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Using Fitness Trackers to Assess the Effects of Physical Activity and Sleep on BMI, Cardiovascular Function, and Salivary Glutathione Concentration

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ABSTRACT

Bolyard C, Adams J, McDade K, Sellers B, Allen C, Marshall S, Stover S. Using Fitness Trackers to Assess the Effects of Physical Activity and Sleep on BMI, Cardiovascular Function, and Salivary Glutathione Concentration. **JEPonline** 2015;18(4):1-9. Increasing exercise duration and frequency can result in excessive production of reactive oxygen and subsequent oxidation of reduced glutathione (GSH). Sleep deprivation can also induce oxidative stress, leading to increased GSH oxidation. It was hypothesized that chronic sleep deprivation and a sedentary lifestyle would have negative impacts on body mass index (BMI) and cardiovascular (CV) function. It was also hypothesized that GSH would be upregulated in response to increasing physical activity and sleep deprivation to neutralize the effects of reactive oxygen. Based on 3 months of data obtained from bracelet-embedded fitness tracking devices, 20 subjects were placed into minimum, moderate, and maximum activity groups as well as minimum, moderate, and maximum sleep groups. There were no significant differences between the 3 activity groups in terms of GSH concentration, indicating an upregulation of GSH in response to increased activity. BMI and heart rate decreased with increasing activity. There were no significant differences between the 3 sleep groups in terms of GSH concentration, which suggested an upregulation of GSH in response to sleep deprivation. There were also no sleep-related differences in BMI or CV function.

Key Words: Aerobic Exercise, Sleep Deprivation, Oxidative Stress

INTRODUCTION

The generation of reactive oxygen species (ROS) such as singlet oxygen, superoxide radical, and hydroxyl radical occurs as a consequence of normal cellular metabolism (31). ROS-associated molecular damage includes DNA strand breaks and single base modifications (10), oxidation of amino acid side chains and fragmentation of polypeptides (18), and the degradation of polyunsaturated fatty acids and phospholipids by lipid peroxidation (3). Neutralization of excess reactive oxygen is carried out by the body's endogenous antioxidant defense system, which includes enzymatic activity of superoxide dismutase (SOD), glutathione peroxidase (GPx), and glutathione reductase (GR), in conjunction with exogenous antioxidants consumed through diet (31). Oxidative stress may be defined as a condition in which the cellular production of reactive oxygen exceeds the body's physiological capacity to render reactive species inactive (3).

Reduced glutathione (GSH) plays a prominent role in the cellular defense against oxidative stress by scavenging ROS, both directly and as a substrate for GPx (9). Previous research has demonstrated that strenuous physical exercise can affect GSH homeostasis by decreasing its tissue concentration, disturbing its cellular redox status, and interfering with its synthesis and transport (13,30). Furthermore, studies suggest that endogenous cellular GSH is not sufficient to withstand the increased oxidation associated with vigorous exercise (14,17). Therefore, it would be beneficial to increase levels of cellular GSH to provide protection against exercise-induced oxidative stress. Such an increase in GSH concentration has been noted in liver (5), skeletal muscle (12), and saliva (4) in response to regular aerobic exercise.

Regular aerobic exercise promotes enhanced cardiovascular (CV) function and a healthy body weight (21,22), as indicated by decreases in heart rate (HR), blood pressure, and body mass index (BMI). The increase in oxygen uptake during aerobic exercise is accompanied by an elevation of ROS. Acute aerobic exercise generates reactive oxygen by creating a disturbance in electron transport that leads to excessive leakage of superoxide radicals (3). However, when a bout of exhaustive exercise is given to well-trained subjects, there is no elevation in oxidative damage (25). Subjects involved in regular exercise appear to produce lower levels of reactive oxygen than untrained individuals (26). Furthermore, long-term endurance training effectively reduces the damage associated with increased oxygen uptake by enhancing the body's antioxidant defenses. It has been demonstrated that GPx (5), GR (6), and SOD (7) activities increase in response to endurance training.

