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Does a single bout of exercise influence subsequent physical activity and sedentary time in overweight boys?

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HIGHLIGHTS

- Our finding is in agreement with the "activitystat" hypothesis.
- An exercise bout reduces the subsequent moderate and vigorous physical activities.
- An exercise session promotes an increase on sedentary time on the following days.

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ABSTRACT

Objective: To assess the influence of a single bout of exercise on subsequent physical activity and sedentary time among overweight boys.
Methods: A crossover study on 24 overweight boys (11–13 years old) was conducted with three different experimental sessions: control, one bout of moderate exercise, and one bout of vigorous exercise. Physical activity was measured using triaxial accelerometers and time spent in light, moderate, vigorous, and sedentary activities was assessed during six days of follow-up. Differences in daily percentage of time spent in sedentary, light, moderate, and vigorous activities among experimental sessions were analyzed using linear mixed-effect models.
Results: Time spent in sedentary behavior was greater after moderate and vigorous sessions compared to the control, with statistically significant differences in trajectories between moderate ($p = 0.04$) and vigorous sessions ($p = 0.006$) compared to controls. Similarly, the time spent in moderate physical activity was smaller after moderate ($p = 0.02$) and vigorous sessions ($p = 0.02$) compared to the control. No differences in sedentary ($p = 0.50$) and moderate ($p = 0.97$) activities were observed between moderate and vigorous sessions. The percentage of time spent in vigorous physical activity showed a greater reduction in vigorous condition compared to moderate and control ($p < 0.01$) conditions, while time spent in light physical activities was not different between sessions.
Conclusions: Our results indicate a compensatory effect after a single bout of exercise due to decreases in moderate and vigorous physical activity and increases in sedentary time during the following six days.

1. Introduction

The prevalence of obesity in adolescents has been increasing in the last few decades [1]. In this context, physical activity and sedentary behavior have become major focal areas in obesity research [2–5].

Physical exercise has been recognized as an important modifiable lifestyle in obesity prevention programs, mainly due to its effects on energy expenditure [6,7]. Conversely, sedentary lifestyle, characterized as any activity that requires very low energy expenditure (≤1.5 METs), such as watching TV or the use of computers, is a risk factor for developing obesity [8–10].

Guidelines for physical activity recommend that children and adolescents engage in at least 60 min of moderate to vigorous physical activity per day for the prevention of obesity and other chronic diseases [11,12]. However, interventions focused on physical activities have

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shown conflicting results related to obesity, both in short- and long-term assessments [13,14].

One possible explanation for this controversy is the "activitystat" hypothesis, which suggests that increased physical activity in one moment is compensated with less subsequent physical activity, thereby maintaining a total physical activity set point [15]. Although this phenomenon has been demonstrated in several studies [16], other researchers have not confirmed this hypothesis [17,18]. Furthermore, it is still extensively debated in the literature [19].

In a recent report published by our group, a single bout of aerobic exercise resulted in a decrease in spontaneous physical activity energy expenditure among overweight adolescents during six days of follow-up after the exercise [20]. However, this information is not sufficient to understand the underlying behavioral mechanisms of such compensation. This decline in spontaneous physical activity energy expenditure can be explained through a reduction in physical activity, an increase in sedentary time, or both.

Therefore, the aim of the present study is to assess the influence of a single bout of exercise on the subsequent time spent in sedentary, light, moderate, and vigorous activities among overweight boys. We hypothesized that the reduction in spontaneous physical activity energy expenditure observed under exercise conditions during the six days of follow-up was due to a reduction in moderate and vigorous physical activities.

2. Materials and methods

The present study is a secondary analysis of a crossover study designed to determine the effect of different exercise intensities on spontaneous physical activity energy expenditure in overweight adolescents. The order of conditions in the crossover study was block randomized. The full description and the results have been published elsewhere [20].

All overweight or obese adolescent boys enrolled in the 6th and 7th grade of a public school in Niteroi (Rio de Janeiro, Brazil) were invited to participate. Female subjects were not included because the hormonal changes across the menstrual cycle can influence energy balance [21]. Therefore, as we sought to understand a complex phenomenon, a homogeneous sample was potentially more reliable for answering our research question.

Adolescents were classified according to the World Health Organization parameters for age and sex [22].

Written informed consent was obtained from all participants before the beginning of the study. The study was approved by the Research Ethics Committee of the Institute of Social Medicine of the State University of Rio de Janeiro (CAAE 34715814.2.0000.5260).

