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Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-007226
Article Type:	Research
Date Submitted by the Author:	17-Nov-2014
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Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Health economics, Health services research
Keywords:	Physical Activity, Economic evaluation, Cost effectiveness, behaviour change, mHealth, Australia

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The cost-effectiveness of the *MobileMums* intervention to increase physical activity among mothers with young children

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Word count (excluding title page, abstract, references, figures, and tables): 3,544

ABSTRACT

Objectives

To determine the cost-effectiveness of the *MobileMums* intervention. *MobileMums* is a 12-week programme which assists mothers with young children to be more physically active, primarily through the use of personalised SMS text-messages

Design

A cost-effectiveness analysis using a Markov model to estimate and compare the costs and consequences of *MobileMums* and usual care.

Setting

This study considers the cost-effectiveness of *MobileMums* in Queensland, Australia.

Participants

A hypothetical cohort of over 36,000 women with a child under one year old is considered. These women are expected to be eligible and willing to participate in the intervention in Queensland, Australia.

Data sources

The model used is informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011. Baseline characteristics for the model cohort, treatment effects, and resource utilisation were all informed by this trial.

Main outcome measures

The incremental cost per quality-adjusted life year (QALY) of *MobileMums* compared with usual care.

Results

The intervention is estimated to lead to an increase of 252 QALYs for an additional cost to the health system of 1.1 million AUD. The expected incremental cost-effectiveness ratio for *MobileMums* is 4,348 AUD per QALY gained. MobileMums has a 98% probability of being cost-effective at a cost-effectiveness threshold of 64,000 Australian dollars (AUD). Varying modelling assumptions has little effect on this result.

Conclusions

At a cost-effectiveness threshold of 64,000 AUD, MobileMums would likely be a cost-effective use of health care resources in Queensland, Australia.

ARTICLE SUMMARY

Article focus

- This paper estimates the cost-effectiveness of the *MobileMums* intervention for Queensland, Australia.

Key messages

- *MobileMums* is likely a cost-effective use of health care resources in Queensland, Australia.

Strengths and limitations of the study

- The analysis is informed by the results from a recent two-arm randomised controlled trial of *MobileMums* and usual care.
- Uncertainty around the costs and consequences of *MobileMums* and usual care has been quantified and has little effect on the conclusions of the analysis.
- The simplicity of the model means that some potentially important effects may have been missed. As physical activity levels were split into only two categories, small changes in an individual's activity would likely not be valued.

INTRODUCTION

Physical inactivity is a leading cause of lost years of healthy life in high-income countries, where chronic diseases are a leading cause of mortality and morbidity.[1] An insufficient level of physical activity, defined as less than 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week, is directly associated with a number of diseases including coronary heart disease, type 2 diabetes, breast cancer and colon cancer.[2] Physical inactivity is also indirectly linked to the negative health consequences of high body mass and high blood pressure, which include many of the aforementioned chronic conditions.

Fifty-seven percent of Australia's adult population were insufficiently active in 2011–12.[3] Begg et al.[4] estimate that 6.6% of the total disease burden in Australia is caused by physical inactivity, explaining around 24% of both cardiovascular disease and diabetes, and around 6% of all cancers. Based on these results, Cadilhac et al.[5] estimate that each year insufficient physical activity causes 45,000 new cases of disease which are associated with a loss of 174,000 disability-adjusted life-years in Australia. Inequalities in activity levels exist, with inactivity more likely in older people, those of lower socioeconomic status, those outside of major cities, and women.[6] Indeed, women with young children are more likely to be physically inactive than both women with no children[7, 8] and women with older children,[9, 10] and it is this group who are the focus of the *MobileMums* intervention evaluated here.

The *MobileMums* programme is a 12-week intervention which designed to assist women with young children increase their physical activity. The intervention's development has previously been discussed.[11] *MobileMums* is initiated with a face to face consultation between the participant and a trained behavioural counsellor. The consultation is used to establish rapport between the participant and counsellor, to gather information required to tailor text-message content and to initiate process of behaviour change through personalised goal setting.[11] Participants receive five text-messages per week during weeks 1 to 4 of the intervention and four messages per week during weeks 5 to 12. The messages are personalised based on the participant's name, the name of their counsellor, the participant's goals and their expected rewards and outcomes for achieving these goals. In addition to receiving the text-messages, participants also have access to a programme handbook, an on-line exercise directory and a Facebook© group. They also receive a refrigerator magnet for self-monitoring and various information brochures on physical activity. As well as requiring behavioural counsellors, delivering the intervention requires programme coordinators to manage the counsellors, assign participants to a counsellor, oversee the text-messages being sent and received, and organise the delivery of other programme materials to participants.

In Australia health resources are generally allocated on a state or territory basis[12] and so a decision on whether to fund *MobileMums* would be made by individual states or territories. The alternative course of action would be to provide usual care. The purpose of this paper is to consider this decision of whether to provide *MobileMums* or usual care from the perspective of Queensland Health, the government department responsible for managing the public health system in Queensland, Australia.

It is assumed that the overarching objective of Queensland Health is to maximise population health subject to their budget. This, therefore, supports the need for an economic evaluation of *MobileMums* to consider the intervention's value for money. While this evaluation is specific to the funding decision faced by Queensland Health, it can be expected that the results reported here will be directly applicable to similar decisions in other Australian states and territories. The generalisability of the results to other high-income countries may be more limited, for example because of differences in the volume and cost of resource use between countries,[13] but the results are likely to be of relevance for all countries experiencing high levels of physical inactivity.

METHODS

Study population

It is expected that *MobileMums* would be offered to all women with children under one year old in Queensland, Australia. With 61,020 women giving birth in Queensland in 2010 and with 413 fetal deaths,[14] the number of women eligible for the intervention in 2011 was 60,607. Based on the randomised control trial conducted in 2011,[15] where of the 511 women assessed for eligibility 306 commenced the baseline assessment, we can expect around 60% of those women who are offered the intervention to participate. This gives 36,364 women in Queensland who would be eligible and willing to participate in the *MobileMums* intervention in 2011, and this is the baseline cohort size considered for this study. This participation estimate is likely conservative as the program would not include the time-consuming assessments that were undertaken purely for research purposes

Modelling health outcomes and costs

A state-based Markov model provides the framework for this analysis and is used to estimate the costs and consequences associated with *MobileMums* and usual care. The development of the model has been informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011. 263 women from around Caboolture, Queensland, received usual care (n=130) or the *MobileMums* intervention (n=133).[15] Data were collected prior to the intervention being received (time 1 – T1: 0 months), after the 12-week *MobileMums* programme was completed (T2: 3 months) and again after a further 6 month no-contact maintenance period (T3: 9 months). The main efficacy findings from the trial have been reported in detail by Fjeldsoe et al.[15] Briefly, while the intervention had a large and statistically significant beneficial effect on activity levels between T1 and T2, there was no statistically significant effect at T3, although the estimated increase in activity remained positive.

These results suggest that *MobileMums* can only be expected to have an effect on activity levels in the short-term. Under the assumption that only long-term changes in activity levels affect the risk of an individual developing future chronic health conditions, the time horizon of the model used here is two years. There are just two states in the model with participants either 'physically inactive' or 'physically active', and an individual is required to be undertaking 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week to be classified as active. An effective physical inactivity intervention increases the likelihood that inactive individuals become active (tpImprove) and/or reduces the likelihood that active individuals become inactive (tpRegress). Individuals move between states using monthly cycles, and spending a month as active or inactive has a cost and health outcome associated with it (described below). An outline of the model is in figure 1.

Health effects

To allow the value for money of *MobileMums* to be compared against interventions across the health system, health effects are expressed in terms of quality-adjusted life-years (QALYs). Given the design of the model used, *MobileMums* can only affect health-related quality-of life, with no mortality effects. The health-related quality-of-life associated with being physically active or inactive was estimated from participants' responses to SF-12 questionnaires at T1, T2 and T3. Missing questionnaire data at each time period (1% of participants at T1, 13% at T2, and 32% at T3) was excluded under the assumption that the missing data bore no relation to observed or unobserved factors in the population. A couple of errors were made in the printing of the SF-12 questionnaires. First, at T1 one question from the SF-12 was omitted in error, and so scores were randomly generated for this dimension. Second, one of the questions offered one too many potential responses at all time periods, and so those who selected this superfluous response were evenly split and moved into either the next best or next worst choice.

Questionnaire were transformed into the EQ-5D, a standardised measure of health outcomes, using an algorithm provided by Gray et al.[16] This provided health-related quality-of-life scores associated with spending a year as physically active or inactive which could range between 0 (equivalent to death) and 1 (equivalent to perfect health). Monthly scores were simply one-twelfth of this. QALYs and costs in the second year were discounted at 5% following the relevant guidelines.[17, 18]

Costing perspective

This study is intended to inform decision making regarding resource allocation across the health system in Queensland. While costs and benefits falling outside of the health system, such as the cost to participants of purchasing goods or services related to undertaking exercise, may be of relevance, there are significant methodological issues in incorporating these effects into the analysis.[19] Consequently, a health system perspective is taken here, with only the costs borne by the health system included. All costs reported are in 2011 AUD and any costs accruing in the second year of the model have been discounted at 5% in line with guidelines for submission to the Medical Services Advisory Committee[17] and the Pharmaceutical Benefits Advisory Committee[18] in Australia.

The estimated cost of providing *MobileMums* across Queensland is based on the costs of delivering the intervention in the randomised controlled trial. [15] To extrapolate these costs assumptions have been required concerning number of behavioural counsellors and programme coordinators required for widespread dissemination. It is assumed that counsellors could be assigned to 30 participants per week while coordinators could cover five counsellors and their participants per week. Counsellors and coordinators are assumed to be health practitioners with, on average, 2 years in their current role and, in terms of Queensland Health's salary scale,[20] paid at a HP3 and a HP4 level, respectively. The costs of developing the computer programme to send text-messages, sending the text- messages and providing other programme materials are assumed to be the same as in the trial.

In addition to the costs of delivering the intervention, the costs relating to participants health care use have also been incorporated. If the intervention reduces future health care use then the cost saving associated with this can be compensate at least part of the cost of delivering *MobileMums*. Participants' reported their use of health care services at T1, T2 and T3 and the average use of those who were physically active and inactive were estimated. As with the SF-12, missing data was excluded (0% of participants at T1, 12% at T2, and 31% at T3). The associated costs were estimated using the Medicare Benefits Schedule for July 2011[21] and Australian hospital statistics.[22]

Expected effects

If *MobileMums* is expected to improve health and reduce costs or reduce health and increase costs then the implications are clear, with the intervention 'dominant' and 'dominated' respectively.[23] However, if *MobileMums* is expected to improve health but increase costs, or reduce health but also reduce costs, then this motivates the estimation of the expected incremental cost effectiveness ratio for *MobileMums* compared against usual care. This ratio is given by the change in costs caused by the intervention divided by the change in QALYs. This can then be compared against the cost-effectiveness threshold. The threshold used here is 64,000 AUD which is based on the estimate by Shiroiwa et al.[24] of the willingness-to-pay for an additional QALY in Australia. If the cost effectiveness ratio for *MobileMums* falls below 64,000 AUD then the intervention can be deemed 'cost-effective'.

Uncertainty

Parameter uncertainty was quantified using Monte Carlo simulations, with the model evaluated 10,000 times, with each simulation involving random draws from each parameter distribution. These distributions are based on the trial data, with transition probabilities and QALYs given beta distributions, while health use and costs are assigned gamma distributions and uniform distributions, respectively. This produces 10,000 sets of incremental costs and effects, and these are presented on a cost-effectiveness plane along with the expected costs and effects and the cost-effectiveness threshold. The probability that *MobileMums* is cost-effective is given by the proportion of sets of costs and benefits at which the intervention would be considered cost-effective. The proportion of sets where the change in QALYs is positive and the change in effect is negative is equal to the probability that *MobileMums* is cost-saving. It is also possible to estimate credible intervals around the expected change in costs and QALYs by taking percentiles of the costs and QALYs produced in the Monte Carlo analysis.[25]

Uncertainty also exists surrounding the modelling assumptions. In particular, three areas stand out for particularly onerous assumptions: transition probabilities after nine months (T3), the number of programme counsellors and coordinators required, and the number of women who would be eligible and willing to participate in the trial. The assumptions used for these areas are the subject of scenario analyses. First, the model is reassessed under the assumption that after T3 all programme activity effects are mitigated entirely, and then again under the assumption that the estimated treatment effect observed at T3 is maintained for a further 15 months, at which point the treatment effect is entirely mitigated. Second, the number of counsellors and coordinators required is increased by 50% and reduced by 50%. And lastly, increasing the cohort size by 50% and reducing it by 50% is considered.

