ORIGINAL ARTICLE

High participation rates are not necessary for cost-effective colorectal cancer screening

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Background: In many countries high participation is an explicit target in screening programmes. The desire for high participation often appears to drive screening policy, although it is increasingly recognized that encouraging high participation may impinge upon the rights of an individual to make an informed choice. One argument offered in support of high participation is that it improves the cost-effectiveness of screening. This is questionable on theoretical grounds, and empirically there are conflicting results. Two recent cost-effectiveness models of faecal occult blood test (FOBT) screening for colorectal cancer (CRC) showed that cost-effectiveness was improved, another showed that cost-effectiveness was worsened and a fourth indicated that cost-effectiveness was unaffected by increasing the participation rate.

Methods: We assessed the extent to which different levels and patterns of participation affect cost-effectiveness, using decision modelling of three CRC screening with FOBT scenarios. We estimate the incremental cost-effectiveness (value for money) ratios for each scenario.

Results: The way in which participation is modelled, particularly assumptions made about the subsequent screening behaviour of non-participants ('if' and 'when' a non-participant attends for subsequent screening), affects the cost-effectiveness estimates for FOBT screening programmes. 100% participation in all screening rounds gives a cost per life year saved (LYS) of US$9705. Cost-effectiveness is worst when people who do not take part in one screening round (initial or subsequent) never take part in any future rounds of screening. Under this scenario, a participation rate of 20% in second and subsequent rounds gives a cost per LYS of US$29,500. Under more realistic assumptions, for example the attendance of even a small proportion of non-participants in subsequent rounds, cost-effectiveness is more favourable and similar to that achieved for full participation: the scenario with a random participation rate of 20% in second and subsequent rounds for both participants and non-participants has a cost per LYS of US$11,270.

Conclusions: Contrary to a commonly held view, high participation in screening programmes is not necessary to achieve cost-effectiveness. Setting high target participation rates in screening programmes does not guarantee cost-effectiveness and may in certain circumstances reduce the cost-effectiveness.

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INTRODUCTION

In many countries screening programmes set explicit targets for participation, with one of the indicators of the success of mass cancer screening programmes being the participation rate of the eligible population.[1–3] The magnitude of population reduction in incidence and mortality from colorectal cancer (CRC) will depend on the rate of participation rate in screening. This view is reflected in the following statement by the International Agency for Cancer Control (IARC):

'the long term success of a screening programme depends upon participation by a substantial proportion of eligible women…'[4]

If maximizing the benefit to the population is the only objective of screening, then high participation is necessary. In a world without resource constraints, endless resources could be devoted to promote the uptake of screening services in order to maximize participation. However, publicly funded mass screening programmes operate within budget constraints and therefore the goal of any programme needs to be framed in terms of resource availability. Thus, one of the objectives of mass screening is to maximize the number of cancer deaths prevented with the available resources. There is a commonly held belief, typified by the following IARC statement, that high participation rates are also necessary to achieve this goal.

'…high participation rates … make a major contribution to the cost-effectiveness.'[4]

This assumption is contestable. In a screening programme, costs can be accrued as two main types: fixed costs, in which we include the costs of equipment, buildings and infrastructure, regular invitations and registries; and variable costs, in which we include costs of screening tests for programme participants, costs of diagnostic investigations for screen-positive people, and the cost of treatment for those found to have the disease of interest. Torgerson and Donaldson argue that participation in screening is unlikely to have much, if any, impact on the final cost-effectiveness ratio.[5] If we consider a screening programme that runs over a defined time period, for example 30 years, where the fixed costs described above are spread over the life of the programme (as is the convention), and the screening, diagnostic and treatment costs (variable costs)

are proportional to the number of participants, the participation rate is unlikely to have a large influence on the program's cost-effectiveness, as the benefits are also accrued proportional to the number of participants.[5] That is, for each round of screening, costs and benefits are likely to accrue approximately proportionally to one another and to the number of participants, all other things, including risk of disease in participants and non-participants, being equal.

