% of ASC/AGC-US, 38.5% of ASC/AGC-H, 55.3% of LSIL, 100% of HSIL Colposcopy rate: 10.8% referred (n = 332); 3.6% performed (n = 111); 66% loss to follow-up Biopsy rate: 2.1% (n = 66), CIN1: 40.9% (n = 27); CIN2: 7.6% (n = 5); CIN3: 6.1% (n = 4); invasive carcinoma: 4.5% (n = 3) HPV test: Sensitivity: 100% (CI: 75.3-100%), specificity: 10.8% (CI: 5.1-19.6%)	1 invasive cancer/1,000 women cotested
Paengchit et al. (2014), Thailand (25)	Quantitative descriptive study MMAT: 100%	Objective: describe prevalence and genotype distribution of HPV in Lampang, Thailand Target: women ages 30-70 Test: Pap-LBC, HR-HPV testing; MSU type: 1 van Period: 01-03/2013 (3 mos.); opportunistic screen	2,000 clients screened; Mean age (range) = 47.8 (30-70)	Test positive for HR-HPV: 5.4% (CI: 4.5-6.5; n = 108) Rate of abnormal cytology: 1.95% (1.4-2.7) Number with HSIL or higher: n = 19 HR-HPV positivity among cytology samples: 4.0%, 60.0%, 89.5% among normal, ASC-US/LSIL, HSIL respectively	9.5 HSIL/1,000 smears ^a
Fregmani et al. (2013), Brazil (27)	Cross-sectional analytic MMAT: 100%	Test: Pap, comparison: Pap LBC MSU type: 1 van Period: 05-12/2010 (8 mos.); opportunistic screen	Pap, Pap-LBC Clients screened: 6,047, 6,001 Mean age (SD): 46.1 (13.1), 46.5 (12.5)	Results for Pap, Pap-LBC: Abnormal call rate: 0.021, 0.01; Specimen adequacy rate: 99.92%, 99.97% ASCUS-US: 0.1% (n = 6), 0.7% (n = 39); ASC-H: 0.3% (n = 21), 0.4% (n = 24); LSIL: 0.3% (n = 19) vs 0.7% (n = 41); HSIL: 0.2% (n = 14) vs 0.4% (n = 22)	Rate of HSIL per 1,000 smears: 2 vs. 4
Swadhiwudhipong et al (1999), Thailand (20)	Mixed: qualitative case-study + quantitative descriptive MMAT: 100%	Objective: measure effect of MSU program on knowledge and attitudes toward screening Target: low-income women residing in rural regions of Thailand, ages 18-65 Test: Pap; MSU type: 1 van; Period: 1992-1996 (5 years); Opportunistic screen	13,081 clients screened; Women surveyed in 1991, 1994, 1997: n = 1,603, n = 1,369, n = 1,576	LSIL: n = 46 (0.4%); HSIL (%): n = 46 (0.4%); detected cases: n = 7 Survey results from 1991, 1994, 1997 Self-reported knowledge of Pap test: 21%, 57%, 76% Self-reported use of Pap test: 20%, 58%, 70%	0.5 cases/1,000 smears 3.5 HSIL/1,000 smears
Megevang et al. (1996), South Africa (15)	Prospective cohort MMAT: 100%	Objective: to identify operational strategies to minimize loss to follow-up Target: low-income women in Capetown Test: (phase I) Pap + Colposcopy referral to FC; (phase II) "See, screen, treat"; Pap + Colposcopy in MSU; MSU type: 1 van; Period: 1993 (8 mos.); opportunistic screen	Phase I, II: clients screened; 2,619, 2,426 Mean age (range): 34 (19-83), 31 (17-78); Total First-screen: 75.2%	Results for Phase 1, 2: Abnormal Pap smears - LSIL: 3.3% (n = 87), 3.5% (n = 87); HSIL: 3.2% (n = 86), 1.3% (n = 33) Effective completion of colposcopy among HSIL: 33% (29/86), 97% (32/33) Operational measures: 50 tests offered per day	0.92/1,000 smears ^a

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Table 3. Descriptive summary of quality, performance indicators, and case detection rates. (Cont'd.)

