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Review Article

Financial incentives for physical activity in adults: Systematic review and meta-analysis update

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ABSTRACT

Objective: To update the evidence on the effects of financial incentives (FI) on physical activity (PA) in adults.
Methods: A systematic search of nine databases (Medline, EMBASE, PsychINFO, Scopus, Web of Science, CINAHL, EconLit, SPORTDiscus, and Cochrane) was conducted to identify randomised controlled trials (RCTs) and pilot RCTs published between June 1, 2018 and March 31, 2024 examining FI-for-PA interventions. 'Vote counting' and random-effects meta-analyses assessed short- (<6 months) and long-term (≥6 months) FI effects, as well as impact during follow-up (incentive withdrawal). Meta-regressions examined moderator effects.
Results: Twenty-nine studies (n = 21 RCT, n = 8 pilot RCTs; median FI size = \$1.19 USD/day) involving 9604 participants were included (60.8 % female, mean age = 42.7 years). 17 of 21 studies reported positive short-term effects. 5 of 5 and 3 of 8 studies, respectively, reported positive long-term and follow-up effects. Among the 15 studies included in daily step count meta-analyses (most commonly reported PA outcome), FI had a moderate effect during short-term interventions (standardized mean difference [SMD] [95 % CI] = 0.52 [0.25–0.78], $p <$ 0.001) and a small effect in follow-up (SMD [95 % CI] = 0.20 [0.01–0.40], p = 0.04). Too few long-term studies reported daily step count to conduct pooled analyses (n = 1). Meta-regressions suggest study length, incentive size, wearable device-use, and goal setting moderate FI effects (p < 0.05).
Conclusions: Twenty-nine studies were identified over a 6-year span. Short-term FI interventions increase PA. The impact on daily step count is clinically significant (≥1000 steps/day). Key contextual factors moderate effects. Evidence is limited regarding long-term and follow-up effects.

1. Introduction

Insufficient physical activity (PA) increases the risk of over 100 chronic conditions (i.e., type 2 diabetes) (Lee et al., 2012; Kohl et al., 2012) yet widespread inactivity persists (World Health Organization, 2021). Associated healthcare costs may reach \$300 billion USD globally by 2030 (World Health Organization, 2022). To begin to address the health and economic consequences of physical inactivity, effective and scalable solutions are needed (e.g., digital PA intervention) (World Health Organization, 2018). Greater smartphone and wearable fitness tracker penetration has made digital PA interventions more accessible in general (Mair et al., 2022). Global smartphone ownership, for example, has increased substantially since 2018 (i.e., 85 % in 2023 vs. 66 % in 2018) (PEW, 2024). The concomitant proliferation of commercially available mHealth apps (i.e., 80 % increase in number published in major app stores since 2013) (IQVIA, 2021) that leverage the latest advances in smartphone technology (e.g., enhanced biometric sensing, 5G network service, artificial intelligence-driven chatbots) (Verizon News Archives, 2019; Gao and Lee, 2019; Aggarwal et al., 2023) has increased the behaviour change potential of digital PA interventions in the public sphere. Despite their potential, however, low engagement (e.g., frequency and depth of use) (Rahman et al., 2017) leading to little or no effect is typical (Singh et al., 2024).

Digital PA interventions grounded in behaviour change theory may work better than those that are not (Fanning et al., 2012). Interventions grounded in behavioural economics, for example, a branch of economics complimented by insights from psychology, have proved to be more effective than those that are not (McGill et al., 2019). Unlike traditional economic theory that assumes people make rational decisions in all instances (Thaler and Sunstein, 2008), behavioural economics has shown

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that systematic errors in thinking, called "decision biases" (Supplementary File A), can lead to irrational choices (e.g., neglecting PA while knowing it's health benefits) leading to poor outcomes (e.g., chronic disease development) (O'Donoghue and Rabin, 2015). For example, the "present bias" describes how individuals place greater emphasis in decision making on immediate consequences or benefits compared to delayed ones (Vlaev et al., 2013). According to behavioural economics, financial incentives (FI), monetary rewards contingent on the achievement of a PA goal for instance, introduce a new immediate benefit to counterbalance the well-known short-term costs of PA (e.g., time out of a busy schedule, uncomfortable feelings) (McGill et al., 2019). While theoretically promising, evidence gaps remain regarding the effectiveness of FI-for-PA.

Previous systematic reviews suggest FI may increase short-term (i.e., <6 months) PA, but not to clinically significant levels (i.e., ≥1000 steps/day) (Luong et al., 2021; Boonmanunt et al., 2022). Evidence of long-term (i.e., ≥6 months, a theoretical definition of behaviour maintenance) (Prochaska and Velicer, 1997) and follow-up (i.e., after incentive withdrawal) effects is less clear (Boonmanunt et al., 2022; Mitchell et al., 2019). For instance, systematic reviews investigating long-term effects have not been able to draw firm conclusions given the limited number of RCTs examining FI effects beyond six months (i.e., only four out of 51 trials included in Luong et al. [2021]). However, positive long-term effects in all four studies suggest FI, as part of a broader intervention package, may promote PA behaviours longer-term. More research is needed to strengthen these findings. Systematic reviews have concluded FI effects at follow-up are not clear with results from pooled meta-analyses contradicting narrative summaries (Luong et al., 2021; Boonmanunt et al., 2022; Mitchell et al., 2019). These gaps are important since many of the health benefits of habitual PA accrue over longer periods (World Health Organization, 2018). This is doubly important as governments (Yao et al., 2020; Department of Health and Social Care, 2021; ParticipACTION homepage, 2024) and private companies (de Buisonjé et al., 2023; Derlyatka et al., 2019; Romanelli et al., 2023) continue to spend scarce resources on FI-for-PA despite little knowledge of their long-term and sustained effects. Furthermore, little empirical evidence exists regarding the contextual factors potentially moderating the impact of PA incentives (e.g., participant [gender, income] and program [length, PA goals] characteristics) (Marchiori et al., 2017). In addition, while FI can be manipulated along 14 design features (Mazar and Soman, 2022) (e.g., magnitude, timing, certainty of incentives) little objective data supports one design over another (De Santis et al., 2022). Finally, the most recent systematic reviews in this area have concluded that the quality of the evidence in general remains weak (e.g., studies with small sample sizes, higher risks of bias included in reviews; reliance on narrative evidence summaries; lack of sensitivity analyses when results are pooled) (Boonmanunt et al., 2022; Mitchell et al., 2019). This is especially true for studies examining FI impacts on different PA behaviours (e.g., weekly minutes of moderate-to-vigorous physical activity [MVPA]) and over the long-term or at follow-up (Luong et al., 2021; Boonmanunt et al., 2022). Given these evidence gaps and the rapidly evolving digital PA landscape (e.g., more accessible technologies with more features) through which contemporary FI are often delivered (IQVIA, 2021; Verizon News Archives, 2019; Gao and Lee, 2019), an updated systematic review with meta-analysis is warranted.

This study, therefore, aims to update the evidence regarding short-term, long-term, and follow-up FI effects on multiple PA behaviours. The secondary objective is to examine the moderating effects of contextual factors (i.e., participant and program characteristics).

2. Methods

2.1. Electronic search

This study updates the authors' 2019 systematic review and meta-analysis examining the impact of FI on PA in adults (Mitchell et al., 2019). The present search strategy adapted the one developed by Mitchell et al. (2019) (see Medline search strategy in Supplementary File B). Notably, the current search included four additional databases to capture articles not retrieved previously (i.e., EconLit, Web of Science, SPORTDiscus, Scopus; Supplementary File B). In total, nine electronic databases (MEDLINE [Ovid], Embase [Ovid], CINAHL [EBSCO], PsychINFO [Ovid], EconLit [EBSCO], Web of Science [Clarivate], Cochrane Central Register of Controlled Trials [CENTRAL], SPORTDiscus [EBSCO], and Scopus [Elsevier]) were searched for English-language, peer-reviewed RCT and pilot RCT studies published between June 1, 2018 and March 31, 2024 (May 30, 2018 was the last day electronic databases were searched by Mitchell et al. [2019]). Other recent reviews in this area searched electronic databases up until July 2019 and December 2020, respectively (Luong et al., 2021; Boonmanunt et al., 2022).

