Moderate Exercise and Bright Light Treatment in Overweight and Obese Individuals

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Abstract

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Objective: Increased physical activity is important given the concern over the growing rates of obesity. The aim of this study is to conduct a controlled investigation of the effects of bright light therapy and exercise on weight loss and body composition in overweight and obese individuals.

Research Methods and Procedures: Twenty-five overweight and obese subjects were assigned to 6 weeks of moderate exercise with or without bright light treatment. Outcome measure included changes in body mass and body composition and ratings of mood, seasonality, and sleep.

Results: Body weight decreased significantly with exercise in subjects in the light and non-light treatment groups, but the change was not significantly different between the groups. Similar results were found for BMI. With exercise, body fat decreased significantly only in the light treatment group. There was a significant effect of the interaction of group by time on body fat composition, but the group by time interaction failed to reach statistical significance for body weight and BMI. Mood scores improved significantly with exercise in the light group, but no significant changes were noted regarding sleep.

Discussion: This preliminary study is the first to show that addition of bright light treatment to a 6-week moderate exercise program can alter body composition by significantly reducing body fat. The reduction in body fat mass is of particular importance, because visceral fat has been particularly implicated as a major factor in the development of the metabolic syndrome. This study is an important step toward finding ways to maximize the effects of exercise.

Key words: body composition, exercise, overweight

Introduction

Obesity and overweight are growing worldwide phenomena of great concern for the World Health Organization (1). In Canada, the combined economic burden from obesity and lack of physical activity is close to 10 billion Canadian dollars, accounting for almost 5% of the total health care expenditure (2). There is the need to aggressively promote lifestyle intervention, especially exercise. Increased physical activity is associated with weight loss, healthier cholesterol and triglyceride levels, improved blood pressure, and a reduced risk of developing diabetes (3). Exercise programs for weight loss are not always successful because of dropout rates, complaints of discomfort during exercise, and an inability to control participants' eating during the program. Furthermore, achieving weight loss in overweight and obese individuals is difficult particularly when complicated by problems with anxiety and depression (4).

There is some indication that bright light therapy might enhance the effectiveness of physical activity for weight loss. Bright light exposure significantly reduced the binge-eating episodes in people with bulimia nervosa (5). In a double-blind study, bulimic women who received 3 weeks of winter bright light treatment also reported a reduced binge frequency between baseline and the active treatment period in comparison to subjects receiving dim red light (6).

There is also evidence that exposure to bright light modifies the processing of serotonergic stimuli in the circadian system (7). An increase in blood serotonin levels in healthy subjects has been noted after bright light treatment (8). Bright light exposure has been reported to have anti-depressant and energizing effects in patients with seasonal affec-

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tive disorder (SAD)[1] (9). Bright light treatment is an effective treatment for SAD (9) and has been shown to be slightly more effective than fluoxetine for the treatment of these patients (10). A recently published multicenter, randomized, controlled study showed that light therapy and the selective serotonin reuptake inhibitor (SSRI) anti-depressant fluoxetine have similar treatment effects in patients who have major depressive episodes with a seasonal pattern over longer treatment periods (11). When used for non-seasonal depressive disorder, patients treated with bright light therapy in addition to SSRI treatment had better outcome than those treated only with SSRIs (12).

Bright light therapy has also been found to be helpful for people with subsyndromal SAD. Individuals with subsyndromal SAD responded favorably to treatment with a dose of 5 hours of daily bright light exposure, divided between the morning and evening hours (13). In patients with subsyndromal SAD, the bright light resulted in a significantly greater reduction in depression ratings compared with dim light (14). Using bright light therapy in the workplace was effective in improving mood, energy, alertness, productivity, and quality of awakening (15).

The mechanism by which light may alter neurohumoral pathways is explained by neural pathways such as the retinohypothalamic tract that transmits neural information to the hypothalamus and suprachiasmatic nucleus (16,17). Direct projections from the retina to the dorsal raphe (18), a region rich in serotonergic neurons, account for the effect of bright light therapy on serotonin production.