2.1. Intervention

The intervention protocol consisted of three conditions (control, moderate and vigorous exercise), with intervals of at least 21 days between exercise sessions.

In the control condition, the adolescents were equipped with an accelerometer to assess physical activity energy expenditure over six days. No specific physical training protocol was used.

The exercise sessions were divided into three phases: warm-up (2 min and 30 s), training (55 min) and cool-down (2 min and 30 s). During the warm-up and the cool-down phases, the adolescents were requested to walk at low-intensity (below or at 64% of maximum heart rate). These phases were similar for moderate and vigorous conditions.

The training phase in the moderate condition was characterized by 4 sets of 10 min of walking at moderate intensity (64% to 76% of maximum heart rate), with 5 min of light walking (below 64% of maximum heart rate) for recovery between sets. The training phase in the vigorous condition was characterized by 4 sets of 10 min of running at vigorous intensity (77% to 95% of maximum heart rate), with 5 min of light walking (below 64% of maximum heart rate) for recovery between sets.

Adolescents were blinded to the order of the sessions. A trained exercise physiologist supervised all exercise sessions and the target heart rate was controlled using heart rate monitors.

2.2. Measurements

2.2.1. Anthropometric

Body weight was measured using a portable electronic scale (Tanita BC-558 Japan) with a 150 kg capacity and 50 g precision. Height was measured using a portable stadiometer (Alturexata, Brazil) with an amplitude of 200 cm and variation of 0.1 cm. Anthropometric measures were analyzed by *Z*-scores of BMI for-age and gender from the World Health Organization distributions (WHO) [23]. Nutritional status was classified according to WHO-recommended cutoffs [22].

2.2.2. Physical activity and sedentary time

Physical activity was measured by triaxial accelerometers (Actical—Phillips—Respironics, Oregon, USA) [24] positioned on the right hip. The accelerometer was placed immediately before sessions on the same day and time for all conditions (control, moderate and vigorous) and removed after six days. Participants were instructed to keep their routine and to wear the monitor during the entire period (waking and sleeping hours), except during water activities.

Based on kcal values, time spent in light, moderate, vigorous and sedentary activities were calculated using Actical default software parameters [25] for each exercise condition. The cut-off point for moderate to vigorous physical activity intensity was defined at 0.100 kcal/min/kg, while that for light to moderate physical activity intensity was at 0.040 kcal/min/kg. The percentage of time spent in sedentary activity was calculated including sleep period.

The criteria used to define the non-use time were either sixty consecutive minutes of zero counts or sixty consecutive minutes of zero energy expenditure. Non-valid days were defined as the days in which non-use time was >14 h. Individuals were excluded from the analysis of the day if they failed to provide a minimum 10 h of valid data [26].

2.3. Data analyses

Percentage of time spent in physical activity categories and in sedentary behavior was calculated based on the time spent in each category (light, moderate, vigorous and sedentary behavior) per day, in minutes, divided by the total time on each day (e.g. 24 h × 60 min), in minutes, multiplied by 100.

Differences in daily percentage of time spent in sedentary, light, moderate and vigorous activities between conditions (control, moderate and vigorous) were analyzed using linear mixed-effect models, which account for correlations between repeated measures over time. Sedentary, moderate and vigorous models incorporated a quadratic term (time × time), accounting for a non-linear change over time ($p < 0.05$). For the light category, the most parsimonious model included only time, condition and time × condition variables. Models of moderate and vigorous categories were adjusted for percentage of time spent in moderate and vigorous activities on the first day, respectively.

Residual analyses of all models were performed, and their distributions showed the adequacy of the fitted models. All analyses were performed using SAS 9.3 (Statistical Analysis System, USA).

3. Results

Twenty-four adolescent overweight boys (mean ± SD: age = 12.6 ± 0.95 years, height = 158.5 ± 10.13 cm, body mass = 60.9 ± 11.89 kg, body mass index = 24.0 ± 2.57 kg m^{-2}) participated in the study. All participants completed all three-crossover conditions.

Of the 144 days (6 days × 24 individuals) that were computed for each condition, there were three non-valid days for the control condition (one on the second day, one on the third day and one on the fourth day), 27 for the moderate exercise condition (one on the first day, seven on the second day, five on the third day, five on the fourth day, four on the fifth day and five on the sixth day) and 26 for the vigorous exercise condition (four on the second day, four on the third day, four on the fourth day, seven on the fifth day and seven on the sixth day). These values were excluded from the analysis. Additionally, a few individuals did not record data during the entire day. For each day, it was expected that each participant had to produce 1440 min of recorded data (60 min × 24 h); however, on the 1st and on the 6th days, for some individuals in the control condition, few minutes were not recorded (minimum time recorded was 1381 min).

