Moderate to Vigorous Physical Activity and Weight Outcomes: Does Every Minute Count?

1. Introduction

Physical activity recommendations for health have broadened from the 1970s "exercise" prescription of 20+ minutes of sustained vigorous physical activity. By the 1990s, recommendations from various agencies including the CDC expanded to include a lifestyle activity alternative: Moderate physical activity (MPA) such as brisk walks, which totaled 30 minutes most days of the week, but which could be accumulated in 8-10 minute bouts (Suitor and Kraak, 2007). Body mass index (BMI) benefits for accumulated bouts have been demonstrated by randomized clinical trials that varied the duration of physical activity bouts but kept the total amount of activity the same. For example, one study found no BMI differences across two treatments: one daily 30-minute walking bouts versus three daily 10-minute walking bouts (Murphy et al., 2002). A review of similar studies yielded mixed but promising results: eight studies found moderate-to-vigorous physical activity (MVPA) training related to lower BMI, with four studies favoring accumulated shorter bouts and only one study favoring the longer 30-minute bout (Murphy et al., 2009).

Such studies informed the most recent 2008 MPA recommendations of 150 minutes/week (US Department of Health and Human Services, 2008), to be accumulated in 10-minute bouts. The review underlying the 2008 MPA guideline judged there was sufficient evidence to support cardiovascular and fitness benefits from accumulated 8-10 minute MVPA bouts, but insufficient evidence to recommend 8-10 minute bouts for healthier BMI (Physical Activity Guidelines Advisory Committee, 2009). The 8-10 minute bout standard was selected because it was the duration typically tested. Yet some clinical trials have shown cardiovascular health benefits for shorter bouts of six minutes (Macfarlane et al., 2006), 5-10 minutes (Coleman et al., 1999; Woolf-May et al., 1999), or even 135-second bouts of stair climbing (Boreham et al., 2000). Evidence suggests that health benefits may accrue from a range of any additional MVPA (Powell et al., 2011; Webb et al., 2011).

Few studies examine the effects of ≤10-minute MVPA bouts on BMI outcomes. One small clinical intervention study showed that 5+ minute bouts related to lower BMI (Coleman et al., 1999). Most relevant to the present study is a study by Strath et al. (2008), which used

2003-2004 National Health and Nutrition Examination Survey (NHANES) data. They tested whether MVPA "nonbouts," defined as <10 minute MVPA bouts, would predict BMI after controlling for ≥10-minute MVPA bouts as well as age, race/ethnicity, smoking status, gender, and self-reported health status. Results showed that nonbouts related to lower BMI but were about one-fourth as powerful as 10+ minute bouts in predicting BMI (coefficients of -0.01 vs. -0.04).

Since the publication of Strath et al. (2008), new research has suggested different standards for both bouts and MVPA thresholds. Although Strath et al. required ≥10-minute continuous MVPA bouts, more recent bout definitions allow for a 1-2 minutes below MVPA threshold in a 10-minute bout to allow for interruptions common in lifestyle physical activity, such as pausing for traffic before walking across streets (Troiano et al., 2008). In addition, most MVPA definitions require higher accelerometer counts per minute (CPM) thresholds than the ≥ 760 CPM (Matthews, 2005) used by Strath et al. Troiano et al. used an MVPA threshold of ≥2020 CPM, computed from a sample-weighted average of prior accelerometer validation studies (Brage et al., 2003; Freedson et al., 1998; Leenders et al., 2001; Yngve et al., 2003). These new standards and definitions suggest the need to update Strath et al.'s (2008) research.

In this study we examine whether healthier BMI is associated with 1-7 minute MVPA bouts, in addition to 8 minutes or longer MVPA bouts. We build on Strath et al.'s work in several important ways. First, we use the recently developed modified 10-minute bouts definition that allows 1-2 minutes below MVPA threshold in a 10-minute bout to allow for interruptions (Troiano et al., 2008). Second, we use 2020 CPM as the intensity threshold for MVPA. Third, we combine NHANES years 2003-2006 for a larger, more updated sample. Fourth, we expand on Strath et al.'s control variables to include other important confounders: poverty status, education, and caloric intake. We hypothesize that short MVPA1-7 bouts relate to lower weight outcomes, net of recommended MVPA8+ bouts and other confounding variables.

