Annals of Behavioral Medicine, 2023, **57**, 277–287
https://doi.org/10.1093/abm/kaac066
Advance access publication 11 November 2022
Systematic Review

Evaluation of the Effectiveness of Behavioral Economic Incentive Programs for Goal Achievement on Healthy Diet, Weight Control and Physical Activity: A Systematic Review and Network Meta-analysis

Suparee Boonmanunt, PhD[1] · Oraluck Pattanaprateep, PhD[1] · Boonsong Ongphiphadhanakul, MD[2] · Gareth McKay, PhD[3] · John Attia, MD PhD[4,5] · Ivo Vlaev, PhD[6] · Ammarin Thakkinstian, PhD[1]

[1]Department of Clinical Epidemiology and Biostatistics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 270 Rama VI Road, Pyathai, Bangkok 10400, Thailand
[2]Department of Medicine, Faculty of Medicine Ramathibodi Hospital, Mahidol University, 270 Rama VI Road, Pyathai, Bangkok 10400, Thailand
[3]Centre for Public Health, School of Medicine, Dentistry, and Biomedical Sciences, Queen's University Belfast, 97 Lisburn Road, Whitla Medical Building, BT9 7BL Belfast, UK
[4]School of Medicine and Public Health, University of Newcastle, Kookaburra Circuit, John Hunter Hospital Campus, New Lambton, NSW 2305, Australia
[5]Hunter Medical Research Institute, Kookaburra Circuit, John Hunter Hospital Campus, New Lambton, NSW 2305, Australia
[6]Warwick Business School, University of Warwick, Coventry CV4 7AL, UK

Oraluck Pattanaprateep,
oraluck.pat@mahidol.edu

Abstract

Background Healthy diet, weight control and physical activity to reduce obesity can be motivated by financial incentives (FI). Behavioral-economic approaches may improve the incentivization effectiveness. This study compares and ranks the effectiveness of standard and behavioral incentivization for healthy diet, weight control, and physical activity promotion.

Purpose To investigate whether behavioral-economic insights improve incentivization effectiveness.

Methods A systematic search of Medline and Scopus was performed from database inception to December 2020. Study characteristics, program designs, and risk ratio (RR) were extracted. A two-stage network meta-analysis pooled and ranked intervention effects.

Results There were 35 eligible RCTs. For diet-weight control, standard FI, deposit contract (deposit), lottery-based incentive (lottery), and standard-FI + lottery increased goal achievement compared to no-FI but only deposit was statistically significant with pooled RRs and 95% confidence intervals (CI) of 1.21 (0.94, 1.56), 1.79 (1.04, 3.05), 1.45 (0.99, 2.13), and 1.73 (0.83, 3.63). For physical activity, standard-FI, deposit, and lottery significantly increased goal achievement compared to no-FI, with pooled RRs of 1.38 (1.13, 1.68), 1.63 (1.24, 2.14) and 1.43 (1.14, 1.80), respectively. In a follow-up period for physical activity, only deposit significantly increased goal achievement compared to no-FI, with pooled RRs of 1.39 (1.11, 1.73).

Conclusion Deposit, followed by lottery, were best for motivating healthy diet, weight control and physical activity at program end. Post-intervention, deposit then standard-FI were best for motivating physical activity. Behavioral insights can improve incentivization effectiveness, although lottery-based approaches may offer only short-term benefit regarding physical activity. However, the imprecise intervention effects were major concerns.

Lay summary

Healthy diet, weight control and physical activity to reduce obesity can be motivated by financial incentives (FI). Behavioral-economic approaches may improve the effectiveness of FI programs. This study aims to investigate whether behavioral-economic insights improve incentivization effectiveness for healthy diet, weight control, and physical activity promotion. We conducted a systematic review of published randomized controlled trials (RCTs), then pooled the interested results, compared and ranked the effectiveness of standard and behavioral incentivization programs by a two-stage network meta-analysis. There were 35 eligible RCTs. For diet-weight control, standard FI, deposit contract (deposit), lottery-based incentive (lottery), and standard-FI + lottery increased goal achievement compared to no-FI but only deposit was statistically significant. For physical activity, standard-FI, deposit, and lottery significantly increased goal achievement compared to no-FI. In a follow-up period for physical activity, only deposit significantly increased goal achievement compared to no-FI. In conclusion, deposit, followed by lottery, were best for motivating healthy diet, weight control and physical activity at program end. Post-intervention, deposit then standard-FI were best for motivating physical activity. This shows that behavioral insights can improve incentivization effectiveness, although lottery-based approaches may offer only short-term benefit regarding physical activity.

Keywords behavioral economic · healthy diet · incentive · network meta-analysis · physical activity · weight control

Introduction

Obesity and overweight represent a substantial health burden that leads to the development of metabolic syndrome [1, 2] and non-communicable diseases, e.g., diabetes, hypertension and cardiovascular diseases [3, 4]. Obesity and overweight are preventable through healthy diet and regular physical activity [3]. However, unhealthy dietary behaviors [5] and insufficient physical activity are omnipresent [6] despite conventional interventions which have mostly focused on legislation (e.g., banning partially hydrogenated oils), taxes (e.g., sweetened beverage tax) and subsidies (e.g., fruit and vegetables), and information provision [7–10]. In addition, financial incentives (FI) [11, 12] have also been used to improve the effectiveness of promotions of healthy diet and physical activity. However, their effectiveness is largely dependent on their design [7, 11, 12]. As such, FI programs informed by behavioral economics [13, 14] may represent a more efficacious approach than a standard FI program to promote healthy diet and physical activity.

Behavioral economics combines insights from economics and psychology to understand particular heuristics that human brain uses to cope with the large burden of complex choices, which lead to predictable systematic biases and errors. Such better understanding of human decision-making provides opportunities for influencing choices that take better account of how people actually respond [15] because the predictable biases can be used to help or nudge people make better choices. Such interventions involving FI include such as deposit contracts (participants risk losing money if they do not meet goals which is effective because people dislike losses more than we like gains of an equivalent amount), lottery-based incentive (meeting goals makes participants eligible for a lottery prize which is effective because people overweight small probabilities), regret lottery (all participants eligible for a lottery ticket but only those meeting goals are eligible to receive the prize which is effective because seen one's ticket drawn and not being eligible for the prize creates an intense regret feeling), and other types of incentive schemes.

A previous meta-analysis [16] was published in 2015 and included seven studies to compare the effectiveness of weight loss between standard FIs, deposit contracts and regret lotteries. We described a protocol for a systematic review and network meta-analysis (NMA) [17] to consider these interventions with additional FIs including price incentives, lottery-based incentives, and group-based payments for several outcomes. The current study focused solely on goal achievement outcomes in healthy diet, weight control, and physical activity by comparison of standard and behavioral economic FIs; the probabilities of being the best interventions for these outcomes were estimated and ranked.

Methods and Analysis

This systematic review and NMA was conducted following the PRISMA guidelines [18] and registered at PROSPERO (CRD42020198024). Review methods were described in the published protocol [17] but are summarized briefly below:

Studies were identified from Medline via PubMed and Scopus databases up to December 2020. Two reviewers (SB and OP) independently selected studies, disagreement was resolved by consensus with a third reviewer (AT).

