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## **The Role of Secondary Prevention in Modern Oncology: Current Trends in Screening for Breast, Colorectal and Cervical Cancer**

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### **ABSTRACT**

**Introduction:** Cancer is a leading cause of death worldwide, with breast, colorectal, and cervical malignancies accounting for a significant portion of the global oncological burden. The success of organised screening programmes is contingent on two factors: clinical efficacy and population participation rates.

**Aim:** The aim is to evaluate the clinical importance and efficacy of screening programmes for breast, colorectal, and cervical cancers.

**Methods:** A narrative review of literature from 2016–2025 was conducted via PubMed and Google Scholar. Key words used: 'screening', 'mammography', 'colonoscopy', 'FIT', 'cytology', 'HPV testing', 'prevention'.

**Results:** Participation in mammography programmes has been demonstrated to reduce breast cancer mortality rates by 41–49%. For colorectal cancer, colonoscopy has been shown to reduce mortality up to 67%, while biennial FIT reduces it by 40%. In the context of cervical cancer, primary HPV testing offers superior sensitivity in comparison with conventional cytological

analysis. Psychosocial barriers and false-positive results remain significant challenges across all programmes.

**Conclusion:** The organised screening of patients is of vital importance in the diagnosis and treatment of the disease. The promotion of public education and the implementation of less invasive methods are pivotal in enhancing population adherence and reducing global cancer mortality.

**KEY WORDS:** screening; oncology; cancer; colonoscopy; mammography; cytology; HPV testing

## 1. INTRODUCTION

In Europe, it is estimated that approximately 4.5 million individuals received a cancer diagnosis in 2022, with a corresponding mortality rate of around 2.0 million. Current projections suggest that these figures will increase in the coming decades. Moreover, cancer has been identified as the second most prevalent cause of mortality among individuals over the age of 65, and the leading cause among those aged 35 to 64. In Europe, the most prevalent female cancers as of 2022 were breast (26.4%), colon (11.8%), and lung (7.9%), while in males, the most prevalent cancers were prostate (20.0%), lung (13.4%), and colon (12.3%). With regard to mortality rates among both sexes, the highest incidence of mortality was observed in the lung (18.9%), colon (12.5%), and breast (7.3%) [1].

The elevated mortality rate associated with cancer is primarily attributable to the fact that, in the early stages of cancer development, the disease often remains asymptomatic. It is imperative that these figures are given full consideration when evaluating the significance of effective and timely cancer diagnosis, particularly in cases of precursor alterations or early asymptomatic stages. In such cases, the opportunity to administer radical treatment to the patient may still be possible. In the context of economic transition, an observed shift towards "Western-style" cancers, including breast and colorectal malignancies, underscores the necessity for early detection to be recognised as a global priority [2]. In response to this challenge, a key strategy employed by modern oncology is the implementation of screening programmes.

The process of screening is defined as the examination for the presence of disease in the absence of symptoms. It is important to note that screening may facilitate the early detection of diseases, thereby enhancing the likelihood of successful treatment [3].

The primary objective of screening tests is to reduce mortality rates from the specific cancer being monitored. It is crucial that the equipment under consideration exhibits both high sensitivity and high specificity. The purpose of screening tests is to identify diseases that present a significant risk to specific populations. The implementation of screening tests is both extensive and long-term. It is imperative that a screening test is socially acceptable in terms of the type of test and the cost of the programme. The method should be characterised by its cost-effectiveness, expeditiousness, ease of execution, and reproducibility. It is vital to emphasise that a disease which is subject to screening must have a scientifically confirmed precancerous condition or early stage that, once detected, can be effectively treated. This enables the patient to maintain their physical health and quality of life [4].

The following review discusses the three major malignancies included in population-based screening programmes: breast cancer, colorectal cancer, and cervical cancer.