In addition, ClinicalTrials.gov and the WHO International Clinical Trials Registry Platform were searched using keywords such as "financial incentive", "physical activity", and "exercise". Reference lists of included articles were screened to identify potentially eligible articles as well. Much like earlier systematic review updates (O'Connor et al., 2020; Patnode et al., 2022; Hoskins et al., 2019), the present review and analysis treated the outcomes of the Mitchell et al. (2019) review as separate. Given the dynamic nature of this area of research (i.e., studies examining the impact of digitally-assessed and delivered FI on PA) (Luong et al., 2021; Boonmanunt et al., 2022; Ananthapavan et al., 2018), studies conducted before 2018 may not be as relevant. Therefore, the latest evidence is the focus of this update. Finally, this review adhered to the methods outlined by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA; Fig. 1, Supplementary File C) (Ardern et al., 2022).

2.2. Eligibility criteria

RCT and pilot RCT studies were included if they reported the effects of incentives on PA in adults aged 18 years or older (i.e., population), with at least one intervention arm receiving FI (i.e., intervention) contingent on an objectively-measured PA behaviour (i.e., outcome); and an equivalent control group without contingent FI (i.e., comparison). In line with previous literature, pilot studies (i.e., > 30 participants) were included to capture the most recent data regarding the effect of FI on PA behaviour (Mitchell et al., 2019; Sim and Lewis, 2012).

2.3. Study selection

Article records were imported into *Covidence*™ systematic review software (Veritas Health Innovation Group, version 2.0). Titles and abstracts were independently reviewed by two reviewers for eligibility (BS and LN). Potentially eligible full texts were retrieved and screened independently by the same two reviewers (BS and LN). At both screening stages, discrepancies were settled via consultation with a third reviewer (ED or MM). Reasons for study exclusion are presented in Fig. 1.

2.4. Data acquisition

A data extraction form adapted from the *Cochrane Handbook for Systematic Reviews of Interventions* (version 6.4, Chapter 5) (Li et al., 2023) was used (Supplementary File D). The form was pretested with five eligible studies. One reviewer (BS) extracted the data from included studies. A second reviewer checked for accuracy (ED). Disagreements were resolved through discussion, with arbitration by a third reviewer (LN or MM). In cases of missing data, authors of included studies were contacted via email.

2.5. Study quality

Two reviewers (BS and LN) assessed the quality of each included

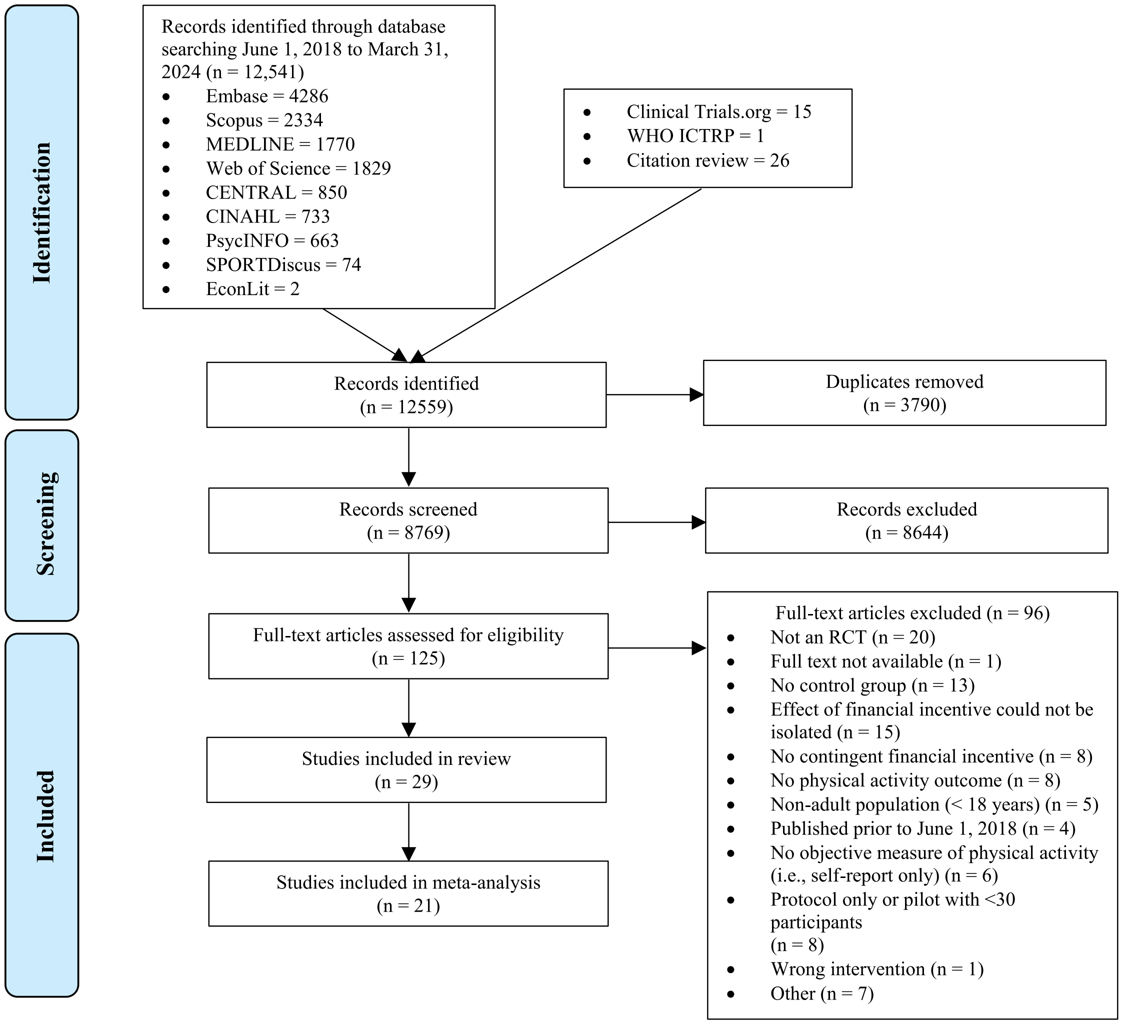


Fig. 1. Flowchart of included and excluded RCTs published between June 2019 and March 2024 examining the impact of financial incentives on physical activity in adults.

article independently using the Effective Public Health Practice Project (EPHPP) quality assessment tool (Supplementary File E) (Armijo-Olivo et al., 2012). Discrepancies were settled via consultation with a third reviewer (ED or MM). The EPHPP includes assessing the risk of bias in five domains (e.g., Domain D: Risk of bias in the blinding process) and assigning an overall risk of bias judgement (Figs. 2 and 3; Supplementary File F).