Search terms were constructed based on interventions and outcomes (more details in Supplementary Table 1 and published protocol [17]). A two-step study selection was performed: First, individual studies from the systematic reviews with or without meta-analysis (SRs/MAs) were selected. Second, relevant individual studies published since the previous SR/MA were selected from the searches.

Systematic reviews were selected if they compared behavioral economic incentive programs with any FI program comparisons (e.g., standard monetary (or equivalent) rewards, price incentives, deposit contract, lottery-based incentive, regret lottery, group-based payment or no incentive), and had any outcome of improvement of healthy diet, weight control, and/or physical activity. Selection of individual studies were based on the following criteria: compared any pair of interventions defined above; interventions were directly implemented on cluster/subject levels; assessed any outcome of improved healthy diet, weight control, and/or physical activity including actual weight, weight change, and others; and published in English or other languages amenable to Google translate.

Given the significant number of studies identified, this report focused on randomized control trials (RCTs) with outcomes of goal achievement on healthy diet, weight control and physical activity (Fig. 1).

Interventions and Outcomes

The primary outcome for this study was goal achievement (success/failure) in healthy diet, weight control and physical activity (gym visits, steps) evaluated at the end of the intervention program and at follow-up period (if available).

Interventions of interest initially stated in the review protocol [17] were standard FI, deposit contract, and lottery (i.e., lottery-based incentive, regret lottery), group-based payment, or no incentive. None of the RCTs included reported group-based payments, only a small number considered lottery-based incentives and regret lottery, which therefore necessitated amalgamation into a single outcome referred to as lottery. As such, four interventions were considered including no FI, standard FI, deposit contract (called deposit), and lottery.

Data extraction and risk of bias assessment

Data extractions and assessment of the risk of bias (RoB) were independently performed by two reviewers (SB and OP). The following data were extracted: setting, study design, FI interventions (i.e., type, goal criteria, target at process or outcome, incentive size, duration, frequency, setting), characteristics of study population (i.e., having non-communicable diseases (NCDs), percentage female, mean age), type of supplementary components (i.e., text reminder, feedback, education classes, self-monitoring), follow-up time during and after incentives, outcomes, and data for pooling (ln risk ratio (RR)).

Incentive per day was calculated to standardize the amount of incentive by dividing the maximum amount of FI rewarded by the program duration (in days). Inflation rates for each country [19] with an exchange rate for purchasing power in US dollars (USD PPP) [20] were calculated for 2020.

RoB for randomized trials was assessed using the Cochrane risk-of-bias tool for randomized trials (RoB2) [21], with disagreement resolved by consensus with a third reviewer (AT).

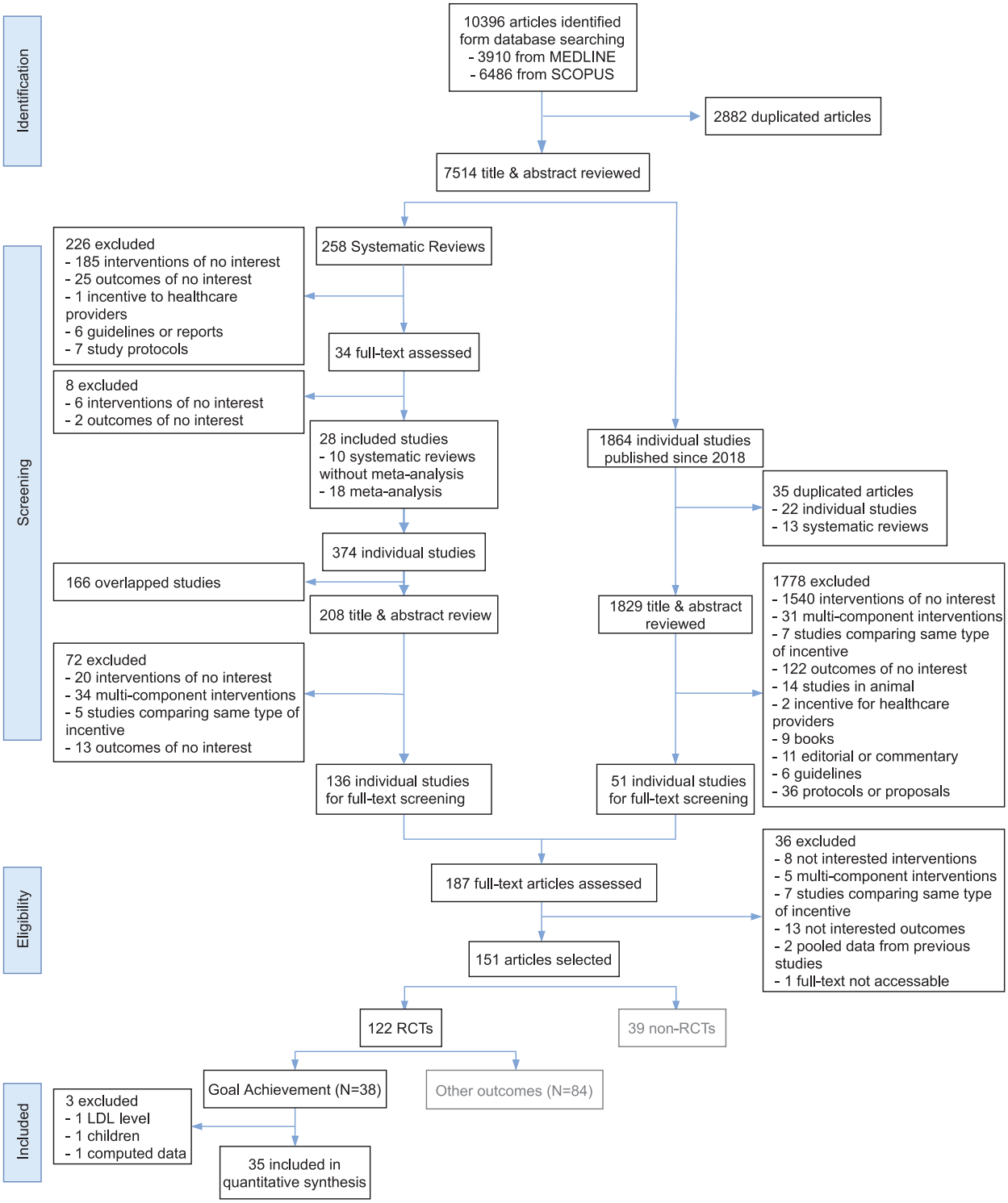

Fig. 1: Flow diagram of selection of studies. .

Statistical Analysis

Direct meta-analysis

Effect sizes (RRs) for goal achievement outcome were estimated and pooled across studies using a random-effect model if heterogeneity was present (Q test p-value < .10 or $I^2 \geq 25\%$), otherwise a fixed-effect model was applied. Heterogeneity was assessed using Cochrane's Q test and I^2 statistics [22–24]. Pre-specified subgroup analysis was performed by criteria of goal achievement (e.g., percentage or absolute weight control or number of gym visits), target (on process/outcome/both), size, frequency and duration of incentive, setting (clinic/non-clinic or gym/non-gym) and participant characteristics (female proportion, having NCDs, mean age). Publication bias was assessed using a funnel plot and Egger's test. If asymmetry

was present, a contour-enhanced funnel plot was constructed to identify the cause of publication bias.