This situation becomes more complicated when considering successive rounds of screening and differing patterns of participation in multiple screening rounds. Recent cost-effectiveness models of faecal occult blood test (FOBT) screening for CRC show discrepant results for the effect of participation on cost-effectiveness. Across the studies, the direction of the effect of participation on cost-effectiveness is inconsistent. None of these models included fixed costs, instead only including variable costs, and all assume the same CRC risk for all participants and non-participants, so the different results concerning cost-effectiveness and participation are not related to the inclusion, or exclusion, of fixed costs or to differential risk of CRC in participants and non-participants. Two studies by Sonnenberg *et al*.[6] and Vijan *et al*.[7] reported that higher participation made screening more cost-effective. Frazier *et al*.[8] reported that higher participation made screening less cost-effective. A fourth study by Whynes *et al*.[9] reported that participation did not influence cost-effectiveness. The influence of participation on cost-effectiveness of FOBT screening seems to be inconsistent.

Understanding the effect of participation on cost-effectiveness in mass cancer screening requires a closer examination of what is meant by participation, how it is modelled in cost-effectiveness analyses, and more generally of the role of decision models in health policy. The aim of this paper is to assess the extent to which cost-effectiveness is affected by different levels and patterns of participation, and the subsequent implications these analyses have for high participation as an objective of screening.

What is 'participation'?

Often referred to as 'compliance' or 'adherence', we use the term 'participation' as it fits better within an informed choice framework. Participation in cancer screening generally refers to the proportion of the target population who undertake the screening test, and is often reported as a single number. However, the initial screening test is only one component of a screening programme. Participation may also refer to the proportion of the eligible population taking part in second and subsequent rounds of screening, to the proportion of people with a positive screen who undergo diagnostic follow-up, and to the proportion of people taking part in surveillance testing (for example, after a positive diagnosis).

Each of these different types of participation may be influenced by other factors, such as age, previous screening history or family history of disease, and can be varied singularly or in combination with each other. This means that the 'participation rate', usually represented by a single parameter in models, will actually depict much more complicated patterns of behaviour.

The scenarios presented here examine the effect on the cost-effectiveness ratio of different patterns of participation with second and subsequent rounds, combined with changes in initial participation. All scenarios assume 100% participation in diagnostic follow-up of positive screens and surveillance after polypectomy.

METHODS

This study is based on analyses using the model kindly provided by Sonnenberg *et al*.[6] Apart from altering patterns of participation, the underlying structure of the model and variable values – for example, costs and disease risks – remain as published by Sonnenberg *et al*.[6]

The Sonnenberg model is a Markov model which begins with a cohort of 100,000 50-year olds who are offered annual FOBT screening and follows them until death. Further details on the model can be found in Sonnenberg *et al*.[6] The cohort approach is a standard method in economic modelling and has also been used in other models of CRC screening.[7–9] The initial participation rate is the proportion of patients who have the FOBT. Patients with a positive FOBT undergo colonoscopy, while those with a normal (negative) result enter the pool of patients waiting for their next FOBT in one year. If no polyp is found on colonoscopy, annual FOBT is resumed 10 years after colonoscopy; if an adenomatous polyp is found, surveillance colonoscopy is repeated every three years until polyps are no longer found. Patients who decline an FOBT in any screening round (initial or subsequent), or those with a positive FOBT who do not have a diagnostic colonoscopy enter a permanent state that Sonnenberg calls 'non-compliance' (non-participants). The probability of developing CRC is based on the age-specific incidence rate from the Surveillance, Epidemiology and End Results Program (SEER).[10] An average incidence of adenomatous polyps of 1% is used.[11,12] The number of cases of cancer prevented is based on an estimate of the efficacy of colonoscopy in reducing the incidence of CRC;[13–16] a median relative risk reduction of 75% is used. The effectiveness is measured in life years saved (LYS) through prevention of CRC and reduced mortality from earlier detection and treatment of cancer and polyps. A five-year mortality of 40% for CRC without screening is assumed.[10] With annual screening, mortality from CRC is reduced by 18%.[17]

