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How does MobileMums work? Mediators of a physical activity intervention

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ABSTRACT

Objectives: To establish which Social Cognitive Theory constructs mediated effects of the MobileMums (MMP) program on increased duration and frequency of moderate-vigorous physical activity (MVPA) in women with young children (<5 years). **Methods:** This secondary data analysis is from a community-based randomised controlled trial. Over 12 weeks, intervention participants received a minimum of 52 individually tailored text messages, one face-to-face and one telephone-delivered session with a trained behavioural counsellor. Participants identified a support person who also received 12 weeks of individually tailored text messages. Control participants received minimal intervention contact. Data were collected pre- and post-program. Five potential mediators were assessed: barrier self-efficacy, goal setting skills, outcome expectancies, perceived environmental opportunity for physical activity and social support for physical activity. **Results:** Improvements in MVPA frequency were mediated by improvements in barrier self-efficacy, goal setting skills, outcome expectancies and perceived social support. Improvements in MVPA duration resulting from the MMP were mediated by improvements in women's barrier self-efficacy and goal setting skills. **Conclusions:** MMP improved targeted theoretical constructs and this led to changes in women's MVPA. These findings are valuable for refinement and translation of the MMP and for further research to create theory- and evidence-based physical activity behaviour change programs for women with young children.

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Introduction

A key role for behavioural health researchers is to not only develop and evaluate programs to elicit meaningful behaviour change but also to identify the mechanisms of the program that effect change. This information facilitates evidence-based program refinement and provides evidence for program developers working with similar population groups, in similar contexts.

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MobileMums is an individually tailored 12-week physical activity program based on Social Cognitive Theory (SCT) that is primarily delivered via mobile telephone text messaging. The program was developed for and with women with young children (<5 years) through an iterative process utilising theory and formative research with the target group (Fjeldsoe, Miller, O'Brien, & Marshall, 2012). Women with young children have been consistently shown to be less active than women of the same age without children (Adamo, Langlois, Brett, & Colley, 2012; Bellows-Riecken & Rhodes, 2008; Berge, Larson, Bauer, & Neumark-Sztainer, 2011; Brown, Mishra, Lee, & Bauman, 2000) and women with older children (Adamo et al., 2012; Brown, Burton, & Rowan, 2007; Miller, Trost, & Brown, 2002; Nomaguchi & Bianchi, 2013). In addition to the many health benefits of physical activity experienced in the general population (Haskell, Blair, & Hill, 2009), women with young children may also benefit from lower risk of: developing postnatal depression (Dipietro et al., 2019; Poyatos-León et al., 2017; Pritchett, Daley, & Jolly, 2017; Teychenne & York, 2013) and retaining excess body weight following pregnancy (Choi, Fukuoka, & Lee, 2013; Dipietro et al., 2019; Ferguson, Daley, & Parretti, 2019; Van der Pligt et al., 2013). Short-term increases in moderate-vigorous intensity physical activity (MVPA) have been demonstrated in previous trials of physical activity interventions designed for this target group (Gilinsky et al., 2015; Keller et al., 2014; Mascarenhas, Chan, Vittinghoff, Van Blarigan, & Hecht, 2018; Maturi et al., 2014; Vincze, Rollo, Hutchesson, Callister, & Collins, 2018), but reports on these trials rarely investigate how the theoretical constructs underpinning the intervention have impacted upon physical activity outcomes (Miller et al., 2002; Cramp & Brawley, 2009; Fahrenwald, Atwood, & Johnson, 2005).

Our pilot research showed that MobileMums produced short-term (mid-intervention) increases in the frequency of self-reported MVPA (Fjeldsoe, Miller, & Marshall, 2010) and that these changes were mediated by mid-intervention improvements in the targeted SCT constructs of self-efficacy and goal setting skills (Fjeldsoe, Miller, & Marshall, 2013). Our initial MobileMums program did not elicit improvements in outcome expectancies, perceived environmental opportunity nor social support. We adapted the program based on these preliminary findings and the improved version of MobileMums was evaluated in a community-based randomised controlled trial. The improved version of MobileMums led to larger effect sizes (compared to the pilot trial) on self-reported MVPA at the end of the intervention. The larger effects were likely driven by the statistically significant increase in MVPA duration (minutes/week; mean change 37.9 (95% CI 9.2, 66.5)) and frequency (days/week; mean change 1.6 (95% CI 0.8, 2.3)) observed in the intervention group, and subsequent statistically significant between-group effects for both of these outcomes (i.e., an intervention effect of 45.4 minutes/week and 1.4 days/week) (Fjeldsoe, Miller, Graves, Barnett, & Marshall, 2015). Accelerometer-measured MVPA did not statistically improve as a result of the improved version of MobileMums, but the trial was not powered to detect this difference (Fjeldsoe et al., 2015).