Network meta-analysis

A network meta-analysis approach was applied to indirectly estimate mixed relative treatment effects where none or only a few direct comparisons were available by borrowing data from a common comparator [25]. As such, relative treatment effects for all possible pairwise comparisons were estimated beyond what would normally be possible through conventional direct meta-analyses approaches. A two-stage network meta-analysis was applied to assess relative treatment effects using a consistency model with common between-study variance [25]. Interventions were coded as 1, 2, 3, 4 for no FI, standard FI, deposit, and lottery, respectively. Mixed relative treatment comparisons between all FIs were then estimated accordingly. The probability of being the best FI program for goal achievement (i.e., highest RR) was estimated using surface under the cumulative ranking curve (SUCRA) method. The probability of goal achievement for each treatment was estimated with 1000-replications and an average probability estimated ranging between 0 and 100%, with a greater value reflecting a higher rank [26]. Inconsistency assumptions were evaluated by a design-treatment interaction model [25]. All analyses were performed using STATA software V.17.1; a p-value<0.05 was considered statistically significant.

Results

Characteristics of Selected Studies

A total of 7,514 studies were identified (Fig. 1), 122 were RCTs, of which 38 reported defined goal achievement in contrast to the remainder which reported other outcomes, see Fig. 1. Three RCTs [27–29] were further excluded leaving 35 RCTs [30–64] (16 and 19 RCTs for diet-weight control and physical activity, respectively) for further details, see Supplementary Fig. 1. Only inclusion of two studies [31, 32] was questioned by both reviewers (SB and OP), and this was solved by discussion and consensus. Comparison pairs (i.e., intervention vs comparator) of goal achievement in diet-weight control and physical activity are described in Table 1 and Supplementary Fig. 2.

All studies were conducted in high-income countries: 26 (74.3%) in the USA, 7 (19.4%) in Europe and 2 (5.9%) in Asia. Study participants from 16 studies had metabolic syndrome including overweight, obesity, prediabetes, diabetes, and hypertension (45.7%). Mean age ranged from 18 to 80.4 with median of 45.1 years; percentage of female ranged from 5.3% to 91.5% with a median of 69.5% (Supplementary Table 2).

Criteria of goal achievement included percentage weight loss (N = 9), absolute weight loss/control (N = 5), choosing healthy snack (N =1), and self-weighing (N = 1) for diet-weight controls; steps (N = 12) and gym visits (N =7) for physical activity. Incentives were paid for process (N = 23), outcome (N = 10), and both (N = 6). The size of financial incentive per day in USD PPP ranged from 0.03 to 38.5 with a median of 1.5. The maximum size of lottery prize ranged from 51 to 356.8 with a median of 103.6 USD PPP. Program duration ranged from 7 days to 1 year with a median of 3 months and payment frequency ranged from daily to every 3 months with a median of every week. Supplementary components included knowledge provision in the form of a booklet/brochure (N = 2), one-time education class (N = 3) and repeated classes (N = 4); counselling (N = 5); feedback (N = 24); self-monitoring (N = 14) (Supplementary Table 2).

Risk of Bias

Of 35 RCTs, 91%, 100%, 97%, 100%, 49% were judged as low RoB for randomization, protocol deviations, missing outcome data, outcome measurement, and reporting bias, respectively (Supplementary Figure 3). Consequently, 54% and 43% of all RCTs were rated as "some concerns" and "low concern" of RoB, respectively, with only a single study identified as high RoB. A RoB assessment was questioned by both reviewers in only a single study [34] and this was resolved by discussion.

Direct meta-analysis

Sixteen RCTs [30–45] compared effects of interventions on goal achievement in diet-weight control including standard FI (N = 8, 12 interventions), deposit (N = 3), lottery (N = 5) and standard FI+lottery (N = 2) versus no FI (Supplementary Figure 2). A meta-analysis was applied (Supplementary Figure 4) indicating deposit and lottery significantly led to goal achievement more often than no FI with pooled RRs [95% confidence interval (95%CI)] of 1.99 (1.36, 2.92) and 1.34 (1.01, 1.80), respectively. In addition, standard FI and standard FI+lottery also performed better than no FI but this was not significantly, with pooled RRs of 1.20 (0.93, 1.53) and 2.22 (0.58, 8.49), respectively.

Nineteen RCTs [46–64] compared effects of interventions on achievement of physical activity goals (Supplementary Figure 2). These effect sizes were pooled across studies indicating standard FI, deposit and lottery were significantly more likely to achieve goal than no FI (1.46 (1.18, 1.79), 1.63 (1.31, 2.03) and 1.44 (1.20, 1.73) respectively, Supplementary Figure 5). In addition, deposit was 1.16 (0.98, 1.38) times more likely to achieve goal than standard FI but this was non-significant.

Degree of heterogeneity (I^2) of pooling was estimated, see Supplementary Table 3. For diet-weight control, the I^2 values were high (78.66%) in standard FI, moderate (53.69% and 60.05%) in standard FI+lottery and lottery. For physical activity, heterogeneity was high (I^2 = 71.31%) in only standard FI vs no-FI but none for the remaining. None of heterogeneity sources could be identified by a meta-regression (Supplementary Table 4). However, subgroup analysis by size of FI per day showed that higher median FI provided greater effect than lower median FI (Supplementary Figure 6), suggesting that as expected, higher financial incentives are more likely to provide a stronger effect than lower financial incentives on goal outcomes for both diet and physical activity. Likewise, additional subgroup analysis showed that the effect of lottery was higher if incentive duration was <180 days, knowledge was provided, and performed in a clinic.

A small study effect was evaluated by Egger's test (Supplementary Table 3) and funnel plots (Supplementary Figure 7 and 9) indicating asymmetry of the funnel on pooling of lottery vs no-FI (p = .03) for diet-weight control and standard FI vs no-FI (p < .001) for physical activity. Contour-enhanced funnel plots (Supplementary Figure 8 and 10) were then constructed for both comparisons indicating that asymmetry was likely due to genuine heterogeneity not just to study size.