Changes in the percentage of light, moderate, vigorous, and sedentary activities after six days of follow-up are shown in Table 1. The percentage of time spent in sedentary behavior was greater after moderate ($\Delta = +6.08$) and vigorous conditions ($\Delta = +4.30$) compared to the control condition ($\Delta = +1.52$), with statistically significant differences in the trajectories between control and vigorous conditions ($p = 0.006$) and between control and moderate conditions ($p = 0.04$). There were no differences in changes between percentage of time spent in moderate and vigorous conditions during the six days ($p = 0.50$) (Fig. 1A).

Changes in the percentage of time in light physical activities (Fig. 1B) were not different between conditions (control vs. vigorous, $p = 0.55$; control vs. moderate, $p = 0.681$; moderate vs. vigorous, $p = 0.34$).

Percentage of time spent in moderate physical activity was smaller after moderate ($\Delta = -5.43$) and vigorous conditions ($\Delta = -4.44$) compared to the control condition ($\Delta = -1.77$), with significant differences in the time trajectories between control and vigorous conditions ($p = 0.01$) and between control and moderate conditions ($p = 0.02$). However, no difference was observed between moderate and vigorous conditions ($p = 0.97$) (Fig. 1C).

Changes in percentage of time spent in vigorous physical activity showed a greater reduction in vigorous condition ($\Delta = -1.45$) compared to moderate ($\Delta = -0.42$) and control conditions ($\Delta = -0.08$) (Table 1), with significant differences between contr l and vigorous conditions ($p < 0.001$), control and moderate conditions ($p = 0.009$) and between moderate and vigorous conditions ($p < 0.001$) (Fig. 1C).

4. Discussion

The main finding of the present study was that a single exercise bout influenced the subsequent physical activities and sedentary time in overweight adolescents, with more time spent in sedentary activities and less time spent in moderate and vigorous physical activities.

Compensatory effects of physical activity on energy expenditure have already been reported in our recent paper [20], however, the behavioral pattern underlying such compensation was not addressed. To our knowledge, this is the first experimental study to examine the effect of moderate and vigorous exercise sessions on all subsequent physical activity intensity categories and sedentary time in adolescents.

Although, several papers have shown that sedentary behavior is an independent risk factor for adverse health outcomes [9,10,27,28] regardless of physical activity levels [29], this subject is still a matter of debate [30,31]. Thus, exploring sedentary behavior in the context of physical activity might be important and our study has shown that an exercise session promoted an increase in the percentage of time spent in sedentary behavior during the subsequent six days.

Most studies have focused only on compensatory changes of moderate to vigorous physical activity [16,17,32–35], but there are some observational studies that have also examined the compensatory effect on light-intensity physical activity and sedentary time in children and adolescents [36–38]. Ridgers et al. [36] assessed the association between time spent in different physical activity intensities and sedentary time on any given day and time spent in these activities on the following day, among children and adolescents aged 8–11 years. The authors found that every additional 10 min spent in moderate to vigorous physical activity was associated with less time in light and in moderate to vigorous physical activity on the following day [36]. Our study showed that a single bout of exercise reduced time spent in moderate or vigorous physical activities, from the second to the sixth days of follow-up but no effect on time spent in light physical activities was observed.

In contrast, two observational studies did not observe compensatory behavior. The one conducted by Baggett et al. [37] demonstrated that higher moderate to vigorous physical activity on a given day was associated with less sedentary time and higher levels of light physical activity. Additionally, moderate to vigorous physical activity was positively associated with moderate to vigorous physical activity on the following day [37]. Similarly, Sigmund et al. [38] showed that the participation of 9 to 11-year-old children in physical education classes promoted a

Table 1
Crude percentage of time (% time) spent in sedentary, light, moderate and vigorous physical activities (PA) and estimated changes from baseline (Δ).

