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

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ABSTRACT

Objective The use of financial incentives to promote physical activity (PA) has grown in popularity due in part to technological advances that make it easier to track and reward PA. The purpose of this study was to update the evidence on the effects of incentives on PA in adults.
Data sources Medline, PubMed, Embase, PsychINFO, CCTR, CINAHL and COCH.
Eligibility criteria Randomised controlled trials (RCT) published between 2012 and May 2018 examining the impact of incentives on PA.
Design A simple count of studies with positive and null effects ('vote counting') was conducted. Random-effects meta-analyses were also undertaken for studies reporting steps per day for intervention and post-intervention periods.
Results 23 studies involving 6074 participants were included (64.42% female, mean age = 41.20 years). 20 out of 22 studies reported positive intervention effects and four out of 18 reported post-intervention (after incentives withdrawn) benefits. Among the 12 of 23 studies included in the meta-analysis, incentives were associated with increased mean daily step counts during the intervention period (pooled mean difference (MD), 607.1; 95% CI: 422.1 to 792.1). Among the nine of 12 studies with post-intervention daily step count data incentives were associated with increased mean daily step counts (pooled MD, 513.8; 95% CI:312.7 to 714.9).
Conclusion Demonstrating rising interest in financial incentives, 23 RCTs were identified. Modest incentives ($1.40 US/day) increased PA for interventions of short and long durations *and* after incentives were removed, though post-intervention 'vote counting' and pooled results did not align. Nonetheless, and contrary to what has been previously reported, these findings suggest a short-term incentive 'dose' may promote sustained PA.

What is already known?

- ► Two systematic reviews and one meta-analysis have determined that financial incentives increase physical activity (PA) in the short term (3 months or less) and while in place.
- ► The evidence regarding long-term (6 months or more) and sustained (after financial incentives are withdrawn) PA increases is mixed.

What are the new findings?

- ► In all, 23 randomised controlled trials were identified over the last 6 years demonstrating the rising interest in financial incentives.
- ► Modest incentives ($1.40 US/day on average and as small as $0.10 US/day) increased PA for interventions of short and long durations *and* after incentives were removed.
- ► Subgroup meta-analyses and 'vote counting' provide insight for incentive programme optimisation. More immediate (within 7 days) incentives for individualised daily step goal achievement (roughly 10%–15% above baseline) offered for longer periods (24 or more weeks) to lower active adults (<7–8000 daily steps), for example, are recommended.
- ► In total, 13 studies compared different behavioural economics-informed incentive designs suggesting these can be harnessed to boost incentive effectiveness as well.

INTRODUCTION

There is a clear dose–response relationship between physical activity (PA) and health with the greatest health benefits seen in physically inactive individuals who become more physically active.[1–3] Routine PA, for example, contributes to the prevention of several chronic conditions such as type 2 diabetes[2] and depression.[4] It is widely recommended that for substantial health benefits adults participate in 150 min of moderate-intensity PA, or 75 min of vigorous-intensity activity, per week.[5] Less strenuous light-intensity PA (not 'huffing and puffing') can also confer health benefits.[6] Furthermore, light-intensity PA such as walking may be more attainable and more likely to be sustained on a population scale. Yet the average US adult accumulates only about half the recommended 10 000 daily steps.[7 8] This 'physical inactivity pandemic' in the USA, and globally,[9] carries a massive financial burden. Conservative estimates suggest physical inactivity costs the global economy $53.8 billion US per year in direct healthcare expenses.[10] Increasing population-level PA, therefore, is an important global public health priority.[11]

Behavioural economics, a branch of economics complimented with insights from psychology, has stimulated interest in using financial incentives to promote PA.[12] Behavioural economics has shown that systematic errors in thinking, called 'decision biases', can lead to poor health outcomes.[12] The 'present bias' is a relevant example when thinking about incentives. Sometimes referred to as 'temporal discounting', present bias describes how a person's value of a reward (eg, better health) decreases the further away in time the reward is realised.[13] Put another way, people tend to respond more to the immediate costs and benefits of their actions than to those experienced in the future.[14] In the case of PA, the *cost* of the behaviour (eg, time, discomfort) is usually experienced in the present and thus overvalued while the *benefits* (eg, health, longevity) are often delayed and thus discounted, tipping daily decisional scales towards inactivity. According to behavioural economics, immediate incentives may be useful in emphasising a short-term PA benefit and motivate more people to be active. Maintaining fidelity to the 'present bias' in designing incentive interventions (ie, not delaying incentives) may increase intervention efficacy.[15 16] Applying a broader range of behavioural economics concepts in the design of incentive programmes may boost intervention effects and reduce reward costs as well.[16] According to a meta-analysis by Haff *et al* (2015) and a mapping review by McGill *et al*[17] (2018) contemporary incentive designs that leverage peoples' 'decision biases' may improve the efficacy of incentive interventions.[17 18]

While behavioural economics has influenced the field of financial health incentives, recent technological advances have also made it easier to track and reward PA. For instance, in 2014, Apple introduced the iOS Health Kit app which translates smartphone accelerometer data into consumer-friendly health information (eg, steps per day).[19] In the past, incentives in clinical trials were usually tied to gym attendance.[20] Now incentives are often contingent on a wider array of PA outcomes (eg, steps per day, minutes of PA) measured by smartphone technology or wearable activity trackers.[21] High rates of smartphone (8 in 10 people)[22] and wearable device (1 in 10 people) use in the USA,[23] for example, offer researchers and public health professionals unprecedented access to instantaneous PA data. These data can be used to set and re-set personalised PA goals, connect users with others, reward daily achievements and so on. This new ability to track and reward PA lends itself to population-level interventions where walking and other activities of daily living are a focus rather than targeting more structured, less accessible, and therefore more difficult to achieve exercise behaviours. The Carrot Rewards smartphone application ('app'), developed in partnership with the Public Health Agency of Canada, is a recent example of incentives tied to smartphone-assessed step counts.[24] Sweatcoin is another popular app that converts step counts into financial rewards.[25]

Despite the potential of incentives for promoting PA, many gaps in the literature remain. The best effect-estimate from the first known incentives-for-exercise meta-analysis in 2013 determined that incentives increased exercise session attendance, the most common PA outcome at the time, by 11.6%.[20] Yet, few of the reviewed studies examined incentives over longer periods (≥6 months; n=1) or post-intervention (after incentives discontinued; n=3) to inform long-term or sustained effects. Only one study rewarded PA assessed by a wearable tracker. Subsequent reviews published between 2014 and 2017 have generally corroborated the 2013 review by suggesting that incentives stimulate but do not necessarily sustain PA.[18 26–28] According to AMSTAR 2 criteria though,[29] these reviews are not as rigorous.[30] Notably, they may have omitted eligible studies[26 27] and did not quantitatively pool data in a meta-analysis.[18 28 31] Furthermore, no review to date has sought to disentangle the heterogeneity between studies through subgroup analyses.

We conducted this review to address several gaps in our understanding of the effect of incentives on PA in light of recent theoretical and technological advances. The primary objective of this review was to assess the randomised controlled trial (RCT) evidence examining the short-term (<6 months) and long-term (≥6 months) effects of incentives on daily step counts. Daily step counts was *a priori* selected as the primary outcome of interest given the growing use of smartphones/wearable trackers that monitor steps, the widely cited public health recommendations regarding steps (ie, 8000 to 10 000/day),[32] and the ease with which studies reporting steps can be compared. Recent validation studies found that the iPhone step counting feature (version 6 or newer), as well as those for Android smartphones (eg, HTC, Motorola) and Fitbit trackers (eg, hip-worn Zip, wrist-worn Flex) were accurate in laboratory and field conditions.[33–35] An important secondary objective of this review was to determine whether the effects of incentives on PA persist into the post-intervention period after incentives are withdrawn. Another secondary objective was to disentangle heterogeneity between studies through subgroup meta-analyses.

METHODS

Electronic search

This study updates the authors' previous systematic review and meta-analysis in which 11 RCTs were examined to determine the influence of incentives on exercise adherence in adults.[20] We adapted the previous search strategy to capture articles not retrieved by the original one (online supplementary file 1). Seven electronic databases (CCTR, CINAHL, COCH, Embase, Medline, PsycINFO, PubMed) were searched for English-language, peer-reviewed studies using an RCT methodology published from January 2012 to May 2018 (the original review included articles published up to June 2012, before Apple introduced the Health Kit app). Reference lists of relevant studies were also hand searched for eligible papers.