Table 1: Characteristics of Included Studies

Study	Country	Intervention	Incentive to process/ outcome	FI per day (USD PPP)	Duration (days)	Frequency (days)	Setting	NCDs	Age (mean)	Follow up day post-program
Goal type: diet										
Achtziger, 2019	Switzerland	no FI standard FI	process	0.64	7	7	non-clinic	No	35.42	N/A
Goal type: weight control										
Colvin, 1983	USA	no FI standard FI	outcome	3.32	77	7	non-clinic	No	NR	182.625
Volpp, 2008	USA	no FI deposit lottery (regret)	outcome	3.35	112	1	clinic	Yes	NR	N/A
Petry, 2011	USA	no FI lottery	outcome	0.03	84	84	clinic	Yes	45.65	N/A
Kullgren, 2013	USA	no FI standard FI	outcome	3.43	168	30	clinic	Yes	45.30	N/A
Leahey, 2015	USA	no FI standard FI + lottery	combined	0.52	91.3125	91.3125	non-clinic	No	45.69	318.9375
Patel, 2016a	USA	no FI lottery (regret)	outcome	1.57	365.25	14	non-clinic	Yes	44.89	N/A
Finkelstein, 2017	Singapore	no FI deposit	outcome	1.32	112	14	clinic	Yes	44.34	121.75
Yancy, 2018	USA	no FI standard FI lottery	outcome	2.90	182.625	1	non-clinic	No	48.99	182.625
VanEpps, 2019	USA	no FI standard FI	process, outcome, combined	2.22	112	7	clinic	Yes	48.79	N/A
Yancy, 2019	USA	no FI lottery	process	0.65	182.625	7	non-clinic	Yes	48.06	182.625
Chin, 2020	USA	no FI standard FI	process, outcome, combined	2.22	112	7	clinic	Yes	NR	N/A
Cleveland, 2020	USA	no FI deposit	outcome	1.47	350	7	non-clinic	No	48.13	N/A
Desai, 2020	USA	no FI standard FI	combined	38.48	365.25	14	clinic	Yes	48.33	N/A
LaRose, 2020	USA	no FI standard FI + lottery	combined	0.54	84	84	non-clinic	Yes	NR	N/A
West, 2020	USA	no FI standard FI	combined	2.20	182.625	7	non-clinic	Yes	48.99	N/A
Goal type: steps										
Petry, 2013	USA	no FI lottery	process	0.03	84	84	non-gym	Yes	63.20	N/A
Kullgren, 2014	USA	no FI lottery	process	3.09	112	7	non-gym	No	71.90	56

Table 1. Continued

Study	Country	Intervention	Incentive to process/ outcome	FI per day (USD PPP)	Duration (days)	Frequency (days)	Setting	NCDs	Age (mean)	Follow up day post-program
Patel, 2016b	USA	no FI lottery (regret)	process	0.64	91	2	non-gym	NR	40.52	91
Patel, 2016c	USA	no FI standard FI deposit lottery	process	1.43	91	1	non-gym	Yes	39.68	91
Patel, 2016d	USA	no FI lottery (regret)	process	0.20	91	7	non-gym	NR	41.32	91
Harkins, 2017	USA	no FI standard FI	process	3.00	112	7	non-gym	NR	80.35	28
Burns, 2018	USA	no FI standard FI deposit	process	1.47	35	7	non-gym	No	19	14
Patel, 2018	USA	no FI lottery (regret)	process	1.32	91	1	non-gym	Yes	41.02	91
Budworth, 2019	UK	no FI standard FI deposit	process	1.58	14	14	non-gym	No	33.78	N/A
Kramer, 2019	Switzerland	no FI standard FI	process	0.30	91.3125	30	non-gym	NR	45.39	N/A
Kramer, 2020	Switzerland	no FI standard FI	process	0.91	42	1	non-gym	NR	41.73	N/A
Tanji, 2020	Japan	no FI standard FI	process	0.48	21	21	non-gym	Yes	61.20	N/A
Goal type: gym visits										
Courneya, 1997	USA	no FI standard FI	process	2.47	31	31	gym	No	36	N/A
Pope, 2013	USA	no FI standard FI	process	5.70	84	7	gym	No	NR	N/A
Pope, 2014	USA	no FI standard FI	process	2.88	168	7	gym	Yes	18	N/A
Royer, 2015	USA	no FI standard FI deposit	process	5.62	28	7	gym	No	39.50	84
Rohde, 2017	The Netherlands	no FI standard FI	process	0.87	197.84	91.25	gym	No	33.28	182.625
Fricke, 2018	Switzerland	no FI standard FI	process	1.32	140	3.5	gym	No	39.14	N/A
van der Swaluw, 2018	The Netherlands	no FI lottery (regret)	process	0.37	91	7	gym	Yes	49.61	91

NR: not reported; N/A: not available; FI: financial incentive, deposit: deposit contract, lottery: lottery-based incentive; USD PPP with 2020 as a base year

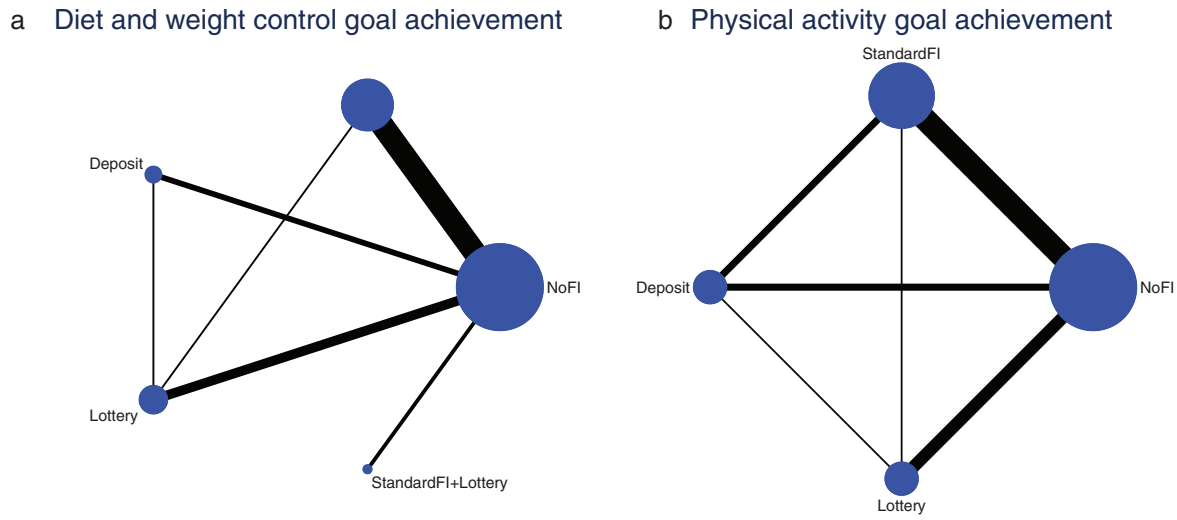

Fig. 2: Network map of different types of financial incentive program on a) diet- weight control goal achievement b) physical activity goal achievement. Size of nodes was weighted by numbers of studies/comparisons. Size of edges was weighted by numbers of subjects in each comparison. Each number on plots represents numbers of studies/comparisons and subjects contributing to the corresponding comparison.

Network meta-analysis

Data used for NMA of goal achievement in diet-weight control and physical activity are provided (Supplementary Table 5-6). For diet-weight control goal achievement, 16 RCTs [30–45] were included consisting of standard FI, deposit, lottery, standard FI+lottery, and no FI (Fig. 2a). All FIs increased the chance of goal achievement compared to no-FI, but only deposit was significant with pooled RR (95%CI) of 1.79 (1.04, 3.05) (Table 2 and Supplementary Figure 11). In addition, deposit was also more likely to lead to goal achievement compared to standard FI and lottery, with lottery more likely than standard FI, although all RRs failed to meet the significance threshold (Fig. 3a and Table 2).