Sleep deprivation impairs memory (1), increases the cortisol stress response (34), and reduces athletic performance (32). It can also produce an increase in resting blood pressure (15). A decrease in SOD activity (29) and an increase in GSH oxidation (24) have been observed in patients with sleep apnea. Insomnia can also lead to oxidative stress. Recent studies indicate a significant increase in malondialdehyde, a biomarker for lipid peroxidation, in human subjects experiencing insomnia (10). Furthermore, studies using rat models have demonstrated increases in GPx activity, as well as GSH concentration, in response to sleep deprivation (27).

With the ever-increasing availability of fitness tracking devices, more and more people are able to personally monitor their daily activity levels, calories consumed, and sleep quality (16). The present study incorporated the use of fitness trackers, in conjunction with biochemical and physiological assessments, to determine the effects of activity level and sleep quality on BMI, CV function, and salivary GSH concentration. It was hypothesized that chronic sleep deprivation and a sedentary lifestyle would have negative impacts on BMI and CV function, and that GSH synthesis would be upregulated in response to increased physical activity or decreased sleep.

METHODS

Subjects

The Institutional Review Board of Davis & Elkins College approved this study. A total of 9 males (age 20 to 60) and 11 females (age 21 to 59) participated. Based on 3 months of activity data obtained from bracelet-embedded fitness tracking devices (Fitbit Flex, Fitbit Inc., San Francisco, CA), subjects were placed into 1 of 3 activity groups: (a) minimum activity (MIN-A); (b) moderate activity (MOD-A); and (c) maximum activity (MAX-A). Subjects in the MIN-A group (n=5) averaged fewer than 8,000 steps·d⁻¹. Subjects who were placed into the MOD-A group (n=9) took between 8,000 and 12,000 steps·d⁻¹. Subjects in the MAX-A group (n=6) averaged more than 12,000 steps·d⁻¹. Based on 3 months of sleep data obtained from the tracking devices, the 20 subjects were also placed into 1 of 3 sleep groups: (a) minimum sleep (MIN-S); (b) moderate sleep (MOD-S); and (c) maximum sleep (MAX-S). Subjects in the MIN-S group (n=4) slept less than 7 hrs·d⁻¹. Subjects in the MOD-S group (n=12) slept between 7 and 8 hrs·d⁻¹. Subjects who were placed into the MAX-S group (n=4) slept more than 8 hrs·d⁻¹.

Data Collection

At the onset of the study, all subjects signed consent forms and agreed to fast and drink only water for at least 8 hrs prior to each sample collection. Each subject was given a bracelet-embedded fitness tracker and a brief tutorial on how to use it. Approximately one month later, each subject reported his/her current age and height. After rinsing with deionized water, each subject provided a 2 to 3 ml saliva sample, which was stored in a polypropylene centrifuge tube at -20°C until analyzed. Body weight, HR, and blood pressure for each subject were measured. BMI was determined by entering height and weight values into an online calculator provided by the National Heart, Lung, and Blood Institute (23). Fitness trackers were synced with a laptop computer, and the previous month's activity and sleep data were recorded for each subject.

Fasting saliva samples were collected twice more, at approximately 1-month intervals. All sample collections (including the initial one) took place between 8:00 a.m. and 10:00 a.m. Subjects were weighed, CV function was assessed via HR and blood pressure, and fitness tracker data were downloaded at the time of each sample collection.

Glutathione Assessment

500 µl of each subject's saliva was centrifuged at 3000 x g for 10 min. Supernatants were deproteinated with 5% metaphosphoric acid and centrifuged again at 1000 x g for 10 min. Resulting supernatants were reacted with 5,5'-dithiobis-2-nitrobenzoic acid (DTNB) at room temperature. DTNB combines with glutathione to generate a yellow product with maximal absorbance at 412 nm (Cuvette Assay for GSH/GSSG, Oxford Biomedical Research, Oxford, MI). All samples were analyzed spectrophotometrically, and GSH concentrations were calculated from the absorbance values using the following formula: $[GSH] = [(A - B) - b] \div a \times df$, where [GSH] is the µM concentration of GSH in the sample, A is the change in absorbance of the sample at 412 nm over 10 min, B is the change in absorbance of the blank (deionized H₂O) at 412 nm over 10 min, "a" is the slope of the GSH standard curve (standards were included in the assay kit), "b" is the intercept of the standard curve, and "df" is the dilution factor of the sample.