Eligibility criteria

RCT studies were included if they reported the effects of incentives on the PA of adults (aged ≥18 years). Studies rewarding multiple health behaviours were included (eg, weight loss, healthy eating, PA) if at least part of the incentive was allocated to a PA behaviour (eg, self-monitoring, gym attendance, daily step count) or outcome (eg, aerobic fitness). Incentives were defined as any cash or non-cash reward with a monetary value, not including gifts of negligible or symbolic value (eg, coffee mug).

Study selection

Article records (titles, abstracts) were independently screened by two reviewers (SO and SK). A third reviewer (MM) was consulted where uncertainty existed. Full texts from eligible studies were retrieved and screened by one reviewer (SO). A second reviewer (MM) was consulted when a study's eligibility was unclear. Reasons for study exclusion are presented in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines flowchart (figure 1).

Data acquisition

Data from eligible studies were systematically abstracted using a protocol informed by the Task Force on Community and Preventive Service's procedure for systematic reviews.[36] Study-level (eg, intervention duration, PA outcomes, incentive design features) and participant-level information (eg, age, baseline PA) was extracted by one reviewer (SO; tables 1 and 2). Authors of included studies were contacted for missing data. A second reviewer (AB) audited all retrieved step count estimates.

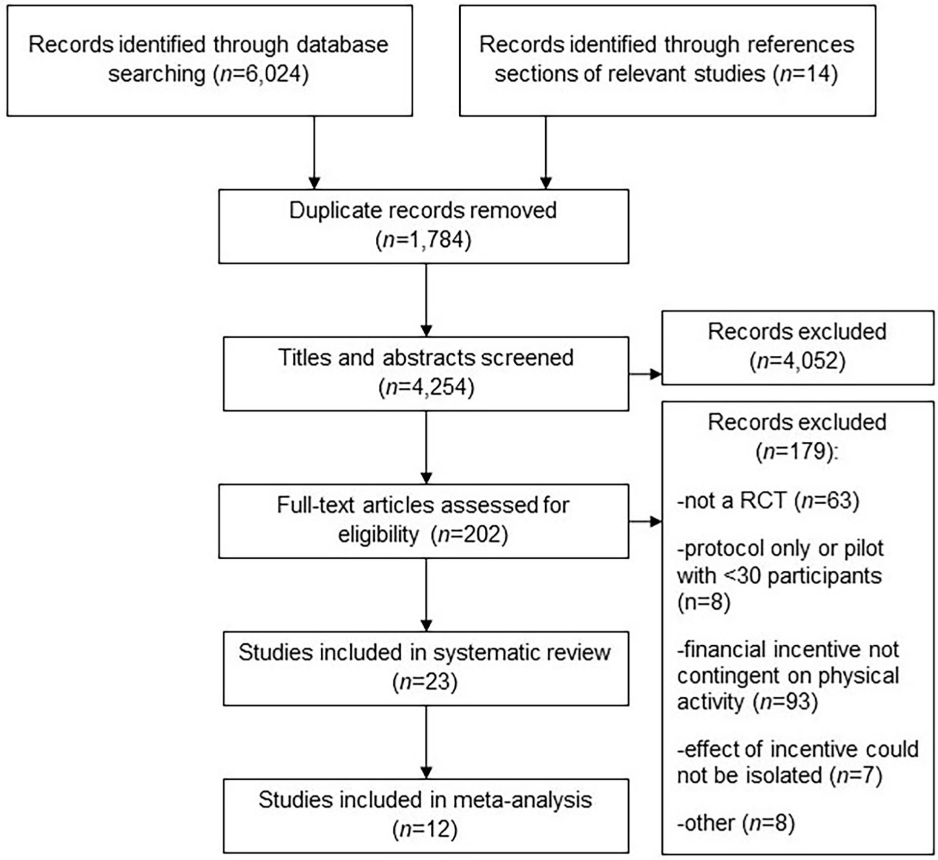


Figure 1 Flowchart of included and excluded RCTs examining the impact of financial incentives on physical activity in adults. RCTs, randomised controlled trials.

Study quality

Two authors (SO and MM) independently assessed the methodological quality of included studies using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies.[37] This tool was developed to systematically appraise public health research studies. The EPHPP was chosen because it has demonstrated excellent inter-rater reliability for the final grade and more conservative bias estimates than the Cochrane Collaboration Risk of Bias Tool. With this tool, each of seven study components (selection bias, study design, confounders, blinding, data collection, dropouts) is assigned a weak (≥2 weak ratings), moderate (one weak rating) or strong (no weak ratings) score. Consensus on global quality assessment ratings was reached by two authors (SO and MM).

Data analysis

A meta-analysis was performed on studies reporting changes in daily step counts. Effect sizes were calculated as the mean difference (MD) in daily step counts between study participants allocated to an incentive-based intervention arm and those allocated to a non-incentive control arm. We pooled study estimates that were statistically adjusted for baseline step counts as these were most consistently reported in the majority of studies. If baseline step count-adjusted effect estimates were unavailable in a study, we also used unadjusted estimates as these were more comparable than fully adjusted estimates. Nonetheless, findings were compared with studies reporting fully adjusted estimates in a sensitivity analysis (described in sensitivity analysis below). We conducted separate analyses of the effects of incentive-based interventions on step counts during (a) the intervention and (b) post-intervention periods. Pooled statistical effects were calculated using a random-effects model. Statistical heterogeneity was assessed using Cochran's *Q* statistic and the I^2 statistic of the proportion of total variation because of heterogeneity.[38] The possibility of publication bias was examined by visually inspecting funnel plots for their skew and asymmetric shape and quantitatively by Egger's test for asymmetry.[39]

Subgroup analyses were used to examine the robustness of the pooled estimates. Subgroups were compared by a number of participant and study characteristics selected *a priori* based on their potential to modify incentive effects.[18 20 31 40–42] These include the following: (1) age (sampling only among older or younger participants vs non-specific), (2) sex, (3) sampling only overweight or obese participants vs non-specific, (4) income, (5) sampling only physically inactive or low active participants versus non-specific, (6) length of the intervention and follow-up periods, (7) monetary value of the incentive (above or below the median incentive value used in included studies), (8) PA measurement method and (9) the main behavioural economics (BE) concept informing the intervention (see table 3 for a list of these concepts). Where possible, sensitivity analyses were performed by comparing estimates based on study quality (weak to moderate vs strong quality), and estimates derived from studies reporting unadjusted or adjusted for baseline walking only versus adjusted estimates (statistically adjusted for participant characteristics as confounders, eg, age, income). The influence of individual studies on the pooled effect estimates was examined by removing one study at a

Table 1 Summary of participant characteristics.

Author (year)	Mean age (years)	Age range (years)	Female, %	Caucasian, %	Income (household)	Overweight/obese, %	Mean BMI	Baseline physical activity level
Acland (2015)[44]	21.9	18–22	68.5	36.0	NR	NR	NR	Mean Godin Leisure-Time Physical Activity score=36.05
Adams (2017)[15]	41.0	18–60	77.1	81.3	$50 000–74 999 (median)	100	34.1	'Insufficiently active' or 'inactive' to be eligible
Andrade (2014)[45]	48.0	18+	90.0	82.0	$59 931±$21 972 (mean)	NR	NR	Mean steps/day=4444 (<6000 steps/day to be eligible)
Babcock (2015)[46]	21.1	18–22	45.0	NR	NR	NR	NR	1.17 gym visits on average in previous week
Carrera (2018)[47]	35.0	18+	58.0	NR	NR	NR	NR	43% exercised one or less times/week in past year
Condliffe (2017)[48]	20.0	18–23	80.0	NR	NR	NR	NR	100% used gym 0–2 times/week
Finkelstein (2016)[21]	35.0	21–65	54.0	0	25%<S$5000/month	57	NR	62% were 'insufficiently active'
Finkelstein (2017)[49]	43.9	NR	65.7	<5.0	70%<S$10 000/month	100	29.7	NR
Harkins (2017)[50]	80.3	65+	74.0	98.0	30%–40% <$50 000	NR	NR	Mean steps/day=4566 (<9000 steps/day to be eligible)
Kullgren[51] (2014)	71.9	65+	70.0	93.0	20%–40% <$50 000	NR	NR	Mean steps/day=6405
Leahey (2015)[52]	46.3	NR	82.5	88.7	NR	NR	33.6	NR
Losina (2018)[53]	65.0	40+	57.0	90.0	24% <$60 000	NR	31.0	Mean steps/day=5100
Patel (2016a)[54]	39.7	NR	78.0	64.2	30% <$50 000	100	33.2	Mean MET-min/week=732.34
Patel (2016b)[55]	40.5	NR	77.3	53.0	22% <$50 000	NR	29.2	Mean MET-min/week=3520.1
Patel (2016c)[56]	41.3	NR	80.7	67.1	19% <$50 000	NR	28.4	Mean MET-min/week=398.95
Patel (2018)[57]	41.0	NR	77.0	69.0	23% <$50 000	100	33.2	Mean MET-min/week=2300
Petry (2013)[58]	63.2	55–75	84.4	93.3	23% <$50 000	NR	NR	47.7% walked <4000 steps/day
Pope (2014)[59]	18.0	NR	63.2	NR	NR	NR	23.5	NR
Rohde (2016)[60]	33.0	10–77	59.0	NR	NR	NR	NR	10 gym visits on average in previous 3 months
Royer (2015)[61]	40.0	NR	48.0	NR	NR	73	28.3	1.98–3.36 self-reported exercise days/week
Shin (2017)[62]	27.8	19–45	0	NR	NR	NR	29.8	Mean activity kcal/week=2809.5
van der Swaluw (2018)[63]	48.0	NR	31.0	90.0	45%<3000 Dutch pounds/month	38 (% obese)	30.0	Mean gym visits/week=1.6
Washington (2016)[64]	25.7	18–66	84.2	NR	NR	NR	24.8	<10 000 steps/day to be eligible