RESULTS

Average effects

The input variables are detailed in Table 1. Around 70% of the women entering the model at T1 are expected to be physically inactive. Under usual care there is a small and gradual expected positive net movement from inactive to active over time, and after 24 months around 35 percent of the initial cohort are expected to be in the active state. The expected effect of *MobileMums* is to cause a substantial increase in physical activity over the duration of the 12-week intervention, with 50 percent of the participants expected to be in the active state at T2. Following the intervention gradual reduction in the proportion of active participants each month is expected, until after 16 months whereby the effect of *MobileMums* has been mitigated entirely. These expected changes in activity levels are presented in figure 2.

		Mean	**Distribution**
Probability of being inactive at T1		0.71	Beta
Probability of moving from inactive to active (tpImprove)	Usual Care (T1 to T2)	0.21	Beta
	MobileMums (T1 to T2)	0.36	Beta
	Usual Care (T2 to T3)	0.15	Beta
	MobileMums (T2 to T3)	0.28	Beta
Probability of moving from active to inactive	Usual Care (T1 to T2)	0.44	Beta

(tpRegress)	MobileMums (T1 to T2)	0.18	Beta
	Usual Care (T2 to T3)	0.29	Beta
	MobileMums (T2 to T3)	0.44	Beta
Yearly health care costs (AUD per participant)	Physically active	56.25	Uniform
	Physically inactive	76.24	Uniform
Cost of delivering MobileMums (AUD per participant)		58.65	Uniform
EQ5D score	Inactive	0.76	Beta
	Active	0.82	Beta

Table 1 Input variables for the Markov model

Time spent in the active state is expected to provide slightly higher utility than time spent in the inactive state, with a year spent as physically active associated with a health-related quality-of-life score of 0.79 compared with 0.76 for a year spent as physically inactive. As *MobileMums* is expected to increase the total number of months spent by the cohort in the active state, the intervention can therefore also be expected to improve health-related quality-of-life. Over 24 months, *MobileMums* is estimated to lead to an increase of 252 QALYs across the cohort of 36,364 women or, equivalently, 0.0069 QALYs per person.

The expected cost of delivering *MobileMums* to the cohort is 2,132,912 AUD, or 59 AUD per person. The breakdown for this cost is shown in Table 2. Almost half the cost is due to the behavioural counsellors. While there are significant costs associated with setting up the programme, such as the development of a computer programme to send personalised text-messages, these costs are of little consequence with a cohort of 36,364 women.

		Total cost (AUD)	Cost per participant (AUD)
Development of the computer program for sending automated text-messages		13,300	0.37
Sending text-messages		581,460	15.99
Providing additional programme materials		581,824	16.00
Behavioural counsellors (24 required)	Salaries	410,700	11.29
	Equipment	33,924	0.93
	Travel costs	363,640	10.00
Programme coordinators (5 required)	Salaries	114,464	3.15
	Office costs	33,600	0.92
Total		2,132,912	58.65

Table 2 Estimated costs of delivering MobileMums in Queensland, Australia

Based on data from the trial it is estimated that active individuals cost the health system 56 AUD a month on average, while inactive individuals cost 76 AUD per month. As *MobileMums* reduces the average number of months spent in the inactive state, the cost of delivering the intervention is partly offset by an expected reduction in health care costs. As a result, the total expected incremental cost to the health system from introducing *MobileMums* is 1,125,706 million AUD, or 31 AUD per person.

With an expected (mean) incremental cost of 1,125,706 million AUD and an incremental improvement in health outcomes of 252 QALYs, the cost-effectiveness ratio for *MobileMums* is approximately 4,348 AUD per QALY gained. At a cost-effectiveness threshold of 64,000 AUD, the intervention can therefore be expected to be cost-effective.

Uncertainty

The incremental costs and consequence produced by the Monte Carlo simulations are in figure 3. *MobileMums* has a 98% probability of being cost-effective at a threshold of 64,000 AUD (98% of simulations are below the sloped threshold line). The intervention has around a 20% probability of being cost-saving and health-improving (20% of simulations in the south-east quadrant).

The results from the scenario analysis are presented in Table 3. None of the changes in assumptions had any substantial effect on the probability that *MobileMums* is cost-effective at a threshold of 64,000 AUD, which remained over 95% under all scenarios. Changes in the assumption surrounding the maintenance of changes in activity levels into the future did, however, have a substantial effect on the probability that *MobileMums* is cost-saving. If changes were entirely mitigated after 9 months (T3) then the intervention would only have a 1% chance of being cost-saving while if the observed difference in activity levels at T3 was maintained for up to 24 months *MobileMums* would have a 35% probability of being cost-saving.

	Mean change (95% credible interval) caused by *MobileMums*			Probability *MobileMums* is	
Scenario	**Total costs (AUD)**	**QALYs**	**Expected (mean) ICER**	**Cost-effective***	**Cost-saving**
Base case	1,125,705 (1,101,935 to 1,149,475)	252 (247 to 257)	4,466	98%	20%
Changes in activity levels entirely mitigated at 9 months (T3)	1,309,558 (1,300,044 to 1,319,072)	206 (204 to 208)	6,358	97%	1%
Changes in activity levels maintained from 9 months to 24 months	1,085,903 (1,060,112 to 1,111,693)	262 (257 to 267)	783	94%	35%
Number of counsellors and coordinators required increased by 50%	1,422,049 (1,398,018 to 1,446,080)	252 (247 to 257)	5,642	97%	16%
Number of counsellors and coordinators required reduced by 50%	829,361 (805,626 to 853,096)	252 (247 to 257)	3,290	98%	24%
Cohort size increased by 50%	1,648,576 (1,612,503 to 1,684,649)	378 (370 to 386)	4,360	98%	21%
Cohort size reduced by 50%	584,309 (572,414 to 596,204)	126 (124 to 128)	4,636	97%	17%

ICER: incremental cost-effectiveness ratio

* at a threshold of 64,000 AUD

Table 3 Results from the scenario analysis to examine whether the intervention remains cost-effective for a range of assumptions.

DISCUSSION

Principal findings

The results from this study suggest the *MobileMums* intervention would be a cost-effective use of health resources in Queensland, Australia. While the expected health benefits of the intervention are only 0.0069 QALYs per person, the intervention is expected to cost just 31 AUD per person. Consequently, the expected cost-effectiveness ratio is 4,465 AUD per QALY is far below the estimated willingness to pay for an additional QALY in Australia of 64,000 AUD.[24] Neither parameter nor modelling uncertainty have a substantial effect on this conclusion.

Study strengths and limitations

This study has been largely informed by the results of a recent 9-month randomised controlled trial. By using a decision-analytic model, it has been possible to extrapolate these findings to consider the costs and consequences of *MobileMums* if it were offered in practice to a large cohort of women and to take into account those costs and consequences that can be expected to occur beyond the trial's time horizon. And while such an approach does require a number of assumptions, these assumptions have been the subject of sensitivity analyses which have shown them to have little effect on the overall conclusion that the intervention is likely cost-effective.

With the effect of *MobileMums* on activity levels expected to last for less than two years, and under the conservative assumption that only longer-term changes in activity will affect the risk of an individual developing future chronic health conditions, the model used here is only required to have a short-time horizon. The simplicity of the model used, with only two health states, has advantages, particularly for ease of exposition. However, there are limitations. In particular, only those changes in activity enough to move participants between the two states of the model are captured, with any changes of activity levels within a state overlooked.

Comparison with other studies

While a number of economic evaluations of physical activity interventions have been undertaken, there is significant methodological heterogeneity making direct comparisons difficult in many cases. Of those studies which use a similar methodology to this one, i.e. using a decision-analytic model as a framework for analysis with the cost per quality-adjusted (or disability-adjusted) life-year, many of the interventions analysed are found to be cost-effective. For example, the 'green prescription' programme in New Zealand is found to have an incremental cost of 3,000 AUD per QALY,[26] while the '10,000 Steps Ghent' intervention is found to be cost-saving.[27] However, the cost-effectiveness of such physical activity intervention is by no means guaranteed. Cobiac et al.[28] find that a GP referral to exercise scheme has an incremental cost of 100,000 AUD per QALY, while a 8-week social support programme is found by Roux et al.[29] to have an incremental cost of 95,000 AUD per QALY.

Interestingly, while these other studies typically assumed that the benefit from physical activity interventions was only through reducing the incidence of future chronic diseases, this study demonstrates that there is also likely an immediate improvement in health-related quality-of-life. Active participants in the trial of *MobileMums* reported higher health-related quality-of-life than those who were physically inactive, which made it possible for *MobileMums* to be expected to be cost-effective even without any long-term changes in activity levels. With this immediate improvement in quality-of-life missed in most analyses of physical activity interventions, these studies may well have underestimated the full benefits from effective physical activity interventions.

Policy implications

Health prevention programmes in Queensland, and across Australia, have recently been going through a period of disinvestment. However, if the goal of the health system is to maximise health outcomes then there seems little reason for prevention health interventions to be treated any differently than a curative intervention. Health care resources should be directed to those uses which provide best value for money, i.e., the greatest improvement in health outcomes for a given level of cost. *MobileMums* can be expected to provide good value for money and is likely a cost-effective use of resource given the estimated willingness-to-pay for an additional QALY in Australia.

There seems little reason to expect that this conclusion would be different in other states and territories in Australia. Levels of physical inactivity can be expected to be similar across Australia as can the effects of the intervention. In addition, costs, such as those associated with the counsellors and coordinators should comparable. While differences in costs such as these make it more difficult to generalise these results to other countries, the results of this study are still likely to be of relevance in many high-income countries with similarly high levels of physical inactivity.

CONCLUSION

MobileMums can be expected to be a cost-effective use of health resources in Queensland, Australia. If the objective of Queensland Health is to maximise population health outcomes given their budget, *MobileMums* should be freely provided.

Figure 1 Outline of the Markov model used to estimate the costs and effects of *MobileMums* and usual care

Figure 2 The expected (mean) effect of *MobileMums* on activity levels

Figure 3 Cost-effectiveness plane for *MobileMums* versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD

ACKNOWLEDGEMENTS

Computational resources and services used in this work were provided by the High Performance Computer and Research Support Unit, Queensland, University of Technology, Brisbane, Australia.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: AM, YM, BF, NG

Performed the experiments: AM, YM, AB, BF, NG

Analysed the data: EB, NG

Wrote the paper: EB, AM, YM, AB, NG

FUNDING INTERESTS

This study was supported by a National Health and Medical Research Council project grant number 614244.

COMPETING INTERESTS

None

ETHICS APPROVAL

The trial used to inform this analysis was registered with the Australian Clinical Trials Registry (ACTRN12611000481976). Ethical clearance was obtained through the Queensland University of Technology Human Research Ethics Committee (Application number 0900001407).

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed

DATA SHARING STATEMENT

The full data set is available by emailing the first author of the study.

