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

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Abstract

We analyzed the relationship between positive changes in physical activity levels and changes in health-related variables in a longitudinal cohort of US based employees. Exercise levels are 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 record the number and intensity of workouts, which is then classified as either light or standard. Clinical measures, which are recorded either by a participant's primary care physician or at employer-sponsored health fairs (worksite events organized by employers that include voluntary blood and other health testing), include Body Mass Index (BMI), cholesterol level and triglycerides, blood glucose level and blood pressure.   We find that working out at both light and standard levels can lead to improvements. We provide models to predict improvements in measures depending on demographic factors, initial health status and number/intensity of workouts. Improvement in clinical measures, however, generally requires sustained and intense physical activity.

Introduction

We examined data from a US-based provider of a workplace health promotion and wellness program, The Vitality Group (TVG; www.thevitalitygroup.com). Program participants earn points for physical activity and other healthy behaviors, which are then exchangeable for rewards. Physical activity levels are self-reported in an annual health risk assessment, but also verified throughout the year either by device or gym utilization. Gym visits are verified through a GPS mobile application: a person has 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 is using a device at the gym an advanced workout may be recorded via the device. For this study we used only verified (via a device) activities. Participants also record a number of self-reported health-related factors (presence of chronic diseases; alcohol and smoking behavior etc.) in addition to clinical (laboratory) measures that are recorded either at employer-sponsored health fairs or by attending physicians.   Physical activity ("workouts") is classified either as light or standard according to the following criteria:

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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

Data

We obtained data on 8,519 members (employees and spouses resident 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. Clinical data were only recorded for a sub-set of members who contributed clinical data either at employer-sponsored health fairs or from the employee's physician.

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.

Table 2: Participant demographics

		Female					Male				
Year	Age Group	N	% Smoker	% Depressed	Avg. Alcohol / wk	Avg. Sleep	N	% Smoker	% Depressed	Avg. Alcohol / wk	Avg. Sleep
2013	-40	1,529	4.4	9.8	1.9	7.1	1,302	6.5	3.8	3.8	7.0
2013	40-60	2,901	5.7	10.2	1.8	6.9	2,119	5.0	5.0	3.5	7.0
2013	60 +	307	4.2	11.4	1.9	6.9	228	3.5	3.1	3.3	7.0
2014	-40	1,396	4.3	12.3	1.9	7.0	1,176	6.5	5.0	3.8	7.0
2014	40-60	3,034	5.3	12.1	1.7	6.9	2,245	4.4	6.0	3.2	7.0
2014	60 +	430	5.6	12.6	1.7	7.0	286	4.6	3.2	3.2	7.0
2015	-40	1,297	4.3	12.8	1.8	7.0	1,102	6.9	5.5	3.9	7.0
2015	40-60	3,133	5.3	12.2	1.8	6.9	2,319	4.2	6.4	3.2	6.9
2015	60 +	503	3.6	12.8	1.6	7.0	344	4.4	4.4	3.3	7.0

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

The association between increased physical activity (PA) and health outcomes, including coronary artery disease, hypertension, stroke, insulin resistance and depression is well-known and documented in numerous studies [1]. The US Department of Health and Human Services recommends "Physical activity most days of the week for at least 30 minutes for adults." [2] Our study investigated the effect of PA on body mass (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 [1] in a review that summarized 8 Randomized Control Trials (RCTs) and 18 observational studies drawn from a sample of over 2000 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. Pillay et al studied the dose-response effect of device-recorded PA on a number of health outcomes [3]. 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 [4]. Other studies of the relationship between PA and BMI have looked at the effect of PA on different levels of body weight, for example [5], [6].

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 [4]. A review article of 54 Randomized Control trials by Whelton et al [7] found that PA reduced systolic b.p. by 3.8 mm Hg. and diastolic b.p. by 2.58 mm Hg. Sub-group results showed increasing reduction in b.p. associated with both more intensive exercise and higher BMI, except for the highest intensity and BMI groups, which had lower changes in blood pressure. A more recent meta-analysis of 9 trials by Semlitsch et al [8] found decreased blood pressure in the range of 5-10 mm Hg (systolic) and 1-6 mm Hg (diastolic). A 2016 meta-analysis by Borjesson et al [9] 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 [4] 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 [10] 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 [11] found that moderate exercise had mostly 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 [12] 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.

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). 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.

1. **Body Mass Index**

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

Table 3: Distribution of Population by Year and Weight Category

					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 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

BMI Model

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

Table 5: BMI Prediction Model

| Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	1.074600	0.215010	4.998	5.91e-07***
BMI.x (Baseline)	0.993165	0.006839	145.227	< 2e-16***
Average Light	0.239804	0.085257	2.813	0.00492**
Average Standard	0.279342	0.061445	4.546	5.54e-06***
Age	-0.007065	0.002268	-3.115	0.00185**
Gender (male)	-0.098658	0.046716	-2.112	0.03473*
BMI.Avg Light[d]	-0.008967	0.002960	-3.030	0.00246**
BMI.Avg Standard[d]	-0.014426	0.002185	-6.602	4.32e-11***

d: Interaction terms.