BMI, body mass index; kcal, kilocalories; MET, metabolic equivalent; NR, not reported; S, Singapore.

time. All meta-analyses were conducted using Comprehensive Meta-Analysis V.3.[43]

A narrative summary of all included studies is also provided using 'vote counting' (simple count of studies with positive and null effects) to explore short-term (<6 months), long-term (≥6 months) and post-intervention (after incentive removal) effects for studies with different outcomes (ie, gym visits, daily step count, self-monitoring, energy expenditure). Studies comparing two or more behavioural economics concepts (head-to-head) are also summarised.

RESULTS

Study characteristics

From an initial return of 6038 studies, 202 full texts were assessed for eligibility (figure 1). In all, 23 studies involving 6074 participants were included in the review (64.42% female, mean age=41.20 years, mean body mass index=29.91 kg/m^2; see table 1).[15 21 44–64] Characteristics of the 23 included studies are outlined in table 2. In total, 19 of 23 studies were conducted in the USA.[15 21 44–48 50–59 61 64] Sample sizes ranged from 19 to 1000 participants. Interventions lasted less than 12 weeks in four studies,[46–48 64] 12–23 weeks in 16 studies,[15 44 45 49–52 54–59 61–63] and 24 or more weeks in three studies.[21 53 60] No interventions extended past 26 weeks. Totally, 18 of 23 studies reported post-intervention PA[21 44 45 47 48 50–52 54–61 63 64] with an average follow-up period of 17.5 weeks after incentive removal. One study received a weak quality rating,[59] 20 received moderate ratings,[15 21 44–46 49–58 60–64] and two strong ratings (online supplementary file 2).[47 48] Number of days a PA goal was met (eg, gym visits) was the most commonly reported outcome (n=17)[21 44–48 50 51 54–58 60 61 63 65 66] though attendance expectations varied widely by study (eg, incentive for one gym visit in a week, nine visits in 6 weeks, etc). In all, 14 studies used wearable trackers or smartphone accelerometers to objectively-assess PA.[15 21 45 49–51 53–58 62 64] Among these, 12 studies reported steps per day and were included in the meta-analysis.[15 21 45 49–51 53–58] All 23 studies leveraged the 'present bias' (table 2). Despite delayed rewards in four studies (the other 19 out of 23 offered incentives within 7 days),[15 45 47 60] this classification made sense given that instant PA data were available to all participants (eg, data from smartphone/wearable trackers, which participants knew was tied to a future incentive). All studies incorporated at least one other behavioural economics concept in addition to 'present bias'. 'Loss aversion' was most commonly used (n=16),[21 45 47 49–51 53 54 56–59 61–64] followed by 'fresh start' (n=13),[21 44 48–51 53 58–63] 'over-optimism' (n=9),[45 49 51 54–58] 'salience' (n=12),[15 44 46 48 52 54–57 60 61 64] 'herd mentality' (n=5)[46 48 51 55 56] and 'commitment' (n=4).[44 49 61 64] Different behavioural econom-

Table 2 Summary of study characteristics and head-to-head comparisons testing behavioural economics decision biases.

Author (year)	Country	n	Effect	Study length	PA measure	Incentive size	Behavioural economics concepts	Head-to-head comparisons (relevant behavioural economics decision biases)
Acland (2015)[44]	USA	120	+/–	12,24	Gym	1.00–3.57	PB, SAL, COM, FS	None
Adams (2017)[15]	USA	96	+/NA	16,0	Fitbit Zip	1.00	PB, SAL	▶ Immediate outperformed delayed incentives (PB) ▶ Adaptive goals outperformed static goals (SAL)
Andrade (2014)[45]	USA	61	±	15,24	Pedometer	0.91–7.00	PB, LA, OO, EE	None
Babcock (2015)[46]	USA	365	+/NA	2,0	Gym	2.50	PB, SAL, HB	▶ Team incentives produced larger increases in gym visits than individual-level ones (HB)
Carrera (2018)[47]	USA	690	–/–	6,8	Gym	0.71–1.42	PB, LA, EE	▶ Pre-selected item-based incentives outperformed cash incentives (LA) ▶ $60 for nine gym visits no more effective than $30 (SAL)
Condliffe (2017)[48]	USA	181	+/+	3,2	Gym	0.29	PB, SAL, HB, EE, FS	▶ Team incentives produced larger increases in gym visits than individual-level ones (HB) ▶ Information on peers' gym attendance promoted more frequent gym use (HB)
Finkelstein (2016)	Singapore	800	+/–	24,24	Fitbit Zip	3.19	PB, LA, COM	None
Finkelstein (2017)[49]	Singapore	161	+/NA	16,0	Pedometer	1.48	PB, LA, OO, COM	▶ Incentives received by participants themselves increased physical activity, but incentives in the form of charitable donations did not (HB)
Harkins (2017)	USA	94	+/–	16,4	Fitbit Alta	2.86	PB, LA	▶ Charitable donations were effective for older participants (HB)
Kullgren (2014)	USA	92	–/–	16,8	Pedometer	3.00	PB, LA, OO, HB	▶ Participants with access to an online peer network walked no more than participants without access (HB)
Leahey (2015)	USA	268	+/NA	12,36	Self-monitor	0.53	PB, SAL	None
Losina (2018)[53]	USA	202	+/NA	24,0	Fitbit Zip	1.82	PB, LA	None
Patel (2016a)	USA	281	+/–	13,13	Smartphone	1.40	PB, LA, OO, SAL	▶ Loss-framed incentives outperformed lottery and gain-framed incentives (LA, OO, PB)
Patel (2016b)	USA	304	+/–	13,13	Smartphone	1.25	PB, OO, SAL, HB	▶ Incentives for individual- combined with team-based goals outperformed either approach alone (HB)
Patel (2016c)	USA	286	+/–	13,13	Smartphone	1.40	PB, LA, OO, SAL, HB	▶ Incentives for performance compared with group median outperformed comparison to 75th percentile (HB))
Patel (2018)[57]	USA	209	+/–	13,13	Smartphone	1.25–1.40	PB, OO, SAL	▶ Daily small lottery incentives combined with jackpot lotteries outperformed either condition alone (PB, SAL, OO)
Petry (2013)[58]	USA	45	+/+	12,24	Pedometer	5.57	PB, LA, OO	None
Pope (2014)	USA	117	+/–	12,20	Gym	4.67	PB, LA, SAL	None
Rohde (2016)	The Netherlands	415	+/+	26,26	Gym	0.09–0.15	PB, SAL, FS	▶ Participants receiving quarterly feedback on the exact number of weeks they met their gym visit goal attended the gym more often than participants who did not (SAL)
Royer (2015)[61]	USA	1000	+/+	12,36	Gym	4.80	PB, LA, SAL, COM, FS	None
Shin (2017)	South Korea	105	+/NA	12,0	Fitmeter	1.24	PB, LA	None
van der Swaluw (2018)	The Netherlands	163	+/–	13/26, 13/0	Gym	0.89	PB, LA, OO	None
Washington (2016)[64]	USA	19	NA/NA	3,1	Fitbit One	2.38	PB, LA, SAL, EE	▶ No difference between $25 deposit contract (participant money is 'on the line') and no-deposit group (LA)

COM, commitment; EE, endowment effect; Effect, evidence of positive (+) or no (–) effect when incentives in place/after incentives withdrawn; FS, fresh start; Fitmeter, combined accelerometer + app;Gym, number of gym visits; HB, herd behaviour; LA, loss aversion;NA, not applicable due to no post-intervention follow-up period; OO, over-optimism;PA, physical activity; PB, present bias; SAL, salience; Self-monitor, self-monitoring of physical activity behaviour; Smartphone, built-in smartphone accelerometer + app;incentive size, incentive magnitude (per person per day in USD); n, sample size;study length, duration in weeks of intervention.