Costs used are those reported by Sonnenberg *et al*.[6] (Table 1). Additional details of component items of group costs are available in Sonnenberg *et al*.[6] Costs for medical, surgical and diagnostic services are calculated; costs also include those for complications (bleeding or perforation) after colonoscopy. The cost of treating CRC has been included by Sonnenberg *et al*. as stage-weighted total cost of care.[18] Only variable costs (for example, costs of screening, diagnosis and treatment) are included; fixed costs (for example, costs of equipment, registers, invitations, facilities and buildings) are not included. This approach is consistent with other published models of CRC screening.[7–9] Costs are

Table 1 Costs included in Sonnenberg model

Cost item	Cost in US$ (2000)
Screening test	
FOBT	3.50
Diagnostic test	
Colonoscopy	696
Polypectomy	1004
Complications	
Bleeding	4360
Perforation	13,000
Cancer treatment	
Stage weighted total cost of care CRC	45,228

in US dollars and based on Medicare payments in 2000; costs and benefits are discounted using an annual rate of 3%.

Modelling participation in cost-effectiveness studies

The key difference between the four published cost-effectiveness models of CRC screening[6–9] is how they treat participation in second and subsequent rounds of screening, particularly the distinction made between participants and non-participants.

We created three screening scenarios (hereafter called scenarios 1, 2 and 3) to explore the effect that different patterns of participation have on cost-effectiveness. Apart from the pattern of participation, all other parameters in the three cost-effectiveness scenarios are identical. Consistent with the published cost-effectiveness models of CRC screening, our scenarios also assume that the risk of CRC is the same for participants and non-participants and that the effectiveness is equal, irrespective of the interval between screens. The costs of strategies to increase participation have also not been included in any of the models. Therefore, any differences in the cost-effectiveness estimates are attributable only to the way in which participation has been modelled. These scenarios are described in more detail in Figure 1 and the Results section.

The cost-effectiveness of different screening patterns is measured by the incremental cost-effectiveness ratio (ICER), and is reported as cost/life year saved (US$/LYS). The calculation of an incremental cost-effectiveness ratio is shown below:

$$\text{ICER} = \frac{\text{Total cost}_{\text{NEW}} - \text{Total cost}_{\text{COMPARATOR}}}{\text{Total effect}_{\text{NEW}} - \text{Total effect}_{\text{COMPARATOR}}}$$

The total cost of a screening programme ('$_{\text{NEW}}$' in the above formula), which includes screening costs and the diagnostic and treatment costs for all screen detected and interval disease, is compared with the cost of no screening ('$_{\text{COMPARATOR}}$' in the above formula), which includes the diagnostic and treatment costs of disease that would present without a screening programme. The effectiveness of a screening programme is measured in the number of years of life generated by people participating in screening, taking into account the mortality benefits from screening. This is compared with the number of years of life generated by people not participating in screening. The difference between these figures gives the number of LYS by participating in screening, compared with not screening. The cost per LYS is the ratio of the difference in costs to the difference in benefit (LYS). A lower cost per LYS represents better value for money because you can 'buy' more life years with a fixed amount of money. These analyses compare FOBT screening ('$_{\text{NEW}}$') with no FOBT screening ('$_{\text{COMPARATOR}}$').

