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ORIGINAL RESEARCH

Health Benefits Associated with an Employer-sponsored Health Promotion Program with Device-reported Activity

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Abstract

Background: As interest has grown in the effect of healthy behaviors on health outcomes, programs have been developed to incent healthy behavior. The growth of devices able to transmit information about program participant activities has allowed researchers to analyze physical activity (PA). We analyzed the relationship between positive changes in device-reported physical activity levels and changes in health-related variables in a longitudinal cohort of US based employees.

Methods: Exercise levels were measured and recorded by a device (such as a pedometer or heart-rate monitor) or gym visit and recorded by the health promotion program provider, The Vitality Group. The devices recorded the number and intensity of workouts, which were then classified as either light or standard. We obtained detailed data on 8,519 individuals who participated continuously between January 1, 2013 and August 31, 2015 in the health promotion program. Clinical measures, which were recorded either by a participant's primary care physician or at employer-sponsored health fair (worksite events organized by employers that include voluntary blood and other health testing), included Body Mass Index (BMI), cholesterol level and triglycerides, blood glucose level and blood pressure. We performed multi-variate regression modeling on the data to evaluate the impact of different variables on the measured health outcomes.

Results: We provide statistical models to predict improvements in clinical measures depending on demographic factors, initial health status and number/intensity of workouts. We find that working out at both light and standard levels can lead to improvements in some clinical measures, specifically body mass index and high-density lipoprotein (for which we found that sustained, regular and intense exercise was beneficial for reducing BMI in obese and overweight participants. Similar results were observed for the high-density lipoprotein model. Unlike prior studies we did not observe any effect of PA on blood pressure. Our models also indicate deterioration in clinical measures over time for participants in the normal range who did not exercise regularly, indicating that regular, sustained exercise is necessary to maintain normal clinical measures over time.

Conclusions: While some improvement in clinical measures is associated with physical activity, our models indicate that improvement in clinical measures generally requires both sustained and intense physical activity.

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INTRODUCTION

As interest has grown in the effect of healthy behaviors on health outcomes, programs have been developed to incent healthy behavior. The growth of devices able to transmit information about program participant activities has allowed researchers to analyze physical activity (PA). We analyzed data recorded from wearable devices of participants in a wellness program.

What is known about the relationship between physical activity and health outcomes?

The US Department of Health and Human Services recommends "Physical activity most days of the week for at least 30 minutes for adults" [1]. The association between increased PA and health outcomes, including coronary artery disease, hypertension, stroke, insulin resistance and depression is well-known and documented in numerous studies [2, 3]. Our study investigated the effect of PA on body mass index (BMI), blood pressure (systolic and diastolic blood pressure) and lipids. A review of the existing literature indicates favorable effects of PA on most of these measures, although the extent of the relationship is affected by factors such as baseline body mass and intensity of PA.

Bratava et al [2] in a review that summarized eight Randomized Control Trials (RCTs) and 18 observational studies found that increased activity was associated with a decrease in BMI of 0.38 and a reduction in systolic blood pressure of 3.8 mm Hg. In a Cochrane review of pedometer-based employer program studies, Freak-Poli and others concluded: "Overall, there was insufficient evidence to assess the effectiveness of pedometer interventions in the workplace" [3]. The studies reviewed found improvment in BMI, waist circumference and fasting blood glucose, but no improvement in blood pressure or biochemical outcomes. Pillay et al [4] studied the dose-response effect of device-recorded PA

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on a number of health outcomes [4]. The authors found an association between the level of activity and body fat, waist circumference and diastolic blood pressure, although the largest influence was that of body composition (percentage body fat). The UK Dept. of Health, in a report entitled "At least 5 per week", examined the evidence for the effect of exercise on a number of different health outcomes [5]. Other studies of the relationship between PA and BMI have looked at the effect of PA on different levels of weight loss, for example [6, 7].

Physical activity is a major independent protective factor against coronary artery disease (CAD), specifically affecting cardiovascular risk factors such as blood pressure, cholesterol levels and insulin resistance. Inactive men and women have almost twice the risk of dying from CAD compared with active people [5]. A review of 54 Randomized Control trials by Whelton et al [8] found that PA reduced systolic blood pressure by 3.8 mm Hg. and diastolic blood pressure by 2.58 mm Hg. Sub-group results showed larger reductions in blood pressure associated with both more intensive exercise and higher BMI, except for the highest intensity and highest BMI groups, which had lower changes in blood pressure. A more recent meta-analysis of 9 trials by Semlitsch et al [9] found decreased blood pressure in the range of 5-10 mm Hg (systolic) and 1-6 mm Hg (diastolic) associated with increased physical activity. A 2016 meta-analysis by Borjesson et al [10] found a similar but larger effect (mean reduction in systolic/diastolic b.p. of 11/5 mm Hg.).