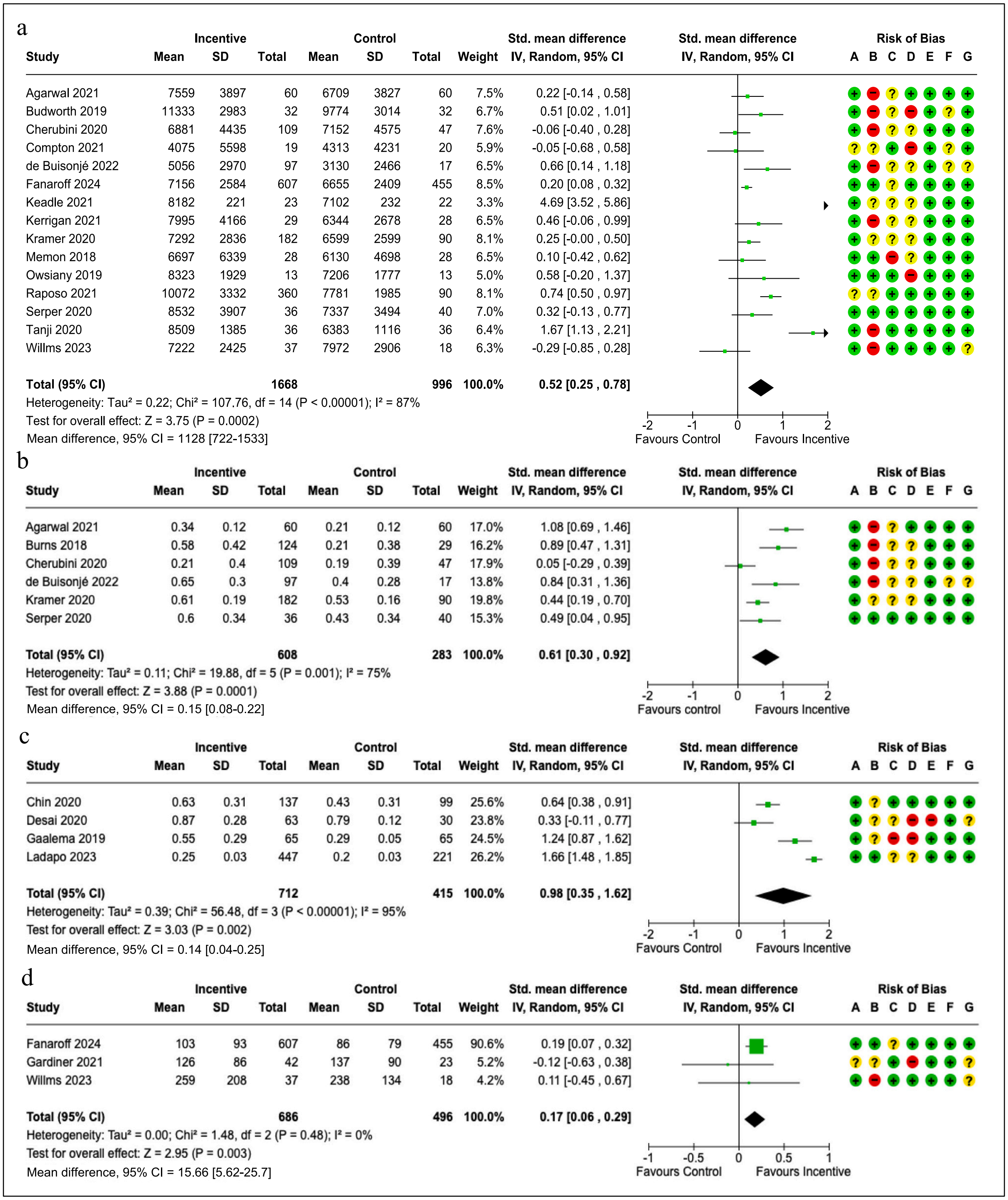
2.6. Statistical analysis

Random effects meta-analyses were undertaken for studies reporting objectively-measured PA behaviour during intervention and follow-up periods. Following the *Cochrane Handbook* (version 6.4, Chapter 16), in instances where trials featured multiple eligible intervention arms, they were pooled together at the study level. This involved combining all relevant FI arms into a single treatment group (Li et al., 2023). To ensure methodological consistency, *Review Manager* (RevMan; Cochrane Collaboration) was used to pool means, calculate standard deviations (SDs), and tally sample sizes. Effect sizes were calculated as the mean difference (MD) and standardized mean difference (SMD) with 95 % confident intervals. Effect sizes were categorized as small (SMD $\geq$ 0.2), medium (SMD $\geq$ 0.5), or large (SMD $\geq$ 0.8) with $p < 0.05$ as the statistically significant threshold (Sullivan and Feinn, 2012). Study estimates statistically adjusted for baseline PA measures (e.g., mean daily step count) and unadjusted measures were pooled. Heterogeneity was examined using the "I^2" statistic, with values above 30 %, 50 %, and 75 % considered moderate, substantial and considerable (Higgins and Thompson, 2002), respectively. For more information regarding analytic approach, see Supplementary File G.

3. Results

3.1. Study characteristics

From a search of 12,541 studies, 133 full texts were assessed for eligibility (Fig. 1). In total, 29 studies were included ($n = 21$ RCT, $n = 8$ pilot RCTs) involving 9604 participants (60.8 % female, mean age = 42.7 [14.7] years, mean body mass index = 31.2 kg/m^2 [4.63]; mean daily step count = 6570; Supplementary File H) (Fricke et al., 2018; Ladapo et al., 2023; Pratt et al., 2023; Willms et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Galarraga et al., 2020; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Piepmeier



a

Study	Incentive Mean	Incentive SD	Incentive Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Agarwal 2021	7559	3897	60	6709	3827	60	7.5%	0.22 [-0.14 , 0.58]	+	−	?	+	+	+	+
Budworth 2019	11333	2983	32	9774	3014	32	6.7%	0.51 [0.02 , 1.01]	+	−	?	−	+	?	+
Cherubini 2020	6881	4435	109	7152	4575	47	7.6%	-0.06 [-0.40 , 0.28]	+	−	?	?	+	+	+
Compton 2021	4075	5598	19	4313	4231	20	5.9%	-0.05 [-0.68 , 0.58]	?	?	+	−	+	?	+
de Buisonjé 2022	5056	2970	97	3130	2466	17	6.5%	0.66 [0.14 , 1.18]	+	−	?	?	+	?	?
Fanaroff 2024	7156	2584	607	6655	2409	455	8.5%	0.20 [0.08 , 0.32]	+	+	?	+	+	+	+
Keadle 2021	8182	221	23	7102	232	22	3.3%	4.69 [3.52 , 5.86]	+	?	?	?	+	+	+
Kerrigan 2021	7995	4166	29	6344	2678	28	6.5%	0.46 [-0.06 , 0.99]	+	−	?	?	+	+	+
Kramer 2020	7292	2836	182	6599	2599	90	8.1%	0.25 [-0.00 , 0.50]	+	?	?	?	+	+	+
Memon 2018	6697	6339	28	6130	4698	28	6.5%	0.10 [-0.42 , 0.62]	+	+	−	?	+	+	+
Owsiany 2019	8323	1929	13	7206	1777	13	5.0%	0.58 [-0.20 , 1.37]	+	+	+	−	+	+	+
Raposo 2021	10072	3332	360	7781	1985	90	8.1%	0.74 [0.50 , 0.97]	?	?	+	+	+	+	+
Serper 2020	8532	3907	36	7337	3494	40	7.0%	0.32 [-0.13 , 0.77]	+	+	+	+	+	+	+
Tanji 2020	8509	1385	36	6383	1116	36	6.4%	1.67 [1.13 , 2.21]	+	−	+	+	+	+	+
Willms 2023	7222	2425	37	7972	2906	18	6.3%	-0.29 [-0.85 , 0.28]	+	−	+	+	+	+	?
Total (95% CI)			**1668**			**996**	**100.0%**	**0.52 [0.25 , 0.78]**							

Heterogeneity: Tau² = 0.22; Chi² = 107.76, df = 14 (P < 0.00001); I² = 87%
Test for overall effect: Z = 3.75 (P = 0.0002)
Mean difference, 95% CI = 1128 [722-1533]

b

Study	Incentive Mean	Incentive SD	Incentive Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Agarwal 2021	0.34	0.12	60	0.21	0.12	60	17.0%	1.08 [0.69 , 1.46]	+	−	?	+	+	+	+
Burns 2018	0.58	0.42	124	0.21	0.38	29	16.2%	0.89 [0.47 , 1.31]	+	−	?	?	+	+	+
Cherubini 2020	0.21	0.4	109	0.19	0.39	47	17.9%	0.05 [-0.29 , 0.39]	+	−	?	?	+	+	+
de Buisonjé 2022	0.65	0.3	97	0.4	0.28	17	13.8%	0.84 [0.31 , 1.36]	+	−	?	?	+	?	?
Kramer 2020	0.61	0.19	182	0.53	0.16	90	19.8%	0.44 [0.19 , 0.70]	+	?	?	?	+	+	+
Serper 2020	0.6	0.34	36	0.43	0.34	40	15.3%	0.49 [0.04 , 0.95]	+	+	+	+	+	+	+
Total (95% CI)			**608**			**283**	**100.0%**	**0.61 [0.30 , 0.92]**							

Heterogeneity: Tau² = 0.11; Chi² = 19.88, df = 5 (P = 0.001); I² = 75%
Test for overall effect: Z = 3.88 (P = 0.0001)
Mean difference, 95% CI = 0.15 [0.08-0.22]

c

Study	Incentive Mean	Incentive SD	Incentive Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Chin 2020	0.63	0.31	137	0.43	0.31	99	25.6%	0.64 [0.38 , 0.91]	+	?	+	+	+	+	+
Desai 2020	0.87	0.28	63	0.79	0.12	30	23.8%	0.33 [-0.11 , 0.77]	+	?	?	−	−	+	?
Gaalema 2019	0.55	0.29	65	0.29	0.05	65	24.5%	1.24 [0.87 , 1.62]	+	?	−	−	+	+	+
Ladapo 2023	0.25	0.03	447	0.2	0.03	221	26.2%	1.66 [1.48 , 1.85]	+	+	?	?	+	+	+
Total (95% CI)			**712**			**415**	**100.0%**	**0.98 [0.35 , 1.62]**							