Nineteen RCTs [46–64] were included in the NMA of physical activity (Fig. 2b). Standard FI, deposit, and lottery significantly increased the chances of goal achievement compared to no-FI with pooled RRs (95%CI) of 1.38 (1.13, 1.68), 1.63 (1.24, 2.14) and 1.43 (1.14, 1.80), respectively (Table 2 and Supplementary Figure 12). Furthermore, among FIs, deposit was superior, followed by lottery and then standard FI, however, these differences were non-significant (Fig. 3b and Table 2).

SUCRA was applied to rank probabilities of being the best intervention (Supplementary Table 7). For diet-weight control goal achievement, deposit was ranked first followed by standard FI+lottery, lottery, standard FI, and no FI. Similarly, for physical activity goal achievement deposit was top-ranked, followed by lottery, standard FI and no FI.

Consistency assumption and publication bias

Inconsistency assumptions were checked, indicating no evidence of inconsistency for both diet-weight control (Chi-square = 2.52, p = .64) and physical activity (Chi-square = 0.33, p = 0.99). Comparison-adjusted funnel plots were created for both outcomes (Supplementary Figure 13-14) and showed asymmetry for physical activity goal achievement (Egger test, p = .01). This asymmetry resulted from the comparison of standard FI with no-FI (Egger test, p = .001), and was mainly due to heterogeneity rather than small-study effects as the contour-enhanced funnel plot identified studies within areas of different significance levels (Supplementary Figure 15).

Follow-up period

Five [32, 35, 37, 38, 40] and 10 studies [47–53, 61, 62, 64] followed up participants after the end of intervention for weight control and physical activity goal achievement (Supplementary Figure 16), respectively. Median follow-up time was 6 (range: 4–10.5) and 4.3 months (range: 2 weeks - 6 months), respectively (Table 1).

Direct meta-analysis showed a non-significant difference in goal achievement on weight control between standard FI and lottery relative to no FI with pooled RRs (95%CI) of 1.07 (0.78, 1.47) and 0.91 (0.62, 1.36), respectively (Supplementary Figure 17). For physical activity, standard FI, deposit and lottery showed better goal achievement than no FI, but only deposit was significant with a pooled RR of 1.44 (1.11, 1.87) (Supplementary Figure 18). Egger's test (Supplementary Table 8) and funnel plots (Supplementary Figure 19-20) identified no asymmetry on pooling.

NMA was performed for physical activity goal achievement (Supplementary Table 6) indicating significant effects of deposit compared to no FI and standard FI with pooled RRs (95%CI) of 1.39 (1.11, 1.73) and 1.25 (1.01, 1.55), respectively (Table 2 and Supplementary Figure 21). SUCRA ranking suggested that deposit was the best option followed by standard FI and lottery in achievement of physical activity (Supplementary Table 7). There was no evidence of inconsistency (Chi-square = 1.38, p = .85). Comparison-adjusted funnel plots and Egger's test (p = .40) identified no asymmetry (Supplementary Figure 22).

Confidence in Network Meta-Analysis

The Confidence In Network Meta-Analysis (CINeMA) [65, 66] approach was applied to assess confidence in the results of our NMAs based on six domains, i.e., within-study bias, reporting bias, indirectness, imprecision, heterogeneity, and incoherence. Each domain was rated as no concerns, some concerns, or major concerns; the overall assessment

Table 2: Estimation of Relative Intervention Effects on Goal Achievements: A Network Meta-analysis

Intervention	Comparator	Diet-Weight control Endline	Physical activity Endline	Physical activity Follow-up
Standard FI	No FI	1.21 (0.94, 1.56)	**1.38 (1.13, 1.68)**	1.11 (0.94, 1.30)
	Deposit	0.68 (0.38, 1.22)	0.85 (0.66, 1.09)	0.80 (0.64, 0.99)
	Lottery	0.84 (0.54, 1.28)	0.96(0.72, 1.28)	1.06 (0.81, 1.38)
	Standard FI + lottery	0.70 (0.32, 1.52)	N/A	N/A
Deposit	No FI	**1.79 (1.04, 3.05)**	**1.63 (1.24, 2.14)**	**1.39 (1.11, 1.73)**
	Standard FI	1.47 (0.82, 2.64)	1.18 (0.92, 1.52)	**1.25 (1.01, 1.55)**
	Lottery	1.23 (0.68,2.22)	1.13 (0.81, 1.58)	1.32 (0.98, 1.79)
	Standard FI + lottery	1.03 (0.42,2.56)	N/A	N/A
Lottery	No FI	1.45 (0.99,2.13)	**1.43 (1.14, 1.80)**	1.05 (0.83, 1.32)
	Standard FI	1.20 (0.78,1.84)	1.04 (0.78, 1.39)	0.95 (0.72, 1.24)
	Deposit	0.81 (0.45,1.47)	0.88 (0.63, 1.23)	0.76 (0.56, 1.02)
	Standard FI + lottery	0.84 (0.37,1.91)	N/A	N/A
Standard FI + lottery	No FI	1.73 (0.83,3.63)	N/A	N/A
	Standard FI	1.43 (0.66,3.10)	N/A	N/A
	Deposit	0.97 (0.39,2.40)	N/A	N/A
	Lottery	1.19 (0.52,2.71)	N/A	N/A

FI, financial incentive;deposit, deposit contract; lottery, lottery-based incentive; and N/A, not available. Bold indicates statistical significance of the results.

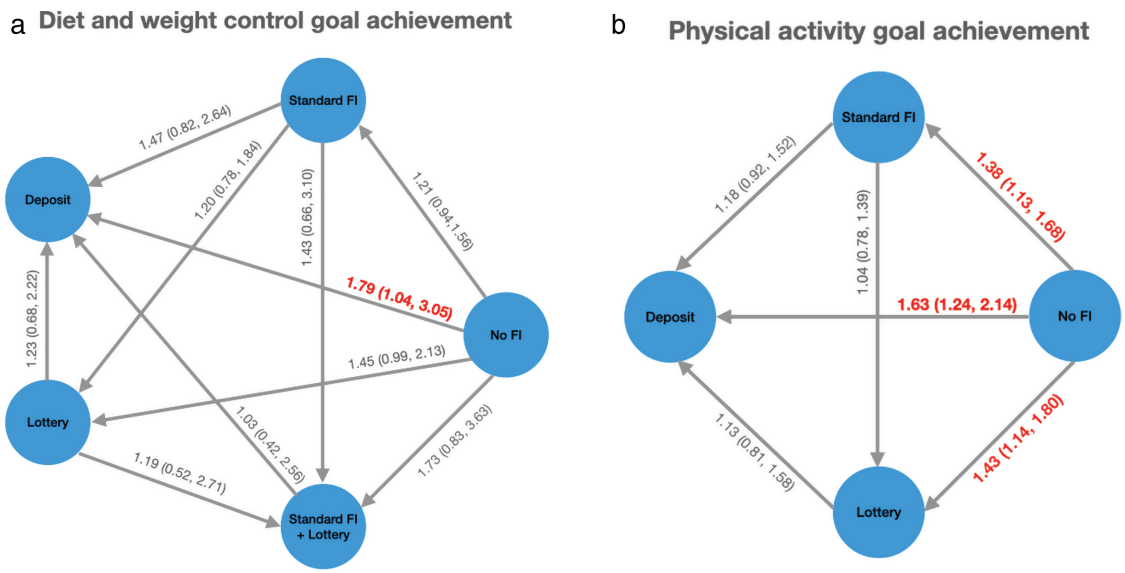

Fig. 3: Pooled effect sizes with 95% confidence interval in parenthesis for each comparison in the network for a) diet-weight control goal achievement b) physical activity goal achievement. Arrows point to the best in each comparison. Bold indicates statistical significance of the results.

was determined by incorporating all domains as very low, low, moderate, or high evidence. For goal achievement in diet-weight control and physical activity during and after implementation of interventions, there were 10, 6, and 6 comparisons, out of which 40%, 50%, and 50% were judged as low confidence, respectively (Supplementary Table 9-11); while the remainder were considered as moderate confidence.