Residual standard error: 2.058 on 8379 degrees of freedom
Multiple R-squared: 0.8877,   Adjusted R-squared: 0.8877
F-statistic: 9466 on 7 and 8379 DF, p-value: < 2.2e-16
The relationship between actual and predicted BMI levels, as shown graphically in Figure 1, is close.

Figure 1: Relationship between actual and predicted BMI
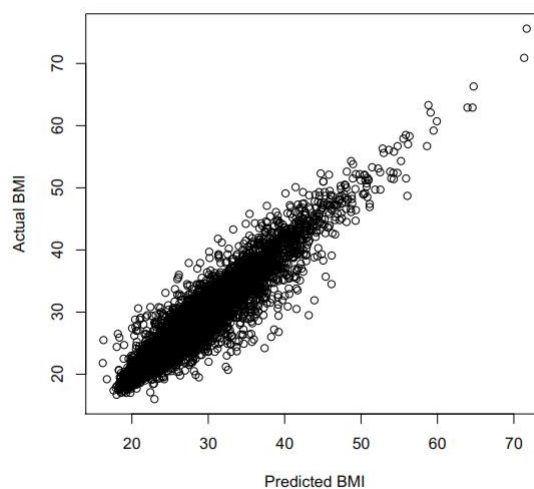
A challenge with this model is interpretation, since the relationship between physical activity and BMI is complex in the sense that it depends on a person's starting BMI. To illustrate, we applied the model to two typical participants.

The first example is a 30 year old female who averages 3 standard workouts and 1 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 1 light workout per week.

Table 6: 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)

Figure 2 is a representation of sample participants (female 30; male 60; both with 1 light workout and a variable number of standard workouts per week).

Figure 2: Effect of Exercise Levels on BMI for selected participants
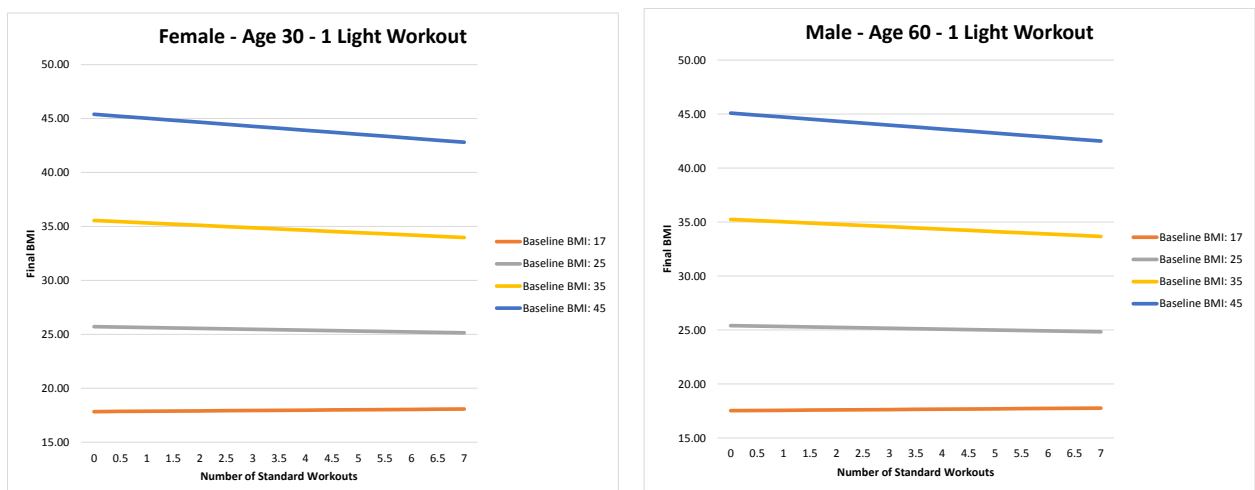
Depending on initial BMI levels, physical activity generally has a beneficial effect on BMI. The exception is the lowest (underweight) category, which shows slight increases, despite increasing physical activity. High levels of physical activity combined with high initial BMI shows significant BMI reductions.

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 both regular, standard workouts (as in the case of the second sample participant, 5 per week).

2. **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.

3. **Serum Cholesterol**

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

Table 7: 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	3705

	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	1.32 (0.35)	3.03
2015		0.23	2.80 (0.79)	8.35		0.36	1.338 (0.37)	4.03
2013					>1.5 (female)	0.36	1.674 (0.44)	4.71
2014						0.36	1.674 (0.45)	4.33
2015						0.54	1.692 (0.47)	4.29

e: N/a denotes missing values.