2. Methods

The National Health and Nutrition Examination Survey (NHANES) measures the health of the U.S. civilian noninstitutionalized population. In 2003-2006 those who could walk were given accelerometers (Actigraph 7164, LLC, Ft. Walton Beach, FL) to wear for a week,

following standard protocols (NHANES, 2004). We focus on adults age 18-64 in our analyses. We exclude adults age 65+ because of the more complicated relationships between BMI and health in older populations (Reynolds et al., 2005). We also exclude those with pregnancies, missing marital and educational data, with BMIs <18.5 or >60, or who did not meet accelerometer data standards, described below. The final sample size is 4,507--2,201 women and 2,306 men.

Variables and Measures

Outcome measures include clinically measured BMI (kg/m^2) and a categorical measure of overweight/obesity (healthy BMI vs. 25-60 BMI). For physical activity measures, we follow Troiano et al.'s (2008) processing of accelerometer data. This requires ≥2020 CPS for the MVPA threshold and four days of 10+ hours of accelerometer wear. Nonwear time is defined by ≥ 60 consecutive minutes of zero activity intensity counts, allowing for 1-2 minutes of <100 CPS. Wear time is defined by 24 hours minus nonwear time. . Some accelerometer data are discarded if units were out of calibration when returned or measured unlikely levels of activity (NHANES, 2006; Troiano et al., 2008).

We test two mutually exclusive physical activity measures: MVPA8+ and MVPA1-7 bouts. MVPA8+ bouts is the equivalent of what Troiano et al. (2008) called a modified 10-minute MVPA bout, which represents the recommended Centers for Disease Control and Prevention bouts. They are defined as ≥10 MVPA minutes that allow for interruptions of 1-2 minutes below threshold and are terminated by 3 minutes below the 2020 CPS threshold. MVPA1-7 minute bouts are > 1 MVPA minute but less than an MVPA8+ minute bout. Mean daily time in both bouts are calculated across all valid days.

Control variables based on past research on BMI (Strath et al., 2008) include age (in years), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanics, and other race/ethnicity), education (less than high school, high school, some college, and college graduate), marriage (married or cohabitating, other status), and self-reported poor health ("fair" or "poor" health versus "good", "very good", or "excellent" health) . We improve upon this model by controlling for other important predictors of weight: poverty status (below poverty level or not, Drewnowski and Specter, 2004), smoking (self-reported current smoking status,

Sisson et al., 2010), and total calories per day (continuous) based on 2-day dietary recalls (Hill et al., 2003). We also control for accelerometer wear time (Van Dyck et al., 2010).

Statistical Analyses

Analyses are conducted with SAS 9.2, including descriptive analyses (Surveymeans and Surveyfreq), linear regression for BMI (Surveyreg), and logistic regression for overweight/obesity (Surveylogistic). Diagnostic tests reveal no problematic levels of multicollinearity. Results with all control variables are presented in tables, but analyses without controls are also summarized in the text.

Past research has found significant gender differences in BMI determinants (Frank et al., 2008) Accordingly, statistical analyses are gender-specific. Analyses correct for the complex sampling design of NHANES as recommended (NHANES, 2005). Sample weights are adjusted for combining 2003-2004 and 2005-2006, and for four days of valid accelerometer wear.

3. Results and Discussion

Individuals achieve substantially more MVPA in shorter duration bouts than the recommended MVPA8+ bouts, with very short 1-2 minute bouts especially prevalent (Figure 1). Males are physically more active than females (Table 1), Males accrue longer mean daily minutes in MVPA1-7 bouts (27.04 daily minutes for males vs. 14.49 daily minutes for females) and MVPA8+ bouts (8.99 daily minutes for males vs. 6.71 daily minutes for females).. Additional frequency analyses (not shown) reveal that 52% of females have only MVPA1-7 bouts, compared with 39% of males. About 48% of females have non-zero values in both MVPA1-7 bouts and MVPA8+ bouts, compared with 61% of males.

[Insert Figure 1 and Table 1 about here]

For women, the regression without control variables shows that each average daily minute spent in MVPA bouts has a BMI point reduction of -0.08 for MVPA1-7 bouts and -0.04 for MVPA8+ bouts. When all control variables are added (Table 2), the BMI point reductions shrink to -0.05 for MVPA1-7 bouts but remain at -0.04 for MVPA8+ bouts. Thus after controlling for other factors, each average daily minute spent in MVPA has the equivalent calorie offset of 3.5 lbs for MVPA1-7 bouts and 2.3 lbs for MVPA8+ bouts, for a 5’6” woman.

