Original Article

Lifestyle characteristics as moderators of the effectiveness of weight control interventions among semiconductor workers

Tzu-Yu Lin [a,c,1], Pei-Ju Liao [b,c,1], Ming-Kuo Ting [d],
Kuang-Hung Hsu [a,c,e,f,g,h,*]

[a] Healthy Aging Research Center, Chang Gung University, Taoyuan, Taiwan
[b] Department of Health Care Administration, Oriental Institute of Technology, New Taipei City, Taiwan
[c] Laboratory for Epidemiology, Department of Health Care Management, Chang Gung University, Taoyuan, Taiwan
[d] Division of Endocrinology and Metabolism, Chang Gung Memorial Hospital at Keelung, Keelung, Taiwan
[e] Department of Emergency Medicine, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan
[f] Department of Urology, Chang Gung Memorial Hospital at Linkou, Taoyuan, Taiwan
[g] Research Center for Food and Cosmetic Safety, College of Human Ecology, Chang Gung University of Science and Technology, Taoyuan, Taiwan
[h] Department of Safety, Health and Environmental Engineering, Ming Chi University of Technology, New Taipei City, Taiwan

ABSTRACT

Background: Workers in high technology industry are experiencing stressful environment and have been ranked as a high risk group for adverse health effects. The effectiveness of worksite health promotion is important for occupational health. This study is to investigate the effect of health interventions on body measurement changes while examining the role of their lifestyle factors.

Methods: A total of 904 participants aged over 30 years were recruited from 14 semiconductor worksites in Taiwan from 2011 to 2015. A multi-settings, quasi-experimental study was conducted that assigned participants into two intervention programs, including exercise program and diet-plus-exercise program. The outcomes include the changes of body weight, waist circumference, body mass index (BMI), and biophysiological indicators. Lifestyle variables include alcohol consumption, cigarette smoking, and regular exercise. Multiple linear regression analyses were performed to test the association.

Results: The findings have demonstrated that one kilogram body weight reduction is associated with a decrease of 0.58 mmHg SBP ($p < 0.001$), 0.29 mmHg DBP ($p < 0.001$), 3.33 mg/dL triglyceride ($p < 0.001$), 0.96 mg/dL total cholesterol ($p < 0.001$), and 0.68 mg/dL LDL ($p < 0.001$). The diet-plus-exercise group had more significant effect on both weight changes and biophysiological changes than exercise-only group ($p < 0.001$). Lifestyle factors, including cigarette smoking, alcohol consumption, and regular exercise, were significant moderators of the effectiveness of health interventions.

* Corresponding author. Laboratory for Epidemiology, Department of Health Care Management, Chang Gung University, 259, Wenhua 1st Rd., Gueishan, Taoyuan 333, Taiwan.
E-mail address: khsu@mail.cgu.edu.tw (K.-H. Hsu).

Conclusions: Both exercise and diet interventions are important to the effectiveness of health promotion in occupational sectors. Lifestyle modifications are vital for weight control programs in improving body shape changes and biophysiological indicators.

At a glance of commentary

Scientific background on the subject

The weight control intervention programs in workplace are important for employees' health and production. Previous studies have demonstrated the effectiveness of different interventions including single-task or diet-plus-exercise on weight control. However, the effect of lifestyle variables on interventional effectiveness under stressful occupational settings such as semiconductor industry is still enigma.

What this study adds to the field

This study has demonstrated the moderating effect of lifestyle behaviors, such as cigarettes smoking, alcohol drinking, exercise, and vegetable/fruit consumptions on biophysiological changes due to weight control interventions. The effect of dual-task interventions on biophysiological changes can be improved while changing lifestyle factors simultaneously.

Introduction

Due to the stressful working environment, semiconductor workers have been ranked as a high-risk group for metabolic syndromes and cardiovascular diseases. Based on periodic health examinations, overweight conditions and hyperlipidemia have been ranked as the top health issues among semiconductor workers. The working style of semiconductor workers is quite different from other occupational categories. The common working shift in the industry alternates between two consecutive 12-hour working days and two days off. In addition, mission-oriented project management has lengthened the working hours for engineering managers. Consequently, a special need for health interventions and exercise programs was noticed in the semiconductor industry.

In 1986, the Ottawa Charter for Health Promotion initiated health promotion reform for specific settings [1]. These settings were designated as worksites, schools, community, and home and family. For most employees, worksites are the places where they spend the majority of their time. Workplaces are therefore excellent locations for health promotion program implementation [2]. In a survey of 730 nationally representative American worksites, the 10 most common health promotion programs were back injury prevention (45.0%), followed by employee assistance (44.7%), stress management (24.9%), nutrition (22.7%), health care consumerism (21.6%), weight management (21.4%), cholesterol reduction (19.9%), physical activity (19.6%), smoking cessation (18.6%), and HIV/AIDS

prevention (14.6%) [3]. An effective health promotion program would be favorable both to the organizations' and the employees' health. Literatures have demonstrated that worksite health promotion can reduce worker absenteeism, turnover, and costs triggered by an unhealthy workforce, such as costs due to worksite accidents and loss of productivity [4–7]. In addition, the health promotion interventions may also reduce employees' inpatient days and medical costs [7–9].