Heterogeneity: Tau² = 0.39; Chi² = 56.48, df = 3 (P < 0.00001); I² = 95%
Test for overall effect: Z = 3.03 (P = 0.002)
Mean difference, 95% CI = 0.14 [0.04-0.25]

d

Study	Incentive Mean	Incentive SD	Incentive Total	Control Mean	Control SD	Control Total	Weight	Std. mean difference IV, Random, 95% CI	A	B	C	D	E	F	G
Fanaroff 2024	103	93	607	86	79	455	90.6%	0.19 [0.07 , 0.32]	+	+	?	+	+	+	+
Gardiner 2021	126	86	42	137	90	23	5.2%	-0.12 [-0.63 , 0.38]	?	?	+	−	+	+	?
Willms 2023	259	208	37	238	134	18	4.2%	0.11 [-0.45 , 0.67]	+	−	+	+	+	+	?
Total (95% CI)			**686**			**496**	**100.0%**	**0.17 [0.06 , 0.29]**							

Heterogeneity: Tau² = 0.00; Chi² = 1.48, df = 2 (P = 0.48); I² = 0%
Test for overall effect: Z = 2.95 (P = 0.003)
Mean difference, 95% CI = 15.66 [5.62-25.7]

Fig. 2. Pooled random-effects analyses of included studies published between June 2019 and March 2024 examining the impact of contingent financial incentives for physical activity among adults during intervention.

Note. Reported as standardized mean difference (SMD) with 95% CI. a, Walking behaviour (mean daily steps). b, Walking behaviour (weekly rate of daily step goal achievement). c, Gym attendance (weekly rate of daily gym attendance). d, Minutes of MVPA (weekly). Risk of bias; A Random sequence generation (selection bias). B, Allocation concealment (selection bias). C, Blinding of participants and personnel (performance bias). D, Blinding of outcome assessment (detection bias). E, Incomplete outcome data (attrition bias). F, Selective reporting (reporting bias). G, other bias.

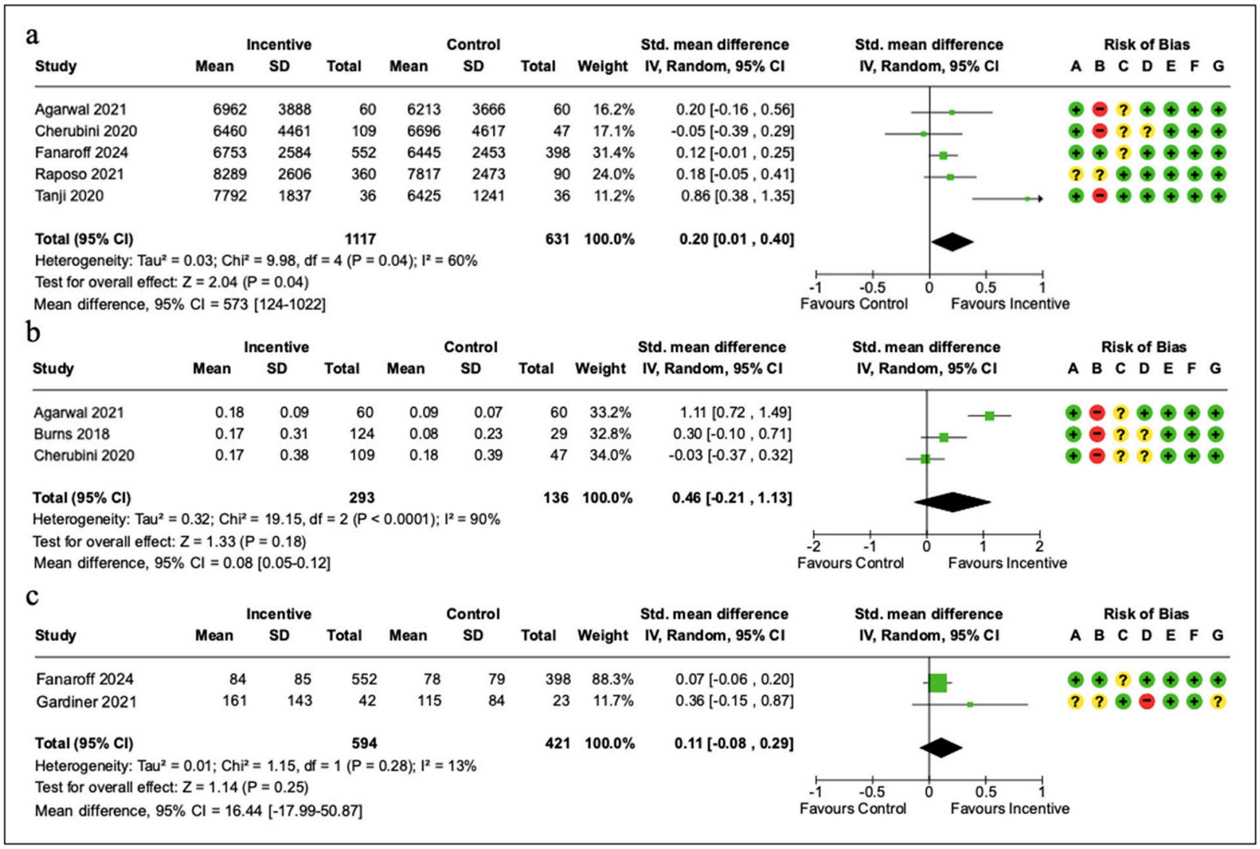


Fig. 3. Pooled random-effects analyses of included studies published between June 2019 and March 2024, examining the impact of contingent financial incentives for physical activity among adults after incentives removed.
Note. Reported as standardized mean difference (SMD) with 95% CI. a, Walking behaviour (mean daily steps). b, Walking behaviour (weekly rate of daily step goal achievement). c, Minutes of MVPA (weekly). Risk of bias; A, Random sequence generation (selection bias). B, Allocation concealment (selection bias). C, Blinding of participants and personnel (performance bias). D, Blinding of outcome assessment (detection bias). E, Incomplete outcome data (attrition bias). F, Selective reporting (reporting bias). G, Other biases.

et al., 2018; Raposo et al., 2021; Strother et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021; Fanaroff et al., 2024). Characteristics of included studies are in Table 1. In total, 18 of 29 studies were conducted in the USA (Ladapo et al., 2023; Pratt et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Galarraga et al., 2020; Gardiner and Bryan, 2021; Kerrigan et al., 2021; Serper et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Piepmeier et al., 2018; Raposo et al., 2021; Strother et al., 2021; Burns and Rothman, 2018; Fanaroff et al., 2024). Sample sizes ranged from 34 to 1547 participants. Multiple eligible intervention arms were pooled into a single treatment group for 15 studies (Willms et al., 2023; Galarraga et al., 2020; Gardiner and Bryan, 2021; Kramer et al., 2020; Desai et al., 2020; Piepmeier et al., 2018; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021; Fanaroff et al., 2024). Interventions lasted less than 12 weeks in 15 studies (Willms et al., 2023; Gaalema et al., 2019; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Tanji et al., 2020; Owsiany, 2019; Piepmeier et al., 2018; Raposo et al., 2021; Strother et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020), 12–23 weeks in eight studies (Fricke et al., 2018; Agarwal et al., 2021; Serper et al., 2020; Chin et al., 2020; Compton et al., 2021; Keadle et al., 2021; Cherubini et al., 2020; Kramer et al., 2019), and 24 or more weeks in six studies (Ladapo et al., 2023; Pratt et al., 2023; Galarraga et al., 2020; Desai et al., 2020; Bilger et al., 2021; Fanaroff et al., 2024). No intervention extended past 52 weeks. Eight of 29 studies reported follow-up PA (Agarwal et al., 2021; Gardiner and Bryan, 2021; Kerrigan et al., 2021; Tanji et al., 2020; Raposo et al., 2021; Burns and Rothman, 2018; Cherubini et al., 2020; Fanaroff et al., 2024), with an average follow-up period of 7.3 weeks [range: 1–26 weeks] after incentive removal. No studies received a weak quality rating, 16 received moderate ratings (Fricke et al., 2018; Ladapo et al., 2023; Pratt et al., 2023; Willms et al., 2023; Gaalema et al., 2019; Galarraga et al., 2020; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Chin et al., 2020; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Budworth et al., 2019; Maca et al., 2020; Kramer et al., 2019) and 13 received strong ratings (Agarwal et al., 2021; Gardiner and Bryan, 2021; Serper et al., 2020; Tanji et al., 2020; Compton et al., 2021; Piepmeier et al., 2018; Raposo et al., 2021; Strother et al., 2021; Burns and Rothman, 2018; de Buisonjé et al., 2022; Cherubini et al., 2020; Bilger et al., 2021; Fanaroff et al., 2024). Number of days a PA goal was met each week was the most commonly reported outcome ($n = 25$) (Fricke et al., 2018; Ladapo et al., 2023; Pratt et al., 2023; Willms et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Galarraga et al., 2020; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Strother et al., 2021; Budworth et al., 2019; Burns and Rothman,