This means when two 5'6" women are compared, holding other things equal, including caloric intake, the woman who engages in one more minute of MVPA1-7 each day weighs 3.5 lbs less than the other woman, while engaging in one more minute of MVPA8+ leads to an additional 2.3lbs less weight.

[Insert Table 2 about here]

For men, the results are similar, but with smaller magnitudes of effects. Without controlling for other factors, one MVPA minute has a BMI point reduction of -0.05 for MVPA1-7 and -0.03 for MVPA8+. After adding control variables, the BMI point reductions shrink to -0.04 for MVPA1-7 but remain at -0.03 for MVPA8+.This equals a 2.7 lbs calorie offset per daily minute of MVPA1-7 and 2.0 lbs for MVPA8+, for a 5'10" man. This means when two 5'10" men are compared, holding other things equal, the man who engages in one more minute of MVPA1-7 each day weighs 2.7 lbs less . In addition, if the man also engages in one more minute of MVPA8+ each day, he weight an additional 2.0 lbs less.

Absent controls, the logistic regressions indicate that both MVPA1-7 and MVPA8+ are associated with a significantly lower probability of overweight/obesity, for males and females. However, when all control variables are added, MVPA1-7 is associated with a significantly lower probability of overweight/obesity for males, but not females (see Table 3). Net of controls, each daily minute in MVPA1-7 bouts is associated with 0.8% lower odds of being overweight/obese for men. Each daily minute in MVPA8+ bouts is associated with 2.1% and 0.8% lower odds of overweight/obesity for women and men, respectively. Thus, our analyses suggest that shorter bouts are inversely related to BMI, but longer bouts may be more important for reducing the odds of being overweight/obese for women.

[Insert Table 3 here]

Briefly, the control variables confirm known patterns, albeit with some significance levels that vary by gender and weight measures. Table 1 shows that average BMIs are in the overweight range. Compared to women, men are more likely to be overweight/obese (71% vs. 61%), to smoke (27% to 20%) and to consume more calories per day (2,697 vs. 1,865). Tables 2 and 3 show that older age and poorer health relate consistently to higher BMI and overweight/obesity. Smoking and college degrees relate to lower BMI and overweight/obesity.

Less consistent effects emerge for marital status, other education categories, poverty, ethnicity/race, calories, and accelerometer hours of wear.

In comparison to Strath et al., our BMI results are similar for longer bouts but more powerful for shorter bouts. We find MVPA8+ bouts have effects of -0.04 and -0.03 for women and men, respectively, and Strath et al. found ≥10 MVPA bouts had effects of -0.04 for the combined gender data set. For MVPA1-7 bouts, we find effects of -0.05 and -0.04 for MVPA1-7 bouts for women and men, respectively, compared to -0.01 for Strath et al.'s MVPA nonbouts (1-9 minutes).

To further explore these differences we estimated models that more closely match Strath et al., by including adults ≥65, estimating with 2003-2004 data only, and eliminating some control variables. However, we are unable to duplicate their findings. We suggest our differences are likely due to our choice of MVPA definition and operationalizations. Our MVPA8+ definition is more relaxed than Strath et al.'s MVPA10+ definition, so it is unlikely that our larger MVPA1-7 coefficient results from shifting MVPA10+ minutes to MVPA1-7. Furthermore, Figure 1 shows that few minutes are spent in the 8-10 minute bout range that differentiates our two bout measures. We suspect the substantial increase in the accelerometer CPM required for the MVPA threshold accounts for the difference. Strath et al. used 760 CPM but we use 2020 CPM, suggesting that higher intensity short bouts are needed to see our stronger associations with lower BMIs.

Further analyses reveal that MVPA1-7 drops from a significant direct predictor of female overweight/obesity to an insignificant predictor once individual age is controlled, indicating complex relationships among overweight/obesity status, MVPA1-7 and gender that warrants future research.

4. Conclusions

In this study we consider the question whether shorter than recommended bouts of MVPA relate to healthier BMIs, even after controlling for the longer recommended bout lengths and many other confounds. Our answer is a solid "yes," in that every daily minute spent engaging in moderate to vigorous physical activity, in either 1 to 7 minutes or 8+ minutes, is associated with lower BMI for both men and women.