Author, year, country	Study design MMAT quality score	Description of intervention (study objective, target population, screening test, MSU type, time period of study)	Sample (number of clients screened or exams, demographics)	Reported cancer screening performance indicators	Cancer detection rate/ ^a 1,000 exams
Thornton et al. (1989), UK (54)	Quantitative descriptive MMAT: 100%	Target: Women >40 employed by worksites in West Surrey/North-East Hampshire region (UK) Test: Pap, CBE (unreported); MSU type: 1 van Period: 1985-1986 (9 mos.); opportunistic screen	568 clients screened	Coverage rate among women in targeted workplaces: 91% Abnormal call rate: $n = 64$ (0.11); Detected cases: 1; Test PPV: 1.5% ^a	1.76 cases/ 1,000 smears
Brindle et al. (1976), UK (49)	Quantitative descriptive MMAT: 100%	Target: women (age unspecified) residing in the UK; Test: Pap; MSU type: 1 van Period: 1973 (3 mos.); opportunistic screen	1,526 clients screened; First-screen: 70%	Abnormal call rate: $n = 10$ (0.66%)	6.6 abnormal/ 1,000 smears
Whitfield et al. (1972), UK (50)	Quantitative descriptive MMAT: N/A	Target: women (16-60) residing in the UK Test: Pap (CBE also offered, results unreported); MSU type: 1 van Period: 1969-71 (3 years); opportunistic screen	1,952 clients screened; first-screen: 70%	Number of cases carcinoma <i>in situ</i> : $n = 4$ Cost measurements (reported in 1972 pounds (£)): Cost per test = £2, average cost per detected CIN3 = £200	2.04 cases of carcinoma <i>in situ</i> /1,000 smears
Mauad et al. (2009), Brazil (70)	Quantitative descriptive MMAT: 100%	Target: 54,238 women ages 40-69 for breast screening, 117,239 women ages 20-69 for cervical screening Test: Film MMG and Pap MSU type: 1 van Period: 2003-2004 (2 years); opportunistic screen	MMG, Pap: clients screened: 7,192, 2,964; First-screen: 44%, 7%	Breast: screening coverage rate: 13%; Abnormal call rate: 7.6% ($n = 549$); biopsy rate: 1.4% ($n = 105$); Detected cases: $n = 22$; test PPV: 4%; ^a biopsy PPV: 20.9% ^a Cervical: screening coverage rate: 2.5% Abnormal call rate: 1.9% ($n = 59$) ^a ; cytologic abnormalities: 0.5% ($n = 15$); ASCUS 0.1% ($n = 3$); CIN1 0.13% ($n = 4$); CIN2 0.1% ($n = 3$); CIN3 0.1% ($n = 3$); invasive squamous cell carcinoma 0.07% ($n = 2$); operational measures: 40 exams offered daily	Breast: 3.1 cases/1,000 exams Cervical: 0.7 cases/1,000 exams
Lynch (1976), USA (94)	Quantitative descriptive MMAT: 50%	Objective: Measure effectiveness of MSU by comparing survival with general U.S. population Target: Adults residing in rural Nebraska; Test: unspecified; MSU type: custom-built house, 6 m x 18 m in dimension (transported using tractor) Period: 1971-1975 (5 years); opportunistic screen	5,232 clients screened (1,984 men and 3,248 women); Mean age (range) = 55 (18-90)	Detected cases: $N = 22$ (8 breast, 7 colon, 2 endometrium, 1 lung, 1 prostate, 1 penis, 1 lip, 1 stomach) 1 cancer diagnosis per 238 clients screened Survival: observed vs. expected deaths: 3 vs. 7.5 (estimated using U.S. cancer mortality rates)	4.2 cases/1,000 people screened
Lynch, (1973), USA (67)	Quantitative descriptive MMAT: 25%	Target: individuals residing in eight communities in Nebraska; Test: MMG (NOS), CBE, Pap, DVI, proctosigmoidoscopy, OVE, laryngoscopy MSU type: custom-built house (transported by tractor) Period: 1971-1972 (2 years); opportunistic screen	3,040 screening exams; Mean age = 60 (males), 56 (females)	Total number of malignancies: $n = 13$ ($n = 64$ including skin) Operational measures: 16 patients scheduled per hour	4.3 cases/1,000 people screened

Abbreviations: CBE, clinical breast exam; CI, 95% confidence interval; DRE, digital rectal exam; DVI, direct visual inspection; FC, fixed-centre; Pap, Papanicolaou smear with conventional cytology; Pap-LBC, Papanicolaou smear with liquid-based cytology; NOS, not otherwise specified; OVE, oral visual examination; VILI, visual inspection with Lugol iodine.