Therefore, the aim of this secondary analysis is to examine which SCT constructs mediated the intervention effect of the improved version of the MobileMums program on increasing self-reported MVPA in women with young children. It is anticipated that the improved version of MobileMums will elicit positive changes in women's barrier

self-efficacy and goal setting skills, as well as outcome expectancies, perceived environmental opportunity and social support for physical activity, and that these improvements will mediate the changes in MVPA. This paper adds to the scarce body of literature investigating how physical activity interventions work in general and specifically for women with young children. It is no longer enough to simply understand if the intervention created change, we need to know how change was supported so that future interventions can be adapted accordingly.

Methods

Reports on our formative research and iterative development processes for creating the MobileMums intervention (Fjeldsoe et al. 2012), detailed methods of the randomised controlled trial (Marshall, Miller, Graves, Barnett, & Fjeldsoe, 2013), the primary evaluation outcomes (Fjeldsoe et al. 2015), and cost-effectiveness outcomes (Burn et al., 2015) are provided elsewhere.

Study design

This was a 9-month, two-arm community-based randomised controlled trial. Participants were randomly allocated to the MobileMums intervention group or minimal contact control group. Data were collected before the program (Time 1), immediately after the 12-week intervention (Time 2) and 6-months after the last intervention contact (Time 3). This secondary analysis uses data from Time 1 and 2.

The trial adhered to the CONSORT guidelines for reporting randomised controlled trials (Begg et al., 1996) and was registered with the Australian Clinical Trials Registry (ACTRN12611000481976). Ethical clearance was obtained through the Queensland University of Technology Human Research Ethics Committee (Application # 0900001407).

Participant eligibility and recruitment

Women with young children were recruited from an Australian regional community via one of three methods: (1) a mailed invitation (followed by a text message and then telephone call) to women from an existing research database who had consented to being re-contacted for research purposes; (2) an invitation sent via a community centre's Facebook© group; and (3) a mailed invitation to women who had participated in a survey about their experience of maternity care (Miller, Thompson, Porter, Armanasco, & Prosser, 2010) and consented to be contacted for further research. Further details on the trial recruitment methods and the outcomes of each recruitment strategy are reported elsewhere (Marshall, Miller, Graves, Barnett, & Fjeldsoe, 2015).

To be eligible, women: had at least one child aged five years or younger; owned a mobile telephone; were not pregnant at the time of consent (participants remained eligible if they fell pregnant during the 9-month trial); lived within the designated residential area (30 km radius of Caboolture, Queensland) and planned to remain there for the next 12 months; and were able to read and understand English. Any woman who

had been advised not to exercise by a healthcare professional was asked to receive clearance before participating. Once eligibility was established, women provided informed verbal consent over the telephone.

While the primary focus of this intervention was to increase women's physical activity, it was also designed to support ongoing participation by widening participants' physical activity support network. For this reason we chose to not exclude women who were identified as physically active during the past week as part of the screening process. Women who were habitually physically active, and did not foresee any benefit of participating opted out of the study during the informed consent process (Marshall et al., 2015). The recruitment strategy thus mimicked how the program may be offered under real-world circumstances where women decide to opt into a program if they would like to increase or maintain their activity levels.

Randomisation

Participants were randomised in three strata according to their Time 1 physical activity frequency, which was assessed using data collected during a brief screening telephone interview from a validated (Marshall et al., 2013; Fjeldsoe et al., 2015) single item asking (on a scale from 0 to 7 days) how many days per week they 'exercised for at least 30-minutes'. Each participant was classified as either: not at all active (exercised 0 days per week); somewhat active (exercised between 1 and 4 days per week) or sufficiently active (exercised 5 days or more per week) (Commonwealth Department of Health and Ageing, 2005). Randomisation was managed by the project coordinator using three lists created using the 'sample' function in the R© software package to create random permuted blocks of size 10 with a 1:1 allocation ratio.