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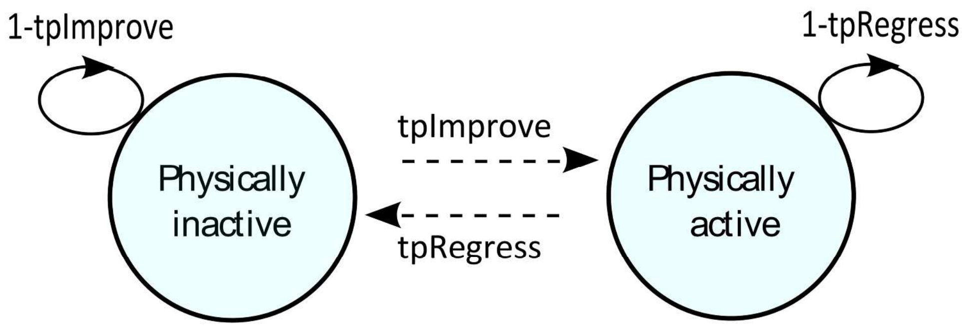
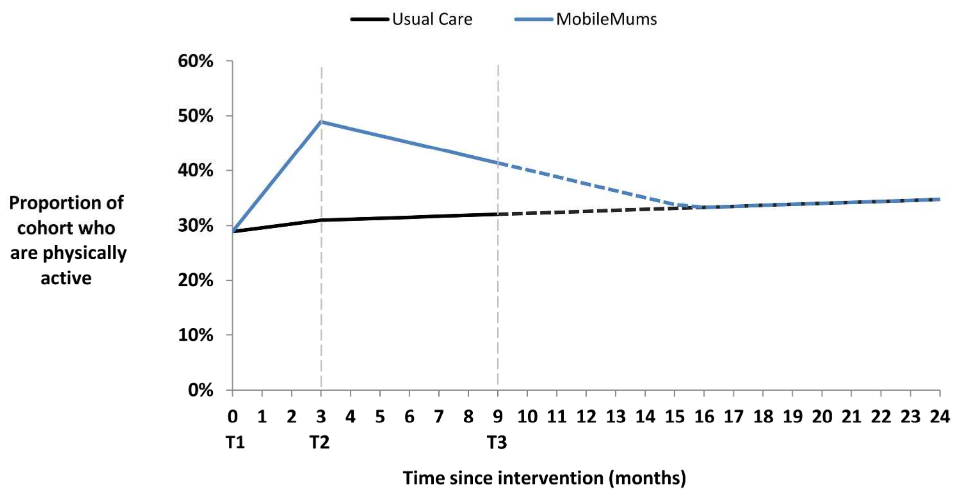
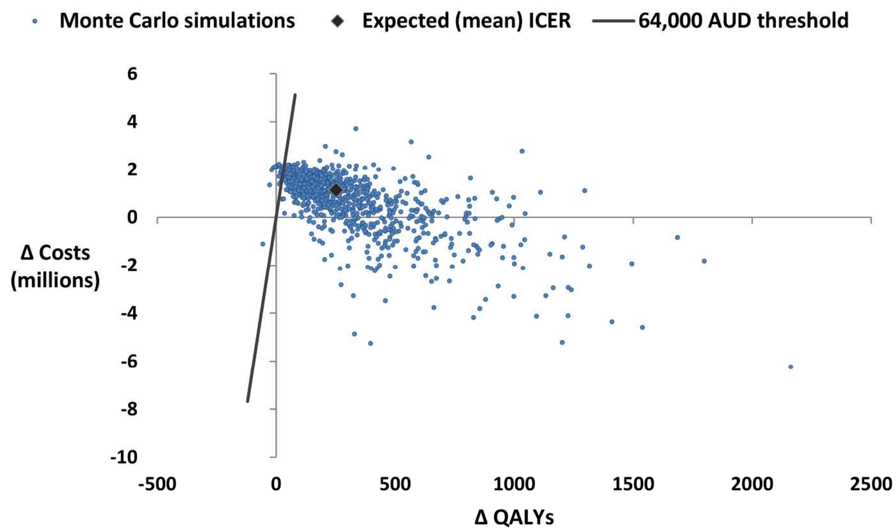


Outline of the Markov model used to estimate the costs and effects of MobileMums and usual care
115x41mm (600 x 600 DPI)



The expected (mean) effect of MobileMums on activity levels
146x79mm (600 x 600 DPI)



Cost-effectiveness plane for MobileMums versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD
147x87mm (600 x 600 DPI)

The CHEERS Checklist is part of the CHEERS Statement. The CHEERS Statement has been endorsed and co-published by the following journals:

BJOG: An International Journal of Obstetrics and Gynaecology
BMC Medicine 2013; 11:80
BMJ 2013;346:f1049
Clinical Therapeutics 27 March 2013 (Article in Press DOI: 10.1016/j.clinthera.2013.03.003)
Cost Effectiveness and Resource Allocation 2013 11:6.
The European Journal of Health Economics 2013 Mar 26. [Epub ahead of print]
International Journal of Technology Assessment in Health Care
Journal of Medical Economics 2013 Mar 25. [Epub ahead of print]
Pharmacoeconomics 2013 Mar 26. [Epub ahead of print]
Value in Health 2013 March - April;16(2):e1-e5

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page 1, Line 3-4
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page 2, Line 3-47
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Page 4, Line 42-57
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 5, Line 5-16
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 4, Line 42-
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 1, Line 12-42
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 4, Line 42-44
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Page 5, Line 32-43
Discount rate	9	Report the choice of discount rate(s) used for costs and	Page 6, Line 19-21

		outcomes and say why appropriate.	
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 5,6 Line 45- 57, 3-11
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	Page 5 Line 17-43
	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Page 6 Line 6-11
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Page 6 Line 12-42
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 6 Line 12- 42
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 5 Line 17- 43
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Page 7 Line 17-27
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 5, 6 Line 50-56, 40-42
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 7,8 Line 45- 57, 3-18

Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	Page 7,8,9 Line 30-57, 3-57, 3-7
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Page 8 Line 8-52,
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 10, 11 Line 3-58, 3-14
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 11 Line 52-55
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 11,12 Line 57, 3

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The CHEERS Statement may be accessed by the publication links above.

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

The citation for the CHEERS Task Force Report is:
Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS)—Explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231-50.

BMJ Open

The cost-effectiveness of the MobileMums intervention to increase physical activity among mothers with young children: a Markov model informed by a randomised controlled trial

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-007226.R1
Article Type:	Research
Date Submitted by the Author:	05-Feb-2015
Complete List of Authors:	Burn, Edward; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Marshall, Alison; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Miller, Yvette; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Barnett, Adrian; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI); Queensland University of Technology, Institute of Health and Biomedical Innovation Fjeldsoe, Brianna; The University of Queensland, School of Population Health Graves, Nicholas; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI)
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Health economics, Health services research
Keywords:	Exercise, Economic evaluation, Cost effectiveness, mHealth, behaviour change

The cost-effectiveness of the *MobileMums* intervention to increase physical activity among mothers with young children: a Markov model informed by a randomised controlled trial

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Keywords: Exercise, Economic evaluation, Cost effectiveness, mHealth, behaviour change

Word count (excluding title page, abstract, references, figures, and tables): 3,906

ABSTRACT

Objectives

To determine the cost-effectiveness of the *MobileMums* intervention. *MobileMums* is a 12-week programme which assists mothers with young children to be more physically active, primarily through the use of personalised SMS text-messages.

Design

A cost-effectiveness analysis using a Markov model to estimate and compare the costs and consequences of *MobileMums* and usual care.

Setting

This study considers the cost-effectiveness of *MobileMums* in Queensland, Australia.

Participants

A hypothetical cohort of over 36,000 women with a child under one year old is considered. These women are expected to be eligible and willing to participate in the intervention in Queensland, Australia.

Data sources

The model was informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011. Baseline characteristics for the model cohort, treatment effects, and resource utilisation were all informed by this trial.

Main outcome measures

The incremental cost per quality-adjusted life year (QALY) of *MobileMums* compared with usual care.

Results

The intervention is estimated to lead to an increase of 131 QALYs for an additional cost to the health system of 1.1 million Australian dollars (AUD). The expected incremental cost-effectiveness ratio for *MobileMums* is 8,608 AUD per QALY gained. MobileMums has a 98% probability of being cost-effective at a cost-effectiveness threshold of 64,000 AUD. Varying modelling assumptions has little effect on this result.

Conclusions

At a cost-effectiveness threshold of 64,000 AUD, MobileMums would likely be a cost-effective use of health care resources in Queensland, Australia.

ARTICLE SUMMARY

Article focus

- This paper estimates the cost-effectiveness of the *MobileMums* intervention for Queensland, Australia.

Key messages

- *MobileMums* is likely a cost-effective use of health care resources in Queensland, Australia.

Strengths and limitations of the study

- The analysis is informed by the results from a recent two-arm randomised controlled trial of *MobileMums* and usual care.
- Uncertainty around the costs and consequences of *MobileMums* and usual care has been quantified and has little effect on the conclusions of the analysis.
- The model's simplicity, with physical activity levels split into only two categories, means that small changes in an individual's activity would likely not be valued.

INTRODUCTION

Physical inactivity is a leading cause of lost years of healthy life in high-income countries, where chronic diseases are a leading cause of mortality and morbidity.[1] An insufficient level of physical activity, defined as less than 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week, is directly associated with a number of diseases including coronary heart disease, type 2 diabetes, breast cancer and colon cancer.[2] Physical inactivity is also indirectly linked to the negative health consequences of high body mass and high blood pressure, which include many of the aforementioned chronic conditions.[1]

Fifty-seven percent of Australia's adult population were insufficiently active in 2011–12.[3] Begg et al.[4] estimate that 6.6% of the total disease burden in Australia is caused by physical inactivity, explaining around 24% of both cardiovascular disease and diabetes, and around 6% of all cancers. Based on these results, Cadilhac et al.[5] estimate that each year insufficient physical activity causes 45,000 new cases of disease which are associated with a loss of 174,000 disability-adjusted life-years in Australia. Inequalities in activity levels exist, with inactivity more likely in older people, those of lower socioeconomic status, those outside of major cities, and women.[6] Indeed, women with young children are more likely to be physically inactive than both women with no children[7, 8] and women with older children,[9, 10] and it is this group who are the focus of the *MobileMums* intervention evaluated here.

The *MobileMums* programme is a 12-week intervention designed to assist women with young children increase their physical activity. The intervention's development has previously been discussed.[11] *MobileMums* is initiated with a face-to-face consultation between the participant and a trained behavioural counsellor. The consultation is used to establish rapport between the participant and counsellor, to gather information required to tailor and personalise text-message content and to initiate the process of behaviour change through personalised goal setting.[11] Participants receive five text-messages per week during weeks 1 to 4 of the intervention and four text-messages per week during weeks 5 to 12. The messages are personalised based on the participant's name, the name of their counsellor, the participant's goals and their expected rewards and outcomes for achieving these goals. In addition to receiving the text-messages, participants also have access to a programme handbook, an on-line exercise directory and a Facebook© group. They also receive a refrigerator magnet for self-monitoring and standard information brochures on physical activity. As well as requiring behavioural counsellors, delivering the intervention requires programme coordinators to manage the counsellors, assign participants to a counsellor, oversee the text-messages being sent and received, and to organise sending other programme materials to participants.

In Australia health resources are generally allocated on a state or territory basis[12] and so a decision on whether to fund *MobileMums* would be made by individual states or territories. The alternative course of action would be to provide usual care. The purpose of this paper is to consider this decision of whether to provide *MobileMums* or usual care from the perspective of Queensland Health, the government department responsible for managing the public health system in Queensland, Australia.

It is assumed that the overarching objective of Queensland Health is to maximise population health subject to their budget. This, therefore, supports the need for an economic evaluation of *MobileMums* to consider the intervention's value for money. While this evaluation is specific to the funding decision faced by Queensland Health, it can be expected that the results reported here will be directly applicable to similar decisions in other Australian states and territories. The generalisability of the results to other high-income countries may be more limited, for example because of differences in the volume and cost of resource use between countries,[13] but the results are likely to be of relevance for all countries experiencing high levels of physical inactivity.

METHODS

Study population

It is expected that *MobileMums* would be offered to all women with children under one year old in Queensland, Australia, regardless of their current level of physical activity. With 61,020 women giving birth in Queensland in 2010 and with 413 fetal deaths,[14] the number of women eligible for the intervention in 2011 was 60,607. We expect around 60% of women who were offered the intervention would participate. This is based on the randomised control trial conducted in 2011,[15, 16] where of the 511 women assessed for eligibility 306 commenced the baseline assessment. This gives 36,364 women in Queensland who would be eligible and willing to participate in the *MobileMums* intervention in 2011, and this is the baseline cohort size considered for this study. This participation estimate of 60% is likely conservative, as the program would not include the time-consuming assessments that were undertaken purely for research purposes. Given the uncertainty around this estimate, we consider the effects of reducing this cohort size by 50% to 18,182 women, and increasing it by 50% to 54,546 women.