^aDenotes hand calculations. The objective is left unspecified for studies which are purely descriptive. If a distinct objective outside of program description was mentioned, this objective was stated. See Supplementary Table S3 for reference to the MMAT scale.

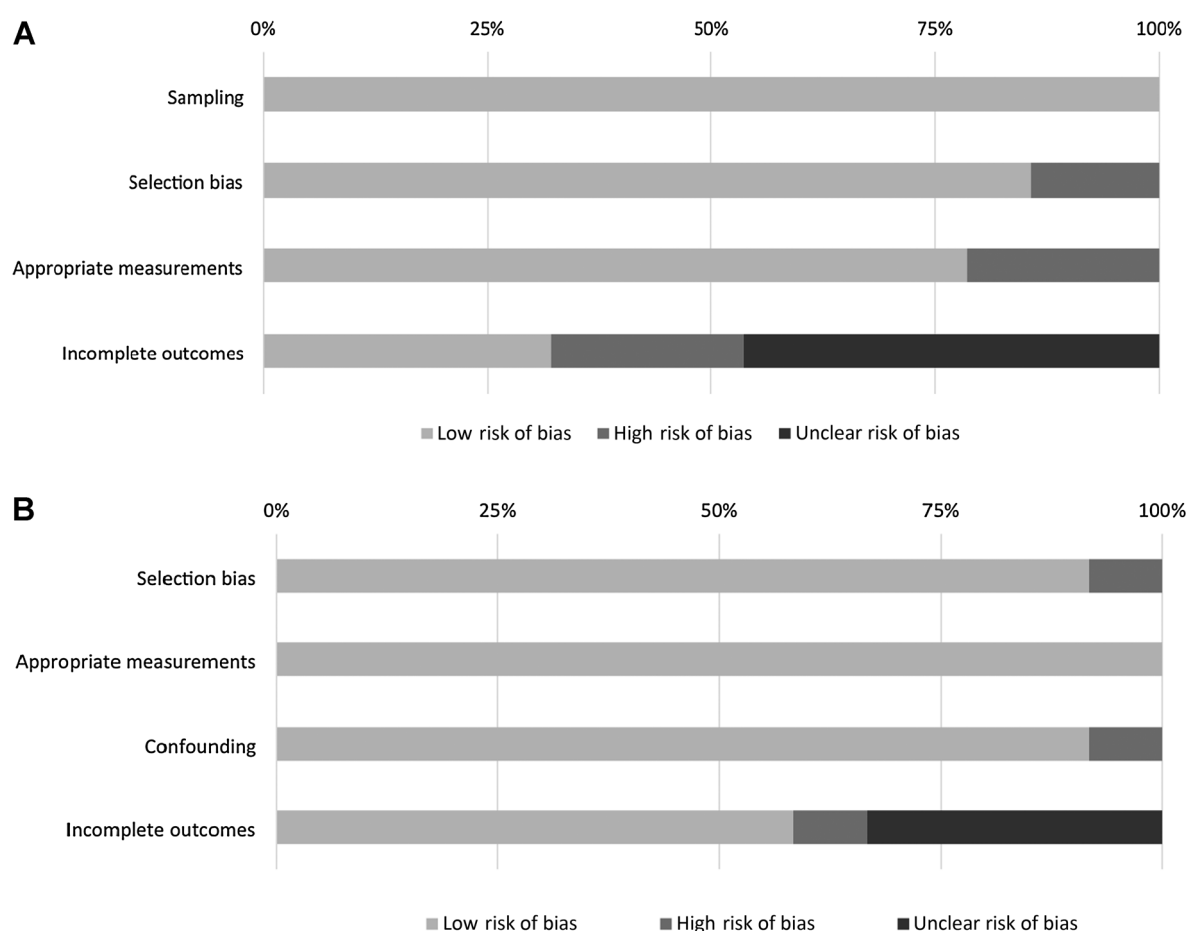


Figure 2. Assessment of risk of bias by study design. Review authors' judgments about each methodologic criterion are presented as percentages across the 22 studies of quantitative descriptive design (A) and 7 studies of nonrandomized observational design (B). Judgments were based on criteria outlined in the MMAT (Supplementary Table S3).

contexts. As displayed in Fig. 3, among 22 breast cancer screening studies reporting performance measures, case detection rates ranged from 2.15 to 14.65 per 1,000 mammography exams. In these studies, patients with abnormal screening results were recalled to fixed clinics for further clinical work-up and diagnostic exams. The broad range in detection rates may be due to differences in contextual factors between programs such as the ages of screened women, proportion of never-screened women, or differences in incidence rates of breast cancer in various settings.