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

Table 8: Prediction Model for LDL Cholesterol

Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	0.8199638	0.0600179	13.645	< 2e-16***
LDL.x (baseline)	0.7404900	0.0167847	44.130	< 2e-16***
Average Light	0.0259658	0.0187830	1.374	0.169447
Average Standard	0.0014570	0.0130562	0.073	0.941538
BMI.x (baseline)	-0.0039832	0.0010630	-3.613	0.000304***
Age	0.0005288	0.0006301	0.884	0.376527
Gender (male)	0.0316759	0.0129418	2.257	0.024028*
Depressed (true)	0.0501718	0.0239416	2.096	0.036150*
LDL.x: Avg Light[d]	-0.01211322	0.0064478	-1.885	0.059430
LDL.x: Avg Standard[d]	-0.0003471	0.0045039	-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

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

HDL Model

Table 9: Prediction Model for HDL Cholesterol

Coefficients	Estimate	Standard Error	t-value	Pr (>|t|)
Intercept	0.4059373	0.0314221	12.919	< 2e-16***
HDL.x (baseline)	0.8401523	0.0147484	56.966	< 2e-16***
Average Light	0.0137499	0.0080172	1.715	0.0864*
Average Standard	0.0129932	0.0057284	2.268	0.0233*
BMI.x (baseline)	-0.0040894	0.0005176	-7.901	3.13e-15***
Age	0.0005762	0.0002866	2.011	0.0444*
Average Alcohol	0.0053439	0.0006237	8.568	< 2e-16***
Gender (male)	-0.1029463	0.0063896	-15.528	< 2e-16***
HDL.x: Avg Light[d]	-0.0105604	0.0051863	-2.204	0.0275*
HDL.x: Avg Standard[d]	-0.0032483	0.0036825	-0.882	0.3777

d: Interaction terms

Residual standard error: 0.2548 on 8105 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

To aid with the interpretation of this model, we apply our model to 2 hypothetical participants. Each sample participant was assigned a BMI of 30 and average weekly alcohol consumption of 5 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.

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)

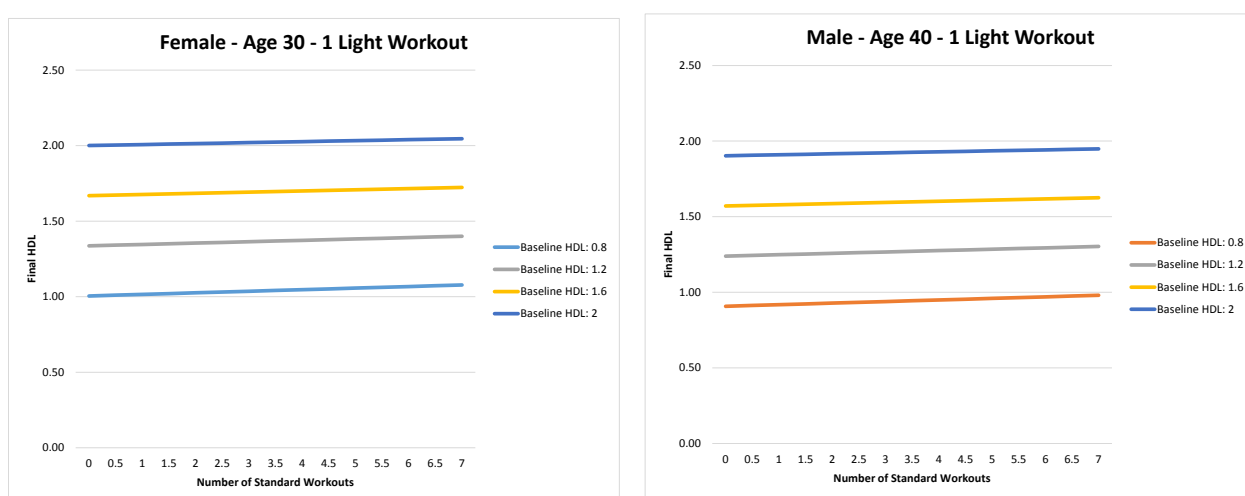**Figure 3: Effect of Exercise Levels on HDL for selected participants**

Figure 3 shows a consistently beneficial effect of physical activity on both participants, with a clear dose-response effect as the amount of physical activity increases.

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 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 studies discussed above we did not observe any effect of PA on blood pressure.

<u>Conclusion</u>

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 was detected in relating these levels of physical activity to 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 the various 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. Our collaboration with the Vitality Group will continue with the addition of (at least) one further year of PA data, including the more-intense workout data that may show more favorable effects of exercise.

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