Most worksite health promotion programs have goals, such as cancer prevention, smoking cessation, cardiovascular disease (CVD) risk reduction, weight control, and physical fitness [10]. The interventions are usually implemented using one or a mix of the following components: education (nutrition and exercise knowledge), counseling, physical activity, dietary suggestions, and policy and environmental modifications [11,12]. With respect to the effectiveness of the intervention, a comprehensive review showed that changes in lifestyle (dietary intake and exercise engagement), weight loss, body mass index (BMI), and biochemical markers (blood pressure, cholesterol, triglyceride, and blood glucose) were generally examined, depending on the individual study design [10].

As a worldwide growing epidemic, obesity tends to induce metabolic abnormalities that contribute to the incidence of diabetes mellitus [13], cardiovascular disease (CVD) [14–16], and hypertension [13,17]. Weight loss has been proposed as an effective means for the primary prevention of these diseases. In addition to the direct effects of weight loss on body fitness, previous studies have demonstrated effects of weight control on blood pressure [17], triglyceride, low-density lipoprotein (LDL), and cholesterol [13,18–22]. According to the literature, the effectiveness of weight control may be affected by participants' lifestyle patterns, such as smoking [23,24], drinking alcohol [25], exercise habits [26], dietary preferences [26–28], and sleep patterns [29]. However, a comprehensive appraisal is needed to test the role of lifestyle variables on the effectiveness of health interventions.

Materials and methods

Sample

This study is a quasi-experiment design conducted in a total of 14 factories in semiconductor industry during 2011–2015. We invited employees with BMI$\geq$26 to participate this study. Participants were free to choose one of the two intervention groups, including exercise alone and diet-plus-exercise. A maximum of 100 participants including 20 diet-plus-exercise were allocated for each factory. As a result, 904 workers were recruited as an intervention participant. Among them, 691 workers followed a 10,000 steps/day walking exercise

program (exercise group), whereas the remaining 213 workers followed the designed exercise program as well as diet consultation program (diet-plus-exercise group). This study was approved by the internal review board (IRB) of Chang Gung Memorial Hospital in Taiwan.

Design

Both of exercise and diet-plus-exercise groups were simultaneously conducted during May—September starting right after their annual health examination during 2011—2015. Both exercise and diet-plus-exercise interventions were a three-month basis program. All participants were asked to return to health center in the factory for weekly examination, including taking blood pressure, measuring body weight, measuring waist circumference, and recording pedometer. During the 3-month intervention, the participants in the exercise group were asked to do the best to reach 10,000 paces per day recorded by a pedometer. In addition to 10,000 paces per day, the participants in the diet-plus-exercise group were asked to fill diary for their daily diet and were given face to face counseling biweekly by a nutritionist (Appendix A).

Measures

The biophysiological tests were performed within one week before and after intervention. For better utilization of workers' annul health examination data, we scheduled the intervention starting from the next Monday after workers' annul health examination enforced by the government and an additional health examination within one week after intervention for participants. The biophysiological tests were sent to the same unit, the department of laboratory medicine in Chang Gung Memorial Hospital, for standardization. Body weight (BW) was measured weekly during the experiment. Biophysiological tests, including systolic blood pressure (SBP), diastolic blood pressure (DBP), waist circumference (WC), triglyceride (TG), total cholesterol (TC), low density lipid (LDL), high density lipid (HDL), impaired fasting glucose (IFG), and uric acid (UA), were measured before and after intervention. These biophysiological tests were examined and analyzed by medical technology analysis machine in Chang Gung Memorial Hospital (Labospect 008 Hitachi Automatic Analyzer, Hitachi High-Technologies Corporation) (Appendix B). In addition, a self-administered questionnaire was implemented to collect basic demographic data and lifestyle variables, including cigarette smoking, alcohol consumption, and regular exercise habit. The participants were asked to answer lifestyle behavior based on their current condition. The answer was rather simple as "No", "Yes", and "Unknown (missing value)". For better understanding lifestyle behavioral changes, the questionnaire was also administered before and after intervention.

Analysis

Descriptive statistics have been used to express the study variables. Categorical variables are displayed as frequency and percentage, and numerical variables are shown as the mean and standard deviation. The comparison of biophysiological measures before and after the interventions was made with paired t test whereas an independent t test was applied to compare two study groups. A Pearson's correlation analysis was applied to demonstrate the association between numerical variables, and multiple linear regression models were used to examine intervention effects on biophysiological changes after multivariable adjustments.

Results

Demographic comparison

The basic characteristics of the two study groups were comparable. The average age of the study groups was approximately 37.05 years old, and the percentage of male participants was 69.58%. Variables of cigarette smoking and history of metabolic syndrome were not significantly different between the study groups [Table 1].

Body weight and BMI

Both study groups showed significant decreases in body weight, BMI, WC, and IFG after the intervention implementation [Table 2]. Table 3 indicates that changes in body weight was positively associated with changes in SBP, DBP, TC, LDL, TG, IFG, and UA while negatively associated with HDL. In addition, the changes in WC were associated with SBP, TC, LDL, and TG while negatively associated with HDL [Table 3].