Twelve studies described cervical cancer MSU programs involving screening exams performed by nurse technicians including: conventional or liquid-based Pap cytology, HPV testing, and visual inspection with acetic acid (VIA); one MSU also offered diagnostic colposcopy exam performed by a clinician (15). All 10 multiphasic programs reported screening for cervical cancer. Notably, many of the cervical cancer screening studies were in low-resource settings in Brazil, Peru, South Africa, India, Thailand, and Taiwan (15, 20, 21, 24–27). The studies report diverse outcomes of detection of precancerous cervical lesions and invasive cancer, as described in Table 3. Because of the inconsistency of reporting measures used, no summary figure of case detection is presented for the cervical cancer screening studies.

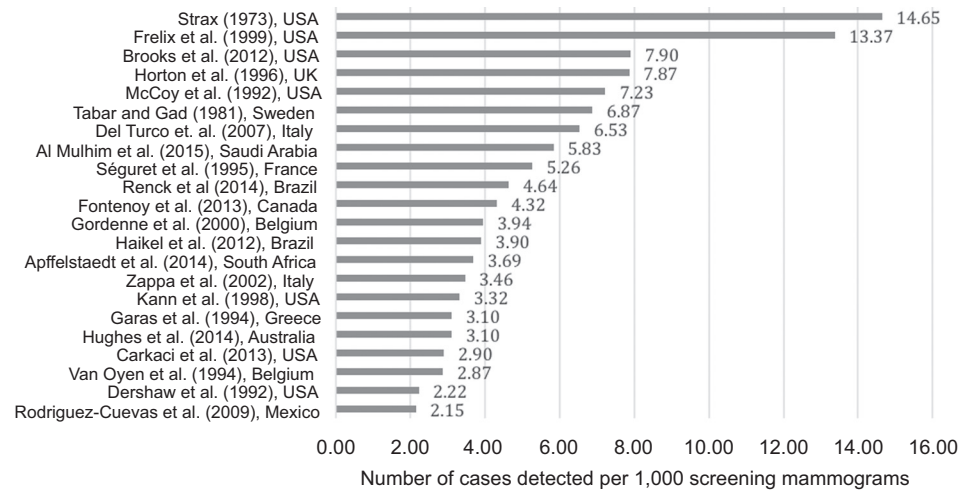
Mechanisms for increasing delivery, access, and demand for screening

Examples of operations of MSUs in regions distant from centralized services include cervical cancer screening in tents in the Andes Mountains of Peru (26); a mammography unit transported by boat and plane to reach Arctic regions in Canada (14); an MSU mammography program serving residents of 26 inhabited islands in Scotland (28); a semi-mobile colonoscopy program for high-risk individuals in South Africa residing over 500 km away from the nearest hospital (29); and MSU interventions for breast and cervical cancer in the rural interior and Amazonian states of Brazil (21, 30). In addition, MSUs fill a unique niche in urban areas by targeting underscreened groups who may be within a reasonable physical proximity to a fixed clinic, but less likely to access services due costs, awareness, and perceived barriers (26, 31–37).

Key factors to the accessibility of services are the time and distance traveled to a screening center. Some studies reported patients' travel to the MSU location to be fairly minimal, with average distances traveled by clients to reach MSU sites of 4.5–34 km (38–40). One study from the United Kingdom found MSUs were located substantially closer to patients than

Figure 3.

Breast cancer case detection rates per study among the subset of breast cancer studies reporting performance indicators ($n = 22$). Crude case detection rates corresponding to the number of detected cases of cancer per 1,000 mammography exams are presented.



fixed clinics; the mean distance per client to an MSU was 6.4 km as compared with fixed clinics that were on average 18.2 km away (41).

Community access to screening

Several MSU programs aimed to increase community access to screening (24, 34, 42–48). An increased screening rate from 44.3% to 63.4% was reported in regions served exclusively by MSUs in Quebec, Canada over a course of eight years (14). A Thai study found an increase in the proportion of women reporting ever receiving a Pap smear from 20% in 1991, to 70% in 1999 due to MSU operations (20).