	Day	1	2		3		4		5		6		
PA categories	Sessions	% time	% time	Δ	% time	Δ	% time	Δ	% time	Δ	% time	Δ	p-Value
Sedentary[a]	Control(n)	68.76	69.10	−1.21	66.77	−1.66	67.13	−1.35	69.61	−0.29	70.48	1.52	0.006‡
	Moderate(n)	66.97	69.16	2.62	72.81	4.53	70.31	5.75	75.95	6.27	71.76	6.08	0.042*
	Vigorous(n)	66.38	70.14	3.25	72.63	5.31	72.12	6.27	72.03	5.84	71.16	4.30	0.503#
Light[b]	Control	19.22	18.56	0.07	19.87	0.13	21.36	0.20	20.13	0.26	18.49	0.33	0.556‡
	Moderate	17.98	18.06	−0.07	17.59	−0.14	19.71	−0.21	16.60	−0.28	17.73	−0.35	0.681*
	Vigorous	17.90	16.66	0.25	17.68	0.51	18.86	0.76	18.50	1.02	18.39	1.27	0.344#
Moderate[c]	Control	11.90	12.04	0.08	13.17	−0.05	11.27	−0.41	10.18	−0.98	10.90	−1.77	0.015‡
	Moderate	14.44	12.61	−2.64	9.52	−4.51	9.83	−5.59	7.30	−5.90	10.41	−5.43	0.018*
	Vigorous	13.80	12.86	−2.48	9.56	−4.16	8.95	−5.05	9.26	−5.14	10.30	−4.44	0.971#
Vigorous[d]	Control	0.12	0.30	0.04	0.19	0.06	0.24	0.04	0.08	0	0.13	−0.08	<0.001‡
	Moderate	0.62	0.16	−0.24	0.08	−0.41	0.15	−0.49	0.15	−0.49	0.10	−0.42	0.009*
	Vigorous	1.92	0.34	−0.97	0.13	−1.59	0.08	−1.71	0.22	−1.71	0.15	−1.45	<0.001#

Number of individuals per day: control session (day 1 = 24; day 2 = 23; day 3 = 23; day4 = 23; day 5 = 24; day 6 = 24); moderate session (day 1 = 23; day 2 = 17; day 3 = 17; day4 = 19; day 5 = 20; day 6 = 19); vigorous session (day 1 = 24; day 2 = 20; day 3 = 20; day4 = 20; day 5 = 17; day 6 = 17).

a linear mixed effect model with time condition time* condition time*time time*time* condition.

b linear mixed effect model with time condition time* condition.

c adjusted for percentage of time of moderate activity on the 1st day.

d adjusted for percentage of time of vigorous activity on the 1st day.

‡ Control vs. vigorous.

* Control vs. moderate.

\# Moderate vs. vigorous.