RESULTS

Scenario 1

Scenario 1 assumes that non-participants in screening never participate in future rounds of screening; screening is offered only to people who have previously participated, and continue to do so. This is the pattern of participation that is modelled in the Sonnenberg *et al*. study.[6] In Figure 1A, we start with an eligible population of 1000 people and everyone participates in the first screening round (100% participation). In screening round 2, 60% of those who screened in round 1 (60% of 1000 = 600) take part in screening, while the remaining 40% (400) go into the pool of non-participants. In screening round 3, 60% of those who screened in round 2 (60% of 600 = 360) take part in screening, while the remaining 40% (240) get added to the pool of non-participants, giving a total of 640 from 1000 who are not participating. This pattern continues for each subsequent round of screening, meaning that the total number of people not screening gets larger with each screening round.

The effect on the cost per LYS of assuming that non-participants do not participate in any future screens ('once a non-participant always a non-participant') is illustrated in Figure 2. The cost per LYS of FOBT gets lower (improves) as the proportion of round 1 participants who continue to take part in subsequent rounds of screening approaches 100%. The cost per LYS at 100% participation is US$9705/LYS; this doubles to approximately US$20,000/LYS at 80% participation. A participation rate of 20% gives a cost per LYS of US$29,500.

The assumption of no further screening if one test is missed in this model of participation means that, as demonstrated in Figure 1, the proportion of the population not participating in screening gets rapidly larger with each screening round. When participation from round 2 onwards is set at a plausible level (e.g. 60%) approximately eight years after the screening programme commences, fewer than 10% of those alive are still being screened; that is, over 90% of people who are still alive are no longer participating in screening. This assumption means that in this model, the costs of screening are predominantly accrued when patients are younger, that is when the age-specific incidence of CRC is lower. It also means that people are no longer participating when they are older and the age-specific incidence of CRC is higher. In summary, the screening cohort in scenario 1 accrue very few benefits as they get older, but have accrued costs when they were younger.

Scenario 2

Scenario 2 assumes that a random proportion of everyone eligible, including non-participants in the initial round, takes part in future rounds of screening. The same rate of participation in round 2 onwards is applied to both participants and non-participants (Figure 1B). This is the pattern of participation modelled in the Frazier study.[8] In the example, there is an initial participation rate of 100% for screening round 1 and a 60% participation rate for all future rounds of screening, regardless of whether someone has taken part in the previous screening round. In Figure 1B, we start with an eligible population of 1000 people, and everyone participates in the first screening round. In screening round 2, 60% of those who screened in round 1 (60% of 1000 = 600) take part in screening, while the remaining 40% (400) go into the pool of non-participants. In screening round 3, 60% of those who screened in round 2 (60% of 600 = 360) and 60% of those who did not screen in round 2 (60% of 400 = 240) take part in screening; 40% of people who screened in round 2 (40% of 600 = 240) and 40% of people who did not screen in round 2 (40% of 400 = 160) do not participate in screening round 3. This means we have 600 screening participants and 400 non-participants, just as we did in screening round 2. This pattern continues for each subsequent round of screening, meaning that the total number of people screening and not screening in each round remains approximately constant.

