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A novel behavioral science-based health checkup program and subsequent metabolic risk reductions in a workplace: Checkup championship

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ABSTRACT

The effectiveness of general health checkups and lifestyle counseling has been questioned. This study examined whether a workplace health promotion program implemented during a health checkup was associated with metabolic syndrome-related indicators. Hakuhodo DY group, one of Japan's largest advertising agencies, implemented a behavioral science-based program called "Checkup Championship" (*Kenshin-sen* in Japanese) in 2019, in which all employees could voluntarily participate. We studied 3697 employees (2818 men and 879 women, mean age: 40.7 years), consisting of 1509 program participants and 2188 non-participants. The characteristics of participants and non-participants were balanced using inverse probability weighting. We used their data from the health checkups in 2018 and 2019 together with other covariates and performed a difference-in-differences analysis using a linear mixed model. After program implementation, greater reductions were observed among participants compared with non-participants in weight (−0.66 kg, 95% confidence interval: −0.84 to −0.47), body mass index (−0.23 kg/m^2, −0.29 to −0.16), waist circumference (−0.67 cm, −0.91 to −0.43), systolic blood pressure (−1.13 mmHg, −2.10 to −0.16), and diastolic blood pressure (−0.84 mmHg, −1.53 to −0.15). In addition, we observed greater reductions in weight, body mass index, waist circumference, and low-density lipoprotein cholesterol among participants who were with two or more risk factors for metabolic syndrome than other participants. We found that participation in a health checkup program based on behavioral science was associated with reduced metabolic syndrome-related indicators. There may be room for improvement in the effectiveness of general health checkups.

1. Introduction

Non-communicable diseases among workers are a global health issue (World Health Organization and Burton, 2010). Obesity in particular is an important modifiable factor that can increase the incidence of diabetes, cardiovascular diseases, cancers, and mortality (Angelantonio et al., 2016; Wang et al., 2011). Many workplaces provide general health checks and lifestyle counseling to maintain workers' health. In Japan, the Occupational Health and Safety Law mandates employer-provided annual health checkups for employees. Additionally, from 2008, Japan has implemented a nationwide screening program for people at high risk of metabolic syndrome (a condition that combines visceral obesity with hypertension, hyperglycemia, and abnormal lipid metabolism) according to National Health Guidance (NHG) interventions. Targets of the NHG are those whose abdominal circumference is 85 cm or more for men and 90 cm or more for women, and at least two of blood pressure, blood glucose, and serum lipids are out of the reference values.

However, the effectiveness of general health checkups and lifestyle counseling to reduce morbidity and mortality has been questioned. A randomized controlled trial on screening and lifestyle counseling involving approximately 60,000 people in Denmark did not find any reductions in incidence of ischemic heart disease, stroke, or mortality

Abbreviations: NHG, National Health Guidance; BMI, Body mass index; SBP, Systolic blood pressure; DBP, Diastolic blood pressure; HbA1c, Hemoglobin A1c level; LDL, Low-density lipoprotein; DID, Difference-in-differences; IPW, Stabilized inverse probability weighting.

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after ten years (Jørgensen et al., 2014). A recent systematic review on general health checkups found no evidence of decreased total mortality, cancer mortality, or fatal/non-fatal ischemic heart diseases (Krogsbøll et al., 2019). A study of NHG interventions found reductions in weight, body mass index (BMI), and waist circumference but no evidence of changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), hemoglobin A1c (HbA1c) level, or low-density lipoprotein (LDL) cholesterol level among the target population (Fukuma et al., 2020).

One possible reason interventions appear ineffective is the difficulty experienced in changing peoples' behaviors. According to the Health Belief Model, perceived benefits and barriers of changing lifestyles are strong behavior predictors (Carpenter, 2010; Janz and Becker, 1984; Rosenstock, 1974), which may be difficult for conventional lifestyle counseling to modify. The Transtheoretical Model posits the following behavior change stages: pre-contemplation, contemplation, preparation, action, and maintenance (Prochaska and DiClemente, 2005). A previous study has shown much of the overweight and obese population in the US was at the pre-contemplation stage (i.e., do not intend to change behaviors within six months) despite having specific metabolic health risks or diseases (S. S. Johnson et al., 2008). In behavioral science, healthy behavior procrastination is explained by time-inconsistent preference or hyperbolic discounting (the tendency to overvalue immediate pleasure while undervaluing long-term consequences) (Y. Wang and Sloan, 2018). Therefore, a behavioral science-based intervention should be considered to change people's behaviors and enhance general health checkups' effectiveness.