Biophysiological changes

Body weight change was associated with selected biophysiological changes when adjusted for age, gender, cigarette smoking, alcohol consumption, regular exercise, and metabolic syndromes [Table 4]. Body weight change was significantly associated with changes in SBP, DBP, TC, LDL, and TG. A 1 kg decrease in body weight caused a decrease of 0.58 mmHg in SBP ($p < 0.001$), 0.29 mmHg in DBP ($p < 0.001$), 3.33 mg/dL in TG ($p < 0.001$), 0.96 mg/dL in TC ($p < 0.001$), 0.68 mg/dL in LDL ($p < 0.001$) while an increase of 0.17 mg/dL in HDL ($p < 0.001$) [Table 4].

Lifestyle

Stratified analyses showed that the association between body weight change and changes of selected biophysiological variables was moderated by various lifestyle factors, such as cigarette smoking, alcohol consumption, and regular exercise habits. In non-smokers, for 1 kg of weight loss the selected indicators displayed improvements, including SBP (0.59 mg/dL, $p < 0.001$), DBP (0.25 mg/dL, $p < 0.01$), TC (0.84 mg/dL, $p < 0.001$), LDL (0.66 mg/dL, $p < 0.001$), and TG (3.51 mg/dL, $p < 0.001$). While in smokers, levels of TC (1.32 mg/dL, $p < 0.01$) and TG (3.37 mg/dL, $p < 0.05$) showed signs of reduction for 1 kg of weight loss [Table 5]. For 1 kg of weight loss, the

Table 1 Baseline demographic characteristics.

Intervention Variable	Total (N = 904)		Exercise (N = 691)		Diet-plus-Exercise (N = 213)		p-value
	Number	%	Number	%	Number	%	
Age (Years old)	37.05 ± 6.69		37.08 ± 6.50		36.95 ± 7.30		0.824
Gender							<0.0001
Male	629	69.58	505	73.08	124	58.22	
Female	275	30.42	186	26.92	89	41.78	
Cigarette smoking							0.305
No	731	80.86	557	80.61	174	81.69	
Yes/ever smoked	152	16.81	115	16.64	37	17.37	
Unknown	21	2.32	19	2.75	2	0.94	
Alcohol drink							0.030
No	581	64.27	430	62.23	151	70.89	
Yes/ever drank	299	33.08	239	34.59	60	28.17	
Unknown	24	2.65	22	3.18	2	0.94	
Regular exercise habit							0.017
No	271	29.98	197	28.51	74	34.74	
Yes	341	37.72	254	36.76	87	40.85	
Unknown	292	32.30	240	34.73	52	24.41	
Metabolic syndrome							0.686
No	518	57.30	399	57.74	119	55.87	
Yes	386	42.70	292	42.26	94	44.13	

Table 2 The anthropometric measures of the study participants.

Intervention Measures[b]	Exercise		Diet-plus-exercise		p-value[a]
	Before	After	Before	After	
BW (kg)	83.94 ± 14.19	81.35 ± 13.87	84.51 ± 15.36	80.77 ± 14.99	0.001
Difference	2.59 ± 4.13***		3.74 ± 4.50***		
BMI	29.28 ± 3.70	28.57 ± 5.84	30.41 ± 4.20	29.06 ± 4.18	0.003
Difference	0.71 ± 4.75***		1.34 ± 1.56***		
WC (cm)	96.30 ± 9.74	91.81 ± 9.75	97.79 ± 11.37	92.03 ± 10.84	0.006
Difference	4.48 ± 5.90***		5.77 ± 6.24***		
SBP (mmHg)	131.81 ± 16.77	125.10 ± 14.72	130.53 ± 18.03	124.04 ± 15.94	0.826
Difference	6.71 ± 15.29***		6.48 ± 12.79***		
DBP (mmHg)	84.03 ± 11.86	78.65 ± 10.23	82.89 ± 12.75	77.65 ± 10.68	0.986
Difference	5.24 ± 10.42***		5.25 ± 9.39***		
TC (mg/dL)	191.31 ± 32.33	187.30 ± 31.99	191.30 ± 32.43	184.81 ± 30.44	0.179
Difference	4.01 ± 23.47***		6.49 ± 23.59***		
HDL (mg/dL)	46.50 ± 10.29	47.20 ± 10.67	46.48 ± 9.57	46.62 ± 8.53	0.225
Difference	0.69 ± 6.44**		0.13 ± 5.71		
LDL (mg/dL)	124.35 ± 31.33	119.79 ± 29.88	125.00 ± 29.51	119.68 ± 28.28	0.642
Difference	4.56 ± 22.80***		5.32 ± 20.36***		
TG (mg/dL)	145.02 ± 88.86	140.03 ± 98.49	142.83 ± 85.21	133.21 ± 104.35	0.462
Difference	4.99 ± 79.12		9.62 ± 83.81		
IFG (mg/dL)	93.62 ± 19.37	93.54 ± 20.40	98.11 ± 30.15	95.27 ± 24.28	0.022
Difference	0.09 ± 13.94		2.85 ± 15.62**		
UA (mg/dL)	6.69 ± 1.52	6.70 ± 2.80	6.36 ± 1.50	6.32 ± 1.56	0.878
Difference	−0.01 ± 2.60		0.01 ± 0.87		

* p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001, performed by a paired t-test comparing pre-test and post-test.
a p-value was determined using an independent t test for the difference between the pre-test and post-test in two groups.
b Abbreviations: BW: body weight; BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; TC: total cholesterol; HDL: high density lipid; LDL: low density lipid; TG: triglyceride; IFG: impaired fasting glucose; UA: uric acid.

participants who were not habitual drinkers showed significant reduction in the selected indicators, especially in TG (3.34 mg/dL, p < 0.001). Participants with predisposed habits of regular exercise, exhibited highly reduction of SBP (0.62 mg/dL, p < 0.01), DBP (0.41 mg/dL, p < 0.01), TC (1.09 mg/dL, p < 0.01), LDL (0.61 mg/dL, p < 0.05), and TG (4.41 mg/dL; p < 0.001) for 1 kg of weight loss [Table 5].