## **2. METHODS**

This narrative review is an analysis of previously published articles, offering a comprehensive overview of the extant findings. The purpose of this review is to emphasise the importance of screening in cancer in relation to breast, colorectal and cervical malignancies. The present review places principal emphasis on mammography in the detection of breast cancer, colonoscopy in the detection of colorectal cancer, and cytology and HPV testing in the detection of cervical cancer.

The articles under review were published on the PubMed and Google Scholar platforms between 2016 and 2025.

The following keywords were included in the search: breast cancer, colorectal cancer, cervical cancer, cancer screening, mammography, colonoscopy, FIT, cervical cytology, HPV testing, early detection, prevention.

### **3. RESULTS**

#### **3.1. Breast cancer**

Breast cancer is the most prevalent malignancy among women worldwide; therefore, organised population-based screening programmes have been developed to facilitate early detection. Mammography, defined as an X-ray examination of the breast, constitutes the primary screening modality [5]. Following recent European Commission recommendations, biennial screening is now advised for women aged 45–74 years [6]. In addition to mammography, breast ultrasonography is frequently used as a complementary imaging technique, particularly in younger women or those with dense breast tissue, where mammographic sensitivity may be reduced [5].

A substantial body of evidence demonstrates the profound impact of mammography screening on clinical outcomes for breast cancer patients. A 2020 analysis reported that participation in regular screening was associated with a 41% reduction in breast cancer mortality within 10 years, alongside a 25% decline in the incidence of advanced-stage disease [7]. Subsequent research from 2021 further highlighted that women attending consecutive screening rounds consistently exhibited a 49% reduction in the risk of fatal breast cancer and a 50% overall mortality reduction within a decade of diagnosis compared to non-participants [8].

The implementation of widespread mammography screening has resulted in a notable 'stage shift' in cancer diagnosis. In accordance with the analysis conducted by Welch et al., there has been a considerable increase in the identification of localized, small tumours, including in situ carcinomas and invasive lesions measuring less than 2 cm. The data indicates that the proportion of these early-stage malignancies in total cases rose significantly from 36% to 68%. Concurrently, the incidence of larger malignancies ( $\geq 2$  cm) experienced a substantial decline, dropping from 64% to 32%. Consequently, the absolute incidence of advanced-stage breast cancer decreased by approximately 30 cases per 100,000 women following the implementation of these screening protocols [9].

In addition to its impact on survival, early diagnosis via mammography is instrumental in reducing the necessity for more intensive clinical interventions. The extant literature indicates that women who do not participate in regular screening are significantly more likely to require invasive procedures, such as mastectomies or systemic chemotherapy. Specifically, the probability of undergoing these aggressive treatments is 3.4 and 2.5 times higher, respectively, among non-participants compared to those diagnosed through screening programs.

This underscores the pivotal function of screening in not only reducing mortality rates but also safeguarding patients' physical integrity and overall quality of life [10].

Nevertheless, the clinical benefits of screening must be evaluated alongside its limitations, such as the potential for overdiagnosis and false-positive results. Overdiagnosis is defined as the detection of indolent cancers that would not have become clinically apparent during a patient's lifetime. In the context of mammography screening, the existence of a considerable level of overdiagnosis is indicated by the available data. For every 162 additional small tumours detected per 100,000 women, it is estimated that only approximately 30 would have progressed to an advanced stage. This suggests that the remaining 132 cases per 100,000 women may represent overdiagnosed lesions [9]. Moreover, the utilisation of screening mammography has been demonstrated to be associated with the occurrence of false-positive findings. The estimated cumulative risk of receiving at least one false-positive result among women who regularly participate in screening is approximately 20%. It is noteworthy that approximately 75% of women referred for further diagnostic evaluation following an abnormal screening result are ultimately found to be cancer-free, thus highlighting the psychological burden associated with the diagnostic process [10].