Modelling health outcomes and costs

A state-based Markov model provides the framework for this analysis and is used to estimate the costs and consequences associated with *MobileMums* and usual care. The development of the model has been informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011.[15] 263 women from around Caboolture, Queensland, received usual care (n=130) or the *MobileMums* intervention (n=133).[16] Data were collected prior to the intervention being received (time 1 – T1: 0 months), after the 12-week *MobileMums* programme was completed (T2: 3 months) and again after a further 6 month no-contact maintenance period (T3: 9 months). The main efficacy findings from the trial have been reported in detail by Fjeldsoe et al.[15] Briefly, while the intervention had a large and statistically significant beneficial effect on activity levels between T1 and T2, there was no statistically significant effect at T3, although the estimated increase in activity remained positive.

These results suggest that *MobileMums* can only be expected to have an effect on activity levels in the short-term. Under the assumption that only long-term changes in activity levels affect the risk of an individual developing future chronic health conditions, the time horizon of the model used here is two years. There are just two states in the model with participants either 'physically inactive' or 'physically active', and an individual is required to be undertaking 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week to be classified as active. An effective physical inactivity intervention increases the likelihood that inactive individuals become active (tpImprove) and/or reduces the likelihood that active individuals become inactive (tpRegress). Individuals move between states using monthly cycles, and spending a month as active or inactive has a cost and health outcome associated with it (described below). An outline of the model is shown in figure 1.

Health effects

To estimate the value for money of *MobileMums*, health effects are expressed in terms of quality-adjusted life-years (QALYs). Given the design of the model used, *MobileMums* can only affect health-related quality-of life, with no mortality effects. The health-related quality-of-life associated with being physically active or inactive was estimated from participants' responses to SF-12 questionnaires at T1, T2 and T3. Mean imputation was used for missing questionnaire data at each time period (1% of participants at T1, 13% at T2, and 32% at T3). Two errors were made in the printing of the SF-12 questionnaires. First, at T1 one question from the SF-12 was omitted in error, and so scores were randomly generated for this dimension. Second, one of the questions offered one too many potential responses at all time periods, and so those who selected this superfluous response were evenly split and moved into either the next best or next worst choice.

Questionnaire responses were transformed into the EQ-5D, a standardised measure of health outcomes, using an algorithm provided by Gray et al.[17] which provides utility scores close to group means, especially for individuals not in poor health. This approach generates health-related quality-of-life scores associated with spending a year as physically active or inactive which could range between 0 (equivalent to death) and 1 (equivalent to perfect health). Monthly scores were simply one-twelfth of this. QALYs and costs in the second year were discounted at 5% following the relevant guidelines.[18, 19]

Costing perspective

This study is intended to inform decision making regarding resource allocation across the health system in Queensland. Consequently, a health system perspective is taken, with only the costs borne by the health system included.[20] While costs falling outside of the health system, such as the cost to participants of purchasing goods or services related to undertaking exercise, may be of interest, they are not are not of direct relevance given the perspective taken here and so have been excluded. All costs reported have been inflated to 2014 AUD and any costs accruing in the second year of the model have been discounted at 5% in line with guidelines for submission to the Medical Services Advisory Committee[18] and the Pharmaceutical Benefits Advisory Committee[19] in Australia.

The estimated cost of providing *MobileMums* across Queensland is based on the costs of delivering the intervention in the randomised controlled trial.[16] To extrapolate these costs, assumptions have been required concerning number of behavioural counsellors and programme coordinators required for widespread dissemination. It is assumed that counsellors could be assigned to 30 participants per week, while coordinators could cover five counsellors and their participants per week. Counsellors and coordinators are assumed to be health practitioners with, on average, 2 years in their current role and, in terms of Queensland Health's salary scale,[21] paid at a HP3 (6,092 AUD per month) and a HP4 (8,150 AUD per month) level, respectively. The costs of developing the computer programme to send text-messages, sending the text- messages and providing other programme materials are assumed to be the same as in the trial.

In addition to the costs of delivering the intervention, the costs relating to participants health care use have also been incorporated. If the intervention reduces future health care use then the cost saving associated will counterbalance the cost of providing *MobileMums*. Participants' reported their use of health care services at T1, T2 and T3 and the average use of those who were physically active and inactive were estimated. As with the SF-12, mean imputation was used for missing data (0% of participants at T1, 12% at T2, and 31% at T3). The associated costs were estimated using the Medicare Benefits Schedule for July 2011[22] and Australian hospital statistics.[23]

Expected effects

The purpose of this evaluation is to estimate the expected value for money of the *MobileMums* intervention, which is indicated by the incremental cost effectiveness ratio (ICER) for *MobileMums.* This ratio is given by the expected (mean) change in costs associated with the intervention divided by the expected change in QALYs.[24] This ratio can then be compared against a cost-effectiveness threshold. The threshold used here is 64,000 AUD which is based on the estimate by Shiroiwa et al.[25] of the willingness-to-pay for an additional QALY in Australia. If the cost effectiveness ratio for *MobileMums* falls below 64,000 AUD then the intervention can be expected to be 'cost-effective'.

Uncertainty

Parameter uncertainty was quantified using Monte Carlo simulations, with the model evaluated 10,000 times, with each simulation involving random draws from each parameter distribution. These distributions are based on the trial data, with transition probabilities and QALYs given beta distributions, while health care utilisation and its associated costs assigned gamma distributions and uniform distributions respectively. This produces 10,000 pairs of incremental costs and effects, and these are presented on a cost-effectiveness plane along with the expected costs and effects and the cost-effectiveness threshold. The probability that *MobileMums* is cost-effective is given by the proportion of pairs of incremental costs and benefits at which the intervention would be considered cost-effective. The percentage of pairs where the change in QALYs is positive and the change in costs is negative is equal to the probability that *MobileMums* is cost-saving. It is also possible to estimate credible intervals around the expected change in costs and QALYs by taking percentiles of the costs and QALYs produced in the Monte Carlo analysis.[26]

Uncertainty also exists surrounding the modelling assumptions. In particular, three areas stand out for particularly onerous assumptions: transition probabilities after nine months (T3), the number of programme counsellors and coordinators required, and the number of women who would be eligible and willing to participate in the trial. The assumptions used for these areas are the subject of scenario analyses. First, the model is reassessed under the assumption that after T3 all programme activity effects are mitigated entirely, and then again under the assumption that the estimated treatment effect observed at T3 is maintained for a further 15 months, at which point the treatment effect is entirely mitigated. Second, the number of counsellors and coordinators required is increased by 50% and reduced by 50%. And lastly, increasing the cohort size by 50% and reducing it by 50% is considered.

RESULTS

Average effects

The input variables are detailed in Table 1. Around 70% of the women entering the model at T1 are expected to be physically inactive. Under usual care there is a small and gradual expected positive net movement from inactive to active over time, and after 24 months around 35 percent of the initial cohort are expected to be in the active state. The expected effect of *MobileMums* is to cause a substantial increase in physical activity over the duration of the 12-week intervention, with 50 percent of the participants expected to be in the active state at T2. Following the intervention gradual reduction in the proportion of active participants each month is expected, until after 16 months whereby the effect of *MobileMums* has been mitigated entirely. These expected changes in activity levels are presented in figure 2.

		Mean	Standard error	Distribution
Probability of being inactive at T1		0.71	0.03	Beta
Probability of moving from inactive to active (tpImprove)	Usual Care (T1 to T2)	0.20	0.04	Beta
	MobileMums (T1 to T2)	0.35	0.05	Beta
	Usual Care (T2 to T3)	0.14	0.04	Beta
	MobileMums (T2 to T3)	0.26	0.05	Beta
	Usual Care (T1 to T2)	0.43	0.08	Beta

Probability of moving from active to inactive (tpRegress)	MobileMums (T1 to T2)	0.18	0.06	Beta
	Usual Care (T2 to T3)	0.33	0.07	Beta
	MobileMums (T2 to T3)	0.45	0.06	Beta
Monthly health care utilisation costs (2014 AUD per participant)	Physically active	53.30	39.20	Uniform and Gamma*
	Physically inactive	75.40	32.62	Uniform and Gamma*
Cost of delivering MobileMums (2014 AUD per participant)		62.64	13.08	Uniform
EQ5D score	Inactive	0.78	0.01	Beta
	Active	0.81	0.01	Beta

* A uniform distribution for health care costs and a gamma distribution for health care utilisation

Table 1 Input variables for the Markov model

Time spent in the active state is expected to provide slightly higher utility than time spent in the inactive state, with a year spent as physically active associated with a health-related quality-of-life score of 0.81 compared with 0.78 for a year spent as physically inactive. As *MobileMums* is expected to increase the total number of months spent by the cohort in the active state, the intervention can therefore also be expected to improve health-related quality-of-life. Over 24 months, *MobileMums* is estimated to lead to an increase of 131 QALYs across the cohort of 36,364 women or, equivalently, 0.0036 QALYs per person.

The expected cost of delivering *MobileMums* to the cohort is 2,277,950 AUD, or 63 AUD per person. The breakdown for this cost is shown in Table 2. Almost half the cost is due to the behavioural counsellors. While there are significant costs associated with setting up the programme, such as the development of a computer programme to send personalised text-messages, these costs are of little consequence with a cohort of 36,364 women.

		Total cost (AUD)	**Cost per participant (AUD)**
Development of the computer program for sending automated text-messages		14,204	0.39
Sending text-messages		620,999	17.08
Providing additional programme materials		621,388	17.08
Behavioural counsellors (24 required)	Salaries	438,628	12.06
	Equipment	36,231	0.99
	Travel costs	388,368	10.68
Programme coordinators (5 required)	Salaries	122,248	3.36
	Office costs	35,885	0.98
Total		2,277,950	62.64

Table 2 Estimated costs of delivering MobileMums in Queensland, Australia, in 2014 AUD

Based on data from the trial it is estimated that active individuals cost the health system 53 AUD a month on average, while inactive individuals cost 75 AUD per month. As *MobileMums* reduces the average number of months spent in the inactive state, the cost of delivering the intervention is partly offset by an expected reduction in these health care costs. As a result, the total expected incremental cost to the health system from introducing *MobileMums* is 1,124,209 million AUD, or 31 AUD per person.

With an expected (mean) incremental cost of 1,124,209 million AUD and an incremental improvement in health outcomes of 130 QALYs, the cost-effectiveness ratio for *MobileMums* is approximately 8,608 AUD per QALY. At a cost-effectiveness threshold of 64,000 AUD, the intervention can therefore be expected to be cost-effective.

Uncertainty

The pairs of incremental costs and consequences produced by the Monte Carlo simulation are shown in figure 3. *MobileMums* has a 98% probability of being cost-effective at a threshold of 64,000 AUD (98% of simulations are below the sloped threshold line). The intervention has around a 19% probability of being cost-saving and health-improving (19% of simulations are in the south-east quadrant).

The results from the scenario analyses are presented in Table 3. None of the changes in assumptions had any substantial effect on the probability that *MobileMums* is cost-effective at a threshold of 64,000 AUD, which remained over 95% under all scenarios. Changes in the assumption surrounding the maintenance of changes in activity levels into the future did, however, have a substantial effect on the probability that *MobileMums* is cost-saving. If changes were entirely mitigated after 9 months (T3) then the intervention would only have a 1% chance of being cost-saving, while if the observed difference in activity levels at T3 was maintained for up to 24 months *MobileMums* would have a 39% probability of being cost-saving.

	Mean change (95% credible interval) caused by *MobileMums*			Probability *MobileMums* is	
Scenario	**Total costs (AUD)**	**QALYs**	**Expected (mean) ICER**	**Cost-effective***	**Cost-saving**
Base case	1,124,209 (1,102,044to1,146,374)	131 (126 to 135)	8,608	98%	19%
Changes in activity levels entirely mitigated at 9 months (T3)	1,363,736 (1,363,736to 1,372,716)	103 (102 to 105)	13,186	97%	1%
Changes in activity levels maintained from 9 months to 24 months	240,173 (217,066 to 263,281)	232 (227 to 236)	1,037	97%	39%
Number of counsellors and coordinators required increased by 50%	1,456,518 (1,434,365 to 1,478,670)	131 (126 to 135)	11,152	98%	15%
Number of counsellors and coordinators required reduced by 50%	823,527 (802,374to 844,680)	130 (127 to 134)	6,306	98%	24%
Cohort size increased by 50% to 54,546 women	1,643,613 (1,610,282 to 1,676,943)	196 (190 to 202)	8,390	98%	20%
Cohort size reduced by 50% to 18,182	585,020 (574,005 to 596,035)	65 (63 to 67)	8,959	98%	17%

ICER: incremental cost-effectiveness ratio

* at a threshold of 64,000 AUD

Table 3 Results from the scenario analyses which examine whether the intervention remains cost-effective for a range of assumptions.