The terms "blood lipids" or "serum cholesterol" refer to LDL, HDL, total cholesterol and triglycerides. Studies cited in [5] show an increase in HDL (protective cholesterol) and triglycerides as a result of exercise, but no effect on LDL or total cholesterol. There also appears to be a dose-response effect. Mann, Beedie and Jimenez [11] reviewed 13 studies and 2 review articles and concluded that while exercise increases HDL, "to reduce LDL cholesterol and triglyceride levels…the intensity of aerobic exercise must be increased." A larger review of 84 studies (58 RCTs) by Tambalis et al [12] found that moderate exercise had a small effect on HDL, with inconsistent results on other lipid measures. High intensity aerobic exercise found stronger indications of improvement in HDL but less frequent improvement in LDL and total cholesterol. A large review of 234 studies by Ruppar et al [13] found a reduction of 8.65 mg/dl in total cholesterol, with larger effects where subjects were obese at baseline and for interventions utilizing low-intensity exercise.

METHODS

Data

We analyzed data from a US-based provider of a workplace health promotion and wellness program, The Vitality Group (TVG; www.thevitalitygroup.com). The Vitality Group is a financial supporter of the Center for Financial Mathematics and Actuarial Research in the Department of Statistics and Applied Probability at the University of California Santa Barbara. Vitality also supports the department's actuarial research class. As part of their support, Vitality provided the de-identified dataset for this study, under a confidentiality and privacy data use agreement.

Program participants earned points for physical activity and other healthy behaviors, which were then exchangeable for rewards. Physical activity levels were self-reported in an annual health risk assessment, but also verified throughout the year either by device or gym utilization. Gym visits were verified through a GPS mobile application: a person had to be at the gym location for at least 30 minutes (the user interface is via a countdown timer on the application). Visits recorded in this fashion give rise to "standard workouts," but if the participant was using a device at the gym, an advanced workout may have been recorded via the device (not reported for this study). For this study we used only verified (via a device) activities. Participants also recorded a number of self-reported health-related factors (presence of chronic diseases; alcohol and smoking behavior etc.) in addition to clinical (laboratory) measures that were recorded either at employer-sponsored health fairs or reported by attending physicians. Physical activity ("workouts") was classified either as light or standard according to the following criteria:

Table 1: Classification of Physical Activity

Device-recorded verified workouts	Light Workouts	Standard Workouts
Steps	5,000-9,999	10,000+
Calories	100-199	200+
Time at 60% Maximum Heart Rate	15 minutes	30 minutes

We obtained data on 8,519 program members (employees and spouses residing in the United States) who participated continuously in the Vitality program and had verified physical activity between January 1, 2013 and August 31, 2015. Members experienced a total of 32 months of participation in the program. These members were a sub-set of a larger dataset that contributed self-reported activity data or clinical data either at employer-sponsored health fairs or from the employee's physician. The sub-set analyzed represents members with complete data during the study period.

Of the participating members, 64 were removed for having a change in BMI of more than 10 units within a year and 69 were removed for having more than 7 workouts per week, resulting in an analysis dataset of 8,386 members. Details of participant demographics are shown in Table 2 (on the following page).

(Analysis datasets for cholesterol levels differed from this - see Table 7.)

Table 2: Patient Demographics

Year	Age Group	Female Average					Male Average				
		N	Smoker[a]	Stress[b]	Alcohol[c]	Sleep[d]	N	Smoker[a]	Stress[b]	Alcohol[c]	Sleep[d]
2013	-40	1,531	4.4	9.8	1.9	7.1	1,303	6.5	3.8	3.8	7.0
2013	40-60	2,901	5.7	10.2	1.8	6.9	2,117	5.1	5.0	3.5	7.0
2013	60 +	307	3.9	11.4	1.8	6.9	227	3.5	3.1	3.3	7.0
2014	-40	1,398	4.3	12.3	1.8	7.1	1,177	6.5	5.0	3.8	7.0
2014	40-60	2,909	5.3	12.1	1.7	6.9	2,186	4.6	6.0	3.2	7.0
2014	60 +	430	5.3	12.6	1.6	7.0	286	4.5	3.1	3.2	7.1
2015	-40	1,297	4.2	12.7	1.8	7.0	1,103	6.9	5.4	3.9	7.0
2015	40-60	2,938	5.3	12.1	1.8	6.9	2,201	4.3	6.4	3.2	7.0
2015	60 +	503	3.8	12.9	1.6	7.0	344	4.4	4.4	3.3	7.0