Table 3 Behavioural economics decision biases used in financial incentive interventions.[17 77*]

'Decision bias'	Description	Examples
Present bias	Preference for a payoff close to the present time rather than in the future	Incentives (*or information about incentives*) given immediately on meeting goal
Loss aversion	Preference to avoid losing something than acquire an equal gain	Information given about incentive lost by failing to meet goal that is, regret
Over-optimism	Over-estimate the probability of positive events; individuals think they have a better chance of winning a lottery than they actually do	1-in-5 chance of earning $5 for goal achievement may have a larger effect than a guaranteed $1 reward
Salience	Information that stands out, is novel, or seems relevant is more likely to affect our actions	Text messages provide timely feedback on incentives earned; variable (mystery) incentives
Herd Behaviour	People do what others are doing instead of making independent decisions	Incentives given to team members only if *all* members meet goal
Commitment	Preference for a consistent self-image, best achieved by making a commitment or pre-commitment	Deposit contract in which own money is lost if fail to meet goal
Fresh start†	Aspirational behaviour around temporal landmarks (eg, January 1, Mondays)	Incentive for reaching daily step goals five times in a week is reset every Monday
Numerosity‡	Tendency for people to equate larger numbers with greater value when comparing currencies of different denominations, even when the actual size is constant	Use of incentives in the form of loyalty points (redeemable for consumer goods) of unclear monetary value

*Explanation: For the purpose of this study, overlapping concepts were grouped together. Present bias included delay discounting and hyperbolic discounting. Loss aversion included endowment effect, regret/anticipated aversion, the IKEA effect and framing. Over-optimism included overweighing of small probabilities. Salience encompassed aspects of mental accounting, and herd behaviour aspects of social norms. See Samson 2014 for more detail.[77]
†The 'fresh start' effect is a concept that emerged in this review, was recently cited in a paper by Chokshi *et al*[78] and is new to the field.
‡The 'numerosity effect' is a concept that emerged completing this review and has been previously described by Wertenbrock *et al*.[79]

ics-informed designs with similar reward sizes were directly compared in 13 studies.[15 21 46–48 50 51 54–57 60 64] See a full description of each study's incentive design features including type, size and probability of rewards in online supplementary file 3.

Meta-analyses

In total, 12 studies were included in the meta-analysis, including 2631 participants. Incentives increased mean daily step counts during the intervention period (pooled MD, 607.1; 95% CI: 422.1 to 792.1) and at follow-up assessment (pooled MD, 513.8; 95% CI: 312.7 to 714.9) (figure 2). As per Higgins and colleagues' classification,[38] heterogeneity was found to be high for studies during the intervention period (I^2=80.8, p<0.0001; Q=114.5) and at follow-up (I^2=85.1, p<0.0001; Q=120.8) which is expected when pooling data from multi-component behavioural interventions. However, heterogeneity was found to be moderate–low in the subgroup analyses suggesting differences may be due to study and participant characteristics (table 4). Studies that were minimally adjusted for baseline walking, or unadjusted, reported a higher pooled MD in daily steps at the intervention period (vs adjusted; 186 steps) and post-intervention (vs adjusted; 155 steps), although these differences were not found to be meaningfully different. Also, pooled effect estimates did not change substantially with the exclusion of any study. Publication bias was a possibility in both assessment periods as funnel plots were moderately asymmetrical (intervention period: Egger regression intercept, 2.23 (p=0.046) and at follow-up assessment: Egger regression intercept, 3.59 (p=0.020)) online supplementary file 4.

Table 4 describes pooled effect estimates by different subgroup variables. During the intervention period, the greatest subgroup differences were observed for studies using wearable trackers (vs smartphones; 834 steps), larger incentives (incentives above vs below median, $1.40 US; 354 steps) and studies that targeted less active (vs non-specific; 474 steps) and older adults (vs non-specific; 358 steps). During the post-intervention period, the greatest subgroup differences were observed for studies using wearable trackers (vs smartphones; 620 steps), larger incentives (620 steps) and studies that targeted overweight or obese adults only (vs non-specific; 411 steps). As well, subgroup analyses suggest that studies with longer intervention periods (>23 weeks) yielded larger post-intervention effects (vs interventions lasting 12–23 weeks; 467 steps).

Narrative summary

All studies

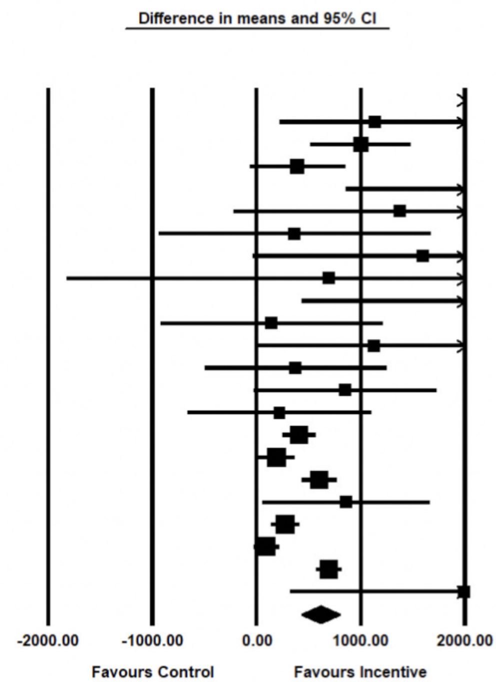
A simple count of studies with positive (n=20)[15 21 44–46 48–50 52–63] and null effects (n=2)[47 51] suggests incentives can increase PA in adults. Among studies demonstrating null effects, one received a moderate quality rating and rewarded daily step count achievement[51] and one received a strong rating and targeted gym attendance.[47] All three studies offering incentives for 24 weeks (or 6 months, the theoretical definition of behaviour maintenance) demonstrated positive effects,[21 53 60] including the study by Rohde & Verbeke[60] which offered the smallest incentive of any study, $0.10 US per person per day. Only four out of 18 studies with follow-up data reported positive post-intervention effects.[48 58 60 61] As well, 13 studies compared different behavioural economics-informed incentive designs. The main findings are summarised in table 2 as well as in greater detail in online supplementary file 5. Taken together, these studies suggest that behavioural economics concepts can be harnessed to boost incentive effectiveness and that in certain situations some may work better than others (eg, charity donations may appeal more to older vs younger participants).

DISCUSSION

Demonstrating the rising interest in financial incentives for PA promotion, 23 studies were identified over the last 6 years alone, compared with 11 in the initial review.[20] Estimates from this meta-analysis suggest financial incentives increased daily step counts for short *and* long duration interventions by 607 steps, or approximately 10%–15%. This is consistent with our first review which also found modest but significant effects (ie, 11.6% increase in exercise session attendance over the short term). Notably, the median incentive size in this review was about $1.50 US per person per day, compared with $10.00 US in the original review. This efficiency may be due in part to recent technological advances that have made tracking and rewarding PA easier and more immediate, as well as a broader application of potent behavioural economics concepts like 'loss aversion',

Intervention Period

Study name	Incentive arm	Difference in means	Standard error	Lower limit	Upper limit	Z-Value
Adams, 2017	Immediate incentive	3907.000	800.572	2337.908	5476.092	4.880
Andrade, 2014	Lottery incentive	1133.000	464.175	223.234	2042.766	2.441
Finkelstein, 2016	Cash incentive	1000.000	244.655	520.484	1479.516	4.087
Finkelstein, 2016	Charity incentive	390.000	232.291	-65.282	845.282	1.679
Finkelstein, 2017	Cash incentive	2173.000	670.078	859.671	3486.329	3.243
Harkins, 2016	Charity incentive	1371.000	809.541	-215.671	2957.671	1.694
Harkins, 2016	Individual + charity incentive	364.000	663.489	-936.414	1664.414	0.549
Harkins, 2016	Individual incentive	1596.000	831.895	-34.484	3226.484	1.919
Kullgren, 2014	Lottery incentive	692.000	1281.595	-1819.879	3203.879	0.540
Kullgren, 2014	Lottery incentive + social support	3172.000	1398.387	431.213	5912.787	2.268
Losina, 2018	Weekly incentives	145.000	542.306	-917.900	1207.900	0.267
Losina, 2018	Weekly incentives + coaching	1127.000	564.730	20.149	2233.851	1.996
Patel, 2016a	Gain incentive	375.000	442.305	-491.901	1241.901	0.848
Patel, 2016a	Loss incentive	849.000	445.408	-23.983	1721.983	1.906
Patel, 2016a	Lottery incentive	220.000	448.861	-659.752	1099.752	0.490
Patel, 2016b	Individual + team incentive	409.000	80.987	250.269	567.731	5.050
Patel, 2016b	Team incentive	193.000	86.133	24.182	361.818	2.241
Patel 2016b	Individual incentive	602.000	83.626	438.097	765.903	7.199
Patel, 2016c	Regret lottery incentive	862.000	409.010	60.355	1663.645	2.108
Patel, 2018	Combined lottery incentive	278.000	67.873	144.971	411.029	4.096
Patel, 2018	Higher frequency lottery incentive	93.000	60.480	-25.539	211.539	1.538
Patel, 2018	Jackpot lottery incentive	695.000	60.320	576.775	813.225	11.522
Petry, 2013	Lottery incentive	1989.000	851.135	320.805	3657.195	2.337
		607.089	94.390	422.087	792.091	6.432



