ORIGINAL ARTICLE

Effect of Financial Incentives on Hypertension Control: A Multicenter Randomized Controlled Trial in China

Liqiang Zheng⬤, Sitong Liu, Yundi Jiao, Yani Wu, Yali Wang, Zhecong Yu, Jiahui Xu, Yingxian Sun⬤, Zhaoqing Sun

BACKGROUND: Poorly controlled hypertension is a great challenge to global public health. Incentive approaches, based on behavioral and economic concepts, may improve patients' adherence to treatment.

METHODS: We conducted a 2-arm randomized controlled trial to test whether financial incentives can help patients with poorly controlled hypertension in China reduce their blood pressure (BP). Participants were randomized 1:1 to the control and intervention groups. All participants received WeChat-based standard education and support for hypertension management. The intervention group received financial incentives, including process- and outcome-based incentives.

RESULTS: No statistically significant differences in BP reduction and hypertension control rates were found between the two groups from baseline to 12-month follow-up. Mean systolic BP decreased from 158.7 to 149.8 mm Hg in the intervention group and 159.7 to 149.5 mm Hg in the control group (P=0.639). Mean diastolic BP decreased from 93.7 to 86.6 mm Hg in the intervention group and 93.9 to 86.3 mm Hg in the control group (P=0.667). Hypertension control rates in the intervention and control groups were 20.8% and 15.8%, respectively (P=0.318). Medication adherence was 84.2% in the intervention group and 86.2% in the control group (P=0.705).

CONCLUSIONS: Financial incentives were effective in the short term for BP control, but a sustained effect of incentive-based BP control was not identified beyond 3 months of intervention. Future studies that focus on identifying the appropriate amount and structure of financial incentives for BP control are warranted.

REGISTRATION: URL: www.isrctn.org; Unique identifier: ISRCTN13467677. (*Hypertension*. 2022;79:2202–2211. DOI: 10.1161/HYPERTENSIONAHA.122.19568.)

Key Words: blood pressure ■ China ■ hypertension ■ motivation ■ randomized controlled trial

Hypertension is a global public health challenge and a major modifiable risk factor of cardiovascular disease and premature death.[1,2] Worldwide, the prevalence of hypertension is increasing at an alarming rate—particularly in China, where 245 million adults currently experience hypertension.[3,4] Despite significant advances in the treatment and management of hypertension, the percentage of controlled hypertension is still low (<50%) in the adult US population.[5] A nationwide survey conducted from 2012 to 2015 showed that among patients with hypertension in China, 46.9% were aware of their condition, 40.7% took antihypertensive medications, and merely 15.3% had controlled blood pressure (BP) <140/90 mm Hg.[6] Therefore, improving hypertension control is of urgent need and great importance.[7]

A recent systematic review and meta-analysis determined that team-based care was the most effective approach to overcome barriers to BP control.[8] However, this study did not include financial incentive-based trials.

See Editorial, pp 2212–2213

Correspondence to: Liqiang Zheng, School of Public Health, Shanghai Jiao Tong University School of Medicine, 227 Chongqing S Rd, Huangpu District, Shanghai 200025, China, Email liqiangzheng@126.com or Zhaoqing Sun, Department of Cardiology, Shengjing Hospital of China Medical University, Shenyang 110004, Liaoning Province, China, Email sunzhaoqing@vip.163.com or Yingxian Sun, Department of Cardiology, First Hospital of China Medical University, Shenyang 110001, Liaoning Province, China, Email yxsun@cmu.edu.cn

NOVELTY AND RELEVANCE

What Is New?

This is the first randomized controlled trial in China to examine whether financial incentives for patients were effective in blood pressure control.
Details of hypertension management in China were considered when determining the financial incentive amount.

What Is Relevant?

A small financial incentive improved blood pressure control at 3 months of intervention, but a sustained effect (beyond 3 months) was not observed.

Clinical/Pathophysiological implications?

Financial incentives slightly controlled blood pressure in hypertensive patients in the short term.
Our findings provide preliminary evidence for the feasibility of using financial incentives in controlling blood pressure in China.

Nonstandard Abbreviations and Acronyms

BP	blood pressure
RCT	randomized controlled trial
RFI	reverse fragility index

Providing financial incentives is more straightforward and less resource intensive than team-based care, particularly in resource-limited settings. Financial incentives can increase patients' motivation and help overcome barriers to treatment adherence.[9] Evidence has shown that offering financial incentives may help improve hypertension control.[10–15] However, the results of current financial incentive-based trials are inconsistent: some trials have yielded negative results, and it is unclear whether providing financial incentives has a sustained effect (eg, >6 months) on hypertension control.[14,16,17] On the other hand, the structure and amount of the financial incentive are considered a critical element in the design of these trials since these parameters have varied considerably in different trials. Some studies designed >2 different interventions, such as financial incentives with phone calls or return letters[11]; it is thus not possible to isolate the effects of financial incentives from other components of such an intervention. Furthermore, the effectiveness of financial incentives on BP control may vary according to the racial background and culture.[18] No study has evaluated the effect of financial incentives on hypertension control in China. Despite the wide implementation of evidence-based BP management programs (such as team-based care) in China, the lack and unequal distribution of health care resources contribute to the low hypertension control rate.[4,19]

Therefore, we designed a 2-arm randomized controlled trial (RCT) to assess the efficacy of financial incentives for BP control among patients with poorly controlled hypertension in China. We hypothesized that financial incentives could reduce BP in patients with poorly controlled hypertension.

METHODS

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Study Design

The 2-arm RCT was conducted in 3 cities of the Liaoning province (Shenyang, Dandong, and Fuxin) in China. Details of the study protocol have been published elsewhere.[14] Our analysis followed the CONSORT 2010 recommendations for the analysis of RCT data. This trial was compliant with the 1975 Declaration of Helsinki guidelines and approved by the Shengjing Hospital of China Medical University Medical Ethics Committee (No. 2019PS397K). All the participants or their guardians provided written informed consent.