Discussion

This study demonstrates that body weight loss through intervention programs is associated with a subsequent decrease in certain biophysiological indicators, including systolic blood pressure, diastolic blood pressure, triglyceride,

Table 3 Correlation matrix between changes in anthropometrical and biophysiological measures.

		Biophysiological measures							
		ΔSBP	ΔDBP	ΔTC	ΔHDL	ΔLDL	ΔTG	ΔIFG	ΔUA
Anthropometrical measures	Δ[a]BW	0.179[***]	0.133[***]	0.179[***]	−0.123[***]	0.139[***]	0.182[***]	0.108[***]	0.079[*]
	ΔBMI	0.008	0.018	0.058	0.040	0.015	0.054	0.017	0.011
	ΔWC	0.102[**]	0.059	0.143[***]	−0.093[**]	0.117[***]	0.150[***]	0.006	0.064

[*] p-value < 0.05, [**] p-value < 0.01, [***] p-value < 0.001, performed by correlation analysis.
[a] 1. Δ Change was calculated by subtracting the post-test values from the pre-test values; 2. Abbreviations: BW: body weight; BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; TC: total cholesterol; HDL: high density lipid; LDL: low density lipid; TG: triglyceride; IFG: impaired fasting glucose; UA: uric acid.

and total cholesterol. In addition, concurrent lifestyle factors, such as smoking habits, drinking alcohol, and regular exercise habits moderate the effectiveness of intervention programs.

Exercise and dietary habit

The intermediate effectiveness of the interventions, such as a reduction in body weight and BMI, is attributable to a reduction in calorie intake as a result of dietary changes and to increased physical activity. The mechanism for weight loss in this study is assumed to be the result of healthy dietary suggestions and calorie reduction learned from the diet-plus-exercise intervention. Prior research has shown that an increased intake of vegetables and fruits contributes to weight reduction among obese patients and hypertensive subjects [28−30]. Exercise has been proven to decrease fatty adipose tissue and to increase glucose tolerance while simultaneously decreasing serum insulin and triglyceride [31−33]. Exercise intervention programs may enhance sustainable weight control by increasing the baseline metabolic rate. The exercise intervention in this study was 10,000 steps per day, as assessed by pedometer, which is currently recommended for adults and has been shown to be feasible for high-tech employees [34−36].

Effective intervention at worksite

At worksites, lifestyle education, exercise, dietary restriction, and individual counseling are popular tools in weight loss programs. Two review articles demonstrated that a diet-plus-exercise intervention is more effective for weight loss compared with the diet-only or exercise-only program [26,37]. The composition of dietary control and regular exercise was thus widely recommended to achieve the goal of higher energy expenditure than consumption. However, this study has demonstrated that the effectiveness of diet-plus-exercise intervention program in reduction of body weight, BMI, and WC, and IFG. The reduction of WC was the most significant in diet-plus-exercise intervention (5.77 mg/dL), compared to exercise intervention (4.48 mg/dL) [Table 2]. Previous studies have suggested that the impact of diet-plus-exercise intervention is better than diet alone [37,38]. Nutritional information delivered through counseling led to better dietary behavior. Diets low in fat but rich in protein and fiber were helpful in reducing waist circumference, blood pressure, cholesterol, triglyceride, and fasting plasma glucose [27,28,39]. Exercise appeared to be associated with improved blood pressure, total cholesterol levels, triglyceride, and insulin

sensitivity [40]. This study further proved that the biophysiological improvements can be achieved by body weight loss under various intervention methods. Although different methods of intervention had primary effects on different biophysiological tests, the body weight loss played a universal role in changes of the selected biomarkers [41,42].