Post-Intervention Period

Study name	Incentive arm	Difference in means	Standard error	Lower limit	Upper limit	Z-Value
Andrade, 2014	Lottery incentive	256.000	717.717	-1150.700	1662.700	0.357
Finkelstein, 2016	Cash incentive	360.000	244.655	-119.516	839.516	1.471
Finkelstein, 2016	Charity incentive	260.000	232.291	-195.282	715.282	1.119
Harkins, 2016	Charity incentive	1099.000	749.245	-369.492	2567.492	1.467
Harkins, 2016	Individual + charity incentive	423.000	709.685	-967.956	1813.956	0.596
Harkins, 2016	Individual incentive	1026.000	781.180	-505.085	2557.085	1.313
Kullgren, 2014	Lottery incentive	3015.000	1345.669	377.536	5652.464	2.241
Kullgren, 2014	Lottery incentive + social support	1833.000	1362.970	-838.372	4504.372	1.345
Patel, 2016a	Gain incentive	153.000	442.189	-713.675	1019.675	0.346
Patel, 2016a	Loss incentive	526.000	438.720	-333.875	1385.875	1.199
Patel, 2016a	Lottery incentive	10.000	449.204	-870.423	890.423	0.022
Patel, 2016b	Individual + team incentive	1077.000	90.058	900.489	1253.511	11.959
Patel, 2016b	Individual incentive	405.000	90.388	227.842	582.158	4.481
Patel, 2016b	Team incentive	10.000	91.475	-169.287	189.287	0.109
Patel, 2016c	Regret lottery	465.000	381.216	-282.169	1212.169	1.220
Patel, 2018	Combined lottery	381.000	58.854	265.649	496.351	6.474
Patel, 2018	Higher frequency lottery incentive	339.000	65.828	209.979	468.021	5.150
Patel, 2018	Jackpot lottery	269.000	59.721	151.949	386.051	4.504
Petry, 2013	Gift incentive	2499.000	368.978	1775.816	3222.184	6.773
		513.813	102.585	312.749	714.876	5.009

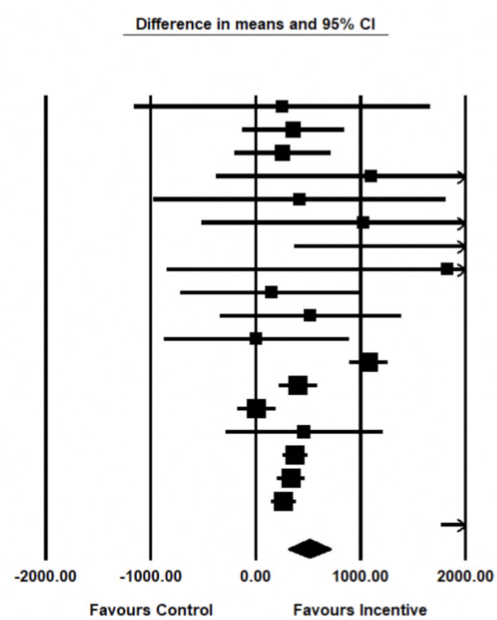


Figure 2 Pooled random-effects analysis of mean differences in daily step counts during the intervention period and at post-intervention follow-up.

'fresh start', 'over-optimism', and 'salience'. Also, 18 out of the 23 included studies (78.3%) tracked PA in the post-intervention period, compared with only 3 out of 11 (27.3%) in the original review providing new insight into the quality of incentive-induced health behaviour change. Regarding sustained effects, vote counting indicated that only four out of 18 studies reported post-intervention benefits. On the other hand, when data were pooled in the meta-analysis, statistically significant daily step count differences were observed 3–6 months after incentives were removed, with an average difference of 514 steps post-intervention. These findings (vote counting vs meta-analysis) might be explained by the lower overall precision of individual studies with generally small sample sizes. Nonetheless, the positive post-intervention effect observed in our pooled analyses provides evidence to contradict the prevailing sentiment that extrinsic rewards undermine intrinsic motivation to engage

Table 4 Pooled random-effects analysis of mean differences in daily step counts during the intervention period and at post-intervention follow-up, by subgroup variable.

Variable	Categories	Intervention: Number of treatment arms	Intervention: Pooled mean difference in daily steps (95% CI)	Intervention: Heterogeneity	Post-intervention: Number of treatment arms	Post-intervention: Pooled mean difference in daily steps (95% CI)	Post-intervention: Heterogeneity
Adjustment of participant characteristics	Adjusted	14	585.7 (829.9 to 341.5)	I^2=66.1, p<0.001, Q=38.3	12	358.4 (535.4 to 181.4)	I^2=92.8, P<0.001, Q=153.1
	Unadjusted	20	771.7 (449 to 1095)	I^2=35.4, P<0.001, Q=409.4	19	513.8 (312 to 715)	I^2=55.1, P<0.001, Q=120.8
Age	Sampling only among older participants	5	1120.7 (227 to 2014)	I^2=37.0, P=0.174, Q=6.4	1	NA	NA
	Non-specific	18	763.0 (408 to 1118)	I^2=66.7, P<0.001, Q=521.3	16	471.4 (284 to 658)	I^2=66.0, P<0.001, Q=44.1
Sex	No categorisation possible	NA	NA	NA	NA	NA	NA
Weight	Sampling only overweight or obese	8	753 (168 to 1338)	I^2=50.1, p<0.001, Q=377.7	6	327.8 (259 to 396)	I^2=0.0, p=0.750, Q=2.7
	Non-specific	15	853.8 (457 to 1251)	I^2=670.4, p<0.001, Q=145.7	13	738.7 (351 to 1127)	I^2=72.2, p<0.001, Q=43.2
Income	No categorisation possible	NA	NA	NA	NA	NA	NA
Baseline PA level	Sampling only physically inactive or low PA	6	1160.8 (606 to 1716)	I^2=0.0, p=0.757, Q=2.6	4	676.6 (-46.5 to 1400)	I^2=0.0, p=0.805, Q=0.985
	Non-specific	17	686.7 (362 to 1011)	I^2=49.0, p<0.001, Q=145.8	15	503.5 (293 to 714)	I^2=48.3, p<0.001, Q=119.2
Median incentive value ($1.40 US)	Above median value	11	861.8 (516 to 1208)	I^2=69.5, p<0.001, Q=135.2	9	1012.4 (315 to 1709)	I^2=54.8, p<0.001, Q=300.2
	Below median value	12	508.3 (298 to 718)	I^2=41.2, p<0.001, Q=89.7	10	392.2 (186 to 599)	I^2=46.8, p<0.001, Q=342.2
Intervention included smartphone or wearable device	Smartphone	10	408.4 (223 to 594)	I^2=52.1, p<0.001, Q=342.7	10	392.2 (186 to 599)	I^2=51.8, p<0.001, Q=307.2
	Wearable device	13	1242.0 (745 to 1739)	I^2=50.9, p<0.001, Q=122.7	9	1012.4 (315 to 1709)	I^2=39.8, p<0.001, Q=322.2
Length of intervention and follow-up	<12 weeks	0	NA	NA	5	1096.9 (328 to 1866)	NA
	12–23 weeks	19	789.1 (455 to 1123)	I^2=46.6, p<0.001, Q=523.9	10	394.3 (216 to 573)	I^2=49.2, p<0.001, Q=83.2
	>23 weeks	4	670.7 (243 to 1099)	I^2=38.3, p=0.182, Q=4.864	4	861.3 (-154 to 1876)	I^2=59.9, p<0.001, Q=29.6

NA, not applicable for the following reasons: unable to categorise data and insufficient number of studies for comparison (<2 studies).
PA, physical activity.

in health behaviours and damage the potential for sustained improvements.[67 68]