Discussion

We performed a NMA to assess the effects of FIs on goal achievement for diet-weight control and physical activity using data from 35 RCTs. Findings suggested that the best interventions for diet-weight control goal achievement at the end of the program were deposit, followed by standard FI+lottery, lottery, and standard FI (compared to no FI). These interventions, with the exception of standard FI+lottery, were also best for physical activity goal achievement. In addition, the benefits of deposit persisted for 2 weeks to 6 months beyond the end of the intervention.

In general, goal achievement for healthy diet, weight control, and physical activity is dependent not only on type of FI but also on the time period beyond the intervention ends. For instance, deposit, lottery, and standard FI were best for

physical activity goal achievement during intervention implementation but only the effect of deposit persisted 4 months after the program had ended, suggesting integrating behavioral insight regarding loss aversion can improve incentive program effectiveness [16, 67, 68]. In addition, deposit increased goal achievement by 47% compared to standard FI; this would have been a clinically significant effect but it did not reach statistical significance. Although lottery represented the second-best option at program end, its effect diminished thereafter suggesting that while lottery generated some short-term benefits, these were less sustainable in the longer term. At the beginning of a lottery program, participants may have overestimated the probability of winning the prize and therefore were highly motivated. When people realize the true expected value of the prize over time, the motivating effect then faded out [53].

Our findings were consistent with those from a previous meta-analysis which found that deposit had the best effect, followed by lottery and standard FI compared to no FI in healthy goal achievement [16]. Although deposit represented the most effective FI, it may face uptake problems given that participants risk losing money if they do not meet goals [61, 69]. Allowing participants to set their own deposit amount aligned with their income may resolve this issue. Nevertheless, deposit is considered fairer and less controversial as individuals finance their own healthy behaviors [67].

According to the self-determination theory, both intrinsically (e.g., pleasure, interest, or challenges) and/or extrinsically motivations (e.g., rewards, commands, or legally restrictions) determine health behaviors [70]. The effect of financial reward, which acts as an external motivation, depends on how the rewards are perceived, e.g., either as supportive, informational, or controlling [71, 72]. If it is perceived as controlling, it might undermine intrinsic motivation leading to unsustainable health behavior change. On the contrary, if it supports or reinforces intrinsic motivation, its effect can last beyond the program end. Financial incentive program, which contains supportive communication and allows participants to have their autonomy on the implementation, might have long-term effect on health behaviors [71].

Previous meta-analysis evidence [73] for traditional interventions such as media campaigns for behavioral change showed only very small effects on diet and exercise (pooled coefficients of 0.05), which was substantially lower than clinically-based interventions of education and counselling (weighted average effect size of 0.51 for diet-weight control) [74]. Other behavioral economic interventions may also prove efficacious as suggested through another recent meta-analysis [75] demonstrating the effectiveness of nudges in both health and food domains with average standardized effects of 0.34 and 0.65, respectively. These interventions provided positive effects similar to deposit contracts in our study, although these could not be directly compared.

Our findings were based on RCT data conducted in developed countries, so application of this evidence in developing countries should be considered with caution. Previous evidence shown that people with low incomes tend to favor lottery compared to those on higher income [76, 77]. Therefore, lottery programs may represent a more feasible option in middle-/low-income countries. Furthermore, RCTs are needed to compare the effectiveness of different types of FIs in middle-/low-income countries, given the current paucity of studies available.

Our study has several strengths. To our knowledge, this is the first NMA synthesizing evidence from all available standard and behavioral FI programs (deposit and lottery including regret lottery) for goal achievement on healthy diet, weight control, and physical activity. FI effects were also assessed beyond the program conclusion, where information was available. However, some limitations could not be avoided. First, some comparisons in NMA were based on only small number of both RCTs and included subjects that met the inclusion criteria, particularly for three of the six comparisons for diet-weight control (number of subjects of 38 to 208) and two of the six comparisons for physical activity (number of subjects of 41 to 139) which were based on data from two studies or less that contributed to the NMA. As a result, estimates of intervention effects were imprecise leading to major concerns for suggestion of deposit and standard FI versus lottery. This lessens the confidence in conclusion for these particular comparisons. However, the conclusion for the other comparisons is not affected as the results from the pairwise direct meta-analysis and NMA are quite similar. Second, the effects of FI programs were subject to low/moderate heterogeneity and the small number of RCTs included were not amenable to sub-group analysis to identify and reduce heterogeneity. Third, approximately 50% of the intervention effects estimated from our NMA had moderate levels of confidence while the remainder had low levels in line with the CINeMA reporting protocols. Our results should therefore be updated when further RCTs have been published.

Conclusions

Behavioral FIs, namely deposit, followed by lottery approaches, represented the best incentives for goal achievement in healthy diet, weight control, and physical activity on program completion. In the longer term, deposit, followed by standard FI, provided the best options for goal achievement for physical activity beyond the intervention timeframe. However, these intervention effects are major concerns due to imprecision. Further update NMA should be performed. Behavioral insight about loss aversion may improve the effectiveness of incentive programs for healthy diet, weight control and physical activity. While lottery-based approaches may provide only potential short-term benefits in the context of physical activity.

Acknowledgments This study was funded by the National Research Council of Thailand (grant number N42A640323).

Compliance with Ethical Standards

Authors' Statement of Conflict of Interest and Adherence to Ethical Standards All authors declared no conflicts of interest.

Author contributions: Suparee Boonmanunt: Conceptualization, Methodology, Formal analysis, Investigation, Data Curation, Writing – Original Draft, Visualization

Oraluck Pattanaprateep: Methodology, Investigation, Writing – Original Draft

Boonsong Ongphiphadhanakul: Conceptualization

Gareth McKay: Writing - Review & Editing

John Attia: Writing - Review & Editing

Ivo Vlaev: Writing - Review & Editing

Ammarin Thakkinstian: Conceptualization, Methodology, Formal analysis, Investigation, Writing – Review & Editing, Supervision, Funding acquisition

Transparency statements: Study and analytic plan preregistration: The study including the analysis plan was preregistered at PROSPERO (CRD42020198024). Link: https://www.crd.york.ac.uk/prospero/

Data availability: De-identified data from this study are not available in a public archive. De-identified data from this study will be made available (as allowable according to institutional IRB standards) by emailing the corresponding author.