MobileMums program

MobileMums comprised multiple program components, including one face-to-face participant counselling session, participant and support person text messages, one mid-program telephone counselling session, and informational and interactive written resources described below. Each component of MobileMums operationalised at least one construct of the SCT (barrier self-efficacy, goal setting skills, outcome expectancies, social support and perceived environmental opportunity) into a behaviour change technique (Fjeldsoe et al., 2013). Supplementary Table 1 maps how each behaviour change technique (Michie et al., 2013) was targeted in the MobileMums intervention and how these aligned with the theoretically proposed mediators of behaviour change (updated from Fjeldsoe et al., 2013).

Face-to-face counselling session

After completing Time 1 assessment, the MobileMums program commenced with a face-to-face session with a trained MobileMums behavioural counsellor. The aim of this session was to: establish rapport between the participant and their MobileMums counsellor, collect information to tailor the text message content, and initiate the behaviour change process. Participants were guided to: reflect on their physical

activity patterns (based on feedback from Time 1 physical activity assessment); identify expected outcomes of being active; set a SMART physical activity goal and reward for reaching their goal; identify barriers to reaching their goal and strategies to overcome them; and identify the support they required for reaching their goal and a specific person to be their MobileMums support person. This session occurred at a time and location identified by the participant (usually their home).

Two tertiary educated counsellors underwent intensive training in the evidence of why promoting MVPA was beneficial, the constructs of the SCT, effective counselling skills (e.g. active listening), and familiarisation with issues specific to the target group. The counsellors were provided with the MobileMums Training Guide, had multiple one-on-one training sessions and engaged in role play training prior to contact with participants. During the program, each counsellor audio-recorded three sessions (selected at random) with permission from the participant; these recordings did not undergo fidelity analysis but were reviewed by the first author to provide counsellors with feedback on their performance.

MobileMums text messages

Over the 12-week program, participants received a minimum of 52 individually tailored text messages sent by a customised, automated web-based program. Text message tailoring was achieved by linking the automated program with a secure database of participant data collected by the counsellors during the face-to-face counselling session. Participants were sent five text messages per week for the first four weeks and four text messages per week thereafter. Weekly text messages included one 'goal check text' sent each Monday asking the participant to respond (e.g. *Jenny did u do all ur planned exercise last wk? Check ur planner magnet & text me back yes or no. Jacqui-MobileMums)*. If a participant replied to this 'goal check text', the program sent an appropriate, tailored reply. Therefore, a participant could receive an additional 11 text replies if they responded to each goal check message (total texts possible = 63).

Text message content was tailored to each participant's: name, counsellor's name, goal, neighbourhood, preferred reward and/or expected outcomes for reaching her goal. In addition, where appropriate the text messages were tailored to the participant's youngest child's name and the support person's name and gender.

Support person text messages

The MobileMums support person who was identified by participants during their face-to-face counselling session also received 12 weeks of individually tailored, theory-based text messages. Support people were sent three theory-based text messages per week encouraging them to offer instrumental, emotional or informational support to their MobileMum. Some of these messages were tailored to how their MobileMum participant responded to her weekly goal check (e.g. *Luke, congratulate Jenny. She met her goal last wk. Can u help make time 4 her reward? It's a bubble bath. Jacqui- MobileMums*).

Week 6 telephone counselling session

During Week 6, participants received a telephone call from their MobileMums counsellor. The aim of this session was to update the participant's physical activity goals and strategies in order to refine text message content in Weeks 7 to 12.

Supplementary resources

Throughout the program participants had ongoing access to their MobileMums Participant Handbook, MobileMums website with searchable, on-line exercise directory, secret MobileMums Facebook© group (which research staff monitored), MobileMums Goal Tracking refrigerator magnet, and information brochures, all of which they received during the initial face-to-face counselling session.

Changes from the pilot version of MobileMums (Fjeldsoe et al., 2010) in developing the version of the program tested here included: a more active, online process to recruit the MobileMums support person; higher dose of texts to the support person (3 texts/week rather than 2 texts/week); more tailoring of the support person texts; participant access to a MobileMums Facebook© group and an on-line exercise directory; higher dose of texts to the participants in Weeks 5–12 (4 texts/week rather than dropping to 3 texts/week); and the initial consult being guided by the MobileMums Participant Handbook which was kept by the client.