DISCUSSION

Principal findings

The results from this study suggest the *MobileMums* intervention would be a cost-effective use of health resources in Queensland, Australia. While the expected health benefits of the intervention are modest, with an average health improvement of only 0.0036 additional QALYs, the cost of the intervention, after taking into account reduced health care utilisation, is low at just 31 AUD per person. Consequently, the expected cost-effectiveness ratio is 8,608 AUD per QALY, which is far below the estimated willingness to pay for an additional QALY in Australia of 64,000 AUD.[5] Neither parameter nor modelling uncertainty have a substantial effect on this conclusion.

Study strengths and limitations

This study has been largely informed by the results of a recent 9-month randomised controlled trial. By using a decision-analytic model, it was possible to extrapolate these findings to consider the costs and consequences of *MobileMums* if it were offered in practice to a large cohort of women and to account for expected costs and consequences beyond the trial's time horizon. Although several assumptions underpin this approach, they were subjected to sensitivity analyses which have shown them to have little effect on the overall conclusion that the intervention is likely cost-effective.

With the effect of *MobileMums* on activity levels expected to last for less than two years, and under the conservative assumption that only longer-term changes in activity will affect the risk of an individual developing future chronic health conditions, the model used here is only required to have a short-time horizon. However, if *MobileMums* does prompt some long-term improvements in physical activity then the benefits of the intervention will be understated. In addition, while the simplicity of the model used has advantages, particularly for ease of exposition, there are limitations. In particular, only those changes in activity enough to move participants between the two states of the model are captured, with any changes of activity levels within a state overlooked.

Comparison with other studies

While a number of economic evaluations of physical activity interventions have been undertaken, there is significant methodological heterogeneity making direct comparisons difficult in many cases. Of those studies which use a similar methodology, i.e. using a decision-analytic model as a framework for analysis with the cost per quality-adjusted (or disability-adjusted) life-year estimated, many of the interventions are found to be cost-effective. For example, the 'green prescription' programme in New Zealand is found to have an incremental cost of 3,000 AUD per QALY,[27] while Cobiac et al.[28] found a pedometer intervention in Australia to be cost-saving and an internet-based intervention to have an incremental cost of 4,000 AUD per QALY. However, the cost-effectiveness of such physical activity intervention is by no means guaranteed. Cobiac et al.[28] find that a referral to exercise scheme has an incremental cost of 100,000 AUD per QALY, while a 8-week social support programme was found by Roux et al.[29] to have an incremental cost of 95,000 AUD per QALY.

Interestingly, while these other studies typically assumed that the benefit from physical activity interventions was only through reducing the incidence of future chronic diseases, this study demonstrates that they are also likely to produce an immediate improvement in health-related quality-of-life. Active participants in the trial of *MobileMums* reported higher health-related quality-of-life than those who were physically inactive, so that *MobileMums* is expected to be cost-effective even without any long-term changes in activity levels. With this immediate improvement in quality-of-life missed in most analyses of physical activity interventions, these studies may well have underestimated the full benefits from effective physical activity interventions.

Policy implications

Health prevention programmes in Queensland, and across Australia, have recently been going through a period of disinvestment. However, if the goal of the health system is to maximise health outcomes then there seems little reason for prevention health interventions to be treated any differently to a curative intervention. While the *MobileMums* intervention can only be expected to provide a modest improvement in health-related quality of life for the average participant, it does provide a meaningful improvement in terms of population health. Health care resources should be directed to those uses which provide best value for money, i.e., the greatest improvement in health outcomes for a given level of cost. Given the relatively low cost of delivering *MobileMums*, the intervention can be expected to provide good value for money and is likely a cost-effective use of health care resources given the estimated willingness-to-pay for an additional QALY in Australia.

Providing the intervention across Australia can be expected to provide a similar level of value for money. Levels of physical inactivity are similar across Australia[3] and costs, such as those associated with the counsellors and coordinators, should also be comparable. While differences in costs make it more difficult to generalise our results to other countries, the results of this study are still likely to be of relevance in many high-income countries with similarly high levels of physical inactivity. It would seem likely that a programme such as *MobileMums* would provide good value for money if provided in such countries. However, this is an area where further research is required.

CONCLUSION

MobileMums can be expected to be a cost-effective use of health resources in Queensland, Australia. If the objective of Queensland Health is to maximise population health outcomes given a finite budget, then *MobileMums* should be freely provided.

Figure 1 Outline of the Markov model used to estimate the costs and effects of *MobileMums* and usual care

Figure 2 The expected (mean) effect of *MobileMums* on activity levels

Figure 3 Cost-effectiveness plane for *MobileMums* versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD

ACKNOWLEDGEMENTS

Computational resources and services used in this work were provided by the High Performance Computer and Research Support Unit, Queensland, University of Technology, Brisbane, Australia.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: AM, YM, BF, AB, NG

Performed the experiments: AM, YM, AB, BF, NG

Analysed the data: EB, NG

Wrote the paper: EB, AM, YM, AB, NG

FUNDING INTERESTS

This study was supported by a National Health and Medical Research Council project grant number 614244.

COMPETING INTERESTS

None

ETHICS APPROVAL

The trial used to inform this analysis was registered with the Australian Clinical Trials Registry (ACTRN12611000481976). Ethical clearance was obtained through the Queensland University of Technology Human Research Ethics Committee (Application number 0900001407).

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed

DATA SHARING STATEMENT

The full data set is available by emailing the first author of the study.

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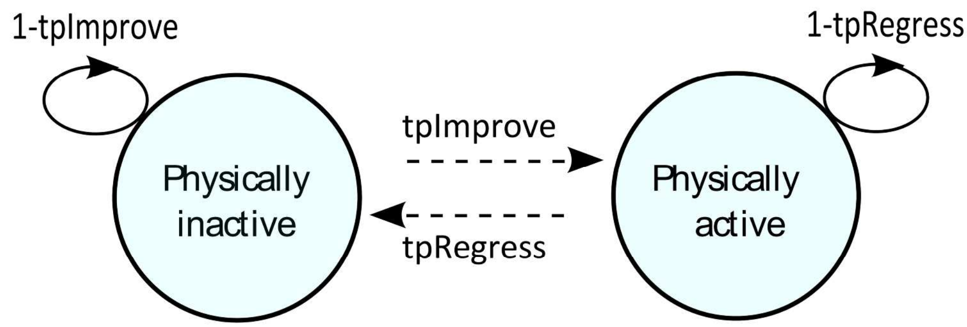

Figure 1 Outline of the Markov model used to estimate the costs and effects of MobileMums and usual care
115x41mm (600 x 600 DPI)

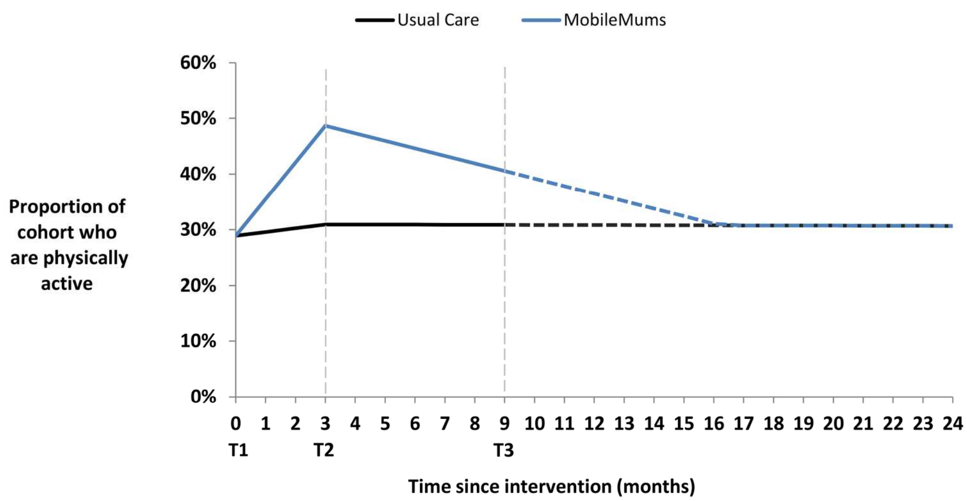

Figure 2 The expected (mean) effect of MobileMums on activity levels
91x48mm (600 x 600 DPI)

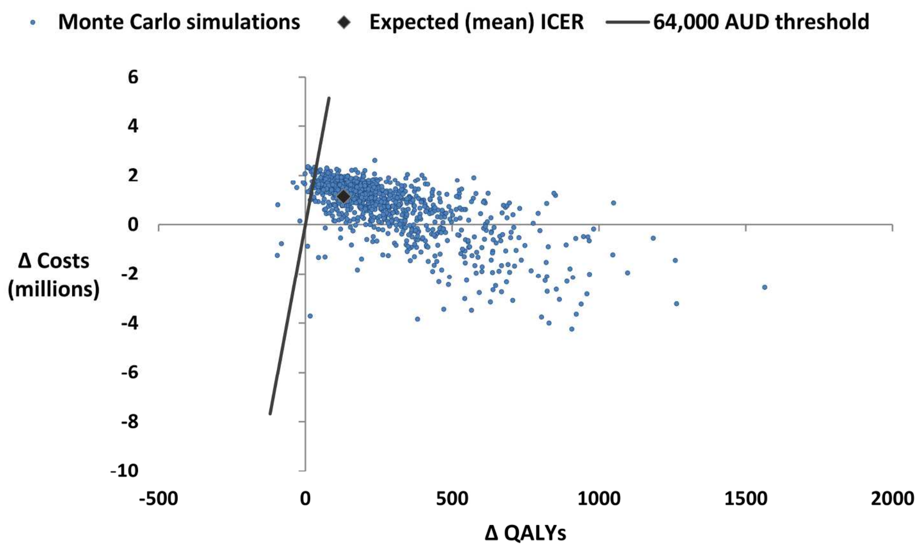

Figure 3 Cost-effectiveness plane for MobileMums versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD
101x58mm (600 x 600 DPI)

The CHEERS Checklist is part of the CHEERS Statement. The CHEERS Statement has been endorsed and co-published by the following journals:

BJOG: An International Journal of Obstetrics and Gynaecology
BMC Medicine 2013; 11:80
BMJ 2013;346:f1049
Clinical Therapeutics 27 March 2013 (Article in Press DOI: 10.1016/j.clinthera.2013.03.003)
Cost Effectiveness and Resource Allocation 2013 11:6.
The European Journal of Health Economics 2013 Mar 26. [Epub ahead of print]
International Journal of Technology Assessment in Health Care
Journal of Medical Economics 2013 Mar 25. [Epub ahead of print]
Pharmacoeconomics 2013 Mar 26. [Epub ahead of print]
Value in Health 2013 March - April;16(2):e1-e5

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page 1 Lines 1,2
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page 2-3 Lines 16-42
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Pages 4-5 Lines 61-109
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 6 Lines 111-121
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 3 Lines 96-109
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 8 Lines 164-189
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 5 Lines 96-98
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Pages 6-7 Lines 134-137
Discount rate	9	Report the choice of discount rate(s) used for costs and	Pages 8, Lines 162-163, 171-172

		outcomes and say why appropriate.	
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 9 Lines 194-200
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	Pages 6,7 Lines 123-144
	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Pages 7,8 Lines 150-163
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Pages 8,9 Lines 173-189
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 8 Lines 170-172
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 9 Lines 122-144
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Pages 6,8 Lines 135-136, 174-176
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 7,9 Lines 148-163, 187-189
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 11 Line 236

Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	Page 12 Lines 256-259
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Pages 12,13 Lines 260-276
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 13-16 Lines 277-344
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 17 Lines 367-369
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 17 Lines 370-371

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The CHEERS Statement may be accessed by the publication links above.

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

The citation for the CHEERS Task Force Report is:
Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS)—Explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231-50.