Participants

Participants with poorly controlled hypertension were selected from 3 hospitals: Shengjing Hospital of China Medical University, Dandong Central Hospital, and Fuxin Mining General Hospital of the Liaoning Health Industry Group. The recruitment period was between September 15, 2019, and January 10, 2020. Inclusion criteria for the participants included (1) participants being aged between 35 and 75 years, (2) the presence of hypertension (BP ≥140/90 mm Hg during 2 separate screening or baseline visits), (3) having WeChat and being able to use it skillfully, (4) staying in their respective city for >12 months, and (5) voluntary participation and provision of written consent to participate in our trial. Exclusion criteria for participants included (1) pregnant women or women who planned to become pregnant within a year, (2) participants with a relocation plan for the coming year, (3) individuals with malignant tumors or severe liver or kidney dysfunction, (4) participants with secondary hypertension, and (5) participants who were unlikely to complete the trial, as judged by a recruiter. Recruiters were uniformly and rigorously trained and had a consistent understanding of the inclusion and exclusion criteria.

Intervention

Participants were randomized to the control and intervention groups in a 1:1 ratio. All participants in the 2 groups received standard WeChat-based education and support for

Table 1. Baseline Characteristics of the Study Population

Characteristics	Intervention (n=103)	Control (n=104)	P value	Effect size*
Age, y; mean±SD	55.0±10.1	56.2±10.6	0.401	−0.117
Women, n (%)	54 (52.4)	51 (49.5)	0.676	−0.029
Currently smoking, n (%)	27 (26.2)	34 (32.7)	0.307	0.071
Current drinking, n (%)	30 (29.4)	28 (27.2)	0.723	−0.025
Physical activity, n (%)	53 (51.5)	52 (50.0)	0.834	−0.015
BMI, kg/m²; mean±SD	27.4±4.9	27.4±4.6	0.967	−0.006
BP, mmHg; mean±SD				
Systolic	158.7±14.5	159.7±15.4	0.647	−0.064
Diastolic	93.7±10.6	93.9±11.1	0.903	−0.018
No. of steps in Wechat (≥6000), n (%)	48 (58.5)	49 (61.3)	0.725	0.028
Use of antihypertensive medications, n (%)	83 (80.6)	85 (81.7)	0.833	0.015
Self-reported medication adherence, n (%)	55 (64.0)	55 (62.5)	0.842	0.015
Medical history, n (%)				
Major CVD	15 (14.6)	23 (22.1)	0.161	0.098
Diabetes	14 (13.6)	23 (22.1)	0.110	0.111
Hypercholesterolemia	28 (27.2)	32 (30.8)	0.570	0.040
TC, mmol/L; mean±SD	5.1±1.1	5.1±1.0	0.665	−0.056
LDL, mmol/L; mean±SD	3.3±0.9	3.2±0.9	0.333	0.140
HDL, mmol/L; mean±SD	1.3±0.3	1.2±0.3	0.415	0.118
TG, mmol/L; mean±SD	2.1±1.5	2.5±3.3	0.225	−0.169
GLU, mmol/L; mean±SD	5.9±2.11	6.1±2.3	0.576	−0.081
Uric acid, µmol/L; mean±SD	339.2±105.1	331.2±107.4	0.589	0.076
Creatinine, µmol/L; mean±SD	66.0±18.6	66.6±19.8	0.813	−0.033

BMI indicates body mass index; BP, blood pressure; CVD, cardiovascular disease; GLU, glucose; HDL, high-density lipoprotein; LDL, low-density lipoprotein; TC, total cholesterol; and TG, triglyceride.

*Effect size: Cohen's d or Phi coefficient.

hypertension management. WeChat is a Chinese multipurpose instant messaging, social media, and mobile payment app with over 1 billion active users. The staff sent relevant information about the treatment and management of hypertension to all participants at the beginning of each week. The participants' questions were answered using WeChat's messaging feature. The physicians answering the questions on WeChat were masked to the group assignment and did not directly communicate with the participants. The research staff collected questions from the participants and returned the answers provided by the physicians.

To increase the response rate, all participants received a participation bonus of ¥100, per person, at baseline. A transportation subsidy of ¥50, per follow-up visit, was also provided. In the intervention group, participants were encouraged to self-measure their BP once a week and record the use of antihypertensive medications. Each participant in the intervention group received a reward of ¥5 every week to record BP measurements correctly. At the 1-, 3-, 6-, and 12-month follow-up visits, the researchers measured participants' BP in the office. Participants whose BP values decreased

by 10 mmHg (compared with their baseline BP values) or who achieved the control criteria (systolic BP/diastolic BP <140/90 mmHg) received a reward of ¥50 or an equivalent gift (shopping cards, phone bills, and cooking oil). As financial incentives, the participants in the intervention group could theoretically earn ¥760 per person in total. This included ¥50 per visit to meet BP improvement goals over 4 follow-up visits (¥200 in total), ¥5 per week for weekly recording and reporting of BP (¥260 in total), and ¥300 per week for completing all visits and questionnaires. The participants in the control group could earn a maximum amount of ¥300 to complete all visits and questionnaires.

Three factors were considered when determining the amount of financial incentives. First, the National Centralized Drug Procurement policy in China aims to reduce drug costs and improve drug procurement mechanisms. For example, the annual cost of amlodipine dropped from ¥300 to ¥60 because of National Centralized Drug Procurement initiatives.[20] The amount of financial incentives we provided covered the medication expenditures of patients with hypertension during the study period. Second, the treatment cost for hypertension was covered with reimbursement rates >50%, according to the national health insurance policy in China. In the 3 areas wherein this trial was conducted, residents' basic medical insurance premiums ranged from ¥320 to ¥390 per year. Our financial incentive amount was sufficient for patients to pay basic health insurance premiums for 1 year. Third, China's health care expenditures only accounted for 7.12% of GDP in 2020, which was low compared with the rest of the world.[21] Therefore, we used a lower amount of financial incentives for hypertension control than did other studies conducted among populations in Western countries. In summary, the theoretical maximum amount of the difference between the 2 groups was ¥460; this was enough to cover 1 year of a health insurance premium and 1 year of antihypertensive drug treatment.

Randomization and Blinding

Randomization was performed after participants were enrolled. The participants were block-randomized into the intervention and control groups in a 1:1 ratio. Randomization was stratified by geographic region, where the total number of stratifications was three. Computer-generated randomization was concealed and performed with a block size of 4, conducted by a statistician who was not involved in the trial, using SAS, version 9.4 (SAS Institute, Inc, Cary, NC). Due to the behavioral nature of the intervention, participants and principal investigators received and gave financial incentives, respectively; thus, neither were blinded to patient allocation. However, the study staff responsible for measuring the BP and the statistician were blinded to group assignment. The details of the randomization were kept confidential until data analysis was complete.