### **3.2 Colorectal cancer**

Colorectal cancer (CRC) is a major global health problem, and it is the second most common cancer among women and the third most common among men. In 2022, CRC was responsible for 12.5% of cancer-related deaths [1]. In accordance with the prevailing European guidelines, it is recommended that asymptomatic individuals aged 50–74 years undergo a screening colonoscopy every 10 years. Furthermore, individuals with a positive family history of colorectal cancer (CRC) should undergo risk-stratified screening. Those with first-degree relatives diagnosed with CRC should initiate colonoscopic surveillance from the age of 40–49 at 10-year intervals. Non-invasive stool-based testing via the fecal immunochemical test (FIT) is recommended at 1–3-year intervals as an effective alternative for individuals who decline invasive endoscopic procedures [11].

The pathogenesis of colorectal cancer is characterised by a protracted and gradual progression, often spanning over a decade and remaining largely asymptomatic in its early stages. The protracted preclinical phase renders the disease highly amenable to screening methodologies, as it allows for the detection and removal of lesions before they undergo malignant transformation [12].

The fecal immunochemical test (FIT) employs hemoglobin-specific antibodies to detect occult bleeding, thereby offering a distinct clinical advantage by obviating the necessity for dietary or medication adjustments prior to testing. Recent data indicate that FIT exhibits high sensitivity for detecting colorectal cancer, ranging from 74% to 81%. However, its efficacy in identifying advanced neoplasia remains considerably more limited, with detection rates ranging between 25% and 27%. Despite its high level of specificity, it is estimated that between 39% and 52% of patients with a positive FIT result do not exhibit evidence of advanced pathology or adenomas upon colonoscopic follow-up, representing a significant rate of false-positive findings [13].

The diagnostic accuracy of FIT is closely linked to tumour stage, size, and anatomical location. Research indicates that fecal hemoglobin concentrations tend to be significantly higher in larger adenomas (>10 mm), distal advanced lesions, and late-stage (III–IV) colorectal cancers relative to early-stage disease. Utilising a cut-off value of 17 µg/g feces, the FIT sensitivity reaches 52% for T1 tumours and 68% for stage I CRC. Conversely, these rates increase to 79–93% for more advanced T stages and 82–92% for stage II–IV cancers. Consequently, the sensitivity for stage I malignancies is approximately 11–33% lower than for more advanced disease. From a population perspective, biennial FIT screening has been shown to be associated with a 34% reduction in advanced-stage CRC and a 40% reduction in mortality. However, this benefit is more pronounced in distal colon cancers, while the test's efficacy remains diminished in cases of proximal tumours [13].

Colonoscopy offers the unique advantage of direct visualisation of the entire colon, facilitating immediate therapeutic intervention through polypectomy. Evidence from large-scale analyses indicates that the implementation of screening colonoscopies is associated with a 67% reduction in colorectal cancer mortality when compared with non-screened populations. This substantial decline was uniformly observed across various anatomical locations, with a 65% reduction documented for right-sided colon cancers and a 75% reduction for malignancies in the left-sided colon and rectum. It is noteworthy that the impact on mortality rates was not significantly different between tumour locations, and these results remained stable even when the analysis was restricted to high-quality screening examinations. In comparison, the same study found that screening sigmoidoscopy was associated with a more modest 36% reduction in mortality – a finding that aligns with results from previous randomised controlled trials [14].

### 3.3 Cervical cancer

In 2022, cervical cancer was the 18th most prevalent form of cancer among women in Europe and the 17th most prevalent cause of cancer-related deaths in the region [1].

Persistent infection with high-risk human papillomavirus (hr-HPV) is recognised as the primary etiological factor in cervical carcinogenesis. The primary prevention of the condition is achieved through the administration of HPV vaccination. Secondary prevention relies on the implementation of organised screening programmes that are based on cytology and, with increasing frequency, hr-HPV testing [15].