Moreover, our results show that every minute in MVPA1-7 bouts is just as beneficial to BMI, if not more beneficial, compared with every minute in MVPA8+ bouts. When two 5'6" women are compared, the one who engages in one more minute of MVPA in 1-7 minute bouts per day is 3.5 lbs less than the other woman, holding other things equal. When two 5'10" men are compared, the one who engages in one more minute of MVPA1-7 per day is 2.7 lbs less than the other men, holding other things equal. Every minute of MVPA1-7 also relates to lower overweight/obesity risk for men, but not for women.

The question of whether MVPA1-7 bouts relate to health is important for prevention efforts. Longer bouts take more deliberate efforts. Although the 1995 CDC/ACSM MVPA guideline of accruing 8-10 minute bouts to 30 or more MVPA minutes on 5/7 days per week has demonstrable health benefits, the reality is that less than 4% of U.S. adults aged 20-59 achieve this guideline (Troiano et al., 2008). If individuals understand that short bouts support healthier BMI, they may be encouraged to weave them into their daily routines.

We acknowledge study limitations and strengths. The cross-sectional data limit our ability to determine cause and effect. In addition, although objective accelerometer measures of MVPA are better than self-report, they do not measure the intensities of some activities, such as swimming. Also, we focused on BMI-related measures, not other health outcomes. Nevertheless, our study utilizes a nationally representative sample and updated MVPA measures, with an extensive list of appropriate control variables. As such, we have more confidence than before that physical activity in bouts shorter than MVPA8+ is related to lower BMI.

In sum, the public health implication from our research is: "Every minute counts!" And every minute counts in a substantial manner. The results support public health and clinical recommendations to make small life-style changes such as taking stairs instead of elevators, or parking further for a longer walk to work or shopping. If done on a regular basis, such MVPA activities are consistent with lower BMI. Although long durations of exercise are beneficial to health, these data show that small but brisk steps are just as beneficial to BMI.

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Figure 1. Average bout time per day by bout length and gender, NHANES 2003-2006