Procedures

Both groups were administered in-person questionnaires. BP was measured at baseline and at the 1-, 3-, 6-, and 12-month follow-up visit marks. Structured questionnaire items included demographic and lifestyle characteristics and the use of antihypertensive medications and concomitant drugs. Demographic and lifestyle characteristics included sex, age, smoking, alcohol drinking, and physical activity.

Table 2. Effects of Intervention on Primary Outcomes Among Participants With Hypertension

	Mean (95% CI)		Net difference in percentage points (95% CI)	P value
	Intervention group	Control group		
Change in systolic BP from baseline, mm Hg				
Month measured				
1	−11.8 (−14.7 to −9.0)	−12.5 (−15.3 to −9.6)	0.6 (−3.4 to 4.7)	0.757
3	−20.9 (−23.7 to −18.1)	−16.1 (−18.9 to −13.2)	−4.8 (−8.8 to −0.8)	0.018
6	−20.5 (−23.3 to −17.6)	−20.3 (−23.1 to −17.5)	−0.1 (−4.2 to 3.9)	0.951
12	−9.6 (−12.4 to −6.9)	−10.5 (−13.3 to −7.8)	0.9 (−4.8 to 3.0)	0.639
Change in diastolic BP from baseline, mm Hg				
Month measured				
1	−4.6 (−6.4 to −2.9)	−5.8 (−7.6 to −4.0)	1.2 (−1.4 to 3.7)	0.369
3	−6.6 (−8.4 to −4.9)	−5.8 (−7.5 to −4.0)	−0.9 (−3.4 to 1.6)	0.499
6	−9.0 (−10.8 to −7.1)	−7.9 (−9.7 to −6.2)	−1.0 (−3.5 to 1.5)	0.431
12	−6.6 (−8.3 to −4.9)	−7.1 (−8.8 to −5.4)	0.5 (−1.9 to 3.0)	0.667

Mixed-effects linear regression models were used to compare the BP change among the intervention and control groups. Participants attending study follow-up visits at months 1, 6, 9, and 12: intervention group (n=109): 90, 92, 86, 96; 6 subjects dropped out before any follow-up visit; control group (n=108): 89, 88, 91, 95, and 81; 4 dropped out before any follow-up visit. BP indicates blood pressure.

Each BP measurement was obtained by study nurses who were masked to group assignment, using a standardized protocol recommended by the American Heart Association.[22] Participants were advised to avoid alcohol, cigarettes, coffee or tea, and exercise at least 30 minutes before BP measurements. After participants rested in the seated position in a quiet room for 5 minutes, trained research personnel measured seated BP from the dominant arm (at the heart level) with an appropriately sized cuff (pediatric, regular adult, large, or thigh). We used a standardized automatic electronic sphygmomanometer (HEM-8102A; Omron, Tokyo, Japan) to eliminate digit preference and minimize interobserver variability.[22] Additionally, for each BP measurement, BP was measured 3× a day for 1 minute, and the mean of the BP values was calculated and used for all subsequent analyses. At the baseline and 12-month follow-up points, BP was measured on 2 consecutive days, and the mean of 6 BP values was used. The participants were asked to report adverse events. If participants experienced excessive BP reduction (systolic BP <100 mm Hg during the day), the study coordinator contacted them to inquire about their health status. In the case of severe adverse events resulting in significant functional impairment or the beginning of radiotherapy, chemoradiotherapy, or surgery, the participant was withdrawn from the study. Removal from the study due to adverse events was evaluated by a cardiologist.

Outcomes

The primary outcome was the net change in systolic BP, defined as the difference in BP between the intervention and control groups, from baseline to the 12-month follow-up period. Since systolic BP has a stronger association with vascular diseases, it was deemed a more reliable measurement than diastolic BP.[16,23] Secondary outcomes included the net change in diastolic BP, rate of BP control (BP <140/90 mm Hg), and change in self-reported medication adherence. Adverse events included coronary heart disease, stroke, and cardiovascular death.

Statistical Analysis

The sample size calculation was based on the following assumptions: a 7-mm Hg change in systolic BP; an SD of 20 mm Hg in systolic BP at a significance level of 0.05, using a 2-sided test with 90% statistical power; and 20% dropout rate. Thus, a sample size of 200 participants per group was required. All analyses were conducted in accordance with the intention-to-treat principle.

Descriptive statistics for all baseline characteristics were reported for each group. Noncontinuous variables are presented as counts and percentages (%), while continuous variables are presented as mean±SD. Baseline characteristics were compared between the intervention and control groups using an independent sample t test, χ^2 tests, or Fisher exact tests. Mixed-effects linear regression models were used to compare BP changes between the intervention and control groups. In these models, participants and clinics were assumed to be random effects, while intervention group, time, and interaction were assumed to be fixed effects. Logistic regression analysis was used to analyze categorical outcomes, including hypertension control and medication adherence.

For negative results, we used the concept of a reverse fragility index (RFI) to provide a measure of confidence in the neutrality of results.[15] The RFI was calculated by subtracting events from the group with a lower number of events while simultaneously adding nonevents to the same group to keep the number of participants constant until the Fisher exact test 2-sided P was <0.05.

Statistical significance was set at $P<0.05$ (2 tailed). Missing data were imputed using a multiple imputation approach. All statistical analyses were performed using SPSS, version 22 (IBM SPSS Statistics for Windows, version 22.0; IBM Corp, Armonk, NY).