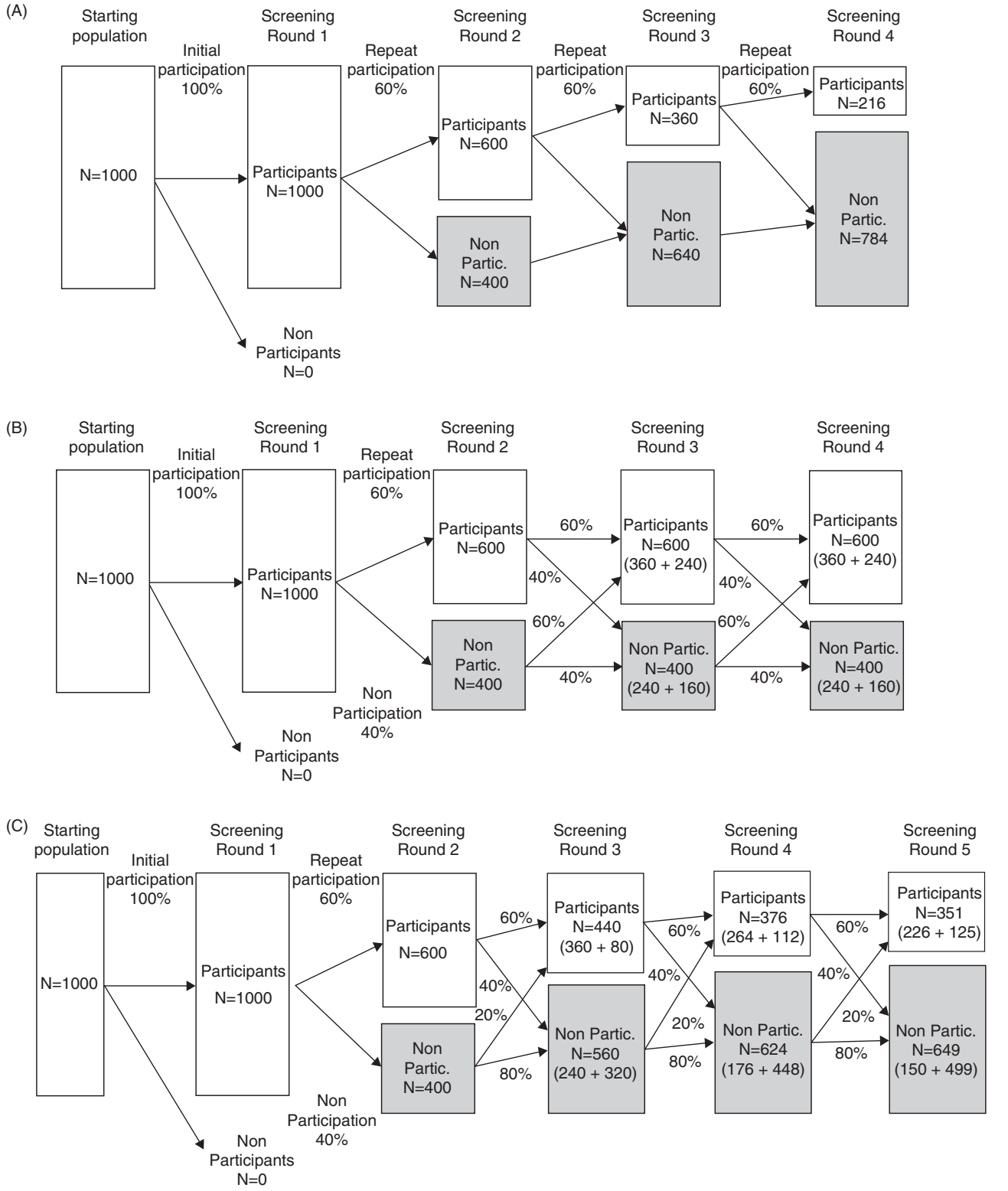

Figure 1 (A) Scenario 1: Schematic of continued non-participation (60% participation rate). (B) Scenario 2, schematic of random participation for round 2 onwards (60% participation rate). (C) Scenario 3, schematic of participation from round 2 onwards depending on previous screening behaviour (60% participation for previous participants, 20% participation for previous non-participants)

The effect on the cost per LYS of assuming that a random percentage of all those eligible for screening in each round actually participate in screening, regardless of whether they have participated previously, is shown in Figure 3. This type of participation has the effect of keeping the number of participants stable in each round, but allowing a random proportion of participants and non-participants to take part in screening in each round. For comparative purposes, the cost-effectiveness curve for Scenario 1 has also been included in Figure 3.