BMJ Open

The cost-effectiveness of the MobileMums intervention to increase physical activity among mothers with young children: a Markov model informed by a randomised controlled trial

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-007226.R2
Article Type:	Research
Date Submitted by the Author:	26-Feb-2015
Complete List of Authors:	Burn, Edward; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Marshall, Alison; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Miller, Yvette; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Barnett, Adrian; Queensland University of Technology, Institute of Health and Biomedical Innovation; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI) Fjeldsoe, Brianna; The University of Queensland, School of Population Health Graves, Nicholas; Queensland University of Technology (QUT), School of Public Health and Social Work and Institute of Health and Biomedical Innovation (IHBI)
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Health economics, Health services research
Keywords:	Exercise, Economic evaluation, Cost effectiveness, mHealth, behaviour change

SCHOLARONE™ Manuscripts

The cost-effectiveness of the *MobileMums* intervention to increase physical activity among mothers with young children: a Markov model informed by a randomised controlled trial

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Keywords: Exercise, Economic evaluation, Cost effectiveness, mHealth, behaviour change

Word count (excluding title page, abstract, references, figures, and tables): 3,965

ABSTRACT

Objectives

To determine the cost-effectiveness of the *MobileMums* intervention. *MobileMums* is a 12-week programme which assists mothers with young children to be more physically active, primarily through the use of personalised SMS text-messages.

Design

A cost-effectiveness analysis using a Markov model to estimate and compare the costs and consequences of *MobileMums* and usual care.

Setting

This study considers the cost-effectiveness of *MobileMums* in Queensland, Australia.

Participants

A hypothetical cohort of over 36,000 women with a child under one year old is considered. These women are expected to be eligible and willing to participate in the intervention in Queensland, Australia.

Data sources

The model was informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011 and registered retrospectively with the Australian Clinical Trials Registry (ACTRN12611000481976). Baseline characteristics for the model cohort, treatment effects, and resource utilisation were all informed by this trial.

Main outcome measures

The incremental cost per quality-adjusted life year (QALY) of *MobileMums* compared with usual care.

Results

The intervention is estimated to lead to an increase of 131 QALYs for an additional cost to the health system of 1.1 million Australian dollars (AUD). The expected incremental cost-effectiveness ratio for *MobileMums* is 8,608 AUD per QALY gained. *MobileMums* has a 98% probability of being cost-effective at a cost-effectiveness threshold of 64,000 AUD. Varying modelling assumptions has little effect on this result.

Conclusions

At a cost-effectiveness threshold of 64,000 AUD, *MobileMums* would likely be a cost-effective use of health care resources in Queensland, Australia.

ARTICLE SUMMARY

Article focus

- This paper estimates the cost-effectiveness of the *MobileMums* intervention for Queensland, Australia.

Key messages

- *MobileMums* is likely a cost-effective use of health care resources in Queensland, Australia.

Strengths and limitations of the study

- The analysis is informed by the results from a recent two-arm randomised controlled trial of *MobileMums* and usual care.
- Uncertainty around the costs and consequences of *MobileMums* and usual care has been quantified and has little effect on the conclusions of the analysis.
- The model's simplicity, with physical activity levels split into only two categories, means that small changes in an individual's activity would likely not be valued.

INTRODUCTION

Physical inactivity is a leading cause of lost years of healthy life in high-income countries, where chronic diseases are a leading cause of mortality and morbidity.[1] An insufficient level of physical activity, defined as less than 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week, is directly associated with a number of diseases including coronary heart disease, type 2 diabetes, breast cancer and colon cancer.[2] Physical inactivity is also indirectly linked to the negative health consequences of high body mass and high blood pressure, which include many of the aforementioned chronic conditions.[1]

Fifty-seven percent of Australia's adult population were insufficiently active in 2011–12.[3] Begg et al.[4] estimate that 6.6% of the total disease burden in Australia is caused by physical inactivity, explaining around 24% of both cardiovascular disease and diabetes, and around 6% of all cancers. Based on these results, Cadilhac et al.[5] estimate that each year insufficient physical activity causes 45,000 new cases of disease which are associated with a loss of 174,000 disability-adjusted life-years in Australia. Inequalities in activity levels exist, with inactivity more likely in older people, those of lower socioeconomic status, those outside of major cities, and women.[6] Indeed, women with young children are more likely to be physically inactive than both women with no children[7, 8] and women with older children,[9, 10] and it is this group who are the focus of the *MobileMums* intervention evaluated here.

The *MobileMums* programme is a 12-week intervention designed to assist women with young children increase their physical activity. The intervention's development has previously been discussed.[11] *MobileMums* is initiated with a face-to-face consultation between the participant and a trained behavioural counsellor. The consultation is used to establish rapport between the participant and counsellor, to gather information required to tailor and personalise text-message content and to initiate the process of behaviour change through personalised goal setting.[11] Participants receive five text-messages per week during weeks 1 to 4 of the intervention and four text-messages per week during weeks 5 to 12. The messages are personalised based on the participant's name, the name of their counsellor, the participant's goals and their expected rewards and outcomes for achieving these goals. In addition to receiving the text-messages, participants also have access to a programme handbook, an on-line exercise directory and a Facebook© group. They also receive a refrigerator magnet for self-monitoring and standard information brochures on physical activity. As well as requiring behavioural counsellors, delivering the intervention requires programme coordinators to manage the counsellors, assign participants to a counsellor, oversee the text-messages being sent and received, and to organise sending other programme materials to participants.

In Australia health resources are generally allocated on a state or territory basis[12] and so a decision on whether to fund *MobileMums* would be made by individual states or territories. The alternative course of action would be to provide usual care. The purpose of this paper is to consider this decision of whether to provide *MobileMums* or usual care from the perspective of Queensland Health, the government department responsible for managing the public health system in Queensland, Australia.

It is assumed that the overarching objective of Queensland Health is to maximise population health subject to their budget. This, therefore, supports the need for an economic evaluation of *MobileMums* to consider the intervention's value for money. While this evaluation is specific to the funding decision faced by Queensland Health, it can be expected that the results reported here will be directly applicable to similar decisions in other Australian states and territories. The generalisability of the results to other high-income countries may be more limited, for example because of differences in the volume and cost of resource use between countries,[13] but the results are likely to be of relevance for all countries experiencing high levels of physical inactivity.

METHODS

Study population

It is expected that *MobileMums* would be offered to all women with children under one year old in Queensland, Australia, regardless of their current level of physical activity. With 61,020 women giving birth in Queensland in 2010 and with 413 fetal deaths,[14] the number of women eligible for the intervention in 2011 was 60,607. We expect around 60% of women who were offered the intervention would participate. This is based on the randomised control trial conducted in 2011,[15, 16] where of the 511 women assessed for eligibility 306 commenced the baseline assessment. This gives 36,364 women in Queensland who would be eligible and willing to participate in the *MobileMums* intervention in 2011, and this is the baseline cohort size considered for this study. This participation estimate of 60% is likely conservative, as the program would not include the time-consuming assessments that were undertaken purely for research purposes. Given the uncertainty around this estimate, we consider the effects of reducing this cohort size by 50% to 18,182 women, and increasing it by 50% to 54,546 women.

Modelling health outcomes and costs

A state-based Markov model provides the framework for this analysis and is used to estimate the costs and consequences associated with *MobileMums* and usual care. The development of the model has been informed by the effectiveness results from a 9-month two-arm community-based randomised controlled trial undertaken in 2011.[15] 263 women from around Caboolture, Queensland, received usual care (n=130) or the *MobileMums* intervention (n=133).[16] Data were collected prior to the intervention being received (time 1 – T1: 0 months), after the 12-week *MobileMums* programme was completed (T2: 3 months) and again after a further 6 month no-contact maintenance period (T3: 9 months). Due to an administrative error the trial was registered retrospectively with the Australian Clinical Trials Registry (ACTRN12611000481976) and 26 of the trial participants were already receiving *MobileMums* or usual care by the time of registration. However, none of these participants had passed T2 when the trial was registered.

The main efficacy findings from the trial have been reported in detail by Fjeldsoe et al.[15] Briefly, while the intervention had a large and statistically significant beneficial effect on activity levels between T1 and T2, there was no statistically significant effect at T3, although the estimated increase in activity remained positive. These results suggest that *MobileMums* can only be expected to have an effect on activity levels in the short-term. Under the assumption that only long-term changes in activity levels affect the risk of an individual developing future chronic health conditions, the time horizon of the model used here is two years.

There are just two states in the model with participants either 'physically inactive' or 'physically active', and an individual is required to be undertaking 30 minutes of moderate- to vigorous-intensity physical activity on at least five days a week to be classified as active. An effective physical inactivity intervention increases the likelihood that inactive individuals become active (tpImprove) and/or reduces the likelihood that active individuals become inactive (tpRegress). Individuals move between states using monthly cycles, and spending a month as active or inactive has a cost and health outcome associated with it (described below). An outline of the model is shown in figure 1.

Health effects

To estimate the value for money of *MobileMums*, health effects are expressed in terms of quality-adjusted life-years (QALYs). Given the design of the model used, *MobileMums* can only affect health-related quality-of life, with no mortality effects. The health-related quality-of-life associated with being physically active or inactive was estimated from participants' responses to SF-12 questionnaires at T1, T2 and T3. Mean imputation was used for missing questionnaire data at each time period (1% of participants at T1, 13% at T2, and 32% at T3). Two errors were made in the printing of the SF-12 questionnaires. First, at T1 one question from the SF-12 was omitted in error, and so scores were randomly generated for this dimension. Second, one of the questions offered one too many potential responses at all time periods, and so those who selected this superfluous response were evenly split and moved into either the next best or next worst choice.

Questionnaire responses were transformed into the EQ-5D, a standardised measure of health outcomes, using an algorithm provided by Gray et al.[17] which provides utility scores close to group means, especially for individuals not in poor health. This approach generates health-related quality-of-life scores associated with spending a year as physically active or inactive which could range between 0 (equivalent to death) and 1 (equivalent to perfect health). Monthly scores were simply one-twelfth of this. QALYs and costs in the second year were discounted at 5% following the relevant guidelines.[18, 19]

Costing perspective

This study is intended to inform decision making regarding resource allocation across the health system in Queensland. Consequently, a health system perspective is taken, with only the costs borne by the health system included.[20] While costs falling outside of the health system, such as the cost to participants of purchasing goods or services related to undertaking exercise, may be of interest, they are not are not of direct relevance given the perspective taken here and so have been excluded. All costs reported have been inflated to 2014 AUD and any costs accruing in the second year of the model have been discounted at 5% in line with guidelines for submission to the Medical Services Advisory Committee[18] and the Pharmaceutical Benefits Advisory Committee[19] in Australia.

The estimated cost of providing *MobileMums* across Queensland is based on the costs of delivering the intervention in the randomised controlled trial.[16] To extrapolate these costs, assumptions have been required concerning number of behavioural counsellors and programme coordinators required for widespread dissemination. It is assumed that counsellors could be assigned to 30 participants per week, while coordinators could cover five counsellors and their participants per week. Counsellors and coordinators are assumed to be health practitioners with, on average, 2 years in their current role and, in terms of Queensland Health's salary scale,[21] paid at a HP3 (6,092 AUD per month) and a HP4 (8,150 AUD per month) level, respectively. The costs of developing the computer programme to send text-messages, sending the text- messages and providing other programme materials are assumed to be the same as in the trial.

In addition to the costs of delivering the intervention, the costs relating to participants health care use have also been incorporated. If the intervention reduces future health care use then the cost saving associated will counterbalance the cost of providing *MobileMums*. Participants' reported their use of health care services at T1, T2 and T3 and the average use of those who were physically active and inactive were estimated. As with the SF-12, mean imputation was used for missing data (0% of participants at T1, 12% at T2, and 31% at T3). The associated costs were estimated using the Medicare Benefits Schedule for July 2011[22] and Australian hospital statistics.[23]

Expected effects

The purpose of this evaluation is to estimate the expected value for money of the *MobileMums* intervention, which is indicated by the incremental cost effectiveness ratio (ICER) for *MobileMums.* This ratio is given by the expected (mean) change in costs associated with the intervention divided by the expected change in QALYs.[24] This ratio can then be compared against a cost-effectiveness threshold. The threshold used here is 64,000 AUD which is based on the estimate by Shiroiwa et al.[25] of the willingness-to-pay for an additional QALY in Australia. If the cost effectiveness ratio for *MobileMums* falls below 64,000 AUD then the intervention can be expected to be 'cost-effective'.