a: Cigarettes/day   b: Kessler Stress Score (range 0-50). [14]   c: Number of alcoholic drinks per week   d: hours/night

Modeling Health Variables

We modeled the relationship between regular device-recorded PA and certain health measures: body mass index (BMI), blood pressure (both diastolic and systolic) and cholesterol (low-density lipoproteins (LDL), high-density lipoproteins (HDL) and triglycerides). A multiple linear regression model was used for each health measure. Factors such as gender, age, and baseline health measure were included in the model to account for potential confounding effects. We particularly studied the interaction effect between PA and baseline health measure in each linear model. We also looked at the relationship between PA and glucose levels; however, blood glucose was not regularly measured for non-diabetic members, while hemoglobin A1c was recorded mostly by patients with diabetes, resulting in a skewed sample of members. For this reason we did not study blood glucose levels further.

RESULTS

Body Mass Index

Distribution of baseline and follow-up BMI measures are shown in Table 3.

Table 4: Number of workouts per week

Year	Light Workouts			Standard Workouts		
	Min	Mean (SD)	Max	Min	Mean (SD)	Max
2013	0	0.86 (1.05)	6.1	0	1.75 (1.65)	7.0
2014	0	1.27 (1.29)	6.8	0	2.24 (1.84)	7.0
2015	0	1.09 (1.04)	7.0	0	1.83 (1.47)	7.0

We modeled the predicted BMI, using a multivariate linear regression model, at the end of the study period (20 months) based on weekly workout habits, baseline BMI (2013), age, and gender.

Results in Table 5 show that the dominant factors affecting BMI are baseline BMI and the level of standard exercise. We can tell this by the magnitude of the coefficient estimates and the p-values.

Table 5: BMI Prediction Model

Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	1.075	0.215	4.998	5.91e-07***
BMI (Baseline)	0.993	0.007	145.227	< 2e-16***
Average Light	0.240	0.085	2.813	0.00492**
Average Standard	0.279	0.061	4.546	5.54e-06***
Age	-0.007	0.002	-3.115	0.00185**
Gender (male)	-0.099	0.047	-2.112	0.03473*
BMI.Avg Light[d]	-0.009	0.003	-3.03	0.00246**
BMI.Avg Standard[d]	-0.014	0.002	-6.602	4.32e-11***

Table 3: Distribution of Population by Year and Weight Category

					Body Mass Index %			
					Under weight	Normal Weight	Over weight	Obese
Year	N	Min	Mean (SD)	Max	< 18.5	18.5 - 25	25 - 30	≥ 30
2013	8,386[a,b]	15.1	27.8 (6.01)	71.5	1	36	35	29
2014	8,386	14.8	27.9 (6.08)	75.9	1	35	35	29
2015[c]	8,386	16.0	28.1 (6.13)	75.6	0.5	35	35	30

[a] The population originally had 8,519 participants; 64 were removed because their BMI changed by more than 10 units and 69 were removed because they averaged more than 7 workouts per week.

[b] 56.5% female; 43.5% male.

[c] 8 months only.

Table 6: Baseline Cholesterol Levels

Low-density Lipoprotein Level		High-density Lipoprotein Level			
LDL Level	Number	HDL Level	Female Number	HDL Level	Male Number
<3.0 (Normal)	5,339 (63%)	< 1.5 (High risk)	1,971 (41%)	< 1.3 (High risk)	2,130 (57%)
>3.0 (High)	3,009 (35%)	> 1.5 (Normal)	2,762 (57%)	> 1.3 (Normal)	1,551(42%)
N/a[e]	171 (2%)	N/a	81 (2%)	N/a	24 (1%)
Total	8,519	Total	4,814	Total	3,705