Table 1
Characteristics of included studies published between June 2019 and March 2024 examining the impact of contingent financial incentives for physical activity among adults.

Author (year)	Country	n	Effect	Study length	PA measure (PA behaviour)	Incentive size	Goal setting	Behaviour change theory	Behavioural economics decision biases
Agarwal (2021)	USA	180	+/+	12/4	Fitbit Alta or Fitbit inspire (steps per day)	1.2	AD/ID	NA	Present bias, commitment, loss aversion, fresh start
Bilger (2021)	Singapore	240	+/NA	26/NA	Fitbit zip (steps per day)	0.6	FX/NI	NA	Present bias, numerosity, salience
Budworth (2019)[a]	UK	80	+/NA	2/NA	Pedometer (steps per day)	1.6[b]	FX/ID	NA	Present bias, commitment, loss aversion, numerosity, endowment
Burns (2018)	USA	153	+/−	5/2	Fitmeter (steps per day)	1.4	FX/NI	Operant conditioning theory	Present bias, commitment, loss aversion, endowment
Cherubini (2020)	Switzerland	282	−/−	16/12	Smartphone (steps per day)	0.8[b]	FX/NI	Self-determination theory, Transtheoretical model	Present bias, over optimism, salience
Chin (2020)	USA	560	+/NA	16/NA	Gym visit	1.3[b]	FX/NI	NA	Present bias
Compton (2021)[a]	USA	40	−/NA	12/NA	Fitbit zip (steps per day)	7.7[b]	AD/ID	NA	Present bias, loss aversion, salience, fresh start
deBuisonje (2022)	The Netherlands	126	+/NA	2/NA	Smartphone (steps per day)	0.5	AD/ID	Regulatory theory	Present bias, commitment, salience, loss aversion, endowment
Desai (2019)	USA	847	+/NA	52/NA	Gym visit	1.2	FX/NI	NA	Present bias, herd behaviour
Fanaroff (2024)	USA	1068	+/+	52/26	Fitbit charge (steps per day, MVPA min)	1.6	AD/ID	Regulatory theory, Behavioural economics	Present bias, loss aversion, fresh start, commitment, salience, goal gradient
Fricke (2018)	Switzerland	1313	+/NA	20/NA	Gym visit	1.3	FX/NI	NA	Present bias, loss aversion
Gaalema (2019)	USA	130	+/NA	2/NA	Gym visit	22.4[b]	FX/NI	NA	Present bias, fresh start
Galarraga (2020)[a]	USA	75	+/NA	52/NA	Gym visit	0.5	FX/NI	NA	Present bias, mental accounting, salience
Gardiner (2021)	USA	68	−/−	3/4	Polar FT60 (MVPA min)	2.5[b]	NA	Theory of planned behaviour	Present bias, mental accounting
Keadle (2021)[a]	USA	51	+/NA	12/NA	Fitbit one (steps per day)	0.4[b]	AD/ID	Self-determination theory, Social cognitive theory	Present bias, mental accounting, salience
Kerrigan (2021)	USA	57	−/−	6/2	Fitbit zip (steps per day)	0.8	AD/ID	Behavioural economics	Present bias, mental accounting, salience
Kramer (2019)	Switzerland	1547	+/NA	13/NA	Fitbit zip (steps per day)	0.3	FX/NI	NA	Present bias, mental accounting
Kramer (2020)	Switzerland	274	+/NA	7/NA	Smartphone (steps per day)	0.9	AD/ID	NA	Present bias, mental accounting, salience
Ladapo (2023)	USA	668	+/NA	52/NA	Gym visit	1.7	AD/NI	Behavioural economics	Present bias, salience
Maca (2020)	Czech Republic	1101	+/NA	3/NA	Smartphone (MVPA min)	0.7[b]	NA	Transtheoretical model	Present bias
Memon (2018)[a]	Pakistan	56	−/NA	5/NA	Smartphone (steps per day)	0.2[b]	FX/NI	NA	Present bias, goal gradient
Owsiany (2019)	USA	42	−/NA	8/NA	Fitbit Alta (steps per day)	0.5	AD/ID	NA	Present bias, fresh start, salience, over optimism
Piepmeier (2018)	USA	64	+/NA	1/NA	Corival ergometer (MVPA min)	2.7[b]	NA	NA	Present bias, mental accounting, salience
Pratt (2023)	USA	1348	+/NA	52/NA	Gym visit	2.1[b]	FX/NI	Social learning theory	Present bias
Raposo (2021)	USA	489	+/+	2/1	Pedometer (steps per day)	1.8[b]	AD/ID	Socioemotional selectivity theory	Present bias, mental accounting
Serper (2020)[a]	USA	127	+/NA	12/NA	Smartphone (steps per day)	1.6	AD/ID	NA	Present bias, loss aversion, endowment, fresh start, salience
Strother (2021)[a]	USA	34	−/NA	4/NA	Fitbit zip (steps per day)	2.6[b]	AD/ID	NA	Present bias, over optimism, salience
Tanji (2020)	Japan	72	+/−	3/3	Pedometer (steps per day)	0.5[b]	FX/NI	NA	Present bias, numerosity
Willms (2023)[a]	Canada	55	+/NA	8/NA	Fitbit inspire 2 (steps per day, MVPA min)	0.2	FX/NI	Self-determination theory	Present bias, commitment, endowment, numerosity

AD, adaptive; Effect, evidence of positive (+) or no (−) effect when incentives in place/after incentives withdrawn; Fitmeter, combined accelerometer + app; FX, fixed; Gym, number of gym/exercise visits; ID, individualized; incentive size, incentive magnitude (per person per day in 2019 USD); n, sample size; NA, not applicable; NI, not individualized; PA, physical activity; Smartphone, built-in smartphone accelerometer + app; study length, duration in weeks of intervention and follow-up; [a], pilot RCTs examining physical activity; [b], incentive size reported as average between highest and lowest a participant could earn per day.

2018; de Buisonjé et al., 2022; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021) though PA goal type varied between studies (e.g., daily step goal, weekly gym visit goal). In all, 21 studies used wearable activity trackers or 'built in' smartphone accelerometers to objectively-measure PA (Willms et al., 2023; Agarwal et al., 2021; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Compton et al., 2021; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Strother et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021; Fanaroff et al., 2024) and 16 studies were conducted with participants self-reporting at least one chronic disease (e.g., cancer, type 2 diabetes, obesity) (Ladapo et al., 2023; Pratt et al., 2023; Willms et al., 2023; Agarwal et al., 2021;

Gaalema et al., 2019; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Serper et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Strother et al., 2021; Bilger et al., 2021; Fanaroff et al., 2024). Nineteen studies reported steps per day (Willms et al., 2023; Agarwal et al., 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Compton et al., 2021; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Strother et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021; Fanaroff et al., 2024), seven reported gym attendance (Fricke et al., 2018; Ladapo et al., 2023; Pratt et al., 2023; Gaalema et al., 2019; Galarraga et al., 2020; Chin et al., 2020; Desai et al., 2020), two reported minutes of MVPA per day or week (Agarwal et al., 2021; Fanaroff et al., 2024), and two reported distance cycled (Desai et al., 2020; Budworth et al., 2019).