Statistical Analysis

Data were subjected to a multiple comparison analysis of variance (ANOVA). Fisher's least significant difference test was employed to compare specific groups in the ANOVA. An alpha level of P<0.05 was regarded as statistically significant. Data are expressed as mean ± standard error.

RESULTS

Physical Activity Effects

As indicated in Table 1, there were no significant differences between the 3 activity groups in terms of GSH concentration, systolic blood pressure (SBP), and diastolic blood pressure (DBP). BMI decreased with increasing activity, with the MAX-A group having a mean BMI significantly lower than that of the MIN-A group. HR also decreased with increasing activity. The MAX-A HR was significantly lower than the MIN-A HR. Within each group, there were no gender- or age-related effects.

Table 1. Effects of Physical Activity on GSH, BMI, and CV Function.

Activity Group	GSH (μM)	BMI	HR (beats·min ⁻¹)	SBP (mm Hg)	DBP (mm Hg)
MIN-A (n=5)	3.58 \pm 1.1	29.7 \pm 0.8	72.5 \pm 2.0	115.5 \pm 1.5	77.9 \pm 1.5
MOD-A (n=9)	3.92 \pm 0.7	25.7 \pm 0.8	67.8 \pm 2.4	118.5 \pm 1.1	78.2 \pm 0.8
MAX-A (n=6)	5.58 \pm 1.1	23.2 \pm 0.4*	57.6 \pm 1.6*	115.6 \pm 1.5	74.7 \pm 1.8

BMI, Body Mass Index; GSH, Reduced Glutathione; HR, Heart Rate; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; Data are presented as mean \pm standard error. *Significantly different from MIN-A values ($P < 0.05$).

Sleep Effects

As indicated in Table 2, there were no significant differences between the 3 sleep groups in terms of GSH concentration, BMI, HR, SBP, and DBP. Within each group, there were no gender- or age-related effects.

Table 2. Effects of Sleep on GSH, BMI, and CV Function.

Sleep Group	GSH (μM)	BMI	HR (beats·min ⁻¹)	SBP (mm Hg)	DBP (mm Hg)
MIN-S (n=4)	3.15 \pm 1.4	24.7 \pm 0.3	61.3 \pm 4.1	120.8 \pm 2.2	77.8 \pm 1.8
MOD-S (n=12)	4.79 \pm 0.7	25.6 \pm 1.3	65.0 \pm 3.1	116.1 \pm 1.5	76.6 \pm 1.7
MAX-S (n=4)	4.00 \pm 1.1	27.3 \pm 2.3	71.8 \pm 4.5	115.8 \pm 3.2	78.3 \pm 1.1

BMI, Body Mass Index; GSH, Reduced Glutathione; HR, Heart Rate; SBP, Systolic Blood Pressure; DBP, Diastolic Blood Pressure; Data are presented as mean \pm standard error. There were no statistically significant differences between the 3 groups.

DISCUSSION

Physical Activity Effects

The American Heart Association recommends 10,000 steps-d⁻¹ for a heart-healthy lifestyle (2). Previous studies (21,22) report significant increases in CV function (as indicated by lowered HR and blood pressure), as well as significant decreases in BMI, in response to regular aerobic exercise. Results of the current study are in partial agreement. While there were no significant blood pressure differences between the 3 activity groups (Table 1), the average HR of the MAX-A group (where subjects were getting more than 12,000 steps-d⁻¹) was significantly lower than that of the MIN-A group (where subjects were getting fewer than 8,000 steps-d⁻¹). Furthermore, the average BMI of the MAX-A, MOD-A, and MIN-A groups was 23.2, 25.7, and 29.7, respectively (Table 1). According to the National Heart, Lung, and Blood Institute (23), a BMI less than 18.5 indicates that an individual is underweight, a BMI between 18.5 and 24.9 represents a normal weight, a BMI between 25 and 29.9 indicates that an individual is overweight, and a BMI of 30 or higher represents obesity. On average, the subjects in the MAX-A group exhibited healthy body weights, while those in the MOD-A and MIN-A groups exhibited average BMIs in the overweight range. It should be noted that the accuracy of BMI is limited, particularly for males in the intermediate BMI ranges, as lean muscle mass is not taken into account (28). The fact that there were no significant differences between salivary GSH concentrations in the 3 activity groups (Table 1) is noteworthy. Because oxidation of GSH will increase as exercise duration and frequency increases (14,17), these results suggest an upregulation of GSH synthesis, or an increased reduction of oxidized glutathione, as a response to the elevated exercise rigor in the MOD-A and MAX-A groups.