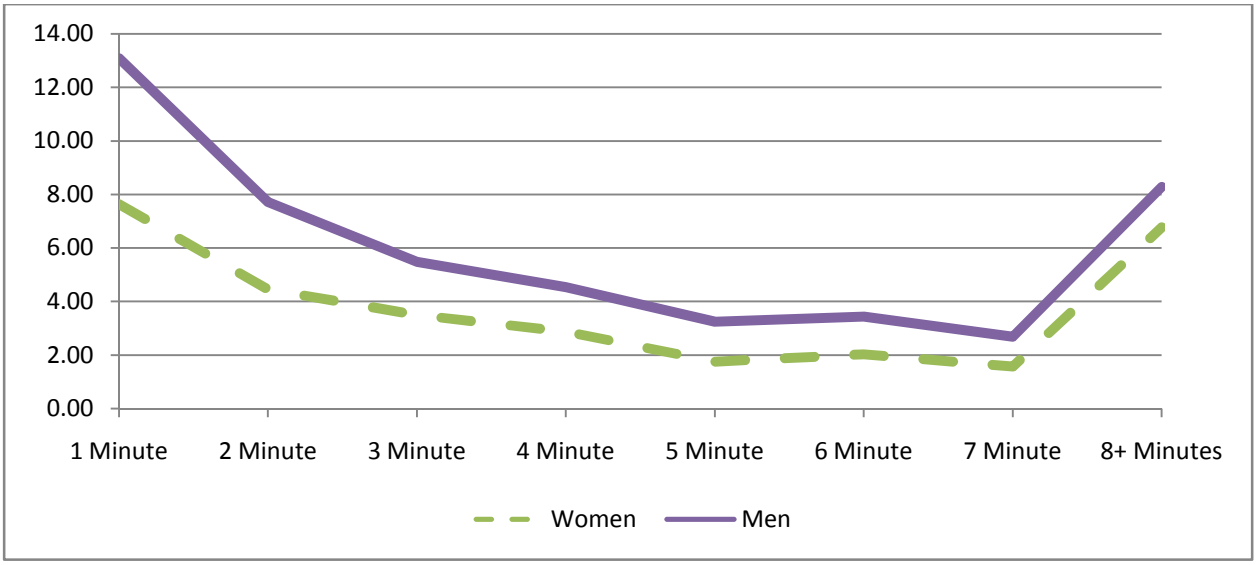

Table 1. Weighted descriptive statistics by gender for NHANES 2003-2006

	Females (n=2201)		Males (n=2306)	
Variable	Mean/%	Std Err.	Mean/%	Std Err.
BMI	28.45	0.25	28.23	0.19
Overweight/Obese (%)	60.90%	1.66%	70.93%	1.46%
MVPA1-7	14.49	0.38	27.04	0.53
MVPA8+	6.71	0.54	8.99	0.47
Age	40.82	0.37	40.01	0.41
Married (%)	63.23%	1.44%	68.93%	1.75%
Less than high school (%)	12.11%	1.04%	15.54%	1.12%
High school graduate (%)	23.59%	0.96%	26.39%	1.13%
Some college (%)	36.82%	1.44%	32.16%	1.18%
College graduate (%)	27.48%	1.77%	25.91%	1.83%
White (%)	68.72%	2.51%	70.51%	2.20%
Black (%)	13.16%	1.60%	11.31%	1.47%
Hispanic (%)	12.30%	1.33%	13.06%	1.48%
Other race (%)	5.81%	0.84%	5.13%	0.69%
Below poverty (%)	11.36%	0.98%	10.69%	0.74%
Daily calories (in 100 cal)	18.65	0.14	26.97	0.20
Smoker (%)	20.31%	1.03%	26.62%	1.16%
Poor/fair health (%)	13.59%	0.94%	11.82%	0.71%
Hours of wear	84.02	0.48	86.51	0.52

Note. NHANES is the National Health and Nutrition Examination Study. BMI is body mass index. MVPA is moderate to vigorous physical activity, measured by accelerometer.

Table 2. Relationship of short and long MVPA bouts to BMI in NHANES 2003-2006: Regression results by gender

	Females (n=2,201)			Males (n=2,306)		
Parameter	Estimate	Std. Err.		Estimate	Std. Err.	
Intercept	26.62	1.11	***	29.91	0.79	***
MVPA1-7	-0.05	0.02	***	-0.04	0.01	***
MVPA8+	-0.04	0.01	**	-0.03	0.01	***
Age	0.07	0.01	***	0.04	0.01	***
Married	-0.45	0.52		0.90	0.33	***
Less than high school	-0.04	0.62		-0.67	0.55	
Some college	-0.16	0.42		-0.37	0.38	
College graduate	-1.85	0.44	***	-1.08	0.38	***
Black	2.38	0.44	***	0.67	0.42	
Hispanic	-0.42	0.51		0.15	0.36	
Other race	-2.99	0.60	***	-1.13	0.70	
Below poverty	0.91	0.57		-1.52	0.33	***
Daily calories (in 100 cal)	0.06	0.03	*	0.00	0.02	
Smoker	-1.24	0.40	***	-1.55	0.25	***
Poor /fair health	2.19	0.58	***	2.27	0.42	***
Hours of wear	-0.01	0.01		-0.02	0.01	***
Adj. R-squared	0.105			0.113		

*** $p < .01$
** $p < .05$
* $p < .10$.

Table 3. Relationship of short and long MVPA bouts to overweight/obesity in NHANES 2003-2006: Logistic regressions by gender

	Females (n=2,201)				Males (n=2306)			
Parameter	Odds-Ratio	95% CL			Odds-Ratio	95% CL		
MVPA1-7	0.991	0.978	1.005		0.992	0.985	0.998	***
MVPA8+	0.979	0.964	0.993	***	0.992	0.985	0.999	**
Age	1.026	1.017	1.035	***	1.033	1.022	1.047	***
Married	1.119	0.887	1.412		1.550	1.155	2.097	***
Less than high school	1.095	0.745	1.609		0.714	0.446	1.020	*
Some college	0.844	0.612	1.164		0.902	0.646	1.280	
College graduate	0.534	0.422	0.674	***	0.602	0.467	0.929	**
Black	2.746	2.070	3.643	***	1.469	0.996	1.956	**
Hispanic	1.169	0.810	1.687		1.606	1.043	2.124	**
Other race	0.370	0.234	0.583	***	0.776	0.364	1.416	
Below poverty	1.150	0.822	1.610		0.497	0.468	0.784	***
Daily calories (in 100 cal)	0.996	0.980	1.013		0.995	0.983	1.007	
Smoker	0.649	0.484	0.869	***	0.518	0.424	0.649	***
Poor /fair health	1.359	1.075	1.718	***	1.500	0.986	2.218	*
Hours of wear	1.002	0.997	1.008		0.994	0.988	1.001	*

*** $p < .01$
** $p < .05$
* $p < .10$.