	Low-density Lipoprotein (LDL)				High-density Lipoprotein (HDL)			
Year	Normal	Min	Mean (SD)	Max	Normal	Min	Mean (SD)	Max
2013	<3.0	0.0	2.78 (0.78)	6.57	>1.3 (male)	0.36	1.291 (0.34)	3.03
2014		0.28	2.80 (0.77)	8.51		0.41	1.320 (0.35)	3.03
2015		0.23	2.80 (0.79)	8.35		0.38	1.338 (0.37)	4.03
2013					>1.5 (female)	0.36	1.674 (0.44)	4.03
2014						0.36	1.674 (0.45)	4.71
2015						0.54	1.682 (0.47)	4.33

Males had a higher chance of a larger BMI value at the end of this study. The fact that the coefficients of the interaction terms of BMI and standard exercise level, and BMI and light exercise levels were both negative indicate that a positive amount of exercise would be helpful in reducing BMI, given the same baseline BMI values.

Blood Pressure

Prior studies have indicated some relationship between physical activity and reduced blood pressure (both diastolic and systolic). We did not observe a significant relationship between physical activity (either light or standard) and blood pressure after controlling for baseline blood pressure, age, BMI, gender and weekly average number of alcoholic drinks.

Serum Cholesterol

Mean levels of high- and low-density lipoproteins were within a normal range. However, there were numbers of participants in each year that fall outside of the normal range: either greater than 3.0 (mmol/l) (LDL) or less than 1.3 (mmol/l) (male) or 1.5 (mmol/l) (female) for HDL (Table 6).

We modeled the effect of physical activity on LDL and HDL separately.

We observed little effect of PA on LDL cholesterol (to be expected, because LDL is impacted more via diet with little effect of activity).

DISCUSSION

The data used for this study has the advantage of being longitudinal (32 months from January 2013 through August 2015) as well as including a number of different variables such as clinical measures and self-reported smoking and alcohol use. Consistent with much of the literature, our models predict improvement in BMI and HDL cholesterol, although in this data we observe no improvement in blood pressure and LDL cholesterol. One overall conclusion from our analysis that is perhaps overlooked by proponents of exercise is that improvement in clinical measures requires sustained, regular and intense physical activity. The need for sustained PA is seen in the trend in BMI for underweight and normal weight participants: BMI tends to increase with time, and only sustained PA at an intense level maintains or reduces BMI in participants below the overweight level. Conversely, our data indicate that improvement in BMI is possible for overweight and obese participants, provided PA is sustained at an intense level. Similar results are observed for the HDL model. Unlike prior studies, we did not observe any effect of PA on blood pressure.

A challenge with this model is interpretation. The presence of significant interaction terms indicates that the relationship between physical activity and BMI is complex; the effect of exercise depends both on the level of exercise and a person's starting BMI. To illustrate, we applied the model to two sample participants.

Table 7: Prediction Model for LDL Cholesterol

Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	0.81996	0.06001	13.645	< 2e-16***
LDL (baseline)	0.74049	0.01678	44.13	< 2e-16***
Average Light	0.02596	0.01878	1.374	0.169447
Average Standard	0.00146	0.01306	0.073	0.941538
BMI (baseline)	-0.00398	0.00106	-3.613	0.000304***
Age	0.00053	0.00063	0.884	0.376527
Gender (male)	0.03168	0.01294	2.257	0.024028*
Depressed (true)	0.05017	0.02394	2.096	0.036150*
LDL.x: Avg Light[d]	-0.01211	0.00645	-1.885	0.05943
LDL.x: Avg Standard[d]	-0.00035	0.00450	-0.085	0.932314

d: Interaction terms

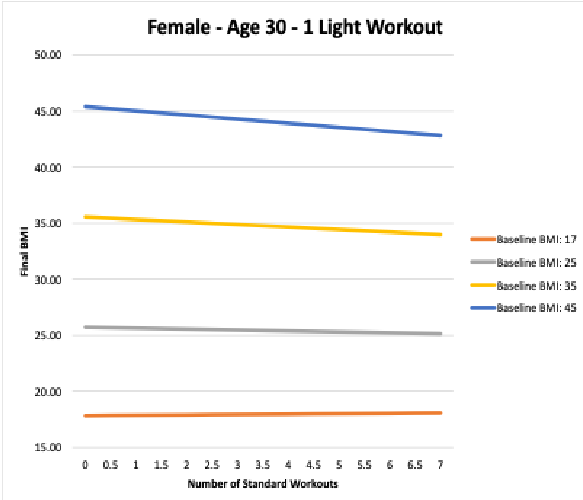
Residual standard error: 0.5584 on 8040 degrees of freedom (337 participants deleted due to missing observations)
Multiple R-squared: 0.5045, Adjusted R-squared: 0.504
F-statistic: 1023 on 8 and 8040 DF, p-value: < 2.2e-16