This study examined the association between participation in an occupational health program, "Checkup Championship" (*Kenshin-sen* in Japanese), and changes in metabolic syndrome-related indicators. We also explored indicator changes by the characteristics of individuals (i.e., being an NHG program target, job title, age group) to explore whether the program was correlated with workplace health disparities. The program aimed at motivating participants to improve their checkup results using multiple behavior change techniques and models including gamification ("the use of game elements and mechanics in non-game contexts" (Seaborn and Fels, 2015)), commitment, and incentivization. We hypothesized that the program participants were motivated to be mindful of their lifestyle including diet and exercise during the intervention period, which in turn linked to improved metabolic outcomes. While the aim of conventional health checkups is early detection of diseases and treatment, Checkup Championship adds entertaining primary prevention opportunities to all, regardless of health risks.

2. Methods

2.1. Study design

Fig. 1 illustrates a sample flow. We examined health checkup data of employees of Hakuhodo DY Holdings, Inc., Hakuhodo, Inc., and Hakuhodo DY Media Partners, Inc. in 2018 and 2019. The Hakuhodo DY group is one of the largest advertising agencies in Japan. Of the employees, 4126 individuals who underwent a health checkup in 2018 were eligible for the program, regardless of position, age, or employment status and could participate for free. The company recruited program participants from August 5 to September 24, 2019 (the intervention period). Employees could decide whether or not to participate in the program by themselves and apply for it through the company's intranet. Hereafter, employees who participated in the program are referred to as "participants" and those who did not participate are referred to as "non-participants." The annual health checkup in 2019 was held from September 2 to October 11; employees could choose their checkup day, and outcomes were measured on the day. Among them, 429 did not have health checkup records in 2019. Thus, our analytical sample consisted of 3697 employees (2818 men and 879 women, mean age: 40.7 years) involving 1509 participants and 2188 non-participants. All individuals involved into this study provided informed consent, and the study design was reviewed and approved by the research ethics committees at the University of Tokyo (2019372NI) and Kyoto University (R3057).

2.2. Intervention

Checkup Championship was developed by Hakuhodo DY Holdings, Inc. The program uniquely employed (1) gamification, (2) commitment, and (3) incentivization as follows. The participants' previous year's health checkup results were set as a benchmark to beat to motivate them to engage in healthy behaviors until health checkup day (gamification). Participants were required to declare their participation on the company's intranet as a personal commitment to future healthy behaviors (commitment) though they could not see whether others participated in the program. Additionally, it was announced at recruitment that employees who improved their results markedly from the previous year would receive rewards (incentivization, see eText 1 and eTable 1 for details). The program provided neither individual goals nor personalized health guidance. Various promotion methods were used, like weekly emails including motivational information (e.g., examples of employees engaging in healthy behaviors and program planners'

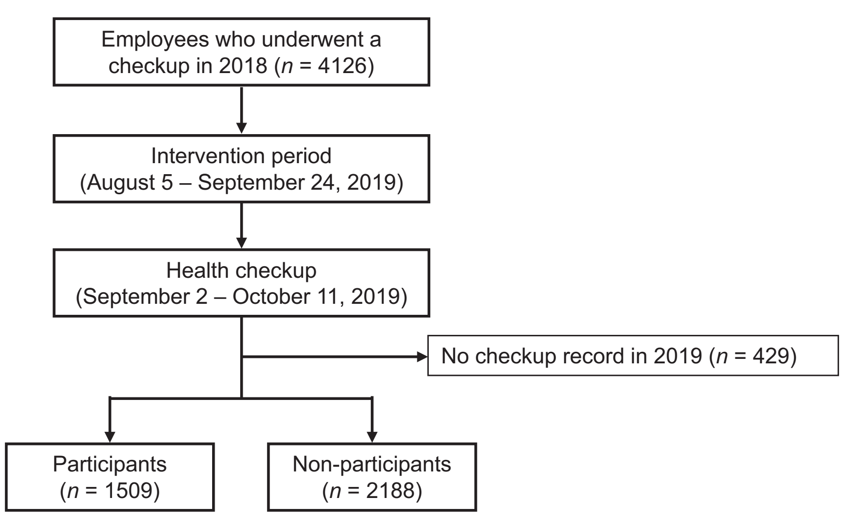

Fig. 1. Sample flow.
Note: Participants could choose the timing of entry in the program and the day of checkup, and thus the duration of program participation varied across individuals.