Analytic code availability: Analytic code used to conduct the analyses presented in this study are not available in a public archive. They may be available by emailing the corresponding author.

Materials availability: Materials used to conduct the study are not publicly available.

Supplementary Material

Supplementary material is available at *Annals of Behavioral Medicine* online.

References

1. Carnethon MR, Loria CM, Hill JO, Sidney S, Savage PJ, Liu K. Risk factors for the metabolic syndrome. *Diabetes Care*. 2004; 27:2707–2715.
2. National Heart Lung and Blood Institute. *Metabolic Syndrome*. Retrieved June 17, 2020, 2020 from https://www.nhlbi.nih.gov/health-topics/metabolic-syndrome
3. World Health Organization. *Obesity and overweight*. Retrieved June 16, 2020, 2020 from https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight
4. World Health Organization. *Noncommunicable diseases*. Retrieved June 17, 2020, 2020 from https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases
5. World Health Organization. *Healthy diet*. Retrieved February 6, 2020 from www.who.int/en/news-room/fact-sheets/detail/healthy-diet
6. World Health Organization. Physical activity. Retrieved February 6, 2020, 2020 from www.who.int/en/news-room/fact-sheets/detail/physical-activity
7. Vlaev I, King D, Darzi A, Dolan P. Changing health behaviors using financial incentives: a review from behavioral economics. *BMC Public Health* 2019; 19:1059.
8. Chokshi DA, Farley TA. Health. Changing behaviors to prevent noncommunicable diseases. *Science* 2014; 345:1243–1244.
9. Ezzati M, Riboli E. Can noncommunicable diseases be prevented? Lessons from studies of populations and individuals. *Science* 2012; 337:1482–1487.
10. Puska P, Ståhl T. Health in all policies-the Finnish initiative: background, principles, and current issues. *Annu Rev Public Health*. 2010; 31:315–283 p following 328.
11. Mitchell MS, Orstad SL, Biswas A, et al. Financial incentives for physical activity in adults: systematic review and meta-analysis. *Br J Sports Med*. 2020; 54:1259–1268.
12. Giles EL, Robalino S, McColl E, Sniehotta FF, Adams J. The effectiveness of financial incentives for health behaviour change: systematic review and meta-analysis. *PLoS One*. 2014; 9:e90347.
13. Hansen PG, Skov LR, Skov KL. Making healthy choices easier: regulation versus nudging. *Annu Rev Public Health*. 2016; 37:237–251.
14. Volpp KG, Asch DA, Galvin R, Loewenstein G. Redesigning employee health incentives--lessons from behavioral economics. *N Engl J Med*. 2011; 365:388–390.
15. Thaler RH, Sunstein CR. *Nudge: Improving Decisions about Health, Wealth, and Happiness*. New Haven, CT, US: Yale University Press, 2008.
16. 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; 29:314–323.
17. Boonmanunt S, Pattanaprateep O, Ongphiphadhanakul B, McKay G, Attia J, Thakkinstian A. Evaluation of the effectiveness of behavioural economic incentive programmes for the promotion of a healthy diet and physical activity: a protocol for a systematic review and network meta-analysis. *BMJ Open* 2020; 10:e046035.
18. Hutton B, Salanti G, Caldwell DM, et al. The PRISMA Extension Statement for Reporting of Systematic Reviews Incorporating Network Meta-analyses of Health Care Interventions: Checklist and Explanations. *Ann Intern Med*. 2015; 162:777–784.
19. International Monetary Fund: Inflation, comsumer prices (annual %). Retrieved September 2, 2021 from https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG
20. OECD: Purchasing power parities (PPP). Retrieved September 4, 2021 from https://data.oecd.org/conversion/purchasing-power-parities-ppp.htm
21. Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ* 2019; 366:l4898.
22. Dawson DV, Pihlstrom BL, Blanchette DR. Understanding and evaluating meta-analysis. *J Am Dent Assoc*. 2016; 147:264–270.
23. Garcia-Alamino JM, Bankhead C, Heneghan C, Pidduck N, Perera R. Impact of heterogeneity and effect size on the estimation of the optimal information size: analysis of recently published meta-analyses. *BMJ Open* 2017; 7:e015888.
24. Baker WL, Michael White C, Cappelleri JC, et al. Understanding heterogeneity in meta-analysis: the role of meta-regression. *Int J Clin Pract*. 2009; 63:1426–1434.
25. White IR:. Network meta-analysis. *Stata J* 2015; 15:951–985.
26. Mbuagbaw L, Rochwerg B, Jaeschke R, et al. Approaches to interpreting and choosing the best treatments in network meta-analyses. *Syst Rev* 2017; 6:79.
27. Faghri PD, Li R. Effectiveness of Financial Incentives in a Worksite Diabetes Prevention Program. *Open Obes J* 2014; 6:1–12.
28. Finkelstein EA, Tan YT, Malhotra R, Lee C-F, Goh S-S, Saw S-M. A cluster randomized controlled trial of an incentive-based outdoor physical activity program. *J Pediatr*. 2013; 163:167–72.e1.
29. Bloch MJ, Armstrong DS, Dettling L, Hardy A, Caterino K, Barrie S. Partners in lowering cholesterol: comparison of a multidisciplinary educational program, monetary incentives, or usual care in the treatment of dyslipidemia identified among employees. *J Occup Environ Med*. 2006; 48:675–681.
30. Volpp KG, John LK, Troxel AB, Norton L, Fassbender J, Loewenstein G. Financial incentive-based approaches for weight loss: a randomized trial. *JAMA* 2008; 300:2631–2637.
31. Achtziger A, Glas A, Kenning P, Rudolph T:. Comparing the effects of financial incentives and implementation intentions on unhealthy snacking behavior in employees. *Curr Psychol*. 2019; 40:4770–4784.
32. Colvin RH, Zopf KJ, Myers JH:. Weight control among coworkers. Effects of monetary contingencies and social milieu. *Behav Modif*. 1983; 7:64–75.
33. Petry NM, Barry D, Pescatello L, White WB. A low-cost reinforcement procedure improves short-term weight loss outcomes. *Am J Med*. 2011; 124:1082–1085.
34. Kullgren JT, Troxel AB, Loewenstein G, et al. Individual- versus group-based financial incentives for weight loss: a randomized, controlled trial. *Ann Intern Med*. 2013; 158:505–514.
35. 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 (Silver Spring)* 2015; 23:70–76.
36. Patel MS, Asch DA, Troxel AB, et al. Premium-Based Financial Incentives Did Not Promote Workplace Weight Loss In A 2013-15 Study. *Health Aff (Millwood)* 2016; 35:71–79.
37. Finkelstein EA, Tham KW, Haaland BA, Sahasranaman A:. Applying economic incentives to increase effectiveness of an