Table 8: Prediction Model for HDL Cholesterol

Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	0.40594	0.03142	12.919	< 2e-16***
HDL (baseline)	0.84015	0.01474	56.966	< 2e-16***
Average Light	0.01375	0.00801	1.715	0.0864*
Average Standard	0.01299	0.00572	2.268	0.0233*
BMI (baseline)	-0.00409	0.00052	-7.901	3.13e-15***
Age	0.00058	0.00029	2.011	0.0444*
Average Alcohol	0.00534	0.00062	8.568	< 2e-16***
Gender (male)	-0.10295	0.00639	-15.528	< 2e-16***
HDL.x: Avg Light[d]	-0.01056	0.00519	-2.204	0.0275*
HDL.x: Avg Standard[d]	-0.00325	0.00368	-0.882	0.3777

d: Interaction terms

Residual standard error: 0.2548 on 8,105 degrees of freedom (270 participants deleted due to missing observations)
Multiple R-squared: 0.697, Adjusted R-squared: 0.6967
F-statistic: 2072 on 9 and 8105 DF, p-value: < 2.2e-16



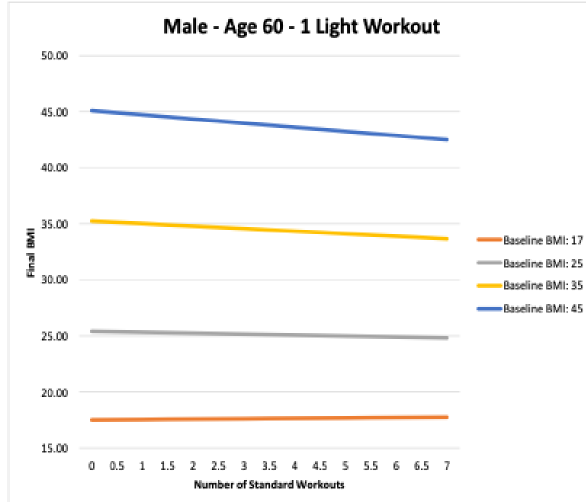


Figure 1: Effect of Exercise Levels on BMI for selected participants

Figure 1 is a representation of sample participants (female 30; male 60; both with one light workout and a variable number of standard workouts per week).

Example 1: Application of the BMI model

The first example is a 30 year old female who averages three standard workouts and one light workout per week for 20 months (% change in parentheses, total change outside of the parentheses). The second example is a 60 year old male who averages 5 standard workouts per week and one light workout per week.

Table 9: Predicted 20-month BMI Measure for Two Sample Participants

Sample Participant	Baseline BMI Level			
	17	25	35	45
1. 30-year old Female; 3 std./1 light w/out weekly	17.94 (5.5)	25.46 (1.9)	34.87 (-0.4)	44.30 (-1.6)
2. 60-year old Male; 5 std./ 1 light w/out weekly	17.70 (4.1)	24.99 (0.0)	34.11 (-2.5)	43.23 (-3.9)

Depending on initial BMI levels, physical activity generally has a beneficial effect on BMI. The exception is the lowest (underweight) category, which shows slight increases in BMI, despite increasing physical activity. High levels of physical activity combined with high initial BMI show significant BMI reductions.

We conclude that while physical activity may result in reduced BMI, the benefits are observed for participants who are overweight or obese at baseline. Participants who are underweight or normal weight at baseline are likely to experience slightly elevated BMI over time, despite regular physical activity. Reduced BMI for these participants requires regular PA at a relatively intense level (30 minutes or more in excess of 60% of maximum heart rate; 10,000 or more steps and 200 calories or more). The second conclusion from this model is that reduction in BMI requires regular, standard workouts (as in the case of the second sample participant, 5 per week).

Example 2: Application of the HDL Model

We apply our model to two hypothetical participants. Each sample participant was assigned a BMI of 30 and average weekly alcohol consumption of five drinks per week. Further details are provided in the table.