RESULTS

The recruitment and retention of research participants are shown in Figure 1. Among the 419 patients initially
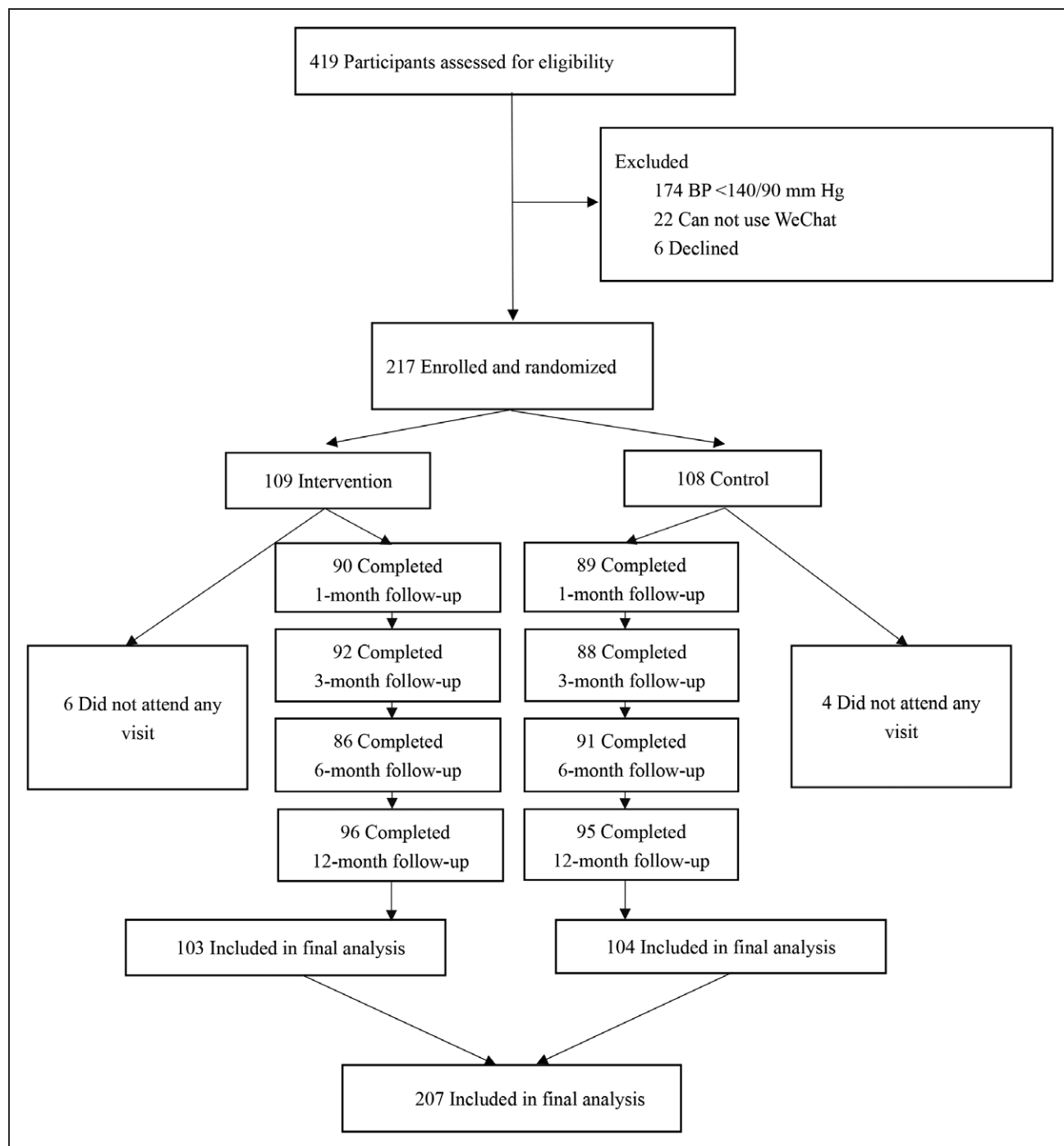
Figure 1. Study flowchart.
BP indicates blood pressure.

screened, 245 met the BP screening criteria. Of these, 217 patients consented to participate in the study and were enrolled; 109 were randomly allocated to the intervention group and 108 to the control group. Ten participants were lost to follow-up immediately after enrollment and did not attend any visits. Ultimately, 103 individuals in the intervention group and 104 in the control group were included in the analysis. Follow-up rates were 86.5%, 86.9%, 85.5%, and 92.3% for the 1-, 3-, 6-, and 12-month follow-up visits, respectively. After each of the 4 follow-up visits at 1, 3, 6, and 12 months, 51, 76, 66, and 58 participants in the intervention group (respectively) received a ¥50 reward. By the end of the study, the intervention group had received an average of ¥540 for each participant. In the control group, each participant received an average of ¥209. After the 12-month follow-up, no statistically significant differences in baseline BP (158.8±12.3/101.4±7.8 mmHg versus

159.2±15.1/93.1±10.8 mm Hg), sex, or age were found between those who dropped out of the study and those who remained in the study.

No significant differences regarding sex, age, baseline BP, medication use, and biochemical measurements were found between the 2 arms of the study (Table 1). Mean baseline BP was 158.7±14.5/93.7±10.6 mm Hg in the intervention group and 159.7±15.4/93.9±11.1 mm Hg in the control group.

As shown in Figure 2, BP in both groups showed a decreasing trend over the 12 months. From baseline to 12-month follow-up, mean systolic BP decreased from 158.7 to 149.8 mm Hg (with a mean decrease of 9.6 mm Hg) in the intervention group and from 159.7 to 149.5 mm Hg (with a mean decrease of 10.5 mm Hg) in the control group.
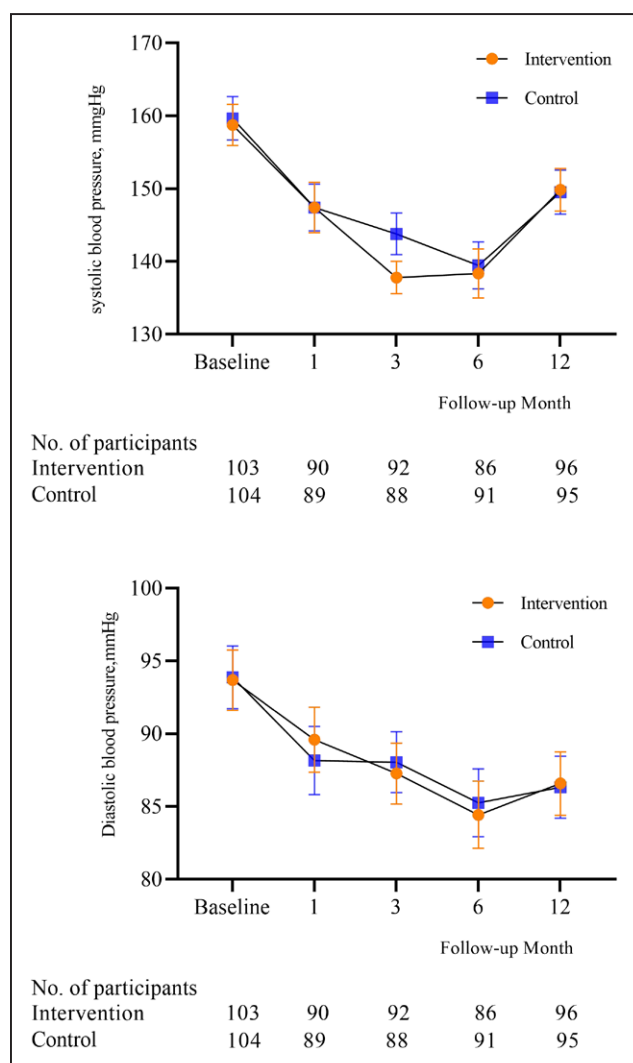

Figure 2. Mean blood pressure level during the 12-month intervention.
Six blood pressure measurements were obtained at baseline and at the 12-month follow-up, during the 2 visits. Three blood pressure measurements were obtained at the 1-, 6-, and 12-month follow-up points during 1 visit. The data points represent mean blood pressure, and error bars represent 95% CIs.