Concurrent lifestyle effects: smoking and alcohol consumption

Stratified analyses have demonstrated that the positive association between weight loss and improvements in the selected biomarkers is more significant among participants with healthier lifestyles, such as non-smokers and regular exercisers. Both academic mechanistic conjectures and practical issues resulted from this analysis can be valuable to future health promotion. Previous studies concerning the effects of smoking on obesity are inconsistent. While some studies reported that a U-shaped relationship existed between the number of cigarettes smoked and body weight among smokers [8,9], some studies claimed that correlations between smoking and the distribution of fat are irrelevant [10]. Compared to nonsmokers, it is generally recognized that smokers tend to have lower BMI but a greater waist-to-hip ratio or waist circumference, which reflects abdominal-type obesity and visceral-fat accumulation. Abdominal obesity increases the risk of metabolic diseases, such as cardiovascular disease, diabetes, hypertension, dyslipidemia, and insulin resistance [24]. On the other hand, the lower BMI is probably attributable to the lower calorie intake and the increased energy expenditure in smokers [46]. Nicotine would suppress the appetite [47], and increase urinary excretion of norepinephrine by stimulating sympathetic nervous system [9,46,49]. In addition to weight-lowering effects, cigarette smoking is characterized by triggering a cluster of metabolic abnormalities, including insulin resistance, and higher plasma levels of total cholesterol, triglyceride, and LDL, as well as lower levels of HDL [43−45]. These unfavorable lipid combinations increase the risk of cardiovascular heart disease, type 2 diabetics mellitus, and hypertension. Although nicotine may increase metabolic rate and decrease metabolic efficiency, this effect was weaker in obese populations [46]. This may partially explain why nonsmokers exhibited more improvements in biophysiological tests than did smokers in this study.

Whether alcohol consumption is a risk factor for obesity remains inconclusive because of the heterogeneity of subjects, types of alcoholic beverage, the frequency of drinking,

Table 4 Linear regression models for associations between the study variables and changes in the selected biophysiological measures.

Stratification Variables	ΔSBP Model I[b]	ΔSBP Model II	ΔSBP Model III	ΔDBP Model I	ΔDBP Model II	ΔDBP Model III	ΔTC Model I	ΔTC Model II	ΔTC Model III
Exercise	—			—			—		
Diet-plus-exercise	0.33 (−1.95, 2.61)		−0.46 (−2.74, 1.81)	0.21 (−1.38, 1.81)		−0.18 (−1.78, 1.42)	2.78 (−0.88, 6.45)		1.47 (−2.18, 5.12)
ΔBW		0.57*** (0.35, 0.80)	0.58*** (0.35, 0.80)		0.28*** (0.12, 0.44)	0.29*** (0.12, 0.45)		0.98*** (0.61, 1.34)	0.96*** (0.59, 1.32)

Stratification Variables	ΔTG Model I	ΔTG Model II	ΔTG Model III	ΔLDL Model I	ΔLDL Model II	ΔLDL Model III
Exercise	—			—		
Diet-plus-exercise	4.81 (−7.55, 17.17)		0.23 (−12.06, 12.53)	1.27 (−2.20, 4.74)		0.33 (−3.14, 3.80)
ΔBW		3.34*** (2.12, 4.55)	3.33*** (2.11, 4.56)		0.69*** (0.35, 1.03)	0.68*** (0.34, 1.03)

*** p-value < 0.001, calculated using a multiple linear regression analysis adjusted for age, gender, cigarette smoking, alcohol consumption, regular exercise, and metabolic syndrome.
[a] 1. ΔChange was calculated by subtracting the post-test values from the pre-test values; 2. Abbreviations: SBP: systolic blood pressure; DBP: diastolic blood pressure; TC: total cholesterol; TG: triglyceride; LDL: low density lipid.
[b] Parameter estimate (95% CI).

and the patterns of drinking among studies. Considerable evidences showed that moderate alcohol consumption was beneficial to reduce the risk of type 2 diabetes and cardiovascular diseases. Some contents in specific alcohol beverages, such as resveratrol in wine, and folate and vitamin B6 in beer, are already known anti-oxidant and anti-inflammatory and are helpful in maintaining lean body weight [47]. In contrast, the metabolic mechanisms of alcohol contributing to weight gain have also been well discussed. Alcohol has the harmful effects on control of food intake by binding to γ-aminobutyric acid receptors and affecting hormones, such as leptin, glucagon-type peptide-1, neuropeptide Y, and serotonin opioids. In addition, alcohol-derived calories are usually added to daily food intake rather than a substitution for food. This passive overconsumption of energy from alcohol constitutes a risk factor for increased visceral or central obesity in association with insulin resistance. In this scene, alcohol-induced obesity is significantly associated with cardiovascular disease and is usually clustered with hypertension, dyslipidemia, and impaired glucose tolerance. Regular alcohol drinkers are therefore observed unfavorable lipid profile in increased blood pressure, LDL, triglyceride, and cholesterol [48,49]. This study demonstrated that both alcohol drinkers and non-alcohol drinkers received benefits from weight loss in reduction of blood pressure, TC, LDL, and TG. However, alcohol drinkers presented better outcome on successful weight loss and more effective on favorably biophysiological changes than non-alcohol drinkers. This finding further confirms the linkage between alcohol consumption and insulin levels affecting body weight maintenance and the related biophysiological functions. Moreover, the findings suggest that the adverse effects of poor lifestyle can be changed by health promotion interventions.

The participants who previously had habits of regular exercise, seemed to have significant effects on blood pressure, total cholesterol and TG. This observation is to affirm the health effects that an exercise intervention can be beneficial to people, especially those without previous exercise habits. Regular exercise participation has favorable effects on plasma lipid and lipoprotein profiles; this impact has been more clearly defined recently. Several mechanisms might account for the antihypertensive effects of exercise training, such as the reductions on sympathetic drive, the decrease of plasma norepinephrine, decrease of endogeneous ouabain-like substance, increase of prostaglandin E, or decrease of plasma renin activity. Regular exercise could change the body fat ratio and insulin resistance, which would lower the prevalence of cardiovascular disease by reducing blood pressure and improving lipid profile [31]. For instance, exercise-induced lipolytic enzyme activity that promotes the degradation of triglyceride-rich lipoproteins [15,16]. The diet change and the weight loss associated with exercise are believed to have favorable effects in lowering LDL and increasing HDL. Meanwhile, the heterogeneity of the intervention exercises, the exercise volumes, the energy expenditures, and the accompanying dietary changes and weight loss shall play a role in the variability of desired lipid changes. As much is known about the benefits of exercise, this study further provides empirical evidence that reinforcing the importance of exercise in any regimens of the health promotion program.