thoughts) and motivational sports-themed posters displayed in company corridors (Fig. 2). Three months post-checkup, participants received feedback, visualized with a radar chart depicting their improvement in indicators and overall health scores (Fig. 2).

2.3. Outcomes

We examined participants' 2018 and 2019 health checkup data, including weight, BMI, waist circumference, SBP, DBP, LDL cholesterol, and HbA1c, which are known predictors of cardiovascular events (Fukuma et al., 2020; Hubert et al., 1983; Nakai et al., 2020).

2.4. Covariates

We selected potential confounders to reduce bias from self-selection into the program. A previous study suggested that participation in a workplace physical activity intervention could be determined by self-rated health, self-efficacy and attitude toward exercise, and sufficient

Fig. 2. Promotion posters and results feedback.

time and energy to engage in exercise (Edmunds et al., 2013). Based on the study, we considered the following covariates: age; sex; job title (manager or non-manager); employment type (regular or non-regular employee); job category (management, account manager, media, knowledge development, affiliate executive, or other); total working hours for 3 months; sleep (more or fewer than 6 h); exercise habits (exercising more than once/month or not); smoking status (smoker or not); and drinking habits (drinker or not). Further, we included the behavior modification stage to consider attitude toward health promotion; it was measured based on the Transtheoretical Model with a 5-point Likert scale (1 = "I do not intend to modify my lifestyle" [pre-contemplation], 2 = "I intend to modify my lifestyle within approximately 6 months" [contemplation], 3 = "I intend to modify my lifestyle and have started with a small step" [preparation], 4 = "I have been engaging in lifestyle modification for fewer than 6 months" [action], or 5 = "I have been engaging in lifestyle modification for more than 6 months" [maintenance]). A binary variable indicating whether the participant was an NHG intervention target (i.e., people aged 40–74 years with waist circumferences greater than 85 cm for men or 90 cm for women and a diagnosis of hypertension, diabetes, or dyslipidemia). Age, sex, job title, employment type, and job category were recorded based on the information on the 2019 checkup day; total working hours were measured from April–June 2019; other covariates were measured using a self-reported questionnaire on the 2018 checkup day.

2.5. Statistical analysis

We conducted a difference-in-differences (DID) analysis to examine the association between program participation and outcomes changes. Outcome differences between 2018 (pre-implementation) and 2019 (post-implementation) were compared between program participants and non-participants. To confirm the parallel trends assumption ("the trends in outcomes between the treated and com-parison groups are the same prior to the intervention" (Dimick and Ryan, 2014)), we compared outcomes between participants and non-participants using data from 2015 to 2018 (data of 3678 out of 3697 participants were available; we could not confirm HbA1c data because measurement started in 2018). There were no differences in outcome trends between participants and non-participants before program implementation (eFigure 1). Regarding the common shocks assumption ("any events occurring during or after the time the policy changed will equally affect the treatment and comparison groups" (Dimick and Ryan, 2014)), we confirmed with program staff that no events from 2015 to 2019 would affect only participants or non-participants.

Program participation was not assigned randomly, which may have led to selection bias. Hence, we incorporated a stabilized inverse probability weighting (IPW) into the analysis. Propensity scores of participation probability were calculated using logistic regression and adjusting for the aforementioned covariates and outcomes measured in 2018 (eTable 2). The c-statistic of the propensity score was 0.61.

DID estimators were calculated using a linear mixed model with random intercepts for individuals; the results of 2 years of health checkups at level 1 were nested into the individuals at level 2. We also explored whether the program was associated differentially with outcome changes by participant characteristics. We hypothesized this entertaining program would be more effective for populations at high risk of cardiovascular diseases (i.e., those with metabolic syndrome [NHG target in 2018], relatively low socioeconomic status [non-manager], and aged 40 years or older) than their counterparts. To examine the hypothesis, our model included a difference-in-differences-in-differences estimator; for example, for NHG target, the estimator was an interaction term indicating the value of 1 if the data were from 2019, the study participant joined the program in 2019, and he/she was an NHG target in 2018. We obtained doubly robust estimators adjusting the outcome model for the covariates using a stabilized IPW with robust standard errors.