In cases where before and after measures of screening uptake were unavailable, using the proportion of never-screened individuals who received their first screening exam through the program can serve as a surrogate measure for increased access. Among breast screening programs, studies reported the proportion of first-screen clients to range from 11% to 72% (18, 30, 36). Cervical cancer screening programs targeting low-income groups reached particularly underserved populations composed of 75% never-screened clients in South Africa (15), and 70% never-screened clients in the United Kingdom (49, 50).

MSU programs have addressed economic barriers to screening by reaching underserved populations. Notably, 31% ($n = 24$) of studies offered screening services free of charge. The majority of studies that discussed fee-for-service economic barriers to screening were based in the United States where no organized breast cancer screening program existed and attending screening was likely to be affected by insurance status (17, 34, 35, 42–44, 47, 48, 51–53). Furthermore, a number of MSU programs have decreased structural barriers by offering screening at the workplace (49, 54–58), shopping centers (50), and retirement homes (59).

Client demand

Client demand for screening is an essential part of attaining population-level screening coverage. MSU qualitative studies used focus groups and surveys to identify women's attitudes towards screening, their perception of the utility of screening and intent to screen (28, 38, 39, 46, 60–64). Among women surveyed following MSU screening, nonadherence to screening guidelines was reported as related to a lack of awareness of early detection, lack of accessible information, negative beliefs or attitudes toward

screening, as well as fear of discomfort/embarrassment, cost, and bad news (34, 61, 63).

Studies reported high levels of overall client satisfaction with the quality of service (24, 62, 64) and adequate levels of comfort and privacy with screening (24, 62, 65). Two studies measured patient preferences and documented preference for MSU relative to fixed-site clinic (24, 62). In contrast, one study reported a lower client satisfaction for MSUs relative to hospital screening in terms of receipt of test results, staff interpersonal skills, privacy, physical surroundings, and general satisfaction (64).

Studies described various methods to promote screening attendance, including direct invitation by mail or telephone, publicity (flyers, radio, car loudspeaker, newspaper), word of mouth, or physician referral (32, 38, 49, 62, 66–69). A study conducted during the initial implementation of a breast and cervical cancer screening program in Brazil found that among various promotion strategies, community health care agents making home visits was the most effective means of recruiting women to begin screening (70).

Determinants of successful follow-up

Compliance to the recommended follow-up of an abnormal screening exam serves as an indicator of the quality of a screening program. Rates of loss to follow-up generally tended to be higher in low and middle-income countries. A 21% loss to follow-up rate of the MSU mammography screening program in Mexico City (71) and a 66% loss to follow-up for colposcopy referrals in the MSU cervical cancer screening program in Brazil (21) were found compared with a 10%–15% loss to follow-up in the MSU breast screening programs in France (72), Greece (73), and Belgium (74). MSU operations should strive to minimize potential delays in the referral pathway and loss to follow-up that may occur due to a delay between the screening test and dissemination of results/availability of treatment. A cervical cancer screening study in South Africa assessed the effect of a "see, screen, treat" intervention to minimize loss to follow-up and found improved rates of completed follow-up when clients with suspected lesions were referred to the MSU for diagnostic colposcopy and lesion excision (15). Ninety-eight percent of patients with high-grade squamous intraepithelial lesions (HSIL) attended MSU colposcopy as compared with 33% complete follow-up when referred for colposcopy at the nearest hospital, which was 30 km away from the MSU site.

Discussion

This review summarizes the evidence regarding the feasibility of MSU interventions for the early detection of cancer. We described existing programs, their performance, and the mechanisms through which they can increase the delivery, access, and demand for screening services. It was evidenced that MSUs can increase access for underscreened groups. Offering early detection services through MSUs is a practical way for service providers to increase physical and economic access to screening while reducing barriers for clients (structural barriers and out-of-pocket costs).