Uncertainty

Parameter uncertainty was quantified using Monte Carlo simulations, with the model evaluated 10,000 times, with each simulation involving random draws from each parameter distribution. These distributions are based on the trial data, with transition probabilities and QALYs given beta distributions, while health care utilisation and its associated costs assigned gamma distributions and uniform distributions respectively. This produces 10,000 pairs of incremental costs and effects, and these are presented on a cost-effectiveness plane along with the expected costs and effects and the cost-effectiveness threshold. The probability that *MobileMums* is cost-effective is given by the proportion of pairs of incremental costs and benefits at which the intervention would be considered cost-effective. The percentage of pairs where the change in QALYs is positive and the change in costs is negative is equal to the probability that *MobileMums* is cost-saving. It is also possible to estimate credible intervals around the expected change in costs and QALYs by taking percentiles of the costs and QALYs produced in the Monte Carlo analysis.[26]

Uncertainty also exists surrounding the modelling assumptions. In particular, three areas stand out for particularly onerous assumptions: transition probabilities after nine months (T3), the number of programme counsellors and coordinators required, and the number of women who would be eligible and willing to participate in the trial. The assumptions used for these areas are the subject of scenario analyses. First, the model is reassessed under the assumption that after T3 all programme activity effects are mitigated entirely, and then again under the assumption that the estimated treatment effect observed at T3 is maintained for a further 15 months, at which point the treatment effect is entirely mitigated. Second, the number of counsellors and coordinators required is increased by 50% and reduced by 50%. And lastly, increasing the cohort size by 50% and reducing it by 50% is considered.

RESULTS

Average effects

The input variables are detailed in Table 1. Around 70% of the women entering the model at T1 are expected to be physically inactive. Under usual care there is a small and gradual expected positive net movement from inactive to active over time, and after 24 months around 35 percent of the initial cohort are expected to be in the active state. The expected effect of *MobileMums* is to cause a substantial increase in physical activity over the duration of the 12-week intervention, with 50 percent of the participants expected to be in the active state at T2. Following the intervention gradual reduction in the proportion of active participants each month is expected, until after 16 months whereby the effect of *MobileMums* has been mitigated entirely. These expected changes in activity levels are presented in figure 2.

		Mean	Standard error	Distribution
Probability of being inactive at T1		0.71	0.03	Beta
Probability of moving from inactive to active (tpImprove)	Usual Care (T1 to T2)	0.20	0.04	Beta
	MobileMums (T1 to T2)	0.35	0.05	Beta
	Usual Care (T2 to T3)	0.14	0.04	Beta
	MobileMums (T2 to T3)	0.26	0.05	Beta

Probability of moving from active to inactive (tpRegress)	Usual Care (T1 to T2)	0.43	0.08	Beta
	*MobileMu*ms (T1 to T2)	0.18	0.06	Beta
	Usual Care (T2 to T3)	0.33	0.07	Beta
	MobileMums (T2 to T3)	0.45	0.06	Beta
Monthly health care utilisation costs (2014 AUD per participant)	Physically active	53.30	39.20	Uniform and Gamma*
	Physically inactive	75.40	32.62	Uniform and Gamma*
Cost of delivering *MobileMums* (2014 AUD per participant)		62.64	13.08	Uniform
EQ5D score	Inactive	0.78	0.01	Beta
	Active	0.81	0.01	Beta

* A uniform distribution for health care costs and a gamma distribution for health care utilisation

Table 1 Input variables for the Markov model

Time spent in the active state is expected to provide slightly higher utility than time spent in the inactive state, with a year spent as physically active associated with a health-related quality-of-life score of 0.81 compared with 0.78 for a year spent as physically inactive. As *MobileMums* is expected to increase the total number of months spent by the cohort in the active state, the intervention can therefore also be expected to improve health-related quality-of-life. Over 24 months, *MobileMums* is estimated to lead to an increase of 131 QALYs across the cohort of 36,364 women or, equivalently, 0.0036 QALYs per person.

The expected cost of delivering *MobileMums* to the cohort is 2,277,950 AUD, or 63 AUD per person. The breakdown for this cost is shown in Table 2. Almost half the cost is due to the behavioural counsellors. While there are significant costs associated with setting up the programme, such as the development of a computer programme to send personalised text-messages, these costs are of little consequence with a cohort of 36,364 women.

		Total cost (AUD)	Cost per participant (AUD)
Development of the computer program for sending automated text-messages		14,204	0.39
Sending text-messages		620,999	17.08
Providing additional programme materials		621,388	17.08
Behavioural counsellors (24 required)	Salaries	438,628	12.06
	Equipment	36,231	0.99
	Travel costs	388,368	10.68
Programme coordinators (5 required)	Salaries	122,248	3.36
	Office costs	35,885	0.98
Total		2,277,950	62.64

Table 2 Estimated costs of delivering *MobileMums* in Queensland, Australia, in 2014 AUD

Based on data from the trial it is estimated that active individuals cost the health system 53 AUD a month on average, while inactive individuals cost 75 AUD per month. As *MobileMums* reduces the average number of months spent in the inactive state, the cost of delivering the intervention is partly offset by an expected reduction in these health care costs. As a result, the total expected incremental cost to the health system from introducing *MobileMums* is 1,124,209 million AUD, or 31 AUD per person.

With an expected (mean) incremental cost of 1,124,209 million AUD and an incremental improvement in health outcomes of 130 QALYs, the cost-effectiveness ratio for *MobileMums* is approximately 8,608 AUD per QALY. At a cost-effectiveness threshold of 64,000 AUD, the intervention can therefore be expected to be cost-effective.

Uncertainty

The pairs of incremental costs and consequences produced by the Monte Carlo simulation are shown in figure 3. *MobileMums* has a 98% probability of being cost-effective at a threshold of 64,000 AUD (98% of simulations are below the sloped threshold line). The intervention has around a 19% probability of being cost-saving and health-improving (19% of simulations are in the south-east quadrant).

The results from the scenario analyses are presented in Table 3. None of the changes in assumptions had any substantial effect on the probability that *MobileMums* is cost-effective at a threshold of 64,000 AUD, which remained over 95% under all scenarios. Changes in the assumption surrounding the maintenance of changes in activity levels into the future did, however, have a substantial effect on the probability that *MobileMums* is cost-saving. If changes were entirely mitigated after 9 months (T3) then the intervention would only have a 1% chance of being cost-saving, while if the observed difference in activity levels at T3 was maintained for up to 24 months *MobileMums* would have a 39% probability of being cost-saving.

	Mean change (95% credible interval) caused by *MobileMums*			Probability *MobileMums* is	
Scenario	**Total costs (AUD)**	**QALYs**	**Expected (mean) ICER**	**Cost-effective***	**Cost-saving**
Base case	1,124,209 (1,102,044to1,146,374)	131 (126 to 135)	8,608	98%	19%
Changes in activity levels entirely mitigated at 9 months (T3)	1,363,736 (1,363,736to 1,372,716	103 (102 to 105)	13,186	97%	1%
Changes in activity levels maintained from 9 months to 24 months	240,173 (217,066 to 263,281)	232 (227 to 236)	1,037	97%	39%
Number of counsellors and coordinators required increased by 50%	1,456,518 (1,434,365 to 1,478,670)	131 (126 to 135)	11,152	98%	15%
Number of counsellors and coordinators required reduced by 50%	823,527 (802,374to 844,680)	130 (127 to 134)	6,306	98%	24%
Cohort size increased by 50% to 54,546 women	1,643,613 (1,610,282 to 1,676,943)	196 (190 to 202)	8,390	98%	20%
Cohort size reduced by 50% to 18,182	585,020 (574,005 to 596,035)	65 (63 to 67)	8,959	98%	17%

ICER: incremental cost-effectiveness ratio

* at a threshold of 64,000 AUD

Table 3 Results from the scenario analyses which examine whether the intervention remains cost-effective for a range of assumptions.

DISCUSSION

Principal findings

The results from this study suggest the *MobileMums* intervention would be a cost-effective use of health resources in Queensland, Australia. While the expected health benefits of the intervention are modest, with an average health improvement of only 0.0036 additional QALYs, the cost of the intervention, after taking into account reduced health care utilisation, is low at just 31 AUD per person. Consequently, the expected cost-effectiveness ratio is 8,608 AUD per QALY, which is far below the estimated willingness to pay for an additional QALY in Australia of 64,000 AUD.[5] Neither parameter nor modelling uncertainty have a substantial effect on this conclusion.

Study strengths and limitations

This study has been largely informed by the results of a recent 9-month randomised controlled trial. By using a decision-analytic model, it was possible to extrapolate these findings to consider the costs and consequences of *MobileMums* if it were offered in practice to a large cohort of women and to account for expected costs and consequences beyond the trial's time horizon. Although several assumptions underpin this approach, they were subjected to sensitivity analyses which have shown them to have little effect on the overall conclusion that the intervention is likely cost-effective.

With the effect of *MobileMums* on activity levels expected to last for less than two years, and under the conservative assumption that only longer-term changes in activity will affect the risk of an individual developing future chronic health conditions, the model used here is only required to have a short-time horizon. However, if *MobileMums* does prompt some long-term improvements in physical activity then the benefits of the intervention will be understated. In addition, while the simplicity of the model used has advantages, particularly for ease of exposition, there are limitations. In particular, only those changes in activity enough to move participants between the two states of the model are captured, with any changes of activity levels within a state overlooked.

Comparison with other studies

While a number of economic evaluations of physical activity interventions have been undertaken, there is significant methodological heterogeneity making direct comparisons difficult in many cases. Of those studies which use a similar methodology, i.e. using a decision-analytic model as a framework for analysis with the cost per quality-adjusted (or disability-adjusted) life-year estimated, many of the interventions are found to be cost-effective. For example, the 'green prescription' programme in New Zealand is found to have an incremental cost of 3,000 AUD per QALY,[27] while Cobiac et al.[28] found a pedometer intervention in Australia to be cost-saving and an internet-based intervention to have an incremental cost of 4,000 AUD per QALY. However, the cost-effectiveness of such physical activity intervention is by no means guaranteed. Cobiac et al.[28] find that a referral to exercise scheme has an incremental cost of 100,000 AUD per QALY, while a 8-week social support programme was found by Roux et al.[29] to have an incremental cost of 95,000 AUD per QALY.

Interestingly, while these other studies typically assumed that the benefit from physical activity interventions was only through reducing the incidence of future chronic diseases, this study demonstrates that they are also likely to produce an immediate improvement in health-related quality-of-life. Active participants in the trial of *MobileMums* reported higher health-related quality-of-life than those who were physically inactive, so that *MobileMums* is expected to be cost-effective even without any long-term changes in activity levels. With this immediate improvement in quality-of-life missed in most analyses of physical activity interventions, these studies may well have underestimated the full benefits from effective physical activity interventions.

Policy implications

Health prevention programmes in Queensland, and across Australia, have recently been going through a period of disinvestment. However, if the goal of the health system is to maximise health outcomes then there seems little reason for prevention health interventions to be treated any differently to a curative intervention. While the *MobileMums* intervention can only be expected to provide a modest improvement in health-related quality of life for the average participant, it does provide a meaningful improvement in terms of population health. Health care resources should be directed to those uses which provide best value for money, i.e., the greatest improvement in health outcomes for a given level of cost. Given the relatively low cost of delivering *MobileMums*, the intervention can be expected to provide good value for money and is likely a cost-effective use of health care resources given the estimated willingness-to-pay for an additional QALY in Australia.

Providing the intervention across Australia can be expected to provide a similar level of value for money. Levels of physical inactivity are similar across Australia[3] and costs, such as those associated with the counsellors and coordinators, should also be comparable. While differences in costs make it more difficult to generalise our results to other countries, the results of this study are still likely to be of relevance in many high-income countries with similarly high levels of physical inactivity. It would seem likely that a programme such as *MobileMums* would provide good value for money if provided in such countries. However, this is an area where further research is required.

CONCLUSION

MobileMums can be expected to be a cost-effective use of health resources in Queensland, Australia. If the objective of Queensland Health is to maximise population health outcomes given a finite budget, then *MobileMums* should be freely provided.