Table 5 The association between 1 kg body weight change and selected biophysiological measures stratified by lifestyle variables.

Stratification[b]	Biophysiological measures				
	Δ[a]SBP	ΔDBP	ΔTC	ΔLDL	ΔTG
Cigarette smoking					
No	0.59*** (0.34, 0.83)	0.25** (0.07, 0.43)	0.84*** (0.43, 1.24)	0.66*** (0.28, 1.04)	3.51*** (2.16, 4.86)
Yes	0.13 (−0.43, 0.70)	−0.005 (−0.38, 0.37)	1.32** (0.44, 2.20)	0.63 (−0.27, 1.52)	3.37* (0.26, 6.48)
Alcohol consumption					
No	0.42** (0.13, 0.70)	0.17 (−0.04, 0.37)	0.80*** (0.35, 1.25)	0.52* (0.10, 0.95)	3.34*** (1.68, 4.99)
Yes	0.68*** (0.29, 1.06)	0.31* (0.03, 0.59)	1.15*** (0.51, 1.79)	0.88** (0.27, 1.50)	3.71*** (1.93, 5.50)
Regular exercise					
No	0.78*** (0.43, 1.13)	0.26* (0.00, 0.52)	0.85** (0.29, 1.41)	0.52 (−0.07, 1.11)	3.04** (1.33, 4.76)
Yes	0.62** (0.24, 1.00)	0.41** (0.16, 0.66)	1.09** (0.47, 1.71)	0.61* (0.07, 1.14)	4.41*** (2.30, 6.51)

* p-value < 0.05, ** p-value < 0.01, *** p-value < 0.001, calculated using a multiple linear regression analysis between body weight change and selected physiological tests after adjusting for age, gender, intervention group, cigarette smoking, alcohol drinking, regular exercise habit, and metabolic syndrome other than stratified variable *per se*.

[a] 1. Δ Change was calculated by subtracting the post-test values from the pre-test values; 2. Abbreviations: SBP: systolic blood pressure; DBP: diastolic blood pressure; TC: total cholesterol; LDL: low density lipid; TG: triglyceride; 3. Parameter estimate (95% CI).

[b] The results of unknown group were not shown in the table.

Significance and implication

Previous studies have examined the impact of interventions such as single-task of exercise or dual-task of diet-plus-exercise program on weight control in the occupational settings. However, the moderating effect of lifestyle factors on the interventional effectiveness remains uncertain, especially for the semiconductor workers under stressful work environment. The works demand employees to achieve pre-determined performance and a tight schedule for work shift. Therefore, their lifestyle and daily activities were for some extents compromised among many employees. This study has demonstrated here is to emphasize the important role of lifestyle factors on the interventional effectiveness in such particular occupation settings. Secondly, this study is a multi-center occupational setting trial with a relatively larger sample size in which provides relatively higher reliable and valid findings than others. This study covers workers from 14 factories in semiconductor industry during the past 5 years. To our best knowledge, this study includes more comprehensive employees in the semiconductor industry in Taiwan. In fact, previous studies have revealed that subjects living with one unhealthy lifestyle practice usually have a cluster of behaviors adverse to health. For instance, smokers tend to live with low physical activity, a low fiber diet, and high alcohol consumption. These risk factors are inter-dependent and interact with each other. Moreover, most researchers have investigated one or two specific lifestyle factors, which provide limited and non-systematic evidence. The advantage of the present study is that it elucidates the independent effects of lifestyle variables on physiological measures while simultaneously adjusting for interrelated adverse behaviors. Our results suggest that for the greatest effectiveness, health interventions should be simultaneously implemented with other healthy lifestyle modifications such as smoking cessation and abstaining from alcohol consumption.

Factors affecting behavioral enthusiasm in weight loss and control are also discussed. According to participants' feedback, self-perception of being overweight and adverse health conditions are the primary triggers for their intention to enroll in the intervention programs. Enforced daily weighing and calorie calculations are deemed as key factors for weight loss. Continued health information sharing through email and/or telephone contacts by the worksite nurses are believed to be vital for success.

Limitations

There are several limitations to this study. Firstly, due to the nature of the demanding work environment in the semiconductor industry, generalizing the results of this study with regard to other industries must be performed with caution. Secondly, the lifestyle variables, such as cigarette smoking and alcohol consumption, were not measured quantitatively, which limits this study's interpretations. Thirdly, the results presented in this study reflected only short-term changes in anthropometrical measures. A longitudinal follow-up is required to observe the sustainable effects of such interventions. Fourthly, the participants in the study groups were recruited from workers with BMI≥26; results may be different with participants selected by other BMI regimens. Nevertheless, standardized study protocol on this homogeneous population is introduced to warrant the quality of this study. Participants receive equal intervention intensity scheduled according to their available leisure time, due to fixed work shifts in this industry. Through the standardization of interventions, a non-differential misclassification in terms of effectiveness for weight loss was assumed. In addition, this overweight population is aware of their potential health problems in which motivation of receiving intervention is at the same high level.