Cervical cytology is a medical procedure that involves the microscopic evaluation of cervical cells. These cells are collected using a spatula or brush and subsequently stained to identify any morphological abnormalities. In the context of cervical screening, a single Papanicolaou (PAP) test performed under quality-assured conditions exhibits a sensitivity of 60% and a specificity of 95% for the detection of high-grade cervical intraepithelial neoplasia (CIN 2+). The relatively high false-negative rate, documented to range from 14% to 33%, is predominantly ascribed to technical limitations inherent in cell sampling and smear preparation [16]. Despite the limitations of the diagnostic process, a thorough evaluation of screening programmes within the European Union indicates that organised cytology-based screening has historically led to a decrease in cervical cancer incidence and mortality by up to 80% in countries with high population coverage. This substantial decrease is primarily attributed to the methodical identification and management of high-grade precancerous lesions, effectively preventing their progression to invasive malignancy [17]. In consideration of the test's limited sensitivity, it is customary to establish screening intervals at three-year intervals. This approach is adopted to ensure diagnostic reliability through serial testing [15].

HPV testing involves the detection of high-risk HPV DNA or mRNA (specifically E6/E7 transcripts) in cervical samples. These samples can be obtained during standard pelvic examinations or through increasingly popular self-sampling methods. It is currently regarded as the most sensitive primary screening modality, with sensitivity exceeding 90% for CIN2+ and over 95% for CIN3+ lesions. In comparison with traditional cytological analysis, HPV testing exhibits superior sensitivity but relatively lower specificity, necessitating careful triage strategies to manage the increased detection of transient infections [16].

In women over 30 years of age, HPV testing is considered particularly appropriate due to its high negative predictive value. A negative result allows for the extension of screening intervals in a safe manner, often to a minimum of five years, and in certain settings, even longer [16].

The clinical effectiveness of HPV-based screening is further supported by the results of large-scale randomised trials. A notable finding emerged from a cluster-randomised trial conducted in India, which demonstrated that a single round of HPV testing resulted in a 53% reduction in the incidence of advanced cervical cancer and a 48% decrease in mortality. In a similar vein, European randomised trials have repeatedly demonstrated that HPV-based screening provides significantly greater long-term protection against invasive cervical cancer than traditional cytology [16].

HPV testing is increasingly regarded as the optimal primary screening method, particularly as the coverage of HPV vaccination programmes increases and the prevalence of CIN consequently declines. Moreover, the utilisation of self-sampling has been demonstrated to attain diagnostic accuracy that is commensurate with that of samples obtained by clinicians. This approach has the potential to substantially enhance participation rates and improve programme accessibility, especially among under-screened populations [16].

The cancers under discussion and the associated screening methodologies, in conjunction with the populations for which they are intended and their capacity to reduce mortality, are outlined in Table 1.

**Table 1. Comparison of screening modalities, target populations, and their impact on mortality reduction**

Type of cancer	Screening test	Target population	Frequency	Mortality reduction
Breast	Mammography	45-74 year old women	Once every 2 years	41–49% reduction in breast cancer mortality [7,8]
Colorectal	FIT	50-74 year old	Once every 2 years	40% reduction in distal CRC mortality [13]
Colorectal	Colonoscopy	50-74 year old	Once every 10 years	67% overall reduction in CRC mortality [14]

<b>Cervical</b>	Cytology	25-64 year old women	Once every 3 years	Up to 80% reduction in mortality [17]
<b>Cervical</b>	HR- HPV test	25-64 year old women	Once every 5 years	up to 50 % reduction in mortality [16]

## 4. DISCUSSION

### 4.1. Breast cancer

Mammography is widely accepted as the gold standard for population-based breast cancer screening programmes. A substantial body of research has demonstrated that it is the only screening modality proven to reduce breast cancer mortality at the population level [7, 8]. However, the diagnostic performance of this test varies across age groups, primarily due to differences in breast tissue composition.