outpatient weight loss program (TRIO) - A randomized controlled trial. *Soc Sci Med* 2017; 185:63–70.
38. Yancy WS, Jr, Shaw PA, Wesby L, et al. Financial incentive strategies for maintenance of weight loss: results from an internet-based randomized controlled trial. *Nutr Diabetes* 2018; 8:33.
39. VanEpps EM, Troxel AB, Villamil E, et al. Effect of Process- and Outcome-Based Financial Incentives on Weight Loss Among Prediabetic New York Medicaid Patients: A Randomized Clinical Trial. *Am J Health Promot*. 2019; 33:372–380.
40. Yancy WS, Jr, Shaw PA, Reale C, et al. Effect of escalating financial incentive rewards on maintenance of weight loss: a randomized clinical trial. *JAMA Netw Open* 2019; 2:e1914393.
41. Chin JY, Matson J, McCauley S, Anarella J, Gesten F, Roohan P. The impact of financial incentives on utilization and outcomes of diabetes prevention programs among Medicaid managed care adults in New York state. *Contemp Clin Trials*. 2020; 91:105960.
42. Cleveland LP, Seward MW, Simon D, et al. BWHealthy Weight Pilot Study: A randomized controlled trial to improve weight-loss maintenance using deposit contracts in the workplace. *Prev Med Rep* 2020; 17:101061.
43. Desai JR, Vazquez-Benitez G, Taylor G, et al. The effects of financial incentives on diabetes prevention program attendance and weight loss among low-income patients: the We Can Prevent Diabetes cluster-randomized controlled trial. *BMC Public Health* 2020; 20:1587.
44. LaRose JG, Leahey TM, Lanoye A, Reading J, Wing RR:. A secondary data analysis examining young adults' performance in an internet weight loss program with financial incentives. *Obesity (Silver Spring)* 2020; 28:1062–1067.
45. West DS, Krukowski RA, Finkelstein EA, et al. Adding financial incentives to online group-based behavioral weight control: An RCT. *Am J Prev Med*. 2020; 59:237–246.
46. Petry NM, Andrade LF, Barry D, Byrne S. A randomized study of reinforcing ambulatory exercise in older adults. *Psychol Aging*. 2013; 28:1164–1173.
47. 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; 41:43S43s–43S50S.
48. 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; 31:746–754.
49. Patel MS, Asch DA, Rosin R, et al. Framing financial incentives to increase physical activity among overweight and obese adults: a randomized, controlled trial. *Ann Intern Med*. 2016; 164: 385–394.
50. 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; 30:416–424.
51. Harkins KA, Kullgren JT, Bellamy SL, Karlawish J, Glanz K. A trial of financial and social incentives to increase older adults' walking. *Am J Prev Med*. 2017; 52:e123–e130.
52. Burns RJ, Rothman AJ. Comparing types of financial INCENTIVES TO PROMOTE WALKING: AN EXPERIMENTAL TEST. *Appl Psychol Health Well Being* 2018; 10:193–214.
53. 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; 32:1568–1575.
54. Budworth L, Prestwich A, Sykes-Muskett B, et al. A feasibility study to assess the individual and combined effects of financial incentives and monetary contingency contracts on physical activity. *Psychol Sport Exerc* 2019; 44:42–50.
55. Kramer JN, Tinschert P, Scholz U, Fleisch E, Kowatsch T. A cluster-randomized trial on small incentives to promote physical activity. *Am J Prev Med*. 2019; 56:e45–e54.
56. Kramer JN, Künzler F, Mishra V, et al. Which components of a smartphone walking app help users to reach personalized step goals? Results from an optimization trial. *Ann Behav Med*. 2020; 54:518–528.
57. Tanji F, Tomata Y, Abe S, et al. Effect of a financial incentive (shopping point) on increasing the number of daily walking steps among community-dwelling adults in Japan: a randomised controlled trial. *BMJ Open* 2020; 10:e037303.
58. Courneya KS, Estabrooks PA, Nigg CR. A simple reinforcement strategy for increasing attendance at a fitness facility. *Health Educ Behav.* 1997; 24:708–715.
59. Pope L, Harvey-Berino J. Burn and earn: a randomized controlled trial incentivizing exercise during fall semester for college first-year students. *Prev Med*. 2013; 56:197–201.
60. 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.
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. 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.
63. Fricke H, Lechner M, Steinmayr A. The effects of incentives to exercise on student performance in college. . *Econ of Educ Rev* 2018; 66:14–39.
64. 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; 52:342–351.
65. Nikolakopoulou A, Higgins JPT, Papakonstantinou T, et al. CINeMA: An approach for assessing confidence in the results of a network meta-analysis. *PLoS Med*. 2020; 17:e1003082.
66. Papakonstantinou T, Nikolakopoulou A, Higgins JPT, Egger M, Salanti G:. CINeMA: Software for semiautomated assessment of the confidence in the results of network meta-analysis. . *Campbell Syst Rev.* 2020; 16:e1080.
67. Sykes-Muskett BJ, Prestwich A, Lawton RJ, Armitage CJ. The utility of monetary contingency contracts for weight loss: a systematic review and meta-analysis. *Health Psychol Rev* 2015; 9:434–451.
68. McGill B, O'Hara BJ, Bauman A, Grunseit AC, Phongsavan P. Are financial incentives for lifestyle behavior change informed or inspired by behavioral economics? A mapping review. *Am J Health Promot*. 2019; 33:131–141.
69. Halpern SD, French B, Small DS, et al. Randomized trial of four financial-incentive programs for smoking cessation. *N Engl J Med*. 2015; 372:2108–2117.
70. Ryan RM, Deci EL. *Self-determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. New York, NY, US: The Guilford Press, 2017.
71. Moller AC, Ntoumanis N, Williams GC. Financial incentives may influence health behaviors, but do we end up with less than we paid for? a self-determination theory perspective. *Ann Behav Med*. 2019; 53:939–941.
72. Hagger MS, Keatley DA, Chan DCK, et al. The goose is (half) cooked: a consideration of the mechanisms and interpersonal context is needed to elucidate the effects of personal financial incentives on health behaviour. *Int J Behav Med*. 2014; 21:197–201.
73. Snyder LB, Hamilton MA, Mitchell EW, Kiwanuka-Tondo J, Fleming-Milici F, Proctor D. A meta-analysis of the effect of mediated health communication campaigns on behavior change in the United States. *J Health Commun*. 2004; 9(Suppl 1):71–96.
74. Mullen PD, Simons-Morton DG, Ramírez G, Frankowski RF, Green LW, Mains DA. A meta-analysis of trials evaluating patient education and counseling for three groups of preventive health behaviors. *Patient Educ Couns*. 1997; 32:157–173.
75. Mertens S, Herberz M, Hahnel UJJ, Brosch T. The effectiveness of nudging: A meta-analysis of choice architecture interventions across behavioral domains. *Proc Natl Acad Sci USA*. 2022; 119:e2107346118.
76. Haisley E, Mostafa R, Loewenstein G. Subjective relative income and lottery ticket purchases. *J Behav Decis Mak*. 2008; 21:283–295.
77. Fu H-N, Monson E, Otto AR. Relationships between socio-economic status and lottery gambling across lottery types: neighborhood-level evidence from a large city. *Addiction* 2021; 116:1256–1261.