The undermining effect of extrinsic awards has historically been based on the tenets of self-determination theory (SDT) and studies examining the impact of incentives on motivation to do enjoyable tasks such as completing puzzles. The assumption that these results can be extended to the use of incentives for health behaviour change has been challenged, however. Promberger & Marteau,[68] for example, found no evidence that incentives undermine intrinsic motivation for health behaviours for which people begin with low levels of intrinsic motivation.[69] In fact, for some, the opposite may be true. Cognitive evaluation theory, a subtheory of SDT, predicts that incentives might boost intrinsic motivation primarily through its action on self-efficacy (if incentives are contingent on realistic, confidence-promoting PA goals).[70] Unfortunately, this review found no studies measuring self-efficacy or self-determined motivation over time to test this hypothesis. In a separate but related paper though Pope *et al* (2014) concluded that intrinsic motivation persisted among college students rewarded to attend the gym, even after incentives were discontinued.[65] Crane *et al*[70] drew similar conclusions when they rewarded weight loss-related behaviours (eg, self-monitoring).[71] In a feasibility RCT, Mitchell *et al*[72] found no preliminary evidence of undermining in a cardiac rehabilitation context.[73] Moller *et al* (2012), on the other hand, found that incentives perceived as controlling, undermined intrinsic motivation to eat healthy and be active.[74] It may be that given the modest nature of most incentives used in the reviewed studies, the rewards were not perceived as controlling by participants. While incongruences exist, this review challenges the assumption that incentives damage intrinsic motivation in all cases and that PA will not be sustained once the incentives are withdrawn. This assumption is consistent with the results of a meta-analysis by Mantzari *et al* (2015) in which smoking cessation was sustained for 3 months after incentive removal.[31]

Unlike previous reviews, this study was able to examine intervention effects by subgroup variables. The large differences in MD magnitudes suggest that the role of these subgroup variables as possible moderators cannot be ruled out. First, studies targeting physically inactive adults reported larger group differences (by

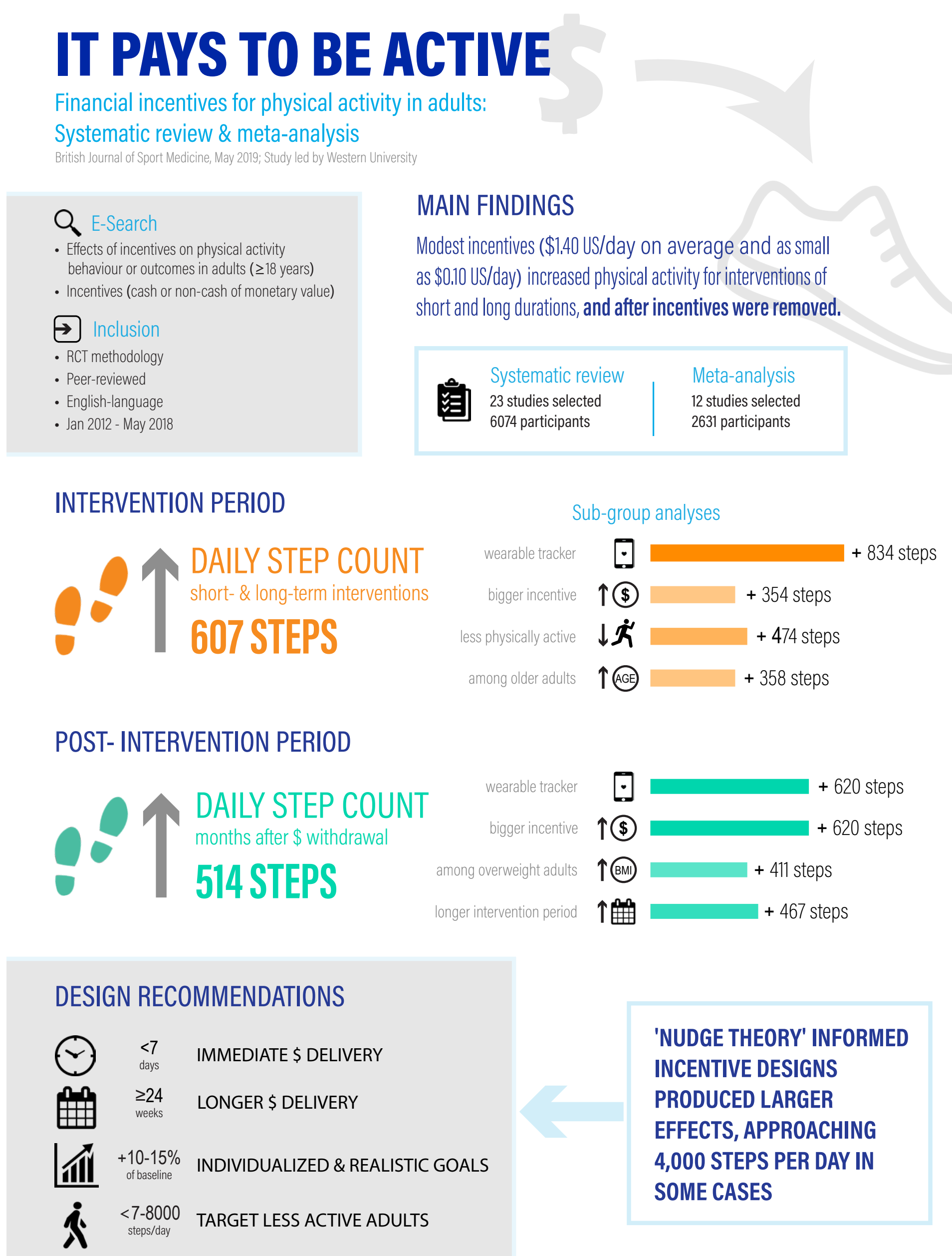


Figure 3 Infographic summary.

almost two times) than those that did not. This quantitative result builds on a similar but qualitative finding from our 2013 review.[20] One reason for this finding may be that inactive adults are more extrinsically motivated to engage in PA.[75] Second, studies targeting older adults yielded larger effects. Older adults are generally less active[7] and have lower incomes[72] which may make them more sensitive to PA incentives.[18] Third, intervention duration may have made a difference, with longer interventions yielding larger post-intervention effects. It is likely that 3 months (the most common intervention duration) is not sufficient time for new PA behaviours to become habitual. Fourth, studies employing wearable trackers outperformed studies using smartphones to track PA. This may have more to do with how PA goals were set in the four Patel *et al* studies using smartphones (ie, 7000 daily step goal regardless of baseline PA or progress) than with the measurement device. Next, larger incentives produced larger effects. This finding is consistent with others' suggesting a dose–response relationship exists between incentives and health behaviours.[40–42] To the contrary, Giles *et al*[28] found that effects decrease as incentive values increase, a finding they indicated to be linked to the complex interplay between incentive value, nature of the incentivised behaviour and participant characteristics.[28] Larger incentives were not necessarily required, however. For example, Adams *et al*[15] offered $1 US per day and produced an increase of 3907 steps compared with the no-incentive control.

Implications

There are several theoretical and practical implications to consider. Theoretically, our empirical analyses support the cognitive evaluation theory suggestion that in some cases incentives may promote behaviour maintenance.[68] Practically, our results may encourage decision-makers to adopt a historically divisive behaviour change technique, though different evidence types (eg, incentive studies with clinical outcomes, cost-effectiveness studies, etc) are still needed. Another practical implication has to do with the effect size. It could be argued that on an individual level, apart from perhaps better glucose control,[76] a 607 daily step count boost may not yield clinically significant changes (eg, blood pressure reduction). However, one must consider that this added effect is over and above that produced by multi-component PA interventions (without incentives) that acted as control. As well, better incentive designs produced larger effects, approaching 4000 steps per day in some cases.[15] Caution is warranted, however, as positive effects *are not automatic*, as seen in studies demonstrating the benefits of one incentive arm/design but not others.[21 50 53–57] Based on our findings, we make the following suggestions to companies (eg, 75% of large US firms offer health incentives to their employees)[76] and governments around the world who are already deploying incentives.[77] More immediate (ie <7 days) incentives for individualised and realistic daily goal achievement (ie, roughly 10%–15% above baseline) offered for longer periods (ie, >24 weeks) for lower active adults (ie, <7–8000 daily steps) are recommended. Automated daily feedback on progress (eg, via text messages or app push notifications) may increase reward 'salience' and possibly reduce the reward size needed. Regarding reward size, roughly $1 US per person per day appears effective for most. For scalability though, even lower rewards may be needed. In this regard, incorporating behavioural economics-informed designs, as listed in table 3, are recommended. Incentives leveraging 'over-optimism' (eg, small daily lotteries), 'loss aversion' (eg, reward taken away with unmet goals), 'herd behaviour' (eg, rewards for small team achievements) and 'salience' (eg, frequent, personalised feedback) are particularly common and effective. Though not widely used among included studies, smartphones may facilitate the passive tracking and immediate rewarding of PA in the future. Last, incentives may be a useful PA intervention 'add-on' given the significant public health implications of even small daily step count increases. A 1% reduction in the number of Canadians categorised as physical inactive (i.e. <5000 daily steps), for instance, would yield annual healthcare savings of 2.1 billion Canadian dollars.[3]