Control group

Women in the minimal contact control group received the same standard physical activity information brochures as the intervention group and had access to a separate information-only website and a separate non-moderated Facebook© group. This treatment was designed to reflect the minimal care that service providers could feasibly deliver without specific funding (e.g., standard print materials, non-moderated Facebook© access).

Data collection

Data were collected via self-administered postal questionnaire and telephone interview at Time 1 and 2. The telephone interviews were conducted by trained research assistants who may not have been blinded to group allocation at Time 2 due to participants disclosing information about their treatment. All participants received a nominal gratuity ($20 gift voucher) for each completed assessment to recognise their contribution to the research.

Physical activity outcomes

The Australian Women's Activity Survey was developed to specifically assess physical activity among women with young children (Fjeldsoe, Miller, & Marshall, 2009) and was administered during the telephone interview at Time 1 and 2. This survey asks respondents to recall the frequency (days/wk) and duration (time/day) of a variety of activities during weekdays and weekend days, with a recall reference

period of a typical week in the past month. It assesses women's activity across five domains (planned, transport, childcare, domestic and work-related) and three intensity levels (light, brisk walking, other moderate and vigorous). The interview-administered Australian Women's Activity Survey has good test-retest reliability and acceptable criterion validity (compared to accelerometer data) (Fjeldsoe et al., 2009). The key variables calculated from the survey were: minutes per week (duration) and days per week (frequency) in the planned and transport domains for MVPA (including brisk walking, moderate and vigorous intensity activities).

Potential mediator outcomes

These outcomes were assessed via self-administered questionnaire, in both groups, at Time 1 and 2.

Physical activity barrier self-efficacy was assessed on a 5-point Likert scale (from 1 'not at all confident' to 5 'very confident'), using a 12-item tool adapted from a previous scale (Marcus & Owen, 1992). Our version included two additional items for women with young children (i.e. I can exercise even when: 'I don't have anyone to look after the kids'; 'I have housework to do'). This adapted version of the scale has demonstrated sensitivity to change among postnatal women (Miller et al., 2002; 2013) and acceptable internal consistency (Cronbachs $\alpha = 0.71$) (Fjeldsoe et al., 2013).

Goal setting skills were measured using the 10-item Exercise Goal-setting Scale (Rovniak, Anderson, Winett, & Stephens, 2002). This scale has good test retest reliability ($r = 0.87$) over an 8-week period (Rovniak et al., 2002). The Exercise Goal-setting Scale items assess setting goals (e.g. I often set exercise goals), self-monitoring (e.g. I usually keep track of my progress in meeting my goals) and problem solving (e.g. If I do not reach my goals, I analyse what went wrong). Each item was measured on a 5-point Likert scale, but following our formative research the original anchors ('does not describe' to 'describes completely') were adapted to 'strongly disagree' to 'strongly agree'. The adapted version of the Exercise Goal-setting Scale had good internal consistency (Cronbachs $\alpha = 0.84$) (Authors, 2013), similar to that of the original scale ($r = 0.89$) (Rovniak et al., 2002).

Outcome expectancy was measured using 10-item scale developed by Rodgers and Brawley (1991). Participants rated outcome likelihood (on an 11-point scale, 0%–100% likelihood) and outcome value (on a 9-point scale of importance) for seven physical activity outcomes. Ratings were multiplied to indicate overall outcome expectancy (range 0–900). Consistent with the creator's recommendations, the specific physical activity outcomes used in this study were determined from formative research with the target population. The most commonly reported positive (weight loss, improved fitness, more energy, less stress, improved mental well-being) and negative outcomes (injury, lost time to do other things) were included. Our previous trial (Fjeldsoe et al., 2013) and others (Cramp & Brawley, 2009) have demonstrated that the measure was sensitive to change in a physical activity intervention among women with young children. The scale had acceptable internal consistency (Cronbachs $\alpha = 0.72$) (Fjeldsoe et al., 2013).

Perceived environmental opportunity for physical activity was measured using 12 items designed and implemented by Hoehner and colleagues (Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 2005). These items were derived from a review of three commonly used questionnaires to assess environmental impact on physical activity participation (Brownson et al., 2004), and assessed on a five point Likert scale from 1 'strongly disagree' to 5 'strongly agree'. Based on our formative research we added two additional items to the scale ('There are footpaths wide enough to fit prams in my neighbourhood' and 'Unattended dogs make it unsafe to walk in my neighbourhood'). The adapted scale has acceptable internal consistency (Cronbachs $\alpha = 0.75$) (Fjeldsoe et al., 2013).