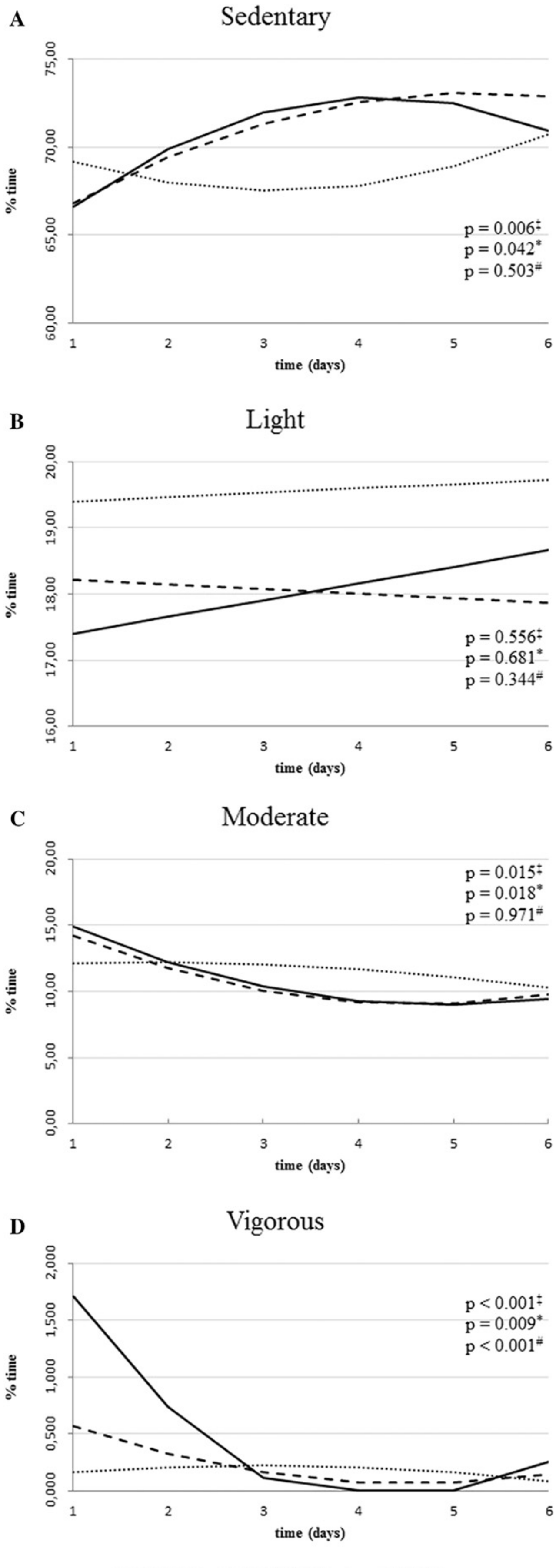

Fig. 1. Estimated mean values of percentage of time per day, for 6 days, monitoring for physical activity categories and sedentary behavior. ‡Control vs. vigorous; *control vs. moderate; #moderate vs. vigorous.

significantly higher overall daily light and moderate to vigorous physical activity compared to the day without exercise classes. In addition, participation in physical activity classes promoted a reduction in overall sedentary time [37].

The association between moderate to vigorous physical activity and sedentary time presented on these studies does not agree with our findings. Characteristics of this hypothesized compensation are unknown, however, one day may not be a sufficient period to observe the whole system adaptation. Our results showed that the increased sedentary time was observed only after the second day and lasted until the sixth day.

In our study, except for vigorous physical activity, exercise intensity was not different on the compensatory patterns for sedentary, light and moderate physical activity. Probably, the energy expenditure difference observed during exercise sessions between moderate and vigorous conditions (57 kcal) was not sufficient to promote different compensatory responses.

The relative outcome (percentage of time) did not allow the interpretation of the results in the context of health recommendations of physical activity and sedentary behavior. However, on day 5, e.g., the difference in sedentary time for the moderate condition, relative to the change in the control condition was about 6% (crude percentage time). This difference corresponded to an increase in 86 min for sedentary time in moderate condition compared to the control condition, for a total of 1440 min. Also in day 5, we observed that the difference in time spent in moderate physical activity for the moderate condition, relative to the change in the control condition was about −3%. This difference corresponded to a reduction of 43 min for moderate physical activity in moderate condition compared to the control condition. Therefore, the effect in terms of health outcomes may be important.

The main strength of this study is the use of an experimental design to investigate the behavior mechanisms underlying the compensatory effect, assessing all physical activities categories and sedentary time. Also, objective measurement of physical activity over a 6-day follow-up period was used. Accelerometer sensors have the advantage of capturing duration, intensity and frequency of physical activities in a time-stamped manner, providing more valid estimates of physical activity than questionnaires.

The present study has some limitations. First, the inclusion of only overweight boys makes it difficult to extrapolate our results to other populations. Second, the use of percentage of time instead of an absolute outcome (time) did not allow us to assess whether these reductions in moderate to vigorous physical activity and increases in sedentary time were clinically significant in the context of health, however, the maximum difference between the total possible time (1440 min) and measured time was low (only 58 min). Third, although sleep is not considered a sedentary activity, percentage of time spent in sedentary activity was calculated taking into consideration the sleep period because accelerometers could not distinguish accurately these activities. However, as we sought to investigate the effect of an exercise session on the subsequent behavior, the inclusion of sleep time in the category of sedentary activity should be appropriate. Finally, due to the order of the sessions, there was a difference of non-valid days observed between sessions, however, the analysis using linear mixed effect models can deal with the missing data.

In summary, our results indicate that a single exercise bout influence the subsequent physical activity and sedentary time among overweight adolescents. The increased physical activity in one moment promoted a decrease in moderate and vigorous physical activities and an increase in sedentary time, on the following six days. Despite the recognized benefits of physical activity, exercise may influence the subsequent sedentary time.

Further experimental researches are needed to 1) clarify the physical activity compensatory effect and the underlying mechanisms of this phenomenon; 2) the effect of different exercise intensities on the following spontaneous physical activities; 3) the effect of the number of training sessions; and 4) the differences between obese and non-obese individuals.

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Competing interests

The authors have declared that no competing interests exist.

Trial registration

ClinicalTrials.gov NCT 02272088.

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