No significant difference in the change in systolic BP was found between the 2 groups at the 12-month follow-up mark ($P=0.639$). Conversely, at the 3-month follow-up mark, a significant difference in the change in systolic BP was found between the 2 groups (−20.9 versus −16.1 mm Hg, with a 4.8-mm Hg decrease relative to the control group; $P=0.018$ [95% CI, −8.8 to −0.8]). By the 12-month mark, mean diastolic BP decreased from 93.7 mm Hg (baseline) to 86.6 mm Hg in the intervention group and from 93.9 mm Hg (baseline) to 86.3 mm Hg in the control group. Diastolic BP was not significantly different between the groups at any of the 4 follow-up visits ($P>0.05$) (Table 2).

The rate of BP control was not significantly different between the 2 groups at the 12-month follow-up mark, regardless of covariate adjustment. However, the rate of BP control between the 2 groups varied across visits. The unadjusted BP control rate at the 1-month follow-up mark was 20.2% (18/89) in the control group and 26.7% (24/90) in the intervention group ($P=0.309$). At 3 months, the BP control rate increased to 33.0% (29/88) in the control group and 48.9% (45/92) in the intervention group. Intervention participants were significantly more likely to achieve a BP <140/90 mm Hg at the 3-month mark ($P=0.030$). At 6 months, the BP control rate increased to 47.3% (43/91) in the control group and 55.8% (48/86) in the intervention group. However, at 12 months, BP control rates were 15.8% (15/95) in the control group and 20.8% (20/96) in the intervention group. Differences between the groups were no longer significant at the 6- or 12-month marks ($P=0.255$ for 6-month and $P=0.368$ for 12-month follow-ups; Table 3). Adjusted odds ratios for the intervention group relative to the control group at different time points are presented in Table 3. After controlling for baseline BP, demographic factors, regular smoking and alcohol use, and other medical conditions, no significant difference in BP control rate was observed between the 2 groups across all 4 follow-up visits ($P>0.05$).

At the 12-month follow-up visit, no significant difference in medication adherence was observed between the control and intervention groups. At all 4 follow-up visits, a significant difference in medication adherence between the intervention and control groups was observed only at the 1-month follow-up mark (adjusted odds ratio, 0.083; $P=0.025$ [95% CI, 0.009−0.728]).

There were no significant subgroup differences in systolic BP reduction between the 2 groups according to age, sex, body mass index, type of hypertension, and cardiovascular risk ($P>0.05$; Figure 3).

The RFI in Table 3 shows the robustness of the unadjusted results of BP control rates. At the 12-month follow-up mark, the RFI for hypertension control was 6, indicating that the outcomes of at least 6 control group participants had to change to alter the significance of the results. No participant experienced excessive BP reduction or cardiovascular-related death, and a total of

Table 3. Unadjusted and Adjusted Results of Hypertension Control at Follow-Up

| | n/Total N (%) | | | | Adjusted odds | | |
	Intervention	Control	P value	RFI	ratio*	95% CI	P value
Month measured							
1	24/90 (26.7)	18/89 (20.2)	0.309	5	1.446	0.683–3.061	0.336
3	45/92 (48.9)	29/88 (33.0)	0.03	NA	1.738	0.884–3.418	0.109
6	48/86 (55.8)	43/91 (47.3)	0.255	6	1.453	0.735–2.873	0.283
12	20/96 (20.8)	15/95 (15.8)	0.368	6	1.527	0.665–3.509	0.318

NA indicates not applicable; and RFI, reverse fragility index.
*Logistic regression models controlling for baseline BP, demographic factors, smoking and alcohol use, and other medical conditions.
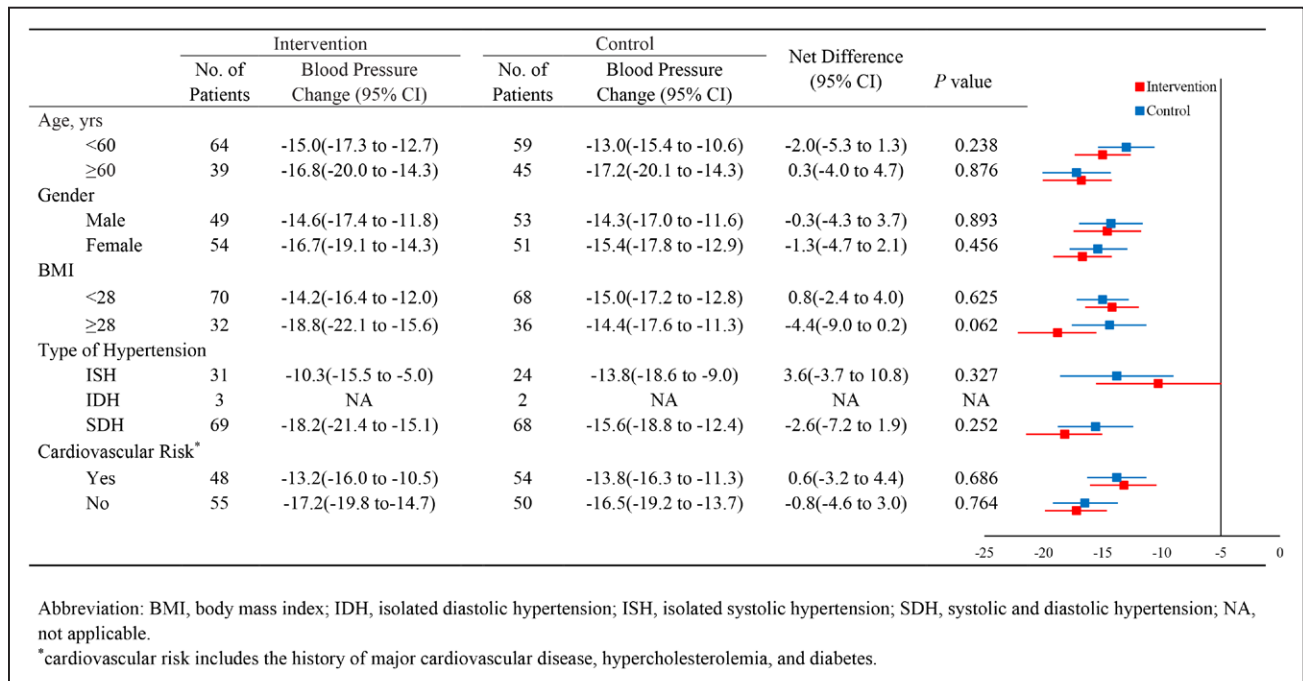
5 people had a stroke—3 in the intervention group and 2 in the control group. No other adverse events were reported. None of the participants withdrew from the study because of adverse events.