Physical activity social support from the participant's partner (husband or defacto) and from their family or friends was assessed on a 5-point Likert scale using the Social Support for Exercise Scale (Sallis, Grossman, Pinski, Patterson, & Nader, 1987). Five items, including an additional one ('offered to mind the kids so I could be more physically active') were assessed on a scale from 1 'never' to 5 'very often'. The original scale has good test-retest reliability ($r = 0.55$–0.79)(Sallis et al., 1987) and this slightly modified version has demonstrated good internal consistency (Cronbachs $\alpha = 0.90$) (Fjeldsoe, Miller, & Marshall, 2013) and sensitivity to change among women with young children (Fjeldsoe et al., 2002, 2013). Participants nominated which scale (i.e. partner; family and friends) should be used to represent the support provided by their MobileMums support person.

Sample size

Sample size was based on the clinically meaningful increase in self-reported MVPA observed in our pilot study at mid-intervention (40 minutes/week) (Fjeldsoe et al., 2010). Using the standard deviation of 102 minutes/week (from survey data), and assuming 80% power and two-sided significance of 5% we needed 102 women per group. Anticipating a 25% dropout, this figure was inflated to 128 per group (256 in total). We were not powered apriori to examine mediators. As such, our interpretation of findings accounted for both the statistical significance and the magnitude of effects.

Statistical analysis

Self-reported MVPA variables and mediator variables were converted to change scores by subtracting Time 1 from Time 2 scores. Mediator variables were also standardised by dividing each score by the standard deviation of the change score, to allow for more meaningful interpretation of unstandardised regression coefficients. Change and standardised change variables sufficiently met the assumptions of normality, independence and homoscedasticity.

Mediation analyses were conducted using the PROCESS tool for SPSS (Hayes, 2013). PROCESS uses ordinary least squares regression to compute coefficients for pathways α, β, c and c' (see Figure 1 for a description of each path), in addition to providing bootstrapped confidence intervals for evaluating the indirect effect. Bootstrapping

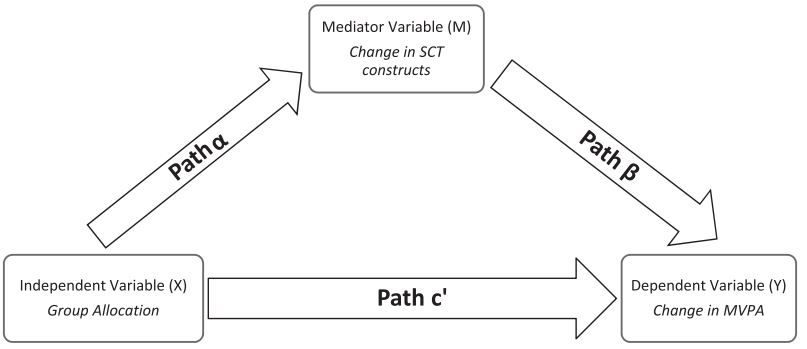

Figure 1. Conceptual model of the proposed simple mediation analyses.
Note. MVPA = moderate-vigorous physical activity; SCT = social cognitive theory; Path α = the effect of group allocation (X) on changes in the mediator (M); Path β = the effect of change in the mediator (M) on change in physical activity (Y), after controlling for the effects of group allocation (X); Path c′ = the 'direct effect' – the effect of group allocation (X) on change in physical activity (Y) after controlling for the effects of change in the mediator (M); $\alpha\beta$ = the 'indirect effect' – the product of the effect of X on M and the effect of M on Y after controlling for the X.

techniques, rather than Sobel tests (as stated in our trial protocol (Marshall et al., 2013)), were used to quantify the indirect effect. Bootstrapping is now widely regarded as a superior method as it does not make assumptions about the normality of the sampling distribution of the indirect effect, which is often asymmetric (Hayes, 2009). Using Model 4 in PROCESS (Hayes, 2013), which allows for the calculation of simple mediation with the inclusion of covariates, analyses were conducted separately for each mediator and each self-reported MVPA outcome (i.e. a single mediator and outcome measure in each analysis). Time 1 scores for the mediator and self-reported MVPA outcome were entered as covariates in each of the respective analyses. Square-root transformations were used for two of the Time 1 variables (i.e. social support from family and friends, MVPA duration) entered as covariates to correct for violations of the assumption of normality. Estimates of the 95% bias-corrected confidence intervals of the indirect effect were derived from 5000 bootstrap samples. Due to small amounts of missing data, analyses were conducted among women who had complete data for the corresponding variables rather than excluding women with incomplete data from all analyses. Analyses were conducted with SPSS version 21.