Of the 3697 participants, 240 had some missing values. To address any potential bias caused by the missing values, we adopted multiple imputations under the missing values using a random assumption (i.e., a missing mechanism was related to other variables measured in the same survey for that participant). Incomplete variables were imputed by a chained equation using all the covariates and outcomes as explanatory variables. We created ten imputed datasets, and the estimates were combined. All analyses were performed using STATA, version 16.1 (Stata Corp, College Station, TX).

3. Results

Table 1 describes study participant characteristics. Most were men and regular employees. In terms of the Transtheoretical Model, program participants were more likely to be at the action and maintenance stages in 2018 and non-participants at the pre-contemplation and contemplation stages. In 2018, a higher proportion of program participants than non-participants were NHG targets and had higher levels of weight, BMI, and waist circumference measurements. eTable 3 compares the means between participants and the non-participants before and after weighting at the baseline. We confirmed that standardized differences between the 2 groups were 0.01 or less; thus, their baseline characteristics were well balanced after weighting. Compared between before and after the intervention, we observed that program participants showed improvements in sleep duration, exercise, and the percentage of those who were at the action and maintenance stages in 2019 (Table 1).

Table 2 displays the results of DID estimation using a linear mixed model with a stabilized IPW, and Fig. 3 depicts the DID estimates by NHG target status. After program implementation, we found reductions in weight (−0.66 kg, 95% confidence interval: −0.84 to −0.47), BMI (−0.23 kg/m^2, −0.29 to −0.16), waist circumference (−0.67 cm, −0.91 to −0.43), SBP (−1.13 mmHg, −2.10 to −0.16), and DBP (−0.84 mmHg, −1.53 to −0.15) among program participants compared with non-participants. Additionally, we observed larger reductions in weight (−0.85 kg, −1.53 to −0.17), BMI (−0.27 kg/m^2, −0.50 to −0.05), waist circumference (−1.15 cm, −1.86 to −0.44), and LDL cholesterol (−5.64 mg/dL, −10.56 to −0.71) among program participants who were 2018 NHG targets than other program participants.

We also examined whether program participation was heterogeneously associated with reductions by job title (eTable 4) and age group (eTable 5). Results showed the associations were identical across different job titles and age groups, except that participants aged 40 years or older saw a considerably greater reduction in weight than participants under 40. For the sensitivity analysis, we conducted a complete case analysis using the data of those without missing values (n = 3457) and obtained similar results (eTable 6).

4. Discussion

This study examined whether participants in an occupational health program, Checkup Championship, improved their metabolic syndrome-related indicators at a 2019 health checkup. We found program participation was associated with reduced weight, BMI, waist circumference, SBP, and DBP. Additionally, considerably greater reductions in weight, BMI, waist circumference, and LDL cholesterol were observed among those who were 2018 NHG targets (i.e., people at high risk for metabolic syndrome). Although we could not compare our results with those of a previous study that examined the NHG's effect because of study population differences, the estimated sizes of the reductions were much larger among our participants who were NHG targets than among participants of the previous study (present study vs. previous study: weight, −1.51 vs. -0.29 kg; BMI, −0.50 vs. -0.10 kg/m^2; waist circumference, −1.82 vs. -0.34 cm) (Fukuma et al., 2020). We also observed reductions in blood pressures and LDL cholesterol, which were not observed in the previous study (Fukuma et al., 2020). Although the estimated changes may seem small in terms of individuals, the changes can have great

Table 1
Characteristics of analytical sample.