Figure 1 Outline of the Markov model used to estimate the costs and effects of *MobileMums* and usual care

Figure 2 The expected (mean) effect of *MobileMums* on activity levels

Figure 3 Cost-effectiveness plane for *MobileMums* versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD

ACKNOWLEDGEMENTS

Computational resources and services used in this work were provided by the High Performance Computer and Research Support Unit, Queensland, University of Technology, Brisbane, Australia.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: AM, YM, BF, AB, NG

Performed the experiments: AM, YM, AB, BF, NG

Analysed the data: EB, AB, NG

Wrote the paper: EB, AM, YM, AB, NG

FUNDING INTERESTS

This study was supported by a National Health and Medical Research Council project grant number 614244.

COMPETING INTERESTS

None

ETHICS APPROVAL

The trial used to inform this analysis was registered retrospectively with the Australian Clinical Trials Registry (ACTRN12611000481976). Ethical clearance was obtained through the Queensland University of Technology Human Research Ethics Committee (Application number 0900001407).

PROVENANCE AND PEER REVIEW

Not commissioned; externally peer reviewed

DATA SHARING STATEMENT

The full data set is available by emailing the first author of the study.

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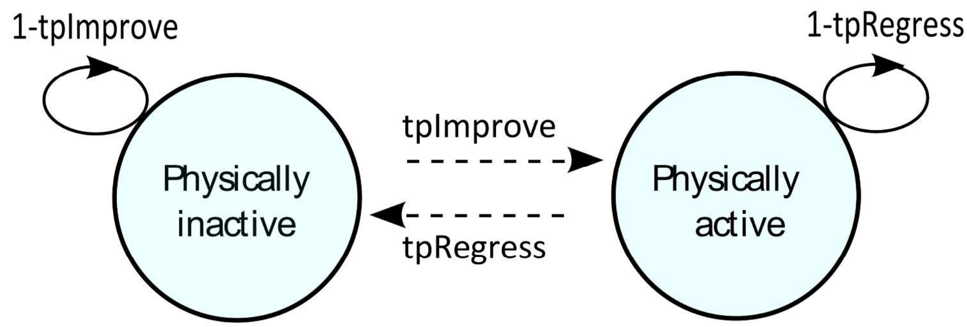

Figure 1 Outline of the Markov model used to estimate the costs and effects of MobileMums and usual care
115x41mm (600 x 600 DPI)

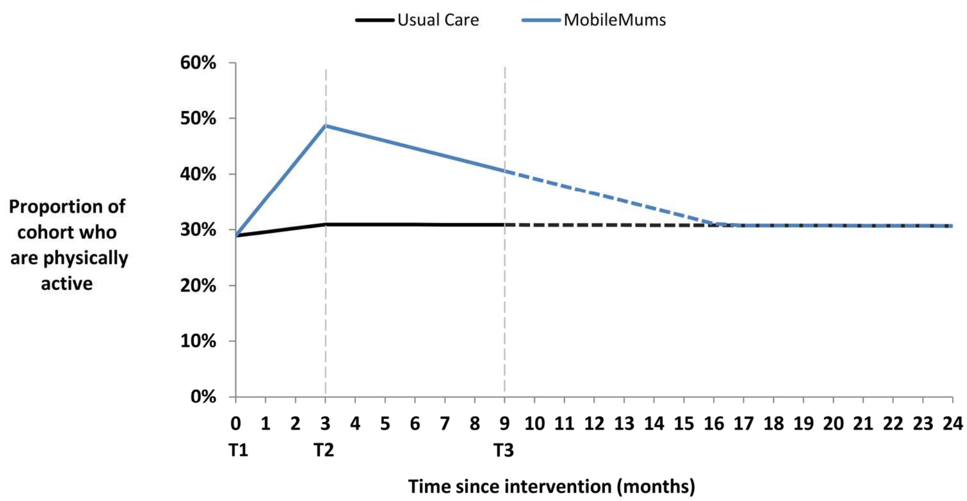

Figure 2 The expected (mean) effect of MobileMums on activity levels
91x48mm (600 x 600 DPI)

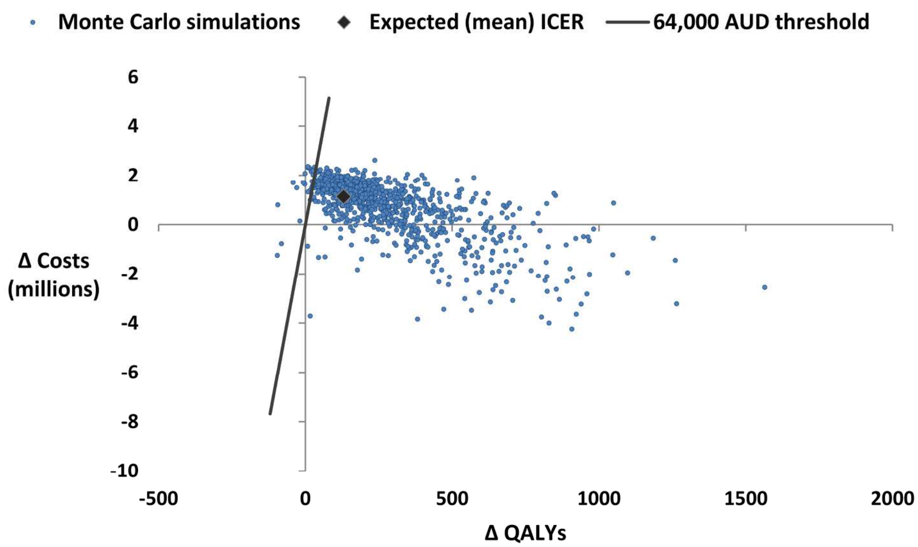

Figure 3 Cost-effectiveness plane for MobileMums versus usual care with 1,000 sets of incremental costs and effects randomly drawn from the 10,000 Monte Carlo simulations along with the expected (mean) incremental costs and effects and a cost-effectiveness threshold of 64,000 AUD
101x58mm (600 x 600 DPI)

The CHEERS Checklist is part of the CHEERS Statement. The CHEERS Statement has been endorsed and co-published by the following journals:

BJOG: An International Journal of Obstetrics and Gynaecology
BMC Medicine 2013; 11:80
BMJ 2013;346:f1049
Clinical Therapeutics 27 March 2013 (Article in Press DOI: 10.1016/j.clinthera.2013.03.003)
Cost Effectiveness and Resource Allocation 2013 11:6.
The European Journal of Health Economics 2013 Mar 26. [Epub ahead of print]
International Journal of Technology Assessment in Health Care
Journal of Medical Economics 2013 Mar 25. [Epub ahead of print]
Pharmacoeconomics 2013 Mar 26. [Epub ahead of print]
Value in Health 2013 March - April;16(2):e1-e5

CHEERS Checklist
Items to include when reporting economic evaluations of health interventions

Section/item	Item No	Recommendation	Reported on page No/ line No
Title and abstract			
Title	1	Identify the study as an economic evaluation or use more specific terms such as "cost-effectiveness analysis", and describe the interventions compared.	Page 1 Lines 1,2
Abstract	2	Provide a structured summary of objectives, perspective, setting, methods (including study design and inputs), results (including base case and uncertainty analyses), and conclusions.	Page 2-3 Lines 16-42
Introduction			
Background and objectives	3	Provide an explicit statement of the broader context for the study. Present the study question and its relevance for health policy or practice decisions.	Pages 4-5 Lines 61-109
Methods			
Target population and subgroups	4	Describe characteristics of the base case population and subgroups analysed, including why they were chosen.	Page 6 Lines 111-121
Setting and location	5	State relevant aspects of the system(s) in which the decision(s) need(s) to be made.	Page 3 Lines 96-109
Study perspective	6	Describe the perspective of the study and relate this to the costs being evaluated.	Page 8 Lines 164-189
Comparators	7	Describe the interventions or strategies being compared and state why they were chosen.	Page 5 Lines 96-98
Time horizon	8	State the time horizon(s) over which costs and consequences are being evaluated and say why appropriate.	Pages 6-7 Lines 134-137
Discount rate	9	Report the choice of discount rate(s) used for costs and	Pages 8, Lines 162-163, 171-172

		outcomes and say why appropriate.	
Choice of health outcomes	10	Describe what outcomes were used as the measure(s) of benefit in the evaluation and their relevance for the type of analysis performed.	Page 9 Lines 194-200
Measurement of effectiveness	11a	*Single study-based estimates:* Describe fully the design features of the single effectiveness study and why the single study was a sufficient source of clinical effectiveness data.	Pages 6,7 Lines 123-144
	11b	*Synthesis-based estimates:* Describe fully the methods used for identification of included studies and synthesis of clinical effectiveness data.	
Measurement and valuation of preference based outcomes	12	If applicable, describe the population and methods used to elicit preferences for outcomes.	Pages 7,8 Lines 150-163
Estimating resources and costs	13a	*Single study-based economic evaluation:* Describe approaches used to estimate resource use associated with the alternative interventions. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	
	13b	*Model-based economic evaluation:* Describe approaches and data sources used to estimate resource use associated with model health states. Describe primary or secondary research methods for valuing each resource item in terms of its unit cost. Describe any adjustments made to approximate to opportunity costs.	Pages 8,9 Lines 173-189
Currency, price date, and conversion	14	Report the dates of the estimated resource quantities and unit costs. Describe methods for adjusting estimated unit costs to the year of reported costs if necessary. Describe methods for converting costs into a common currency base and the exchange rate.	Page 8 Lines 170-172
Choice of model	15	Describe and give reasons for the specific type of decision-analytical model used. Providing a figure to show model structure is strongly recommended.	Page 9 Lines 122-144
Assumptions	16	Describe all structural or other assumptions underpinning the decision-analytical model.	Pages 6,8 Lines 135-136, 174-176
Analytical methods	17	Describe all analytical methods supporting the evaluation. This could include methods for dealing with skewed, missing, or censored data; extrapolation methods; methods for pooling data; approaches to validate or make adjustments (such as half cycle corrections) to a model; and methods for handling population heterogeneity and uncertainty.	Page 7,9 Lines 148-163, 187-189
Results			
Study parameters	18	Report the values, ranges, references, and, if used, probability distributions for all parameters. Report reasons or sources for distributions used to represent uncertainty where appropriate. Providing a table to show the input values is strongly recommended.	Page 11 Line 236

Incremental costs and outcomes	19	For each intervention, report mean values for the main categories of estimated costs and outcomes of interest, as well as mean differences between the comparator groups. If applicable, report incremental cost-effectiveness ratios.	Page 12 Lines 256-259
Characterising uncertainty	20a	*Single study-based economic evaluation:* Describe the effects of sampling uncertainty for the estimated incremental cost and incremental effectiveness parameters, together with the impact of methodological assumptions (such as discount rate, study perspective).	
	20b	*Model-based economic evaluation:* Describe the effects on the results of uncertainty for all input parameters, and uncertainty related to the structure of the model and assumptions.	Pages 12,13 Lines 260-276
Characterising heterogeneity	21	If applicable, report differences in costs, outcomes, or cost-effectiveness that can be explained by variations between subgroups of patients with different baseline characteristics or other observed variability in effects that are not reducible by more information.	N/A
Discussion			
Study findings, limitations, generalisability, and current knowledge	22	Summarise key study findings and describe how they support the conclusions reached. Discuss limitations and the generalisability of the findings and how the findings fit with current knowledge.	Page 13-16 Lines 277-344
Other			
Source of funding	23	Describe how the study was funded and the role of the funder in the identification, design, conduct, and reporting of the analysis. Describe other non-monetary sources of support.	Page 17 Lines 367-369
Conflicts of interest	24	Describe any potential for conflict of interest of study contributors in accordance with journal policy. In the absence of a journal policy, we recommend authors comply with International Committee of Medical Journal Editors recommendations.	Page 17 Lines 370-371

For consistency, the CHEERS Statement checklist format is based on the format of the CONSORT statement checklist

The CHEERS Statement may be accessed by the publication links above.

The **ISPOR CHEERS Task Force Report** provides examples and further discussion of the 24-item CHEERS Checklist and the CHEERS Statement. It may be accessed via the *Value in Health* link or via the ISPOR Health Economic Evaluation Publication Guidelines – CHEERS: Good Reporting Practices webpage: http://www.ispor.org/TaskForces/EconomicPubGuidelines.asp

The citation for the CHEERS Task Force Report is:
Husereau D, Drummond M, Petrou S, et al. Consolidated health economic evaluation reporting standards (CHEERS)—Explanation and elaboration: A report of the ISPOR health economic evaluations publication guidelines good reporting practices task force. Value Health 2013;16:231-50.