In total, 21 studies were included in meta-analyses (Ladapo et al., 2023; Willms et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Cherubini et al., 2020; Fanaroff et al., 2024). Twenty-six of 29 studies incorporated a goal setting intervention component (Fricke et al., 2018; Ladapo et al., 2023; Willms et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Gardiner and Bryan, 2021; Memon et al., 2018; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Tanji et al., 2020; Chin et al., 2020; Compton et al., 2021; Desai et al., 2020; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Cherubini et al., 2020; Fanaroff et al., 2024). Twelve studies used individualized (i.e., tailored to individual) and adaptive goals (i.e., adjusted based on recent PA behaviour) (Fricke et al., 2018; Agarwal et al., 2021; Gardiner and Bryan, 2021; Kerrigan et al., 2021; Compton et al., 2021; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Fanaroff et al., 2024). Thirteen studies tied FI to non-individualized (i.e., same goal for all participants) and fixed goals (i.e., goal persists throughout intervention) (Fricke et al., 2018; Pratt et al., 2023; Willms et al., 2023; Gaalema et al., 2019; Galarraga et al., 2020; Memon et al., 2018; Tanji et al., 2020; Chin et al., 2020; Desai et al., 2020; Piepmeier et al., 2018; Burns and Rothman, 2018; de Buisonjé et al., 2022; Kramer et al., 2019). One study tied FI to non-individualized and adaptive PA goals (Ladapo et al., 2023). Behaviour change theories informed the interventions of 12 studies (Ladapo et al., 2023; Willms et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Gardiner and Bryan, 2021; Memon et al., 2018; Keadle et al., 2021; Owsiany, 2019; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022), behavioural economics (Ladapo et al., 2023; Agarwal et al., 2021; Compton et al., 2021) and self-determination theory (Willms et al., 2023; Keadle et al., 2021; Cherubini et al., 2020) being the most commonly cited. All 29 studies leveraged the "present bias" (Table 1), with one study including delayed rewards (Gardiner and Bryan, 2021) and the other 28 offering incentives within one week. All but three studies (Pratt et al., 2023; Chin et al., 2020; Maca et al., 2020) incorporated at least one other behavioural economics decision bias. "Salience" was the most common (n = 13) (Ladapo et al., 2023; Galarraga et al., 2020; Kerrigan et al., 2021; Kramer et al., 2020; Serper et al., 2020; Compton et al., 2021; Keadle et al., 2021; Owsiany, 2019; Piepmeier et al., 2018; Strother et al., 2021; de Buisonjé et al., 2022; Cherubini et al., 2020; Bilger et al., 2021), followed by "loss aversion" (n = 8) (Fricke et al., 2018; Agarwal et al., 2021; Serper et al., 2020; Compton et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Fanaroff et al., 2024), "mental accounting" (n = 8), [48,49,51,52,58,60,61,]"commitment" (n = 6) (Willms et al., 2023; Agarwal et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Fanaroff et al., 2024), "fresh start" (n = 6) (Agarwal et al., 2021; Gaalema et al., 2019; Serper et al., 2020; Compton et al., 2021; Owsiany, 2019; Fanaroff et al., 2024), "numerosity" (n = 4) (Willms et al., 2023; Tanji et al., 2020; Budworth et al., 2019; Bilger et al., 2021), "endowment effect" (n = 5) (Willms et al., 2023; Serper et al., 2020; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022), "over-optimism" (n = 3) (Owsiany, 2019; Strother et al., 2021; Cherubini et al., 2020), "goal gradient" (Memon et al., 2018; Fanaroff et al., 2024) (n = 2) and "herd behaviour" (n = 1) (Desai et al., 2020) (Supplementary File A). Different incentive designs with similar reward sizes were directly compared in 18 studies (Ladapo et al., 2023; Willms et al., 2023; Galarraga et al., 2020; Gardiner and Bryan, 2021; Kerrigan et al., 2021; Kramer et al., 2020; Chin et al., 2020; Desai et al., 2020; Owsiany, 2019; Piepmeier et al., 2018; Raposo et al., 2021; Budworth et al., 2019; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020; Cherubini et al., 2020; Kramer et al., 2019; Bilger et al., 2021).

3.2. Meta-analyses

Among the 29 included RCTs, 21 provided data appropriate for meta-analysis (Fig. 2), including 4064 participants. Among these, seven studies reported follow-up data, including 1966 participants. Five trials did not report effect estimates (i.e., could not be calculated or imputed) (Pratt et al., 2023; Galarraga et al., 2020; Strother et al., 2021; Kramer et al., 2019; Bilger et al., 2021) and three studies reported PA measures that could not be combined (Fricke et al., 2018; Piepmeier et al., 2018; Maca et al., 2020) (Supplementary File I). Emails were sent to the corresponding authors of five included articles to retrieve data needed for pooled analyses (Pratt et al., 2023; Galarraga et al., 2020; Strother et al., 2021; Kramer et al., 2019; Bilger et al., 2021). Two responses were received (Pratt et al., 2023; Galarraga et al., 2020) but with no additional data to include (Supplementary File I). Publication bias was not likely as funnel plots were moderately symmetrical across PA measures (e.g., intervention period: Egger regression intercept for mean daily steps, 0.469 [p = 0.115] and at follow-up: Egger regression intercept for mean daily steps, 0.291 [p = 0.662]; Supplementary File J).

3.2.1. Walking behaviour (mean daily steps)

Nineteen out of 29 (65.5 %) trials measured daily step count change using Fitbits™, pedometers, or other objective measures (e.g., 'built in' smartphone accelerometer). Of these, 15 (n = 2664) were suitable to pool. The average intervention length was 10.7 weeks [range: 2–52 weeks] with only one intervention lasting more than six months (Fanaroff et al., 2024). Evidence suggests that FI produced medium daily step count increases during interventions (MD [95 % CI], SMD [95 % CI] = 1128 [722–1533], 0.52 [0.25–0.78], $p < 0.001$; I^2 = 87 %; Fig. 2a). Data from five trials (n = 1748) were pooled to examine follow-up effects (Agarwal et al., 2021; Tanji et al., 2020; Raposo et al., 2021; Cherubini et al., 2020; Fanaroff et al., 2024). The average length of follow-up was 9.2 weeks [range: 1–26 weeks] with only one study with a follow-up period longer than six months (Fanaroff et al., 2024). Estimates suggest FI sustained a small increase in mean daily step count at follow-up (MD [95 % CI], SMD [95 % CI] = 573 [124–1022], 0.20 [0.01–0.40], p = 0.04, I^2 = 60 %; Fig. 3a).

3.2.2. Walking behaviour (weekly rate of daily step goal achievement)

Six out of 29 (20.6 %) trials assessed the proportion of pre-determined daily step count goals met using objective measures. Among these, all six (n = 891) were suitable to pool. The average intervention length was 9.0 weeks [range: 2–16 weeks] with no intervention lasting longer than six months. Pooled estimates suggest FI produced medium increases in daily step count goal achievement (MD [95 % CI], SMD [95 % CI] = 0.15 [0.08–0.22], 0.61 [0.30–0.92], $p < 0.001$; I^2 = 75 %; Fig. 2b). In two trials (n = 429), FI did not yield positive follow-up effects (MD [95 % CI], SMD [95 % CI] = 0.08 [0.05–0.12], 0.46 [−0.21–1.13], p = 0.18, I^2 = 90 %; Fig. 3b). The average length of follow-up was 6.0 weeks [range: 2–12 weeks] with no follow-up lasting more than six months.

3.2.3. Gym attendance (days attended per week)

Seven out of 29 (24.1 %) studies reported gym attendance. Of these, four ($n = 1127$) were suitable to pool. The average intervention length was 30.5 weeks [range: 2–52 weeks] with two interventions lasting more than six months (Ladapo et al., 2023; Desai et al., 2020). Evidence suggests FI had a large effect on gym attendance (MD [95 % CI], SMD [95 % CI] = 0.14 [0.04–0.25], 0.98 [0.35–1.62], $p = 0.002$, $I^2 = 95$ %; Fig. 2c) during intervention. No trials measured gym attendance after incentives were removed.