	Participant (n = 1509)		Non-participant (n = 2188)	
	Pre-intervention (2018)	Post-intervention (2019)	Pre-intervention (2018)	Post-intervention (2019)
Men, n (%)	1176 (77.9)		1642 (75.1)	
Age, year, mean [SD]		40.6 [10.5]		40.8 [10.6]
Manager, n (%)		359 (23.8)		419 (19.2)
Regular employee, n (%)		1350 (89.5)		1929 (88.2)
Missing, n (%)		33 (2.2)		57 (2.6)
Job category, n (%)				
Management		234 (15.5)		220 (10.1)
Account manager		575 (38.1)		676 (30.9)
Media		114 (7.6)		261 (11.9)
Knowledge development		43 (2.8)		44 (2.0)
Affiliate executive		20 (1.3)		65 (3.0)
Other		506 (33.5)		902 (41.2)
Missing		17 (1.1)		20 (0.9)
Total working hours for three months, hour, mean [SD]		508.0 [116.7]		493.7 [138.8]
Missing, n (%)		37 (2.5)		32 (1.5)
Sleep more than six hours, n (%)	726 (48.1)	800 (53.0)	1035 (47.3)	1068 (48.8)
Missing, n (%)	33 (2.2)	28 (1.9)	95 (4.3)	94 (4.3)
Exercise more than once in a month, n (%)	976 (64.7)	1052 (69.7)	1308 (59.8)	1343 (61.4)
Missing, n (%)	33 (2.2)	28 (1.9)	96 (4.4)	94 (4.3)
Smoker, n (%)	385 (25.5)	381 (25.2)	626 (28.6)	610 (27.9)
Missing, n (%)	32 (2.1)	28 (1.9)	95 (4.3)	94 (4.3)
Drinker, n (%)	1249 (82.8)	1248 (82.7)	1755 (80.2)	1737 (79.4)
Missing, n (%)	32 (2.1)	28 (1.9)	95 (4.3)	94 (4.3)
The behavior modification stage, n (%)				
Pre-contemplation	262 (17.4)	226 (15.0)	406 (18.6)	413 (18.9)
Contemplation	565 (37.4)	492 (32.6)	832 (38.0)	850 (38.8)
Preparation	260 (17.2)	257 (17.0)	354 (16.2)	355 (16.2)
Action	159 (10.5)	202 (13.4)	206 (9.4)	196 (9.0)
Maintenance	231 (15.3)	304 (20.1)	295 (13.5)	279 (12.8)
Missing	32 (2.1)	28 (1.9)	95 (4.3)	95 (4.3)
NHG intervention target, n (%)	282 (18.7)	242 (16.0)	332 (15.2)	348 (15.9)
Missing, n (%)	32 (2.1)	34 (2.3)	95 (4.3)	106 (4.8)
Weight, kg, mean [SD]	67.8 [13.0]	67.5 [12.8]	66.5 [12.5]	66.9 [12.7]
BMI, kg/m^2, mean [SD]	23.3 [3.5]	23.2 [3.4]	23.0 [3.4]	23.1 [3.4]
Waist, cm, mean [SD]	82.4 [9.9]	82.2 [9.3]	81.5 [9.3]	82.3 [9.4]
SBP, mmHg, mean [SD]	119.0 [16.4]	116.8 [16.1]	118.9 [16.7]	118.2 [17.2]
Missing, n (%)	4 (0.3)	5 (0.3)	14 (0.6)	17 (0.8)
DBP, mmHg, mean [SD]	73.0 [12.5]	72.3 [12.1]	73.5 [12.5]	73.3 [12.9]
Missing, n (%)	4 (0.3)	5 (0.3)	14 (0.6)	17 (0.8)
HbA1c, %, mean [SD]	5.3 [0.4]	5.2 [0.3]	5.3 [0.5]	5.2 [0.4]
Missing, n (%)	0 (0.0)	0 (0.0)	1 (0.05)	1 (0.05)
LDL cholesterol, mg/dL, mean [SD]	118.0 [30.4]	119.2 [28.9]	118.5 [30.5]	120.5 [29.6]
Missing, n (%)	0 (0.0)	0 (0.0)	3 (0.1)	2 (0.1)

Abbreviations: SD, standard deviation; NHG, the national health guidance; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; LDL, low-density lipoprotein.

impacts on population health. For example, it was estimated that a 2 mmHg reduction in DBP would result in a 17% decrease in hypertension, a 6% decrease in coronary heart disease, and a 15% decrease in stroke and transient ischemic attacks in the US population (Cook et al., 1995).