It is only when the rate of participation in round 2 onwards falls below 10% that there is any substantial effect on cost-effectiveness. In a situation where a high proportion of people participate in the initial round of screening, but a low proportion take part in all subsequent rounds, the cost accrued for the first round constitutes a very high

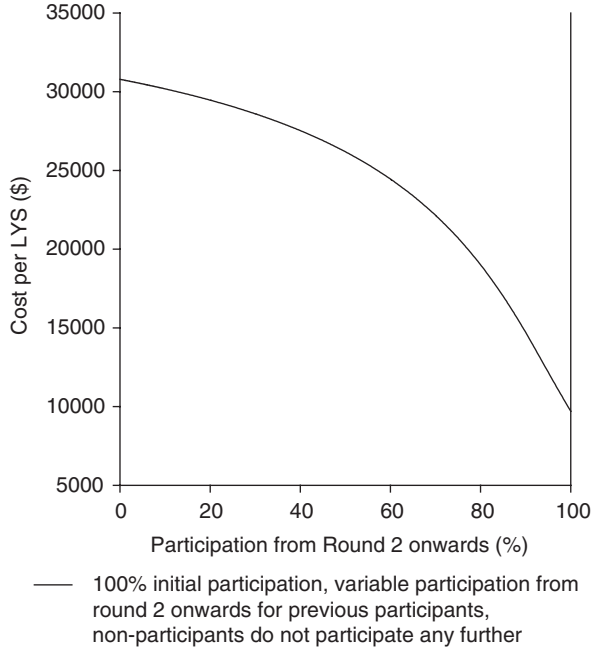

Figure 2 Scenario 1: The effect of continued non-participation on cost-effectiveness

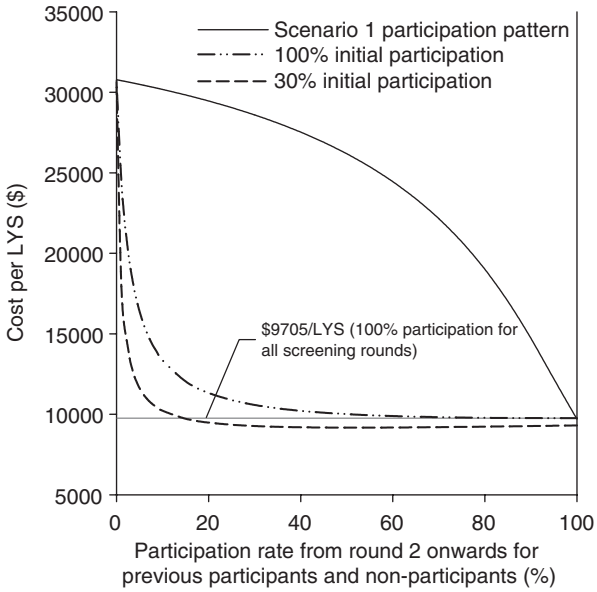

Figure 3 Scenario 2: The effect of random participation in round 2 onwards on cost-effectiveness

proportion of the total cost over the programme. We also examined the effect of less than 100% participation in the initial round (30% initial participation was modelled).

For participation of 100% in all screening rounds, the cost per LYS is US$9705. If participation in the initial round is less than 100%, the proportion of total screening costs made up by screening in the initial round is lower; therefore the cost per LYS is also lower; for example, at 30% initial participation and 20% participation from round 2 onwards, the cost per LYS is US$9,429/LYS compared with US$11,270/LYS at 100% initial participation and 20% participation from round 2 onwards. At initial participation rates of between 30% and 100%, the cost per LYS is between the values for these two rates. When the participation in round 2 onwards is greater than or equal to the participation in the initial round, the cost per LYS remains similar to or slightly better than that for full participation. In some cases this means that lower participation is more cost-effective (has a lower cost per LYS) than higher participation.