3.2.4. Minutes of MVPA (weekly)

Five out of 29 trials (17.2 %) measured minutes of MVPA and three ($n = 1182$) were suitable to pool. The average intervention length was 21.0 weeks [range: 3–52 weeks] with only one intervention lasting more than six months (Fanaroff et al., 2024). Meta-analysis suggests FI had a small effect on minutes of MVPA per week (MD [95 % CI], SMD [95 % CI] = 15.66 [5.62–25.7], 0.17 [0.06–0.29], $p = 0.003$; $I^2 = 0$ %; Fig. 2d). In two trials ($n = 1015$), FI had a small effect on minutes of MVPA per week at follow-up (MD [95 % CI], SMD [95 % CI] = 16.44 [−17.99–50.87], 0.11 [−0.08–0.29], $p = 0.25$, $I^2 = 13$ %; Fig. 3d). The average length of follow-up was 15.0 weeks [range: 4–26 weeks] with only one study with a follow-up period longer than six months (Fanaroff et al., 2024).

3.3. Meta-regression

Meta-regression analyses revealed no relationship between participant characteristics and FI effects on daily step count (age, $p = 0.35$; % female, $p = 0.94$). A number of program characteristics, however, appear to moderate FI effects. Incentive size (d [95 % CI] = 0.599 [0.004–1.195], $p = 0.049$) and wearable devices (d [95 % CI] = 0.67 [0.11–1.22], $p = 0.022$), for example, were significantly and positively associated with increased mean daily step count. The presence of goal setting in general (e.g., adaptive/fixed, individualized/non-individualized) was positively associated with increased mean daily steps (d [95 % CI] = 0.509 [0.091–0.927], $p = 0.021$) as well. More specifically, adaptive and individualized goals were independently associated with increased mean daily steps (d [95 % CI] = 0.62 [0.04–1.19], $p = 0.037$; 0.61 [0.065–1.145], $p = 0.031$, respectively). An inverse association between intervention duration and mean daily step count was also found (d [95 % CI] = −0.632 [−0.012-(−1.235)], $p = 0.046$) (Supplementary File K).

3.4. Sensitivity analyses

The effects of FI on minutes of MVPA during intervention were dampened after removing one pilot RCT (Willms et al., 2023). Otherwise, results did not change with the exclusion of pilot RCT data from pooled analyses. Pooled results were also unchanged when removing 'unclear' or 'high' risk of bias studies, as well as studies reporting unadjusted effects (Supplementary File L). When daily step count data from studies retrieved from the previous meta-analysis (Mitchell et al., 2019) were included ($n = 12$) in exploratory meta-analyses, results were similar as well: (a) during intervention (MD [95 % CI], SMD [95 % CI] = 973 [692–1254], 0.39 [0.23–0.54], $I^2 = 82$ %, $p < 0.001$) and (b) follow-up (MD [95 % CI], SMD [95 % CI] = 609 [221–996], 0.18 [0.05–0.32], $I^2 = 67$ %, $p = 0.007$) (Supplementary File L).

3.5. Quality of the body of the evidence

Pooled results and the quality of the body of evidence are summarized in Supplementary File F. The EPHPP checklist suggests that the quality of evidence is moderate-to-strong (Supplementary File E).

3.6. Narrative summary

Excluding pilot trials not sufficiently powered to detect group differences, the majority of RCTs in this review (17/21) (Fricke et al., 2018; Ladapo et al., 2023; Pratt et al., 2023; Agarwal et al., 2021; Gaalema et al., 2019; Kramer et al., 2020; Tanji et al., 2020; Chin et al., 2020; Desai et al., 2020; Piepmeier et al., 2018; Raposo et al., 2021; Burns and Rothman, 2018; de Buisonjé et al., 2022; Maca et al., 2020; Kramer et al., 2019; Bilger et al., 2021; Fanaroff et al., 2024) demonstrated positive FI effects with fewer studies (4/21) (Gardiner and Bryan, 2021; Kerrigan et al., 2021; Owsiany, 2019; Cherubini et al., 2020) reporting null effects. Among the four RCTs reporting null effects, two rewarded daily step counts and received moderate quality ratings (Kerrigan et al., 2021; Owsiany, 2019), one rewarded daily step counts and received a strong quality rating (Cherubini et al., 2020), and one targeted minutes of MVPA per week and received a strong quality rating (Gardiner and Bryan, 2021). All five studies offering incentives for at least 24 weeks reported positive effects (Ladapo et al., 2023; Pratt et al., 2023; Desai et al., 2020; Bilger et al., 2021; Fanaroff et al., 2024), including one study (Bilger et al., 2021) that offered very modest incentives worth $0.61 USD per person per day. Only three out of eight studies with follow-up data reported positive effects (Agarwal et al., 2021; Raposo et al., 2021; Fanaroff et al., 2024). Notably, among the 18 studies comparing different incentive designs with similar FI magnitudes, several insights emerged: personal gain incentives were more effective than charitable (i.e., "mental accounting") incentives (Kramer et al., 2020; Piepmeier et al., 2018; Raposo et al., 2021; Kramer et al., 2019), process-based incentives tied to intermediary processes (i.e., daily steps) were more effective than outcome-based incentives (i.e., weight loss; "salience") (Ladapo et al., 2023; Chin et al., 2020; Bilger et al., 2021), small daily incentives were more effective than large delayed incentives (i.e., "present bias") (Gardiner and Bryan, 2021; Kerrigan et al., 2021), and no PA difference was found for deposit (i.e., upfront financial commitment that can be earned back) versus non-deposit incentives (i.e., no financial commitment required; "loss aversion") (Burns and Rothman, 2018; de Buisonjé et al., 2022).

4. Discussion

4.1. Main findings

This systematic review and meta-analysis sought to update the evidence on the effects of FI on PA in adults. Studies providing FI not contingent on PA behaviour were excluded (Banach et al., 2023; Vitzthum et al., 2024). Pooled estimates suggest modest FI increased several PA behaviours while the intervention was present (i.e., walking, gym attendance, MVPA). Unlike previous reviews (Luong et al., 2021; Mitchell et al., 2019), daily step count increases surpassed the 1000 step per day threshold for clinical significance (i.e., 1128 steps/day) (Banach et al., 2023). Pooled estimates using daily step count data, however, suggest effects gradually diminish over time as well as after FI are withdrawn. These findings should be interpreted with caution, however, given the relatively small number of studies examining long-term ($n = 5$) and post-incentive ($n = 8$) effects. The effect size reduction following incentive removal is larger than previously reported (555 vs. 94 steps/day) (Mitchell et al., 2019). While too few studies examined FI impacts beyond six months to draw firm meta-analysis conclusions regarding long-term effects, vote counting results demonstrate promise with all five long-term studies yielding positive effects. Although the attainment of short-term, clinically-significant PA increases is important, the absence of long-term and follow-up evidence warrants further study (Luong et al., 2021; Mitchell et al., 2019).

4.2. Secondary findings

Several secondary findings emerged from meta-regression and vote counting. While certain program and participant characteristics (i.e., study length, incentive size, wearable device-use, and goal setting) influenced FI effects, others did not (i.e., behaviour change theory, age, gender, and baseline PA). These findings are similar and dissimilar to what has been previously reported in the FI-for-PA literature (Vitzthum et al., 2024; Milkman et al., 2021; Gong et al., 2016). For example, in their FI-for-PA review, Vitzthum et al. (2024) reported greater effectiveness when goal setting was incorporated (Vitzthum et al., 2024). On the other hand, a number of studies have shown behaviour change theory to be associated with greater intervention effectiveness (Milkman et al., 2021; Milne-Ives et al., 2020; Mertens et al., 2022). This disparity might be due to differences in intervention design and implementation. For example, some interventions may not fully leverage theoretically-grounded behaviour change components potentially diluting their impact (e.g., stating that self-determination theory [SDT] was used but neglecting SDT's focus on satisfying basic psychological needs of autonomy, competence, and relatedness for more internalized motives to be physically active) (Deci and Ryan, 2002). While evidence for incorporating behaviour change theory in FI intervention design appears mixed, more research is needed to identify theories best suited to guide FI intervention design and evaluation (Mertens et al., 2022). The behaviour change wheel (BCW), for example, is a framework combining 19 theories at the core of which sits the Capability, Opportunity, Motivation-Behaviour (COM-B) model (Michie et al., 2011). This relatively new model provides insight into which intervention components may prevent or facilitate health behaviours. It can also help with the identification of intervention functions (there are nine e.g., education, incentivization) that target deficits in one or more components (Deci and Ryan, 2002). The breadth of considerations built-into the BCW and the COM-B model more specifically, may offer a more comprehensive framework for designing interventions that support long-term change (Michie et al., 2011; Sui et al., 2022). A few notable findings also emerged from vote counting: (a) FI may increase different PA behaviours in adults in the short- and long-term; (b) evidence of sustained effects is limited (i.e., 37.5 % of RCTs show positive follow-up effects); (c) behavioural economics-informed incentive designs may boost short-term intervention effects (e.g., personal gain, process-based, and more immediate FI).