There were several possible mechanisms through which the program could enhance general health checkups' effectiveness. First, the program attracted participants using gamification. One of gamification's theoretical foundations is self-determination theory, which emphasizes intrinsic motivation to initiate activities to meet the basic psychological needs of (1) autonomy, (2) competence, and (3) relatedness rather than extrinsic motivation, which relies on external goals such as rewards or punishments (Deci and Ryan, 2012). Gamification intrinsically motivates people by promoting enjoyment; a previous review suggested it positively impacts health behaviors (D. Johnson et al., 2016). Thus, the program embodied intrinsic motivation's 3 components: participants had the autonomy to enroll; the goal-setting of beating their previous year's performance resulted in self-increased competence; relatedness was enhanced by implementing the program as a company-wide event where employees could participate with colleagues. Moreover, this program seized the opportunity of the timing of the Tokyo 2020 Olympics and evoked intrinsic motivation with sports-themed promotion posters.

Second, the program elicited commitment from participants by requiring them to declare their participation on the company's intranet. People may tend to prioritize current pleasures and procrastinate healthy behaviors, but the self-enforcing contract forced the present self to be accountable and made participants conduct actions to better their future selves. This program feature was categorized as a soft commitment in contrast to a hard commitment, in which participants were charged a penalty if they failed to reach a goal (White and Dow, 2015). A penalty in a hard commitment contract can be a barrier to health program participation (especially for those who do not intend to modify their lifestyle; thus, it can widen health disparity), while a soft commitment is so generous that employees can participate easily and enhance their autonomy (Promberger et al., 2011). The program's user interface was designed to enable participation with a simple click of the entry button on the system, which succeeded in easily eliciting commitment even from busy individuals. Further, given the limited program period, the "to-go" frame of the goal-setting (i.e., overcome last year's results "by" the health checkup day) was able to leverage commitment more effectively than a "to-date" frame (i.e., the status has improved "so far") (Baek and Yoon, 2020).

Third, the program incentivized participants to improve their health checkup results. It has been shown that financial incentives can

Table 2
The DID estimations for program participation and changes in outcomes.

	Weight			BMI			Waist circumference		
	Coef.	95% CI		Coef.	95% CI		Coef.	95% CI	
Participation	0.17	−0.48	0.82	0.07	−0.13	0.28	0.11	−0.44	0.65
Year 2019	0.51	0.40	0.62	0.16	0.12	0.20	0.81	0.67	0.95
Participation * Year 2019 (DID)	−0.66	−0.84	−0.47	−0.23	−0.29	−0.16	−0.67	−0.91	−0.43
NHG target	12.09	10.78	13.39	3.79	3.39	4.19	10.36	9.43	11.30
NHG target * participation	−1.08	−2.86	0.70	−0.45	−1.00	0.10	−0.71	−2.04	0.62
NHG target * Year 2019	−0.28	−0.65	0.09	−0.09	−0.22	0.03	−0.49	−0.87	−0.10
NHG target * Participation * Year 2019 (DIDID)	−0.85	−1.53	−0.17	−0.27	−0.50	−0.05	−1.15	−1.86	−0.44
	SBP			DBP			HbA1c		
	Coef.	95% CI		Coef.	95% CI		Coef.	95% CI	
Participation	−0.12	−1.15	0.91	0.13	−0.66	0.92	0.02	−0.02	0.05
Year 2019	−0.68	−1.26	−0.11	0.15	−0.26	0.55	−0.08	−0.09	−0.07
Participation * Year 2019 (DID)	−1.13	−2.10	−0.16	−0.84	−1.53	−0.15	−0.02	−0.04	0.005
NHG target	7.60	5.70	9.50	7.14	5.62	8.66	0.17	0.10	0.23
NHG target * participation	1.52	−1.49	4.52	0.81	−1.53	3.15	−0.09	−0.19	0.01
NHG target * Year 2019	0.23	−1.29	1.76	−0.28	−1.49	0.93	−0.02	−0.05	0.02
NHG target * Participation * Year 2019 (DIDID)	−2.48	−5.15	0.19	−1.95	−3.94	0.04	0.00	−0.07	0.07

	LDL cholesterol		
	Coef.	95% CI	
Participation	−0.47	−2.54	1.60
Year 2019	2.50	1.60	3.40
Participation * Year 2019 (DID)	−0.05	−1.64	1.55
NHG target	12.10	8.44	15.76
NHG target * Participation	1.61	−3.87	7.09
NHG target * Year 2019	−0.69	−3.59	2.21
NHG target * Participation * Year 2019 (DIDID)	−5.64	−10.56	−0.71