DISCUSSION

To address the challenging issue of hypertension control, we conducted a randomized trial using a behavioral economics theory-based intervention. BP decreased in both the control and intervention groups, with an average systolic BP reduction of 12 mm Hg. Financial incentives were statistically effective for the net decrease in systolic BP and the rate of BP control, but this effect was observed only in the early stage (at the 3-month follow-up mark). This effect was not observed at the 1-, 6-, and 12-month follow-up marks.

Financial incentives are proven to induce changes in health-related behavior, such as smoking cessation, weight loss, glycemic control, and hypertension control, thereby aiding in disease management.[11,14,16,17,24,25] Nevertheless, providing financial incentives to patients with hypertension is not always effective. Kaboli et al[11] used 3 interventions to encourage patients to talk to their doctors about antihypertensive medication intensification. To prompt patients, one group received a letter; the second group received a letter and a financial incentive; and the third group received a letter, a financial incentive, and a telephone call. After 12 months, improved BP control was evident only in the group receiving all 3 interventions. Shapiro et al[14] offered intervention participants a combination of fixed payments, contingent payments, and lotteries (eg, payment per mm Hg of improved BP, or a lottery card, to meet the health goals set by the researchers) in a highly disadvantaged minority population. This study revealed that financial incentives for measuring home BP aid in achieving short-term improvement in systolic BP control. However, this effect was

| | Intervention | | Control | | Net Difference | | |
	No. of Patients	Blood Pressure Change (95% CI)	No. of Patients	Blood Pressure Change (95% CI)	(95% CI)	P value	
Age, yrs							
<60	64	-15.0(-17.3 to -12.7)	59	-13.0(-15.4 to -10.6)	-2.0(-5.3 to 1.3)	0.238	
≥60	39	-16.8(-20.0 to -14.3)	45	-17.2(-20.1 to -14.3)	0.3(-4.0 to 4.7)	0.876	
Gender							
Male	49	-14.6(-17.4 to -11.8)	53	-14.3(-17.0 to -11.6)	-0.3(-4.3 to 3.7)	0.893	
Female	54	-16.7(-19.1 to -14.3)	51	-15.4(-17.8 to -12.9)	-1.3(-4.7 to 2.1)	0.456	
BMI							
<28	70	-14.2(-16.4 to -12.0)	68	-15.0(-17.2 to -12.8)	0.8(-2.4 to 4.0)	0.625	
≥28	32	-18.8(-22.1 to -15.6)	36	-14.4(-17.6 to -11.3)	-4.4(-9.0 to 0.2)	0.062	
Type of Hypertension							
ISH	31	-10.3(-15.5 to -5.0)	24	-13.8(-18.6 to -9.0)	3.6(-3.7 to 10.8)	0.327	
IDH	3	NA	2	NA	NA	NA	
SDH	69	-18.2(-21.4 to -15.1)	68	-15.6(-18.8 to -12.4)	-2.6(-7.2 to 1.9)	0.252	
Cardiovascular Risk*							
Yes	48	-13.2(-16.0 to -10.5)	54	-13.8(-16.3 to -11.3)	0.6(-3.2 to 4.4)	0.686	
No	55	-17.2(-19.8 to-14.7)	50	-16.5(-19.2 to -13.7)	-0.8(-4.6 to 3.0)	0.764	

Abbreviation: BMI, body mass index; IDH, isolated diastolic hypertension; ISH, isolated systolic hypertension; SDH, systolic and diastolic hypertension; NA, not applicable.
*cardiovascular risk includes the history of major cardiovascular disease, hypercholesterolemia, and diabetes.

Figure 3. Difference in systolic blood pressure changes among patients with hypertension, by subgroup.

only observed during the 6 months of the intervention but was not sustained after incentives were withdrawn. In another trial conducted among New York State Medicaid managed care patients, financial incentives had a negligible impact on BP control regardless of whether the participants were delivered process incentives, outcome incentives, or a combination of the two.[17] In our trial (which was the first RCT in China to assess the effect of financial incentives on BP control), financial incentives were effective in the short term, but the effect was not sustained in the long term. Therefore, the effect of financial incentives likely differs substantially based on the structure of the incentives, the population involved, and the study design.

In our trial, the lack of a sustained effect of financial incentives on BP control may be a result of various reasons. First, the amount and structure of our incentive payments may not have been attractive enough to participants, despite our payments being sufficient to cover 1 year of health insurance premiums and antihypertensive drug use. Our incentives were not substantial compared with the amount of the incentive payments in another study (where this study yielded positive results, using incentives that averaged >8% of annual income).[14] Future research should increase the amount of the financial incentives to obtain a more sustained effect on BP control. Second, the immediacy of financial incentives, also known as present bias in economics, may also have influenced the sustainability of this intervention on BP control.[26,27] Participants were likely to focus on the treatment in the initial phase but were prone to burnout during long term, sustained focus on treatment. Thus, the effect of financial incentives may be more pronounced in the early stages of a trial. Third, after participants had received the intervention for 3 months, the COVID-19 pandemic began in China. Participants may have focused more on COVID-19 prevention and thus neglected BP control as a result. Fourth, the absence of noticeable symptoms of hypertension and delay in adverse complications reduces risk perception, leading to poor patient awareness of the risks of hypertension.[28] Despite short-term improvement in BP, no benefit in somatic symptoms can be immediately observed in patients with hypertension. Thus, financial incentives essentially did not change perceptions, beliefs, and attitudes toward BP control.