Conflicts of interest

The authors declare that they have no competing interests.

Acknowledgment

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bj.2018.09.002.

REFERENCES

[1] WHO. Ottawa charter for health promotion. Can J Public Health 1986;77:425—30.
[2] Whitehead D. Workplace health promotion: the role and responsibility of health care managers. J Nurs Manag 2006;14:59—68.
[3] Linnan L, Bowling M, Childress J, Lindsay G, Blakey C, Pronk S, et al. Results of the 2004 national worksite health promotion survey. Am J Public Health 2008;98:1503—9.
[4] Chu C, Breucker G, Harris N, Stitzel A, Gan X, Gu X, et al. Health-promoting workplaces—international settings development. Health Promot Int 2000;15:155—67.
[5] Schultz AB, Lu C, Barnett TE, Yen LTC, McDonald T, Hirschland D, et al. Influence of participation in a worksite health-promotion program on disability days. J Occup Environ Med 2002;44:776—80.
[6] Renaud L, Kishchuk N, Juneau M, Nigam A, Téreault K, Leblanc MC. Implementation and outcomes of a comprehensive worksite health promotion program. Can J Public Health 2008;99:73—7.
[7] Baicker K, Cutler D, Song Z. Workplace wellness programs can generate savings. Health Aff 2010;29:304—11.
[8] Bly JL, Jones RC, Richardson JE. Impact of worksite health promotion on health care costs and utilization. Evaluation of Johnson & Johnson's live for life program. J Am Med Assoc 1986;256:3235—40.
[9] Goetzel RZ, Ozminkowski RJ. The health and cost benefits of work site health-promotion programs. Annu Rev Public Health 2008;29:303—23.
[10] Anderson LM, Quinn TA, Glanz K, Ramirezet G, Kahwati LC, Johnson DB, et al. The effectiveness of worksite nutrition and physical activity interventions for controlling employee overweight and obesity. A systematic review. Am J Prev Med 2009;37:340—57.
[11] Engbers LH, van Poppel MNM, Chin A, Paw MJM, van Mechelen W. Worksite health promotion programs with environmental changes. A systematic review. Am J Prev Med 2005;29:61—70.
[12] Matson-Koffman DM, Brownstein JN, Neiner JA, Greaney ML. A site-specific literature review of policy and environmental interventions that promote physical activity and nutrition for cardiovascular health: what works? Am J Health Promot 2005;19:167—93.

[13] Sjostrom CD, Lissner L, Wedel H, Sjostrom L. Reduction in incidence of diabetes, hypertension and lipid disturbances after intentional weight loss induced by bariatric surgery: the SOS intervention study. Obes Res 1999;7:477—84.
[14] Muto T, Yamauchi K. Evaluation of a multicomponent workplace health promotion program conducted in Japan for improving employees'cardiovascular disease risk factors. Prev Med 2001;33:571—7.
[15] Nilsson PM, Klasson EB, Nyberg P. Life-style intervention at the worksite- reduction of cardiovascular risk factors in a randomized study. Scand J Work Environ Health 2001;27:57—62.
[16] Laakso M, Lehto S. Epidemiology of risk factors for cardiovascular disease in diabetes and impaired glucose tolerance. Atherosclerosis 1998;137:S65—73.
[17] Neter JE, Stam BE, Kok FJ, Grobbee DE, Geleijnse JM. Influence of weight reduction on blood pressure. A meta-analysis of randomized controlled trials. Hypertension 2003;42:878—84.
[18] Goldstein DJ. Beneficial health effects of modest weight loss. Int J Obes Relat Metab Disord 1992;16:397—415.
[19] Williamson DF. Intentional weight loss: patterns in the general population and its association with morbidity and mortality. Int J Obes Relat Metab Disord 1997;21:S14—9.
[20] Poobalan A, Aucott L, Avenell A, Jung R, Broom J, Grant AM. Effects of weight loss in overweight/obese individuals and long-term lipid outcomes: a systematic review. Obes Rev 2004;5:43—50.
[21] Aucott L, Poobalan A, Smith WCS, Avenell A, Jung R, Broom J. Effects of weight loss in overweight/obese individuals and long-term hypertension outcomes. A systematic review. Hypertension 2005;45:1035—41.
[22] Moy F, Sallam AAB, Wong M. The results of a worksite health promotion programme in Kuala Lumpur, Malaysia. Health Promot Int 2006;21:301—10.
[23] Chiolero A, Jacot-Sadowski I, Faeh D, Paccaud F, Cornuz J. Association of cigarettes daily smoked with obesity in a general European adult population. Obes Res 2007;15:1311—8.
[24] Chiolero A, Faeh D, Paccaud F, Cornuz J. Consequences of smoking for body weight, body fat distribution, and insulin resistance. Am J Clin Nutr 2008;87:801—9.
[25] Suter PM. Is alcohol consumption a risk factor for weight gain and obesity? Crit Rev Clin Lab Sci 2005;42:197—227.
[26] Miller ER, Erlinger TP, Young DR, Jehnet M, Charleston J, Rhodeset D, et al. Results of the diet, exercise, and weight loss intervention trial (DEW-IT). Hypertension 2002;40:612—8.
[27] Nowson CA, Worsley A, Margerison C, Jorna MK, Godfrey SJ, Booth A. Blood pressure change with weight loss is affected by diet type in men. Am J Clin Nutr 2005;81:983—9.
[28] Svendsen M, Blomhoff R, Holme I, Tonstad S. The effect of an increased intake of vegetables and fruit on weight loss, blood pressure and antioxidant defense in subjects with sleep related breathing disorders. Eur J Clin Nutr 2007;61:1301—11.
[29] Vorona RD, Winn MP, Babineau TW, Eng BP, Feldman HR, Ware JC. Overweight and obese patients in a primary care population report less sleep than patients with a normal body mass index. Arch Intern Med 2005;165:25—30.
[30] Little P, Kelly J, Barnett J, Dorward M, Margetts B, Warm D. Randomised controlled factorial trial of dietary advice for patients with a single high blood pressure reading in primary care. BMJ 2004;328:1054—9.
[31] Henriksson J. Influence of exercise on insulin sensitivity. Eur J Prev Cardiol 1995;2:303—9.
[32] Ivy JL. Role of exercise training in the prevention and treatment of insulin resistance and non-insulin-dependent diabetes mellitus. Sports Med 1997;24:321—36.
[33] Horowitz JF. Fatty acid mobilization from adipose tissue during exercise. Trends Endocrinol Metab 2003;14:386—92.
[34] Iwane M, Arita M, Tomimoto S, Satani O, Matsumoto M, Miyashita K, et al. Walking 10,000 steps/day or more reduces