However, there are several challenges and risks involved with offering screening via MSUs as compared with fixed clinics. Referral systems and challenges with follow-up are a major issue. In an MSU setting, the exam is generally conducted by a nurse technician on the MSU and any abnormalities that are found upon interpreting the exam, will require the patient to travel to a fixed clinic to visit a physician on a separate date, whereas a fixed clinic may have the flexibility to conduct a diagnostic exam on the same day and minimize potential losses to follow-up. In addition, MSUs face unique risks when compared with fixed clinics—poor roads may necessitate the recalibration of sensitive diagnostic machinery if transported by MSU. Finally, client perceptions of MSUs may differ from fixed-clinics, as MSUs are generally perceived as less clinical than hospital-based clinics. This review did not focus on the clinical considerations of screening tests with respect to their effectiveness in reducing morbidity or mortality for cancer sites. However this serves as an area for future study to determine whether MSUs are as clinically effective as fixed facilities.

The body of evidence summarized by these studies is modest. The study designs were largely descriptive single-group studies, with few high-quality observational studies and RCTs documenting the performance of MSUs, the latter type representing the highest level of evidence, followed by observational studies and descriptive studies (75). Among studies that were appraised for methodologic quality, we found a low risk of bias for measures including sampling, selection bias, and valid measurements. However, several studies were methodologically weak and at high risk of bias for the incomplete reporting of outcome measures. Therefore, although the overall methodologic quality of the studies summarized by our review was at a moderately low risk of bias, the strength of evidence continues to be limited. A weakness of this quality review is that some studies scored decently on the MMAT scale, despite shortcomings in design and reporting. We found the MMAT scale was restrictive with respect to scoring the methodologic quality of screening studies. The design and methods employed by future studies of MSUs should pay particular attention to reporting of complete outcomes.

There are potential risks associated with screening in general, particularly if the test and the medical procedures that are required in consequence are inefficiently administered. This includes the potential for missing cancers (false negatives) and patients undergoing unnecessary clinical follow-up if they test positive but do not have the disease (false positives). Regrettably, risks of screening may be worsened in settings where follow-up is limited, because individuals with abnormal tests may not return and the period between screening rounds may extend beyond the recommended intervals, thus permitting development of interval cancers. Few studies reported the potential for false negative test results which can be measured

as the number of interval cancers occurring within 24 months of a negative test result or by reporting test specificity (13, 21, 72, 76). Using a descriptive single-group study design measuring rates of cancer detection at baseline (cross-sectional), and without follow-up data, it is not possible to assess the rates of false-negative results. With respect to prevalence of false positives, due to the wide ranges of reported positive predictive values of tests and the lack of reporting on confounding characteristics in the study population (most notably age) it was not possible to summarize rates of false positives across studies.

The findings of individual studies have limited generalizability. The quantitative findings in terms of test performance cannot be directly compared between studies or generalized to other settings due to differences in baseline risk of cancer and the non-reporting of age-standardized detection rates. The qualitative outcomes such as the acceptability of a given cancer screening test and client satisfaction levels with MSU services are also highly contextual, and cannot be generalized across studies.

Insufficient evidence was available to describe the cost-effectiveness of MSU interventions but we hypothesize that MSUs have lower start-up costs compared with fixed sites but may face greater maintenance costs for technology and equipment due to stress caused by road travel. Conducting studies to investigate the cost-effectiveness of MSU programs relative to fixed clinics should be a priority.

The MSU studies included in this review were not restricted by study design, types of screening tests used, or types of outcomes reported. This broad inclusion criterion is both a strength and a limitation of this review. Studying multiple MSU interventions emphasized the versatility of MSU programs but limits the depth of analysis for performance outcomes of individual programs. The literature search was limited to programs that explicitly described the methods of screening as mobile or used a synonym listed within the search (Supplementary Table S1). The search was designed to be as robust and detailed as possible. However, it is possible that some studies were overlooked. Publication bias may have led to nonpublication of MSU studies of high and poor quality that do not report their findings in peer-reviewed journals. This review was only able to synthesize published results.

This review synthesizes the available knowledge regarding MSU interventions for cancer screening. MSUs can be an important health system component to expand screening coverage to rural areas or to urban residents who fail to be reached by health promotion messages or lack medical insurance. Overall, our findings highlight the value of MSU interventions, specifically with respect to increasing access to early detection services. More evidence is needed to provide comparative information on the cost-effectiveness and effectiveness of MSU interventions as compared with fixed-clinics to inform decision making for health care providers or policymakers.

Disclosure of Potential Conflicts of Interest

No potential conflicts of interest were disclosed.

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BLOOD CANCER DISCOVERY

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