4.3. Similar literature

The results of this study should be interpreted in light of similar literature. Past research has highlighted the utility of FI while present and in the short-term with mixed long-term and follow-up findings (Luong et al., 2021; Mitchell et al., 2019). For example, Mitchell et al. (2019) and Luong et al. (2021) found FI increased mean daily step count in the short-term (MD [95 % CI] = 781 [455–1123], $p < 0.05$ and MD, SMD [95 % CI] = 754, 0.25 [0.13–0.36], $p < 0.01$, respectively). In comparison, this review reported larger, clinically significant short-term effects on daily step count. This may be due to greater emphasis on refined goal setting approaches, or higher chronic disease prevalence among populations studied (Gong et al., 2016; Haas et al., 2024). Regarding long-term effectiveness, pooled analyses could not be completed in this study given the smaller number of included studies examining long-term effects while reporting heterogeneous PA behaviours. However, the inverse association between intervention duration and mean daily step count (d [95 % CI] = −0.632 [−0.012–1.235], $p = 0.04$) suggests effectiveness may wane over time. Fanaroff et al. (2024) and Ladapo et al. (2023), however, found that FI programs grounded in behaviour change theory and incorporating goal setting features may drive long-term change. Mitchell et al. (2019) reported long-term (i.e., >23 weeks) daily step count improvements (MD [95 % CI] = 670 [243–1099]. In contrast, Luong et al. (2021) did not examine pooled long-term effects of FI on daily step count. Lastly, at follow-up Luong et al. (2021) found PA was not sustained (SMD [95 % CI] = 0.11 [0.00–0.22], $p = 0.07$) whereas Mitchell et al. (2019) found largely sustained effects for mean daily step count (MD [95 % CI] = 513 [312–714], $p < 0.05$). This stands in contrast to the notable effect size reduction observed here at follow-up (i.e., 555 steps/day). One reason for this might be that studies included in this review contained shorter intervention periods, potentially limiting participant's time to establish lasting PA routines, making them more likely to reduce activity levels once FI were removed (Gardner et al., 2021). Notably, only eight of the 29 included studies (27.6 %) in this review tracked PA after incentive removal, compared to 18 out of the 23 studies (78.3 %) in Mitchell et al. (2019). This may reflect a methodological shift in the literature with more recent research focusing on short-term FI effects at the expense of learning more about sustained benefits. Among the 29 included studies, 16 (55.2 %) involved populations with at least one chronic disease, whereas Mitchell et al. (2019) included only seven out of 23 studies (30.4 %) and Luong et al. (2021) included only 12 out of 51 (23.5 %) studies. Interestingly, 11 out of 16 studies (68.8 %) examining FI-for-PA among populations with a chronic disease reported positive effects for studies of both short- and long-duration. This may be because chronic disease populations may be less physically active at baseline with more room to improve during intervention (Haas et al., 2024). The median incentive size in this review was $1.19 USD per person per day (range: $0.23–$22.44 USD/day) compared to $1.50 USD per person per day (range: $0.09–$7.00 USD/day) in Mitchell et al. (2019) and $2.08 USD per person per day (range: $0.26–$33.15 USD/day) in Luong et al. (2021). This modest incentive magnitude decrease may reflect increasing recognition that more efficient incentive designs are needed to maximize scalability (Rondina Ii et al., 2020).

4.4. Implications

Findings suggest FI can promote a variety of PA behaviours in the short-term. For walking behaviours (i.e., daily step count) short-term increases are clinically significant. This may be important for clinicians and other decision makers (e.g., in government, large companies) (Yao et al., 2020; Department of Health and Social Care, 2021; ParticipACTION homepage, 2024; de Buisonjé et al., 2023; Derlyatka et al., 2019; Romanelli et al., 2023) looking for new ways to stimulate PA that meaningfully improve clinical outcomes (e.g., systolic blood pressure) (Banach et al., 2023). Incorporating moderator insights (e.g., goal setting, behavioural economics-informed incentives, chronic disease status) in intervention design may futher increase effect sizes and returns-on-investment. Short-term improvements do not necessarily extend long-term, however, or into post-incentive periods. While too few studies have examined these issues to know for sure, the limited evidence to-date suggests that if FI interventions include strategies to support autonomy (e.g., take steps at any PA intensity), build competence (e.g., incremental goal setting), and enhance relatedness (e.g., progress sharing), long-term and sustained effects may be possible (Deci and Ryan, 2002; Ntoumanis et al., 2020). Since the health and economic benefits of PA depend on demonstrated—not assumed—long-term change, however, expectations should be reasonably managed until evidence summaries include more longitudinal research.

4.5. Strengths and limitations

This systematic review adhered to the *Cochrane Handbook for Systematic Reviews of Interventions* (Version 6.4, Chapter 5) (Li et al., 2023) to enhance review quality. For example, this study employed the validated EPHPP tool to assess evidence quality (Armijo-Olivo et al., 2012), adhered to the PRISMA guidelines[36] (e.g., flow chart), and minimized potential biases (e.g., reporting bias) by registering the review protocol (PROSPERO # CRD42023394572). Several limitations must be considered when interpreting results. First, restricting the search to a six-year time frame (June 2019 to March 2024) may have excluded earlier relevant studies, potentially limiting the breadth of evidence captured. However, by concentrating on the latest literature, this review provides a clean picture of FI effectiveness in contemporary intervention designs, including the latest technologies and theoretical (i.e., behavioural economics) applications. Second, exclusion of FI studies without a non-incentive control group (i.e., studies comparing different incentive design arms only) limits conclusions regarding better FI designs. Third, heterogeneity of PA behaviours among included studies limits the ability to conduct pooled analyses and the statistical power of those analyses. Fourth, meta-regression conclusions rely on studies reporting mean steps per day changes only. Analyses of other PA behaviours may have yielded different results. However, mean daily step count meta-regressions extend the literature by empirically testing effect moderators. Fifth, only five and eight studies examined long-term and follow-up effects, respectively, limiting the strength of those conclusions. Last, while this study included only RCTs and pilot RCTs, future reviews should incorporate robust quasi-experimental studies conducted in 'real-world' settings (e.g., government initiatives, incentive-based workplace wellness programs) (Yao et al., 2020; Romanelli et al., 2023). Investigating incentives in practical contexts, alongside greater reporting of psychological outcomes (e.g., internalized motivation), could provide more insight into how short-term FI benefits can be extended into long-term and sustained effects.

5. Conclusion

This systematic review and meta-analysis found that FI promoted several PA behaviours in the short-term, including daily step count to clinically significant levels. More research is needed to elucidate FI effects over time and after incentives are withdrawn. Contextual factors were also identified that moderate effects and should be considered for better FI-for-PA intervention design in the future.

Authorship contribution statement

BS and MM conceptualised and designed the study, drafted the initial manuscript, coordinated and supervised data collection, analysed the data and reviewed and revised the manuscript. HP, LV, and MM critically revised the manuscript. BS was responsible for the overall content as guarantor. All authors (BS, HP, LV, MM) approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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CRediT authorship contribution statement

Babac Salmani: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Harry Prapavessis:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software. **Leigh M. Vanderloo:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Marc S. Mitchell:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Conceptualization.

Declaration of Competing Interest

MM (PI) provided unpaid consulting services to Caterpillar Health Inc. between January 2021 and January 2023 (~10 hours per month). The company agreed to provide funding in the form of a course-buyout during a previous academic year (September 2021 to May 2022; $15,000 CAD) to free up time for MM to continue to provide such service. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2025.108237.

Data availability

Data Extraction Table (Reference data) (Figshare)

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