Results

Participants

Three-hundred and six participants consented, and 263 (86%) completed Time 1 assessments and were randomised. The retention rate of the randomised sample was 86% at Time 2 ($n = 226$; end-of-intervention), but this retention rate was significantly different for the intervention group (82%) compared to the control group (90%) (odds ratio (OR) = 2.49, $p = .06$, 95% CI [1.01, 6.72]). This difference in retention rates was likely due to the higher contact burden for the intervention including repeated contact that provided more opportunity for intervention participants to withdraw. Kruskal-Wallis tests revealed no significant differences in demographic characteristics for women with and without complete data at Time 2. The mean age of the trial sample

Table 1. Demographic and physical activity characteristics of participants randomly allocated to each study groups.

	Intervention group ($n = 133$)	Control group ($n = 130$)
	Mean (standard deviation)	
Age (years)	32.2 (5.2)	33.2 (5.3)
BMI (kg/m^2)	24.9 (11.3)	27.4 (10.0)
Age of youngest child (months)	26.4 (16.7)	26.8 (15.2)
	Median (25th–75th percentiles)	
Days per week with 30 minutes of exercise at baseline (single-item screener)	1 (0–2)	1 (0–3)
	n (%)	
Became pregnant during trial	14 (10.5%)	11 (8.5%)
Only one child to be cared for whilst exercising	38 (28.6%)	46 (35.4%)
Marriage status- no partner	15 (11.3%)	16 (12.3%)
Identify as Aboriginal or Torres Strait Islander	2 (1.5%)	2 (1.5%)
Income- less than $600 weekly household income	10 (7.5%)	16 (12.3%)
Education- Year 10 highest education level	25 (18.8%)[a]	31 (23.8%)[a]
Employment status – full time home duties	58 (43.6%)	61 (46.9%)

[a]One intervention participant and two control participants did not report education level.

Table 2. Coefficients and standard error (SE) or 95% confidence intervals (95% CI) of the relationship of each mediator with change in self-reported MVPA frequency (days per week).

		Relationship with frequency of MVPA			
Potential mediator	*n*	α (SE)	β (SE)	c'(SE)	$\alpha\beta$ (95% CI)
Barrier self efficacy	207	0.40 (0.13)**	1.19 (0.30)***	1.17 (0.54)*	0.48 (0.18–0.97)[#]
Goal setting skills	206	0.70 (0.12)***	1.06 (0.32)**	0.88 (0.57)	0.74 (0.26–1.44)[#]
Outcome expectancies	205	0.26 (0.14)	0.78 (0.28)**	1.54 (0.54)**	0.20 (0.01–0.52)[#]
Perceived environmental opportunity	202	0.08 (0.14)	0.58 (0.28)*	1.50 (0.55)**	0.04 (–0.10 to 0.29)
Social support from family/ friends	206	0.51 (0.12)***	0.63 (0.32)*	1.20 (0.56)*	0.33 (0.01–0.83)[#]
Social support from partner	178	0.61 (0.12)***	0.81 (0.36)*	1.02 (0.62)	0.50 (0.14–1.05)[#]
Social support from Mobile Mums support person	201	0.45 (0.12)***	0.53 (0.33)	1.20 (0.58)*	0.24 (–0.04 to 0.67)

Note. *$p < .05$, **$p < .01$, ***$p < .001$.
[#]Significant indirect effect.

was 33 (±5 years), 21% reported an education level no higher than grade 10 in secondary school and 47% reported engagement in full-time home duties (Table 1).