Abbreviations: Coef., coefficient; CI, confidence interval; NHG, the national health guidance; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; LDL, low-density lipoprotein; DID, difference-in-differences; DIDID, difference-in-difference-in-differences.
Note: The models were calculated using a linear mixed model with random intercepts for individuals. They were adjusted for age, sex, job title, employment type, job category, total working hours, sleeping hours, exercise habits, smoking status, drinking habits, and the behavior modification stage.

effectively contribute to lifestyle modifications such as physical activity, smoking cessation, and dietary behaviors (Mitchell et al., 2020; Notley et al., 2019; Purnell et al., 2014). The program also attracted participants with the raffle of meal vouchers based on improvement from the previous year, even if they did not place in the top tier. A previous study showed that a lottery incentive design was more likely to make workers complete health risk assessments than an incentive equivalent to the lottery's expected value, which would be given to all eligible participants (Haisley et al., 2012).

Despite these advantages, our results should be interpreted with caution because there were several limitations in this study. First, there may have been selection bias because program participation was not assigned randomly. To address the possible bias, we conducted a doubly robust estimation using a stabilized IPW and confirmed the groups of participants and non-participants were comparable after weighting. However, if participants were more health conscious and healthier than non-participants regardless of program participation, the observed reductions in the outcomes may have been overestimated. Nonetheless, we confirmed the trends in the outcomes were parallel between participants and non-participants before program implementation. Moreover, we adjusted for the behavior modification stage to consider a difference in health consciousness between the two groups. Second, the generalizability of our findings is limited because the program was implemented within one company, and most of the study participants were men. Program effectiveness should be examined in other settings. Third, we did not consider duration of program participation. Although the program was implemented in the company simultaneously, participation timing varied among participants. Some may have participated in the program two months before the day of a health checkup and engaged in modifying lifestyles, but others may have clicked the entry button even on the day of a health checkup. Additional verification is needed to check whether participation timing can differentiate the effect size. Fourth, we did not explore whether the outcome reductions remained after the program ended. Additionally, it was difficult to evaluate changes in some indicators such as HbA1c in the short study period. Thus, a follow-up study is needed to ascertain the extent to which program participants maintain their health behaviors and outcomes after the end of program, compared to those who received only annual health checkups. Fifth, while the program employed various behavioral science techniques, we were unable to evaluate each component's effectiveness. In addition, although we observed improvements in sleep duration, exercise, and the behavior modification stage, we could not confirm whether these improvements resulted from participation in this program because it did not aim to improve specific behaviors and outcomes. A further study specifying the mechanisms improving behaviors and outcomes and examining their cost-effectiveness will be valuable. Finally, some components may have affected even non-participants, violating the stable unit treatment value assumption (for example, sending emails to all employees and displaying posters in corridors may have motivated non-participants as well as participants), which may have underestimated the program participation effect. Additionally, if non-participants received any follow-up assistance as a part of the usual checkup in 2018, it could also attenuate the estimated association.

5. Conclusions

In conclusion, the present study examined the association between participation in an occupational health promotion program based on behavioral science and metabolic syndrome-related indicators. We observed a reduction in weight, BMI, waist circumference, SBP, and DBP among program participants. More considerable reductions in weight, BMI, waist circumference, and LDL cholesterol among people who were at high risk of metabolic syndrome indicated the potential to shrink health disparities in the workplace. Our findings suggest that, if we