Scenario 3

In practice, it is likely that screening behaviour will fall somewhere between the two extreme cases of Scenario 1 and Scenario 2. Scenario 3 reflects this, where participation in subsequent screens is dependent upon previous screening behaviour (Figure 1C). One participation rate is applied to those who took part in the previous screen, and a different rate is applied to those who did not take part in the previous screen. We start with an eligible population of 1000 people, and everyone participates in the first screening round. In screening round 2, 60% of those who screened in round 1 (60% of 1000 = 600) take part in screening, while the remaining 40% (of 1000 = 400) go into the pool of non-participants. In screening round 3, 60% of those who screened in round 2 (60% of 600 = 360) and 20% of those who did not screen in round 2 (20% of 400 = 80) take part in screening; 40% of people who screened in round 2 (40% of 600 = 240) and 80% of people who did not screen in round 2 (80% of 400 = 320) do not participate in screening round 3. This means we have 440 screening participants and 560 non-participants. This pattern continues for each subsequent round of screening, meaning that over time the total number of people participating in each round slowly decreases, but it still allows a proportion of non-participants to take part in each round.

The impact on cost-effectiveness of modelling this scenario is presented in Figure 4. The uppermost line shows the effect of 100% initial participation and 60% participation for previous participants, with varying rates of participation for previous non-participants. The lower line indicates 30% initial participation, with 60% participation for previous participants and varying rates of participation for previous non-participants.

Figure 4 suggests that even including a small proportion of people who have not screened in the previous round keeps the cost-effectiveness ratio reasonable. It is only when the rate of participation of previous non-participants is very low (less than 10%) that there is an appreciable impact on cost-effectiveness.

With high initial participation, a constant (e.g. 60%) participation rate of previous participants and a low participation of previous non-participants, essentially the same pool of people are being screened each round. This means that each round of screening continues to accrue costs, but fewer benefits. With lower initial participation there is a larger pool of non-participants; so when the participation rate of previous non-participants is increased the total costs will remain approximately the same, as they are proportional to the total number screened, but the benefit will be greater because there are more people who have not screened previously and therefore have disease to be detected. This means cost-effectiveness is improved because the total benefits are greater; that is, there is a higher payoff for the same cost. For example, with fixed initial 100% participation, 60% participation of those screened in the previous round and 20% participation of those not screened in the previous round, the cost per LYS is US$10,885/LYS. When initial participation is decreased to 30%, the cost per LYS is US$9127/LYS. This means that in

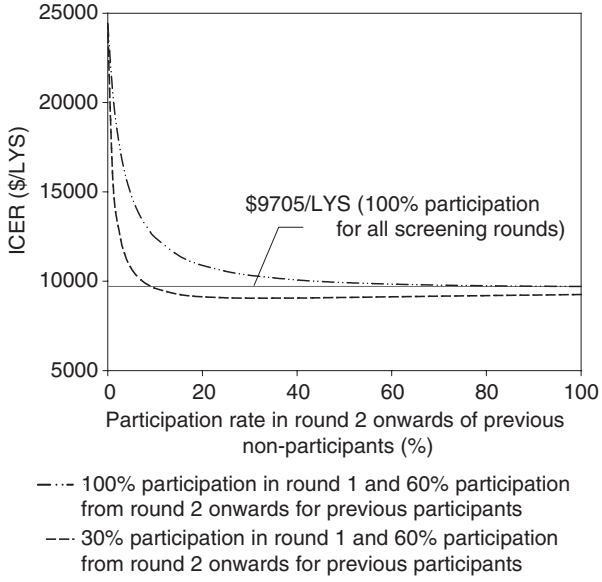

Figure 4 Scenario 3: The effect of differential re-participation and initial participation on cost-effectiveness

some cases lower participation (particularly initial participation) is actually more cost-effective than full participation in all screening rounds, which has a cost per LYS of US$9705/LYS. This effect is consistent across a range of participation rates for previous participants.

DISCUSSION

In many countries screening programmes set explicit targets for participation, with one of the indicators of success of mass cancer screening programmes being the participation rate of the eligible population.[1–3] One argument offered in support of this is that high participation improves cost-effectiveness. However, recent cost-effectiveness models of FOBT screening for CRC showed inconsistent results concerning the effect of participation on cost-effectiveness.[6–9] We have demonstrated that the discrepancy in cost-effectiveness results between these three models is explained by how each model treats participation in second and subsequent rounds of screening, particularly the distinction they make between participants and non-participants.