However, the unsustainable effect of financial incentives on BP control cannot negate this intervention's significance. Our findings provide preliminary evidence of the feasibility of using financial incentives for BP control in China.[29] On the other hand, we used the RFI for our negative results to provide a measure of confidence in the neutrality of results when assessed from a clinical perspective.[15] The *P* values in our trial are marginally above the $P=0.05$ threshold, but this does not necessarily mean that our economic stimulus intervention was ineffective. RFI could be used as an alternative method to understand null trial results and convey uncertainty numerically to guide clinical interpretation and future research.[30]

Overall, financial incentives were effective in the short term for controlling hypertension, but no sustained effects were found in the long term. We conducted the first RCT in China to examine whether financial incentives for patients are effective in BP control. In 2009, China implemented the National Primary Public Health Services program, where the screening and management of hypertension was a vital part of this program. We expected our study to reveal a means of improving BP control using a small financial incentive in a Chinese context with limited health care expenditures, consistent with the National Primary Public Health Services's purport. Our results suggest that financial incentives might be an alternative approach to hypertension control in China, at least in the short term.

Limitations

Several limitations of this RCT must be acknowledged. First, due to the COVID-19 pandemic, the clinical studies were interrupted.[31] Residents were self-isolated or quarantined and had limited access to public places. Additionally, health care professionals were committed to critical tasks to control the pandemic. These obstacles disrupted the recruitment of participants. Ultimately, 207 (52%) of the original 400 participants were recruited. Based on an actual sample size of 207, with all other assumptions remaining the same, the recalculated statistical power was 71%. Therefore, we cannot rule out that the null findings of this trial might be attributed to insufficient statistical power regarding the detection of a significant difference in primary outcomes. However, given the minimal difference in systolic BP by the end of the intervention between the 2 groups, it is unlikely that financial incentives provided a significant benefit in reducing systolic BP, even if complete recruitment was achieved. Second, nearly all prepandemic cardiology-related clinical trials were put on hold during the pandemic.[32] Thus, we used remote BP monitoring at the 3- and 6-month follow-ups.[33] BP measurements were taken through live video calls, and trained research staff guided the participants to measure BP correctly at home, based on standard protocol.[34] Third, China is geographically, culturally, and socioeconomically diverse; thus, generalizing the findings of this study to other Chinese populations must be performed with caution.

Conclusions

Based on this RCT conducted in a Chinese population, a small financial incentive improved BP control at 3 months of intervention, but a sustained effect of BP control (beyond 3 months) was not observed. Future studies that focus on identifying the appropriate

amount and structure of financial incentives for BP control are warranted.

Perspectives

This RCT, conducted in a Chinese population, demonstrated that financial incentives could slightly control BP in hypertensive patients in the short term; however, the effects of financial incentives on BP control were not sustainable. Our findings provide initial evidence of the feasibility and potential of financial incentives for hypertension management in China. Details regarding hypertension management in China were considered when determining the amount of the financial incentives in our trial. Future studies that focus on identifying a more appropriate amount and structure of financial incentives for BP control are warranted.

REFERENCES

1. He J, Irazola V, Mills KT, Poggio R, Beratarrechea A, Dolan J, Chen CS, Gibbons L, Krousel-Wood M, Bazzano LA, et al; HCPIA Investigators. Effect of a community health worker-led multicomponent intervention on blood pressure control in low-income patients in Argentina: a randomized clinical trial. *JAMA.* 2017;318:1016–1025. doi: 10.1001/jama.2017.11358

2. Lewington S, Clarke R, Qizilbash N, Peto R, Collins R; Prospective Studies Collaboration. Age-specific relevance of usual blood pressure to vascular mortality: a meta-analysis of individual data for one million adults in 61 prospective studies. *Lancet.* 2002;360:1903–1913. doi: 10.1016/s0140-6736(02)11911-8

3. Hypertension Group of Cardiovascular Branch of Chinese Medical Association, Editorial Board of Chinese Journal of Cardiovascular Diseases. Expert consensus on the comprehensive management of blood pressure and dyslipidemia in Chinese hypertensive patients. *J Geriatr Cardiol.* 2021;49:554–563. doi: 10.3760/cma.j.cn112148-20210202-00128

4. Lu J, Lu Y, Wang X, Li X, Linderman GC, Wu C, Cheng X, Mu L, Zhang H, Liu J, et al. Prevalence, awareness, treatment, and control of hypertension in China: data from 1·7 million adults in a population-based screening study (China PEACE Million Persons Project). *Lancet.* 2017;390:2549–2558. doi: 10.1016/S0140-6736(17)32478-9

5. Muntner P, Hardy ST, Fine LJ, Jaeger BC, Wozniak G, Levitan EB, Colantonio LD. Trends in blood pressure control among US adults with hypertension, 1999-2000 to 2017-2018. *JAMA.* 2020;324:1190–1200. doi: 10.1001/jama.2020.14545

6. Wang Z, Chen Z, Zhang L, Wang X, Hao G, Zhang Z, Shao L, Tian Y, Dong Y, Zheng C, et al; China Hypertension Survey Investigators. Status of hypertension in China: results from the China Hypertension Survey, 2012-2015. *Circulation.* 2018;137:2344–2356. doi: 10.1161/CIRCULATIONAHA.117.032380

7. Curfman G, Bauchner H, Greenland P. Treatment and control of hypertension in 2020: the need for substantial improvement. *JAMA.* 2020;324:1166–1167. doi: 10.1001/jama.2020.13322

8. Mills KT, Obst KM, Shen W, Molina S, Zhang HJ, He H, Cooper LA, He J. Comparative effectiveness of implementation strategies for blood pressure control in hypertensive patients: a systematic review and meta-analysis. *Ann Intern Med.* 2018;168:110–120. doi: 10.7326/M17-1805

9. DeFulio A, Silverman K. The use of incentives to reinforce medication adherence. *Prev Med.* 2012;55 suppl:S86–S94. doi: 10.1016/j.ypmed.2012.04.017

10. Zhang Y, Tang W, Zhang Y, Liu L, Zhang L. Effects of integrated chronic care models on hypertension outcomes and spending: a multi-town clustered randomized trial in China. *BMC Public Health.* 2017;17:244. doi: 10.1186/s12889-017-4141-y

11. Kaboli PJ, Howren MB, Ishani A, Carter B, Christensen AJ, Vander Weg MW. Efficacy of patient activation interventions with or without financial incentives to promote prescribing of thiazides and hypertension control: a randomized clinical trial. *JAMA Netw Open.* 2018;1:e185017. doi: 10.1001/jamanetworkopen.2018.5017