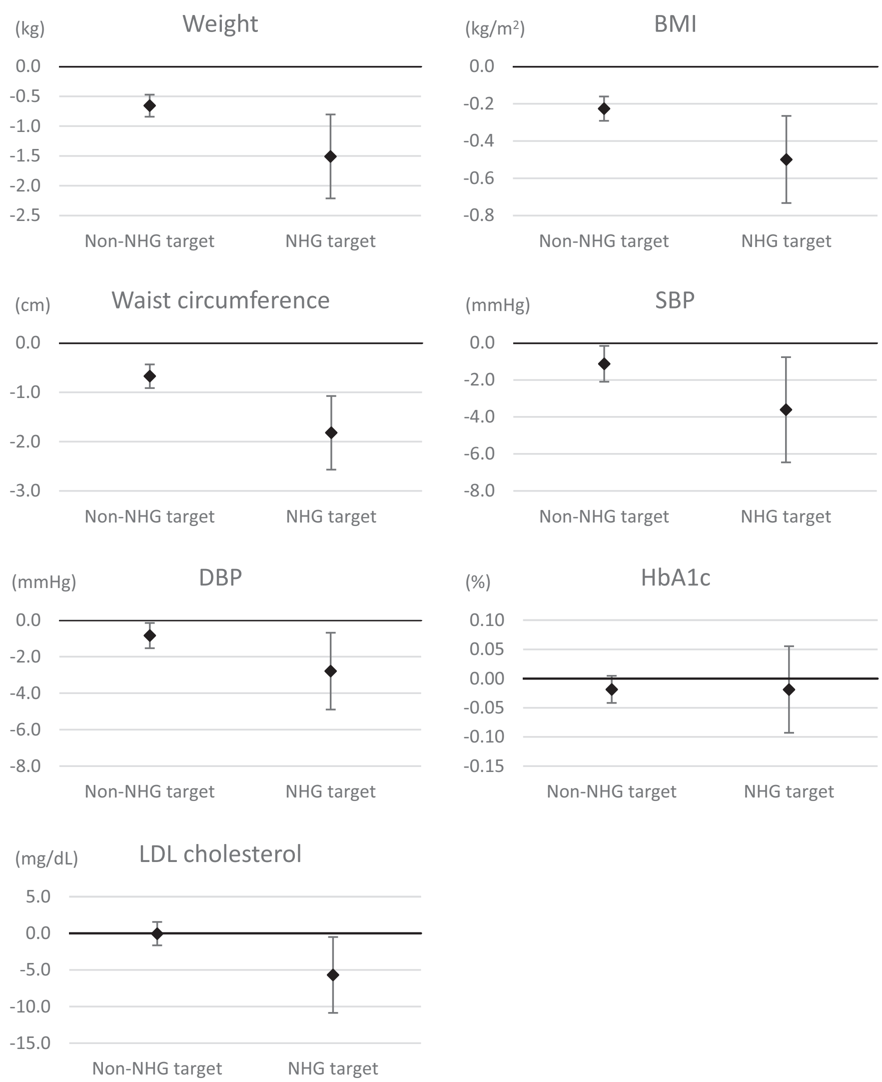

Fig. 3. The DID estimates by the status of the NHG target.
Abbreviations: DID, difference-in-differences, Non-NHG, those who were not the target of the national health guidance in 2018; BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; HbA1c, hemoglobin A1c; LDL, low-density lipoprotein.
Note: Non-NHG, 2956 individuals; NHG target, 614 individuals. The vertical line represents the DID estimates (participation * year 2019) by the status of the NHG target with 95% confidence intervals.

could correctly estimate the causal effects, a health program using gamification, commitment, and incentivization can enhance the effectiveness of workplace general health checkups to prevent obesity and cardiovascular diseases. Additionally, by employing behavioral science, such a program may be cost-effective compared with a conventional intervention for populations at high risk for metabolic syndrome because it does not require personalized health guidance to encourage lifestyle modification. There may be room for improvement in the effectiveness of general health checkups.

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CRediT authorship contribution statement

Hanae Nagata: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft. **Koryu Sato:** Methodology, Software, Validation, Formal analysis, Writing – original draft. **Maho Haseda:** Conceptualization, Methodology, Writing – review & editing, Supervision. **Yumiko Kobayashi:** Conceptualization, Writing – review & editing, Project administration. **Naoki Kondo:** Conceptualization, Methodology, Resources, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

Naoki Kondo received research funding from Hakuhodo DY Holdings Inc. The fund was to conduct epidemiologic studies using the data provided by the company. The funding contract had conditions and restrictions on data availability (e.g., prohibiting the publication of specific data such as the data with which the company's salary structure was inferred) but no restrictions on selecting study topics, study designs, analysis, interpretation, writing of the article, or the decision to submit the article for publication. In addition, NK advised the company on evaluating the studied program after implementation but had no role in developing its design.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2022.107271.

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