Mediators of intervention effects on self-reported MVPA frequency

The MobileMums program led to significant increases in barrier self-efficacy, goal setting skills, and social support from family and friends, from partners and from MobileMums support persons (Table 2; α paths). Increases in barrier self-efficacy ($p <$ .001), goal setting skills ($p = .001$), outcome expectancy ($p = .005$), perceived environmental opportunity ($p = .042$) and social support from family and friends ($p = .050$), and from partners ($p = .025$) were related to improved frequency of self-reported MVPA (Table 2; β paths). The association between group allocation and increased frequency of self-reported MVPA was mediated by improved barrier self-efficacy ($\alpha\beta = 0.48$, 95% CI = 0.18–0.97), goal setting skills ($\alpha\beta = 0.74$, 95% CI = 0.26–1.44), outcome expectancy ($\alpha\beta = 0.20$, 95% CI = 0.01–0.52), social support from family and friends ($\alpha\beta = 0.33$, 95% CI = 0.01–0.83) and social support from partners ($\alpha\beta = 0.50$, 95% CI = 0.14–1.05; Table 2).

Table 3. Coefficients and standard error (SE) or 95% confidence intervals (95% CI) of the relationship of each mediator with change in self-reported MVPA duration (minutes per week).

		Relationship with duration of MVPA			
Potential mediator	*n*	α (SE)	β (SE)	c'(SE)	$\alpha\beta$ (95% CI)
Barrier self efficacy	209	0.41 (0.12)**	38.37 (13.99)**	43.57 (25.41)	15.53 (3.40 to 36.08)#
Goal setting skills	208	0.71 (0.12)***	31.25 (14.75)*	34.13 (26.58)	22.24 (1.90 to 49.61)#
Outcome expectancies	207	0.23 (0.14)	22.66 (13.07)	54.46 (25.58)*	5.27 (–0.43 to 17.10)
Perceived environmental opportunity	204	0.08 (0.14)	19.73 (13.16)	49.61 (25.64)	1.66 (–2.51 to 12.24)
Social support from family/ friends	208	0.52 (0.12)***	21.17 (15.05)	41.25 (26.41)	11.00 (–2.90 to 31.00)
Social support from partner	180	0.61 (0.12)***	14.32 (17.04)	52.42 (29.47)	8.77 (–7.00 to 27.32)
Social support from Mobile Mums support person	203	0.45 (0.12)***	5.95 (15.21)	55.09 (26.98)*	2.69 (–10.54 to 17.76)

Note. *$p < .05$, **$p < .01$, ***$p < .001$.
#Significant indirect effect.

Mediators of intervention effects on self-reported MVPA duration

The MobileMums program led to significant improvements in barrier self-efficacy, goal setting skills and social support from family and friends, from partners and from MobileMums support persons (Table 3; α paths). Improvements in barrier self-efficacy ($p = .007$) and goal setting skills ($p = .035$) were associated with increased self-reported MVPA duration (Table 3; β paths). The association between group allocation and increases in self-reported MVPA duration was mediated by improvements in barrier self-efficacy ($\alpha\beta = 15.53$, 95% CI = 3.40–36.08) and goal setting skills ($\alpha\beta = 22.24$, 95% CI = 1.90–49.61; Table 3).

Discussion

This secondary analysis of MobileMums trial data showed that the improvements observed in self-reported MVPA frequency were mediated by improvements in women's barrier self-efficacy, goal setting skills, outcome expectancies and perceived social support, while improvements in self-reported MVPA duration were mediated by improvements in barrier self-efficacy and goal setting skills. Changes in perceived environmental opportunities did not mediate the intervention effects on MVPA frequency or duration.

These findings align with those from earlier mediational analyses of physical activity interventions among women with young children (Miller et al., 2002; Cramp & Brawley, 2009; Fahrenwald et al., 2005) and also complement and extend the findings of our pilot MobileMums study (Fjeldsoe et al., 2013). Both versions of MobileMums significantly improved women's barrier self-efficacy, goal setting skills and social support (i.e. Path α findings). In the pilot study mediation was only significant at mid-intervention (not end of intervention), while the current trial demonstrated significant mediators of end of intervention effects. This suggests increased longevity of the improved program's impact on targeted mediators beyond the first six weeks. These analyses also revealed another step-wise improvement from the pilot version of MobileMums whereby improvements in outcome expectancies and perceived social support were detected as mediators, when they were not in the pilot trial. Iterative improvements made to the program specifically targeted these theoretical constructs

and these findings thus reaffirm the benefits of an iterative approach to program development that accounts for progressive learnings.