Limitations and future directions

Our results should be interpreted with caution in light of some key limitations. First, the meta-analyses were limited to studies reporting mean changes in steps per day. Analyses of other PA variables may have yielded different results. A second limitation is the small sample size in the majority of studies. Examining studies with larger sample sizes is expected to lower heterogeneity estimates and better elucidate findings. Additionally, research examining potential mechanisms (eg, self-efficacy, self-determined motivation) through which incentives influence behaviour would be beneficial. Fourth, we acknowledge publication bias and the possibility that selective reporting may undermine the generalisability of our findings. Furthermore, our subgroup analysis yielded overlapping CIs and therefore we cannot be certain as to how the incentives-for-PA effects may differ by participant and study characteristics. More studies are needed that sample under-represented groups (eg, lower-income adults). Fifth, the clinical benefits of PA are usually reserved for those who meet recommended levels of moderate-intensity to vigorous-intensity PA and sustain PA behaviour for longer periods,[32] and so more longitudinal research examining increases in moderate–vigorous PA is also needed. No intervention or follow-up period lasted longer than 6 months which limits the applicability of these findings. Last, the external validity of the results is limited. A review of quasi-experimental studies evaluating incentives in 'real-world' settings (eg, incentive-based workplace wellness programme, government initiatives, apps) would provide valuable insight into the effectiveness of different incentive designs in practice.

CONCLUSION

This systematic review and meta-analysis found that incentives increased PA for interventions of short and long durations *and* after incentives were removed, though the count of studies with positive post-intervention effects was modest (see figure 3 for Infographic summary). Nonetheless, and contrary to what has been suggested for years, a short-term incentive 'dose' may promote sustained PA post-intervention. Improvements, therefore, can be expected when technology-enabled, behavioural economics-informed incentives are added to multi-component PA interventions. More work is needed, however, to replicate these findings in light of some of this review's limitations.

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Competing interests From 2015 to 2017 Marc Mitchell was the sole proprietor of a program evaluation company called Incentive Avenue Inc. Currently, he is the Principal Behavioural Insights Advisor for an incentive-based mHealth application company called Carrot Insights Inc. He reports consulting income from Carrot Insights Inc. in the past 36 months and company stock options as well. Furthermore, Stephanie Orstad worked as an independent contractor for Incentive Avenue Inc. in 2016. The other authors declare that no competing interests exist.

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REFERENCES

1 Warburton DER, Charlesworth S, Ivey A, *et al*. A systematic review of the evidence for Canada's physical activity guidelines for adults. *Int J Behav Nutr Phys Act* 2010;7.
2 Wahid A, Manek N, Nichols M, *et al*. Quantifying the association between physical activity and cardiovascular disease and diabetes: a systematic review and meta-analysis. *J Am Heart Assoc* 2016;5. doi:10.1161/JAHA.115.002495. [Epub ahead of print: 14 Sep 2016].
3 Krueger H, Turner D, Krueger J, *et al*. The economic benefits of risk factor reduction in Canada: tobacco smoking, excess weight and physical inactivity. *Can J Public Health* 2014;105:e69–78.
4 Schuch FB, Vancampfort D, Firth J, *et al*. Physical activity and incident depression: a meta-analysis of prospective cohort studies. *Am J Psychiatry* 2018;175:631–48.
5 US Department of Health and Human Services. *Physical activity guidelines for Americans*. 2nd edition. Washington: DC, 2018.
6 Borgundvaag E, Janssen I. Objectively measured physical activity and mortality risk among American adults. *Am J Prev Med* 2017;52:e25–31.
7 Althoff T, Sosič R, Hicks JL, *et al*. Large-scale physical activity data reveal worldwide activity inequality. *Nature* 2017;547:336–9.
8 Bassett DR, Wyatt HR, Thompson H, *et al*. Pedometer-measured physical activity and health behaviors in U.S. adults. *Med Sci Sports Exerc* 2010;42:1819–25.
9 Kohl HW, Craig CL, Lambert EV, *et al*. The pandemic of physical inactivity: global action for public health. *The Lancet* 2012;380:294–305.
10 Ding D, Lawson KD, Kolbe-Alexander TL, *et al*. The economic burden of physical inactivity: a global analysis of major non-communicable diseases. *The Lancet* 2016;388:1311–24.
11 World Health Organization. *Global action plan on physical activity 2018-2030: more active people for a healthier world*. Geneva, 2018.
12 Thaler R, Sunstein C. Chapter 1. In: *Nudge: improving decisions about health, wealth and happiness*. Yale University Press, 2008.
13 Barlow P, Reeves A, McKee M, *et al*. Unhealthy diets, obesity and time discounting: a systematic literature review and network analysis. *Obesity Reviews* 2016;17:810–9.