In premenopausal women, a higher proportion of dense glandular tissue significantly impairs mammographic sensitivity. This is primarily due to the fact that both dense breast parenchyma and malignant lesions manifest as radiopaque (white) areas on imaging; this absence of contrast can effectively mask underlying tumours, resulting in a higher incidence of false-negative results [5,10]. Conversely, postmenopausal women characteristically manifest substantial fatty replacement of glandular tissue, a phenomenon that enhances image contrast and thereby enables more precise lesion detection. Beyond its diagnostic impact, high breast density is recognised as a potent independent risk factor for breast cancer; women with extremely dense breasts face a four- to six-fold increased risk compared to those with predominantly involutinal, fatty tissue [5,10].

The false-negative rate of mammography has been reported to range from 3% to 30%, depending on patient characteristics and tumour biology [10]. Interval cancers, diagnosed between scheduled screening examinations, account for approximately 28–33% of cancers detected in screened populations and may reflect either rapidly growing tumours or previously missed lesions [10].

In order to address the limitations associated with tissue overlap, digital breast tomosynthesis (DBT) has been introduced. This three-dimensional imaging technique has been shown to enhance lesion visibility by minimising the superimposition of anatomical structures. Consequently, it has been demonstrated to result in increased cancer detection rates and a

reduction in false-positive findings when compared with conventional digital mammography [10].

Despite the existence of free screening programmes in Poland, participation rates remain suboptimal. A study of the participation rates in screening mammography between 2012 and 2015 revealed that only 20–40% of eligible women underwent the procedure. Furthermore, in 2022, the participation rate was reported at 34% [10]. Despite the expansion of the national programme to encompass women aged 45–74 years and the potential of digital technologies to improve diagnostic performance, the population-level effectiveness of screening is predominantly contingent on adherence. Consequently, enhancing participation rates is paramount to achieving a reduction in breast cancer mortality rates in Poland.

## **4.2. Colorectal cancer**

Colorectal cancer remains one of the most common malignancies in Europe, representing a major public health burden [12]. The well-established adenoma–carcinoma sequence provides a strong biological rationale for screening, as the removal of precancerous lesions can prevent cancer development [11]. Consequently, organised screening programmes play a central role in reducing CRC mortality.

Colonoscopy is regarded by many as the reference standard for CRC screening, offering high sensitivity for both adenomas and advanced neoplasia, alongside the unique therapeutic advantage of immediate polypectomy [11, 14]. Recent findings from the NordICC (Northern-European Initiative on Colorectal Cancer) trial provide a nuanced perspective on its population-level impact. In the intention-to-screen analysis, individuals who were invited to undergo a colonoscopy demonstrated an 18% reduction in the risk of developing colorectal cancer within a 10-year period. While the study did not initially demonstrate a statistically significant decrease in CRC-related mortality in the overall invited group, per-protocol analyses suggest that those who underwent the procedure experienced a mortality risk reduction of approximately 50% [18]. Nevertheless, the invasive nature of the procedure – requiring rigorous bowel preparation and often sedation – remains a barrier, as potential complications and patient discomfort can negatively impact participation rates.

Faecal immunochemical testing (FIT) represents a non-invasive alternative to colonoscopy. It has demonstrated good sensitivity for detecting colorectal cancer, although its performance in identifying advanced adenomas is lower compared with colonoscopy [13].

Overall, current evidence supports both colonoscopy and FIT as effective CRC screening strategies. The optimal approach should be tailored to national healthcare resources, population risk profiles, and participation rates. Strengthening organised screening programmes remains essential to further reduce colorectal cancer incidence and mortality [13,14].

In Europe, colorectal cancer incidence remains high, highlighting the need to optimise screening participation and accessibility. Improving awareness and reducing barriers to colonoscopy may significantly enhance the effectiveness of national screening programmes.

### **4.3. Cervical cancer**

Cytology has historically been regarded as the gold standard for cervical cancer screening. Nevertheless, the subsequent discovery of a strong causal relationship between persistent high-risk HPV infection and cervical carcinogenesis has resulted in a shift in the diagnostic paradigm. Consequently, HPV DNA testing has emerged as a superior screening modality and is increasingly recommended as the preferred primary method in international guidelines [19].