This improved version of the MobileMums program did not elicit changes in perceived environmental opportunity. Based on similar findings in the pilot trial, we added the on-line, searchable exercise directory to this version of MobileMums and made more frequent reference to local opportunities for exercise in the tailored text messages. However, our process evaluation showed that women did not engage with the online directory (Fjeldsoe et al., 2010), which may explain the lack of impact on this construct of the SCT. It is also possible that the actual environment (as opposed to the perceived environment) in which women were living was unsupportive for women to be active with young children, thus limiting the potential for improving women's perceptions. We did not collect data on the actual opportunities present in participant's neighbourhoods in this trial. It is also possible that improving women's perception of environmental opportunities takes longer than 12 weeks and that repeat exposure and attempts to access environmental opportunities in many different contexts are required to elicit changes in this construct. Finally, there is some cross-sectional evidence to suggest that the association between women's perceived opportunity for physical activity and leisure-time physical activity is attenuated by their psychological and social factors, particularly for women with medium or high psycho-social support (Cleland, Ball, & Crawford, 2013). This may explain the lack of findings for perceived environmental opportunity in this trial. Future research needs to examine how women's perceptions of their environment shape their physical activity behaviours, is attenuated by their psychological and/or social influences and how this may be shifted over time.

There were no consistent patterns of the mediation effects of social support on physical activity across the three sources assessed (i.e. family and friends, partner, nominated MobileMums support person). The program may have improved women's skill in obtaining social support from multiple sources, outside of their direct MobileMums support person, and this diversity of support sources may have diluted the findings.

Two reviews in the past decade have summarised the evidence on mediators of physical activity behaviour change, one among non-clinical adults (Rhodes & Pfaeffli, 2010) and one in overweight or obese adults (Teixeira et al., 2015). Both reviews suggested that self-regulation consistently and significantly mediated changes in physical activity. Teixeira and colleagues (2015) also found that high autonomous motivation and self-efficacy frequently mediated changes in physical activity in overweight or obese adults. Importantly, both reviews caution that there remains a relatively small number of mediational studies, and those available employ poor quality methodology. Few physical activity interventions designed for women with young children have evaluated the mediators of change (Miller et al., 2002; Cramp & Brawley, 2009; Fahrenwald et al., 2005). Generally, those that have evaluated mediators have reported findings consistent with the current trial, in that barrier self-efficacy, social support for physical activity (Miller et al., 2002) and self-regulatory efficacy (Cramp & Brawley, 2009) act as mediators of increased physical activity.

This trial was not powered appropriately to detect mediational effects. The lack of statistical power increases risk of Type II errors in our interpretation of the analyses. Notably, there were different mediators of intervention effects for MVPA frequency and duration outcomes, which may be a spurious finding due to Type I error and the multiple comparisons made in this secondary analysis. Multiple mediator models were not used in this analysis due to the small sample. This limits the theoretical conclusions that can be drawn because the SCT principle of reciprocal determinism suggests that the proposed mediators interact to impact on behaviour. Physical activity was assessed via self-report measures in this secondary analysis. In comparison to objective measures, self-reported physical activity may be over-reported due to recall inaccuracy or social desirability bias, or under-reported due to the constraints of questions asked (Prince et al., 2008). However, we used the Australian Women's Activity Survey to assess physical activity, which was specifically designed to minimise reporting biases by encouraging women to report all of their activities. Finally, the sample of women recruited into this trial may not have been representative of the broader community of women from which it was sampled.

In an era of increased focus on intervention content and design reporting it is concerning to note the ongoing lack of mediator evaluations in the literature. There has been a surge in reviews of publications reporting on the behaviour change techniques used in effective behaviour change interventions (Michie, West, Sheals, & Godinho, 2018). These evidence syntheses are informative, but the mere presence or absence of a behaviour change technique in an intervention design does not speak to its causal impact on the targeted behaviour, as is illustrated through a mediational analysis. The findings of this analysis have helped the authors to refine MobileMums and inform the 'active ingredients' to maintain in adapting the program for wide-scale dissemination. This paper also adds valuable knowledge for researchers and practitioners striving to create evidence-based physical activity behaviour change programs for women with young children.

Disclosure statement

The authors declare that they have no conflict of interest.

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Data availability statement

Data can be made available upon request.

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