14 Camerer CF, Loewenstein G, *et al*. *Advances in behavioral economics*. Princeton University Press: Princeton, 2003.
15 Adams MA, Hurley JC, Todd M, *et al*. Adaptive goal setting and financial incentives: a 2 × 2 factorial randomized controlled trial to increase adults' physical activity. *BMC Public Health* 2017;17.
16 Loewenstein G, Asch DA, Volpp KG. Behavioral economics holds potential to deliver better results for patients, insurers, and employers. *Health Affairs* 2013;32:1244–50.
17 McGill B, O'Hara BJ, Bauman A, *et al*. Are financial incentives for lifestyle behavior change informed or inspired by behavioral economics? A mapping review. *Am J Health Promot* 2019;33.
18 Haff N, Patel MS, Lim R, *et al*. The role of behavioral economic incentive design and demographic characteristics in financial incentive-based approaches to changing health behaviors: a meta-analysis. *Am J Health Promot* 2015;29:314–23.
19 Apple. Apple unveils iOS 8, the biggest release since the Launch of the APP store, 2014. Available: https://www.apple.com/ca/newsroom/2014/06/02Apple-Unveils-iOS-8-the-Biggest-Release-Since-the-Launch-of-the-App-Store/
20 Mitchell MS, Goodman JM, Alter DA, *et al*. Financial incentives for exercise adherence in adults: systematic review and meta-analysis. *Am J Prev Med* 2013;45:658–67.
21 Finkelstein EA, Haaland BA, Bilger M, *et al*. Effectiveness of activity trackers with and without incentives to increase physical activity (TRIPPA): a randomised controlled trial. *Lancet Diabetes Endocrinol* 2016;4:983–95.
22 Nieslen. *The U.S. digital consumer report*, 2014.
23 Ledger D, McCaffrey D. Inside Wearables- how the science of human behavior change offers the secret to long-term engagement 2014.
24 Mitchell M, White L, Lau E, *et al*. Evaluating the carrot rewards APP, a population-level incentive-based intervention promoting step counts across two Canadian provinces: a quasi-experimental study . *JMIR Mhealth Uhealth* 2018.
25 Derlyatka A, Fomenko O, Eck F, *et al*. Bright spots, physical activity investments that work: Sweatcoin: a steps generated virtual currency for sustained physical activity behaviour change. *Br J Sports Med* 2019;04.
26 Strohacker K, Galarraga O, Williams DM. The impact of incentives on exercise behavior: a systematic review of randomized controlled trials. *Annals of Behavioral Medicine* 2014;48:92–9.
27 Barte JCM, Wendel-Vos GCW. A systematic review of financial incentives for physical activity: the effects on physical activity and related outcomes. *Behavioral Medicine* 2017;43:79–90.
28 Giles EL, Robalino S, McColl E, *et al*. The effectiveness of financial incentives for health behaviour change: systematic review and meta-analysis. *PLoS ONE* 2014;9:e90347.
29 Shea BJ, Reeves BC, Wells G, *et al*. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ* 2017;358.
30 Luong M-LN, Bennell KL, Hall M, *et al*. The impact of financial incentives on physical activity in adults: a systematic review protocol. *Systematic Reviews* 2018;7.
31 Mantzari E, Vogt F, Shemilt I, *et al*. Personal financial incentives for changing habitual health-related behaviors: a systematic review and meta-analysis. *Preventive Medicine* 2015;75:75–85.
32 American College of Sports Medicine. Chapter 1. In: *Guidelines for exercise testing and prescription*. 10 ed. China: Wolters Kluwer, 2018.
33 Duncan MJ, Wunderlich K, Zhao Y, *et al*. Walk this way: validity evidence of iPhone health application step count in laboratory and free-living conditions. *J Sports Sci* 2017:1–10.
34 Hekler EB, Buman MP, Grieco L, *et al*. Validation of physical activity tracking via android Smartphones compared to ActiGraph Accelerometer: laboratory-based and free-living validation studies. *JMIR mHealth and uHealth* 2015;3:e36.
35 Evenson KR, Goto MM, Furberg RD. Systematic review of the validity and reliability of consumer-wearable activity trackers. *Int J Behav Nutr Phys Act* 2015;12.
36 Zaza S, Wright-De Agüero LK, Briss PA, *et al*. Data collection instrument and procedure for systematic reviews in the guide to community Preventive Services. Task Force on community Preventive Services. *Am J Prev Med* 2000;18(1 Suppl):44–74.
37 Armijo-Olivo S, Stiles CR, Hagen NA, *et al*. Assessment of study quality for systematic reviews: a comparison of the Cochrane collaboration risk of bias tool and the effective public health practice project quality assessment tool: methodological research. *J Eval Clin Pract* 2012;18:12–18.
38 Higgins JPT, Thompson SG. Quantifying heterogeneity in a meta-analysis. *Stat Med* 2002;21:1539–58.
39 Egger M, Davey Smith G, Schneider M, *et al*. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997;315:629–34.
40 John LK, Loewenstein G, Volpp KG. Empirical observations on longer-term use of incentives for weight loss. *Prev Med* 2012;55(Suppl):S68–S74.
41 Jeffery RW. Financial incentives and weight control. *Prev Med* 2012;55(Suppl):S61–S67.
42 Paul-Ebhohimhen V, Avenell A. Systematic review of the use of financial incentives in treatments for obesity and overweight. *Obes Rev* 2008;9:355–67.
43 Borenstein MHL, Higgins J, Rothstein H. *Comprehensive meta-analysis version 2*. Englewood NJ: Biostat, 2005.
44 Acland D, Levy MR. Naiveté, projection bias, and habit formation in Gym attendance. *Manage Sci* 2015;61:146–60.
45 Andrade LF, Barry D, Litt MD, *et al*. Maintaining high activity levels in sedentary adults with a reinforcement-thinning schedule. *J Appl Behav Anal* 2014;47:523–36.
46 Babcock P, Bedard K, Charness G, *et al*. Letting down the team? Social effects of team incentives. *J Eur Econ Assoc* 2015;13:841–70.
47 Carrera M, Royer H, Stehr M, *et al*. Can financial incentives help people trying to establish new habits? Experimental evidence with new gym members. *J Health Econ* 2018;58:202–14.
48 Condliffe S, Işgın E, Fitzgerald B. Get thee to the gym! A field experiment on improving exercise habits. *J Behav Exp Econ* 2017;70:23–32.
49 Finkelstein EA, Tham K-W, Haaland BA, *et al*. Applying economic incentives to increase effectiveness of an outpatient weight loss program (TRIO) - A randomized controlled trial. *Soc Sci Med* 2017;185:63–70.
50 Harkins KA, Kullgren JT, Bellamy SL, *et al*. A trial of financial and social incentives to increase older adults' walking. *Am J Prev Med* 2017;52:e123–30.
51 Kullgren JT, Harkins KA, Bellamy SL, *et al*. A mixed-methods randomized controlled trial of financial incentives and peer networks to promote walking among older adults. *Health Educ Behav* 2014;41(1_suppl):43S–50.
52 Leahey TM, Subak LL, Fava J, *et al*. Benefits of adding small financial incentives or optional group meetings to a web-based statewide obesity initiative. *Obesity* 2015;23:70–6.
53 Losina E, Collins JE, Deshpande BR, *et al*. Financial incentives and health coaching to improve physical activity following total knee replacement: a randomized controlled trial. *Arthritis Care Res* 2018;70:732–40.
54 Patel MS, Asch DA, Volpp KG. Framing financial incentives to increase physical activity among overweight and obese adults. *Ann Intern Med* 2016;165.
55 Patel MS, Asch DA, Rosin R, *et al*. Individual versus team-based financial incentives to increase physical activity: a randomized, controlled trial. *J Gen Intern Med* 2016;31:746–54.
56 Patel MS, Volpp KG, Rosin R, *et al*. A randomized trial of social comparison feedback and financial incentives to increase physical activity. *Am J Health Promot* 2016;30:416–24.
57 Patel MS, Volpp KG, Rosin R, *et al*. A randomized, controlled trial of Lottery-Based financial incentives to increase physical activity among overweight and obese adults. *Am J Health Promot* 2018;32:1568–75.
58 Petry NM, Andrade LF, Barry D, *et al*. A randomized study of reinforcing ambulatory exercise in older adults. *Psychol Aging* 2013;28:1164–73.
59 Pope L, Harvey J. The efficacy of incentives to motivate continued fitness-center attendance in college first-year students: a randomized controlled trial. *J Am Coll Health* 2014;62:81–90.
60 Rohde KIM, Verbeke W. We like to see you in the gym—A field experiment on financial incentives for short and long term gym attendance. *J Econ Behav Organ* 2017;134:388–407.
61 Royer H, Stehr M, Sydnor J. Incentives, commitments, and habit formation in exercise: evidence from a field experiment with workers at a Fortune-500 company. *Am Econ J Appl Econ* 2015;7:51–84.
62 Shin DW, Yun JM, Shin J-H, *et al*. Enhancing physical activity and reducing obesity through smartcare and financial incentives: a pilot randomized trial. *Obesity* 2017;25:302–10.
63 van der Swaluw K, Lambooij MS, Mathijssen JJP, *et al*. Commitment lotteries promote physical activity among overweight adults-a cluster randomized trial. *Ann Behav Med* 2018;52:342–51.
64 Washington W, McMullen D, Devoto A. A matched deposit contract intervention to increase physical activity in underactive and sedentary adults. *Transl Issues Psychol Sci* 2016;2:101–15.
65 Johnston M, Sniehotta F. Financial incentives to change patient behaviour. *J Health Serv Res Policy* 2010;15:131–2.
66 Pope L, Harvey J. The impact of incentives on intrinsic and extrinsic motives for fitness-center attendance in college first-year students. *Am J Health Promot* 2015;29:192–9.
67 Deci EL, Koestner R, Ryan RM. A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychol Bull* 1999;125:627–68. discussion 92-700.
68 Promberger M, Marteau TM. When do financial incentives reduce intrinsic motivation? comparing behaviors studied in psychological and economic literatures. *Health Psychology* 2013;32:950–7.
69 Deci E, Ryan R. *Handbook of self-determination research*. Rochester, NY: University of Rochester Press, 2002.
70 Crane MM, Tate DF, Finkelstein EA, *et al*. Motivation for participating in a weight loss program and financial incentives: an analysis from a randomized trial. *J Obes* 2012;2012:1–9.
71 Mitchell MS, Goodman JM, Alter DA, *et al*. The feasibility of financial incentives to increase exercise among Canadian cardiac rehabilitation patients. *J Cardiopulm Rehabil Prev* 2016;36:28–32.
72 Biswas A, Oh PI, Faulkner GE, *et al*. Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Ann Intern Med* 2015;162:123–32.
73 Moller AC, Buscemi J, McFadden HG, *et al*. Financial motivation undermines potential enjoyment in an intensive diet and activity intervention. *J Behav Med* 2014;37:819–27.

74 Teixeira PJ, Carraça EV, Markland D, *et al*. Exercise, physical activity, and self-determination theory: a systematic review. *Int J Behav Nutr Phys Act* 2012;9.

75 Statistics Canada: population estimates on July 1st, by age and sex and tax filers and dependants with income by total income, sex and age, 2017. Statistics Canada. Available: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110000801&pickMembers%5B0%5D=1.35 [Accessed cited June 29, 2018].

76 Willis Towers Watson. Best practices in health care employer survey report; 2018. https://www.willistowerswatson.com/en/insights/2018/01/2017-best-practices-in-health-care-employer-survey [Accessed 15 Dec 2018].

77 Samson A. *The behavioral economics guide 2014*, 2014.

78 Chokshi NP, Adusumalli S, Small DS, *et al*. Loss-Framed financial incentives and personalized Goal-Setting to increase physical activity among ischemic heart disease patients using wearable devices: the active reward randomized trial. *J Am Heart Assoc* 2018;7. doi:10.1161/JAHA.118.009173. [Epub ahead of print: 13 Jun 2018].

79 Wertenbroch K, Soman D, Chattopadhyay A. On the perceived value of money: the reference dependence of currency numerosity effects. *J Consum Res* 2007;34:1–10.