High participation is not always necessary to achieve a cost-effective CRC screening programme. Yet the assumptions made about participation and how it is modelled can substantially influence the apparent cost-effectiveness of CRC screening. The cost per LYS is highest (worst) when people who do not take part in one screening round never screen again; that is, they are removed from the pool of eligible screening participants. Attendance of even a small proportion of these non-participants in some subsequent screens makes the cost per LYS more favourable and similar to that achieved for full participation. It is only when participation from round 2 onwards falls below 10% that the cost-effectiveness significantly worsens. Yet, under some plausible circumstances, low participation is more cost-effective than full participation. At equal rates of participation in second and subsequent rounds, higher initial participation has worse cost-effectiveness than lower initial participation, because high initial participation carries the same cost but fewer benefits in screening for age-related cancers.

Although there is some information in the literature regarding participation,[19–23] information on patterns of behaviour is insufficient to form the basis of an accurate set of model assumptions. Further information is needed on the patterns of screening behaviour of eligible participants in screening, not only on the frequency of attendance, but also on the intervals between screens. We should use existing screening programmes to collect data on actual attendance patterns which could then inform cost-effectiveness estimates and subsequently guide screening policy.

Two additional issues should be considered in future models of CRC screening. First, the current published models, and our scenarios, assume the same underlying risk of CRC for participants and non-participants. Participation in screening has been positively associated with socioeconomic status.[24] In other cancers, for example breast cancer, there is evidence to suggest that women of higher socioeconomic status have a higher underlying risk of disease, suggesting that participants may have a higher risk of disease than non-participants.[25–27] To accurately model cancer screening, empirical data are needed on the possible differences in risk of CRC between participants and non-participants.

Second, published models often assume that each screen will have an equivalent effect in decreasing incidence and mortality from CRC. However, the cost-effectiveness will depend on screening behaviour of the target population. With lower initial participation, there is a larger pool of 'non-participants'; so when the participation rate of previous non-participants is increased the total costs will remain approximately the same, as they are proportional to the total number screened, but the benefit will be greater because there are more people who have not screened previously and therefore have disease to be detected. This means that cost-effectiveness is improved because the total benefits are greater; that is, there is a higher payoff for the same cost. This is akin to commencing screening at an older age when the balance of potential benefit to harms or costs is likely to be more favourable from both the individual and the programme perspectives.

Increasing the frequency of screening would result in a lower yield of polyps and early cancers per screen and therefore worse cost-effectiveness. Taking this issue into account would make lower participation even more cost-effective than demonstrated here.

International health policy bodies (United States Preventive Services Task Force,[28] UK National Screening Committee,[29] Canadian National Committee on CRC Screening,[30] National Health and Medical Research Council of Australia[31]) recommend that clinicians screen men and women aged 50 years or older for CRC at least every two years. The UK National Screening Committee has recently recognized the need for informed choice in screening,[32] whereby individuals are given information on the harms and risks of screening as well as benefits. However, target (high) participation rates remain an objective of screening services.[2,3] There is a concern that the need for informed choice in screening[32,33] may lower the participation rate.[1–3] This concern is based on the assumption that informed choice will decrease uptake of screening.[33] Even if informed choice does lower participation, and there is little evidence to suggest that this does happen,[34,35] our results indicate that screening can still be cost-effective even with low rates of participation. Advocating informed choice is likely to not compromise the cost-effectiveness of screening; indeed, in some situations it may be improved.

Contrary to a commonly held view, high participation in CRC screening programmes is not necessary to achieve cost-effectiveness. Setting high target participation rates as a programme objective[1–3] does not guarantee cost-effectiveness. CRC screening with FOBT can be as – or even more – cost-effective at low rates of participation.

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