Sleep Effects

According to the National Heart, Lung, and Blood Institute (23), the optimal amount of sleep needed at night to “perform adequately, avoid a sleep debt, and not have problem sleepiness during the day” is between 7 and 8 hrs for adults. However, sleep needs vary from person to person. Some individuals may require as few as 6 hrs-d⁻¹ or as many as 10 hrs-d⁻¹. Results of the current study demonstrated no significant differences in BMI, CV function, or GSH concentration between the 3 sleep groups (Table 2). The lack of significant differences between salivary GSH concentrations in the 3 groups may indicate an upregulation of GSH in response to sleep deprivation. However, it is also possible that the MIN-S group did not really represent sleep deprivation. The average amount of sleep in the group was 6 hrs-d⁻¹. The sample size was also rather small (n=4), as most of the study’s volunteers exhibited healthy sleeping schedules. While variations in sleep quality or quantity can be age-related (23), there were no age-related effects within the 3 sleep groups in the current study.

There were no subjects exhibiting minimum activity in conjunction with minimum sleep. There was one individual (subject D3) who exhibited both maximum activity and maximum sleep. However, subject D3’s BMI, CV, and GSH values were not significantly different from those of other subjects in the MAX-A and MAX-S groups.

Effectiveness of Fitness Trackers

A pedometer is a portable device that counts the steps a person takes by detecting motion of the hands or hips. According to the American Heart Association (2), a pedometer step count is much more accurate than a physical activity self-report in terms of predicting weight loss. A sleep actigraph is a wrist-worn device that can be used to assess an individual’s sleep/wake behavior. Although a previous study has suggested that actigraphy is prone to overestimating sleep in certain individuals (11), it can still provide useful information about sleep in the natural sleep environment (20). The Fitbit Flex uses a 3-dimensional accelerometer to track steps, distance, calories burned, and active

minutes. It also monitors how long and how well you sleep (8). It effectively combines the functions of a pedometer and a sleep actigraph in a single wrist-worn device.

The primary advantage of using fitness trackers in this type of study is the accuracy of the data they provide. Previous research indicates that self-reporting of physical activity may result in biased estimates of moderate-to-vigorous activity (35). Furthermore, even though actigraphy may be prone to overestimating sleep, self-reporting of sleep quality and quantity is even more unreliable (33). An additional benefit of the fitness tracking device is the motivation it may provide to its user. The science news website LiveScience gave the Fitbit Flex a favorable review because the “wirelessly connected app provides a lot of data to allow you to work toward your goals and monitor your progress” (19). In an informal interview following the final data collection, participants in the current study were asked if they were motivated by data provided by the tracking device. Sixteen of the 20 participants answered in the affirmative, and several subjects actually purchased their own fitness trackers following the study.

CONCLUSIONS

Based on results of the current study, increasing physical activity can have a positive effect on both BMI and HR. Taking more than 12,000 steps·d⁻¹ significantly decreased both variables. Furthermore, the enhanced CV function and healthy body weight associated with increased activity were accompanied by an upregulation of GSH to compensate for any oxidative stress. Results of the study also suggest that sleeping less than 7 hrs·d⁻¹ or more than 8 hrs·d⁻¹ has no effect on CV function, BMI, or GSH concentration. However, more data will be needed to confirm this assertion, as the sample sizes in the current study were quite small. Finally, the use of fitness trackers appears to be a viable method of data collection. Trackers are much more accurate than self-reporting, and the data they generate can provide motivation for individuals interested in monitoring their health and fitness.

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