The clinical superiority of primary HPV testing over traditional methods is evidenced by its significantly higher sensitivity in detecting CIN3+ lesions. While cytology remains a highly specific diagnostic tool, its effectiveness is limited by a moderate and variable sensitivity, which is estimated to be approximately 50–70% for CIN2+ lesions [19]. Evidence from large-scale clinical investigations indicates that HPV-based screening, particularly when incorporating 16/18 genotyping, offers superior long-term protection compared to cytology alone. Furthermore, the high negative predictive value of HPV testing allows for the safe extension of screening intervals, enhancing the overall efficiency of cervical cancer prevention programmes [19].

An alternative strategy that has been employed in clinical practice is co-testing, which involves the simultaneous application of liquid-based cytology (LBC) and HPV DNA testing. This combined approach has been demonstrated to enhance diagnostic sensitivity beyond the capabilities of either method used in isolation. By leveraging both morphological and molecular data, co-testing aims to minimise the risk of missed lesions. However, it must be acknowledged that no screening modality achieves absolute detection rates [20].

To further enhance diagnostic accuracy, strategies such as co-testing (combining LBC with HPV DNA testing) have been proposed. While this approach increases sensitivity beyond that of either method in isolation, it does not fully address the psychological and social barriers to screening, such as embarrassment or lack of access to specialized clinics. In this context,

HPV self-sampling represents a transformative opportunity; it maintains high diagnostic accuracy while significantly improving participation rates among under-screened populations by offering a more private and less invasive alternative [16, 20].

Cervical cancer can be regarded as a preventable disease when considering the availability of HPV vaccines [21]. The availability of the HPV vaccine provides a significant opportunity to reduce the incidence of cervical cancer in developing countries, where 80% of cases occur. The utilisation of the HPV vaccine has been demonstrated to reduce the incidence of this cancer, with a documented reduction of up to 90% in girls vaccinated before the age of 17. A single dose has been shown to provide protection against new persistent infections with HPV 16 and 18, with a success rate of up to 97.5%. The findings, when considered collectively, underscore the pivotal role of HPV vaccination in the reduction of cervical cancer rates, with the potential to eradicate the disease in many regions [22].

#### **4.4. Psychosocial Determinants**

A critical aspect of population-based screening is its psychosocial impact on participants. Although the potential for invasive procedures, such as colonoscopies, to elicit anxiety, and the possibility of false-positive results in mammography and HPV testing, may initially evoke anxiety, a comprehensive systematic review suggests that these adverse effects are generally transient.

Across breast, colorectal, and cervical cancer screenings, patients' psychological distress typically peaks during the waiting period for results or diagnostic follow-up but returns to baseline levels once clinical certainty is achieved. These findings underscore the significance of efficacious health education and transparent communication, thereby ensuring that the immediate emotional burden does not eclipse the considerable long-term mortality benefits of early cancer detection [23].

### **5. CONCLUSION**

The implementation of organised screening programmes constitutes a pivotal element in the early diagnosis of breast, colorectal, and cervical cancers during their asymptomatic phases. The early detection of precancerous lesions or nascent malignancies has been shown to significantly enhance the probability of radical, life-saving treatment while preserving the patient's overall quality of life. Despite the fact that these examinations are fully funded by public healthcare systems, such as the National Health Fund (NFZ) in Poland or the National Health Service (NHS) globally, participation rates remain suboptimal.

The phenomenon of low screening uptake is multifactorial in nature, stemming from insufficient health education as well as significant psychological and social barriers. In order to

enhance engagement, it is essential to augment public educational initiatives and cultivate stronger doctor-patient relationships, particularly at the primary care level. Furthermore, the development and promotion of less invasive screening modalities, such as FIT or HPV self-sampling, has the potential to mitigate patient anxiety and enhance the overall effectiveness of early cancer detection. The efficacy of secondary prevention in the contemporary field of oncology is contingent upon a transition from a passive approach to active population adherence.

**Disclosure:**

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