12. Petersen LA, Simpson K, Pietz K, Urech TH, Hysong SJ, Profit J, Conrad DA, Dudley RA, Woodard LD. Effects of individual physician-level and practice-level financial incentives on hypertension care: a randomized trial. *JAMA.* 2013;310:1042–1050. doi: 10.1001/jama.2013.276303

13. Patel MS, Asch DA, Rosin R, Small DS, Bellamy SL, Heuer J, Sproat S, Hyson C, Haff N, Lee SM, 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. doi: 10.7326/M15-1635

14. Shapiro MF, Shu SB, Goldstein NJ, Victor RG, Fox CR, Tseng CH, Vangala S, Mogler BK, Reed SB, Villa E, et al. Impact of a patient-centered behavioral economics intervention on hypertension control in a highly disadvantaged population: a randomized trial. *J Gen Intern Med.* 2020;35:70–78. doi: 10.1007/s11606-019-05269-z

15. Khan MS, Fonarow GC, Friede T, Lateef N, Khan SU, Anker SD, Harrell FE Jr, Butler J. Application of the reverse fragility index to statistically nonsignificant randomized clinical trial results. *JAMA Netw Open.* 2020;3:e2012469. doi: 10.1001/jamanetworkopen.2020.12469

16. Owolabi MO, Gebregziabher M, Akinyemi RO, Akinyemi JO, Akpa O, Olaniyan O, Salako BL, Arulogun O, Tagge R, Uvere E, et al. Randomized trial of an intervention to improve blood pressure control in stroke survivors. *Circ Cardiovasc Qual Outcomes.* 2019;12:e005904. doi: 10.1161/CIRCOUTCOMES.119.005904

17. VanEpps EM, Troxel AB, Villamil E, Saulsgiver KA, Zhu J, Chin JY, Matson J, Anarella J, Roohan P, Gesten F, et al. Financial incentives for chronic disease management: results and limitations of 2 randomized clinical trials with New York medicaid patients. *Am J Health Promot.* 2018;32:1537–1543. doi: 10.1177/0890117117753986

18. Haff N, Patel MS, Lim R, Zhu J, Troxel AB, Asch DA, Volpp KG. 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. doi: 10.4278/ajhp.140714-LIT-333

19. Li Y, Yang L, Wang L, Zhang M, Huang Z, Deng Q, Zhou M, Chen Z, Wang L. Burden of hypertension in China: a nationally representative survey of 174,621 adults. *Int J Cardiol.* 2017;227:516–523. doi: 10.1016/j.ijcard.2016.10.110

20. Yunnan Provincial Healthcare Security Administration. Blue book on the progress and effectiveness of medicare drug management reform. 2021. http://ylbz.yn.gov.cn/index.php?c=show&id=2121.

21. Ayanian JZ. Crucial questions for US health policy in the next decade. *JAMA.* 2021;325:1397–1399. doi: 10.1001/jama.2021.1470

22. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves JW, Hill MN, Jones DH, Kurtz T, Sheps SG, Roccella EJ; Council on High Blood Pressure Research Professional and Public Education Subcommittee, American Heart Association. Recommendations for blood pressure measurement in humans: an AHA scientific statement from the Council on High Blood Pressure Research Professional and Public Education Subcommittee. *J Clin Hypertens (Greenwich).* 2005;7:102–109. doi: 10.1111/j.1524-6175.2005.04377.x

23. Izzo JL Jr, Levy D, Black HR. Clinical advisory statement. Importance of systolic blood pressure in older Americans. *Hypertension.* 2000;35:1021–1024. doi: 10.1161/01.hyp.35.5.1021

24. Volpp KG, Troxel AB, Pauly MV, Glick HA, Puig A, Asch DA, Galvin R, Zhu J, Wan F, DeGuzman J, et al. A randomized, controlled trial of financial

incentives for smoking cessation. *N Engl J Med.* 2009;360:699–709. doi: 10.1056/NEJMsa0806819

25. Kullgren JT, Troxel AB, Loewenstein G, Asch DA, Norton LA, Wesby L, Tao Y, Zhu J, Volpp KG. Individual- versus group-based financial incentives for weight loss: a randomized, controlled trial. *Ann Intern Med.* 2013;158:505–514. doi: 10.7326/0003-4819-158-7-201304020-00002

26. Hayden BY. Time discounting and time preference in animals: a critical review. *Psychon Bull Rev.* 2016;23:39–53. doi: 10.3758/s13423-015-0879-3

27. 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. doi: 10.1186/s12889-019-7407-8

28. Mills KT, Rubinstein A, Irazola V, Chen J, Beratarrechea A, Poggio R, Dolan J, Augustovski F, Shi L, Krousel-Wood M, et al. Comprehensive approach for hypertension control in low-income populations: rationale and study design for the hypertension control program in Argentina. *Am J Med Sci.* 2014;348:139–145. doi: 10.1097/MAJ.0000000000000298

29. The Blood Pressure Lowering Treatment Trialists' Collaboration. Pharmacological blood pressure lowering for primary and secondary prevention of cardiovascular disease across different levels of blood pressure: an individual participant-level data meta-analysis. *Lancet.* 2021;397:1625–1636. doi: 10.1016/S0140-6736(21)00590-0

30. Kyriakides PW, Schultz BJ, Egol K, Leucht P. The fragility and reverse fragility indices of proximal humerus fracture randomized controlled trials: a systematic review. *Eur J Trauma Emerg Surg.* 2021. doi: 10.1007/s00068-021-01684-2

31. Siontis GC, Sweda R, Windecker S. Cardiovascular clinical trials in the era of a pandemic. *J Am Heart Assoc.* 2020;9:e018288. doi: 10.1161/JAHA.120.018288

32. Selvaraj S, Greene SJ, Khatana SAM, Nathan AS, Solomon SD, Bhatt DL. The Landscape of cardiovascular clinical trials in the United States initiated before and during COVID-19. *J Am Heart Assoc.* 2020;9:e018274. doi: 10.1161/JAHA.120.018274

33. Gaba P, Bhatt DL. The COVID-19 pandemic: a catalyst to improve clinical trials. *Nat Rev Cardiol.* 2020;17:673–675. doi: 10.1038/s41569-020-00439-7

34. Green BB, Cook AJ, Ralston JD, Fishman PA, Catz SL, Carlson J, Carrell D, Tyll L, Larson EB, Thompson RS. Effectiveness of home blood pressure monitoring, web communication, and pharmacist care on hypertension control: a randomized controlled trial. *JAMA.* 2008;299:2857–2867. doi: 10.1001/jama.299.24.2857