blood pressure and sympathetic nerve activity in mild essential hypertension. Hypertens Res 2000;23:573–80.

[35] Tudor-Locke C, Bassett Jr DR. How many steps/day are enough? Preliminary pedometer indices for public health. Sports Med 2004;34:1–8.

[36] Schneider PL, Bassett Jr DR, Thompson DL, Pronk NP, Bielak KM. Effects of a 10,000 steps per day goal in overweight adults. Am J Health Promot 2006;21:85–9.

[37] Wu T, Gao X, Chen M, van Dam RM. Long-term effectiveness of diet-plus-exercise interventions vs. diet-only interventions for weight loss: a meta-analysis. Obes Rev 2008;10:313–23.

[38] Curioni CC, Lourenco PM. Long-term weight loss after diet and exercise: a systematic review. Int J Obes 2005;29:1168–74.

[39] Morenga LAT, Levers M, Williams S, Brown R, Jim M. Comparison of high protein and high fiber weight-loss diets in women with risk factors for the metabolic syndrome: a randomized trial. Nutr J 2011;10:40–9.

[40] Stewart KJ, Bacher AC, Turner K, Lim JG, Hees PS, Shapiro EP, et al. Exercise and risk factors associated with metabolic syndrome in older adults. Am J Prev Med 2005;28:9–18.

[41] Hersey J, Williams-Piehota P, Sparling PB, Alexander J, Hill MD, Isenberg KB, et al. Promising practices in promotion of healthy weight at small and medium-sized US worksites. Prev Chronic Dis 2008;5:1–11.

[42] Christensen JR, Faber A, Ekner D, Overgaard K, Holtermann A, Karen S. Diet, physical exercise and cognitive behavioral training as a combined workplace based intervention to reduce body weight and increase physical capacity in health care workers- a randomized controlled trial. BMC Publ Health 2011;11:671–81.

[43] Duthie GG, Arthur JR, Beattie JAG, Brown KM, Morrice PC, Robertson JD, et al. Cigarette smoking, antioxidants, lipid peroxidation, and coronary heart disease. Ann NY Acad Sci 1993;686:120–9.

[44] Connelly PW, Petrasovits A, Stachenko S, MacLean DR, Little JA, Chockalingam A. Prevalence of high plasma triglyceride combined with low HDL-C levels and its association with smoking, hypertension, obesity, diabetes, sedentariness and LDL-C levels in the Canadian population. Canadian Heart Health Surveys Research Group. Can J Cardiol 1999;15:428–33.

[45] Maeda K, Noguchi Y, Fukui T. The effects of cessation from cigarette smoking on the lipid and lipoprotein profiles: a meta-analysis. Prev Med 2003;37:283–90.

[46] Audrain JE, Klesges RC, Klesges LM. Relationship between obesity and the metabolic effects of smoking in women. Health Psychol 1995;14:116–23.

[47] Lazarus R, Sparrow D, Weiss ST. Alcohol intake and insulin levels. The normative aging study. Am J Epidemiol 1997;145:909–16.

[48] Aguilera MT, de la Sierra A, Coca A, Estruch R, Fernández-Solá J, Urbano-Márquez A. Effect of alcohol abstinence on blood pressure. Assessment by 24-hour ambulatory blood pressure monitoring. Hypertension 1999;33:653–7.

[49] Suter PM, Vetter W. The effect of alcohol on blood pressure. Nutr Clin Care 2000;3:24–34.