The 30-year old female has a high-risk HDL level under 1.50 and the 40 year old male under 1.30; working out at the levels indicated improves HDL levels for most participants, but this is insufficient to move any participant from a high-risk HDL level to a normal level. As with the BMI model, this model indicates greater effects for participants with higher-risk baseline levels of HDL (<1.5 (Female) or < 1.3 (Male) and for more regular and more intense activity. The results suggest, however, that to achieve and maintain a normal HDL level through exercise alone requires both very regular and relatively intense physical activity. These effects are illustrated in Figure 2 (on the following page).

Table 10: Predicted 20-month HDL Level for Two Sample Participants

Sample Participant	Baseline HDL Level			
	0.8	1.2	1.6	2.0
1. 30-year old Female; 3 std./1 light w/out weekly	1.03 (28.9)	1.35 (12.9)	1.68 (4.9)	2.00 (0.07)
2. 40-year old Male; 5 std./ 1 light w/out weekly	0.95 (19.5)	1.28 (6.4)	1.60 (-0.1)	1.92 (-4.1)

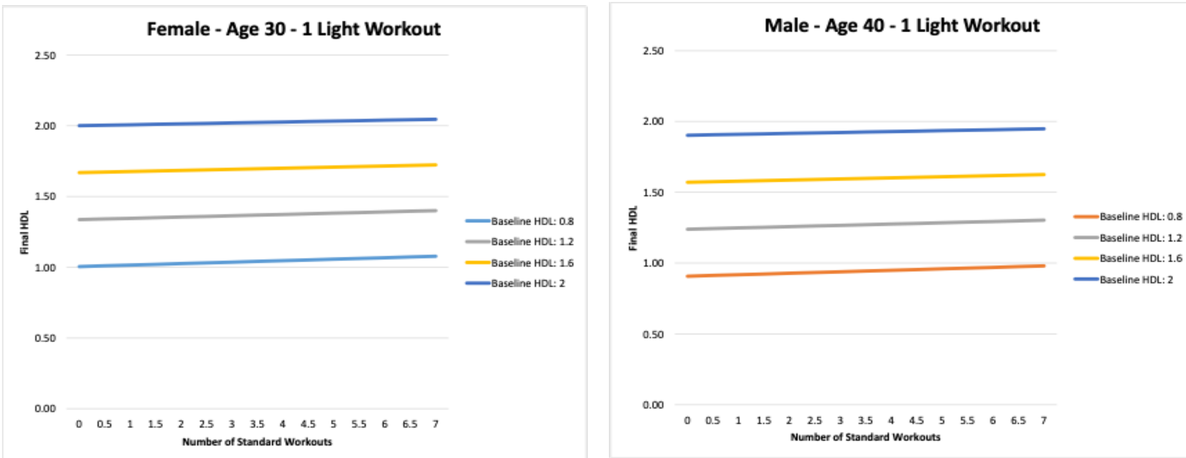


Figure 2: Effect of Exercise Levels on HDL for selected participants

Figure 2 shows a consistently beneficial effect of physical activity on both participants, with a clear dose-response effect as the amount of physical activity increases.

LIMITATIONS

This was a retrospective study of data collected as part of a wellness-incentive program. While the number of participants was fairly large, participants were not selected at random and the incentive program was offered selectively by employers. Actual exercise data were not available as a result of a restriction placed by the device supplier and therefore activities were categorized. The lack of a higher category of exercise (to be added in future studies) meant that we could not evaluate more-intense activity participants.

CONCLUSIONS

Physical activity even at low levels can have positive impacts on measurable health metrics. The physical activity levels as defined in this study (light and standard) had the largest impacts on BMI and HDL cholesterol levels, but little to no effect on either blood pressure or LDL cholesterol levels. The Vitality Group has added another category for physical activity for more intense workouts (> 15,000 steps, > 400 calories, > 45 minutes), so future analyses can examine in more detail the dose-response effect of the intensity of workouts on health outcomes. In addition, we may be able to detect positive changes in blood pressure and LDL cholesterol levels once this additional information on the level of physical activity is known.

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Authors' contributions: ID conceived the original idea for the study. WH and XL performed data analyses. This paper was written by ID with input from all co-authors. ID is guarantor for this paper. All authors read and approved the final manuscript.
Ethics approval and consent to participate: The study was conducted on de-identified administrative data and does not require Ethics approval.
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