In addition to its neurohumoral role in mood regulation, serotonin is one of the neurotransmitters involved in moderating food intake (19,20) and has been implicated as a controller of body weight by regulating energy balance (21). In humans, serotonergic agents are used therapeutically to control body weight in obese individuals by promoting decreased food intake (22,23). Appetite suppressants such as D-fenfluramine increase central serotonin levels (24), and pharmacological agents that selectively facilitate serotonin neurotransmission promote weight loss (25), whereas drugs that block serotonin transmission have the opposite effect (26). Ghadirian et al. (27) have proposed that seasonal affective disorder and bulimia share a common neurobiologic abnormality of serotonergic dysfunction. Disturbances of mood, appetite, and weight regulation are well documented in seasonal affective disorder (28–30).

Based on evidence of the link between bright light, serotonin, mood, and food intake, it has been suggested that bright light therapy can improve weight loss, but the literature on the subject is sparse. In a case report, an average weight loss of 1.5 to 2 kg was noted in three obese women after 6 weeks of 1 hour of bright light therapy without exercise (31). Another study of nine female subjects found that body mass loss after exercise was significantly greater after exposure to bright light therapy (32). These researchers also observed that the exercise-induced increases of core body temperature and the production of lactic acid were lower in the bright light condition. The discomfort from lactic acid build-up in muscles can significantly limit exercise performance, because blood lactate has been shown to be a major contributor to the perception of exertion and feelings of aches and pain during exercise (33). In turn, the perception of effort is one of the factors that limit exercise (34). These findings, albeit requiring more research, suggest that bright light may help to reduce the unpleasant side effects of exercise and thereby reduce dropout in exercise programs. However, further research is needed in this area.

Further evidence suggests a role for bright light treatment in the elevation of mood (35), increased vitality (36), and improved sleep (37) in non-depressed individuals. These factors are particularly important in maintaining motivation for an exercise program during the late fall, winter, and early spring months, when sunlight is reduced and when the colder weather promotes a more sedentary lifestyle.

Bright light therapy is unique in that it may have the potential to maximize the effects of a moderate exercise plan, impact carbohydrate metabolism, and reduce soreness. Bright light is considered the treatment of choice for SAD, but it may also have beneficial effects on mood in healthy subjects. Both aerobic exercise and administration of bright light have a positive effect on mood and health-related quality of life. This favorable effect was seen in those people who reported recurring seasonal symptoms but also in the people whose symptoms did not fulfill the criteria used for subsyndromal SAD. Combining physical exercise with bright light administration has beneficial effects on mood and health-related quality of life compared with physical exercise alone (35). A controlled study of the effects of bright light and exercise on weight loss and body composition in overweight and obese individuals has never been conducted.

Research Methods and Procedures

Overweight and obese male and female subjects were recruited for this study. Subjects had a body weight between 115% and 150% of normal body weight (38) for their sex, height, and age group. Ethics approval was granted by the University Health Network Research Ethics Board (REB 03–0184-BE). The eligibility of each subject was determined by a physician member of the team who conducted an interview and a physical examination on each study patient initially and the study coordinator who went over the inclusion and exclusion criteria with the study patients. Patients who were depressed (as determined by a psychia-

[1] Nonstandard abbreviations: SAD, seasonal affective disorder; SSRI, selective serotonin reuptake inhibitor; POMS, Profile of Mood States; CES-D, Centre for Epidemiological Studies in Depression; SPAQ, Seasonality Pattern Assessment Questionnaire; ESS, Epworth Sleepiness Scale; FIS, Fatigue Impact Scale.

trist member of the team) or had a history of untreated sleep disorders were excluded from the study. Follow-up assessment appointments were booked at the 3-week, 6-week, and 3-month points in the study. The study subjects were followed during each exercise day by the study coordinator to ensure that subjects exercised for the correct amount of time and at the appropriate level.

Recruited study subjects were assigned to one of two groups for this randomized, controlled, longitudinal study: 1) bright light treatment with exercise and 2) exercise without bright light. Bright light treatment (5000 lux) was provided using the lightweight, portable Litebook light therapy device (The Litebook Co., Alberta, Canada). Each study patient randomized to the bright light group received a lightbox for daily use over the 6-week period. On the days when they did not exercise, patients were instructed to use the lightbox for an hour each day, but this could be broken up into two 30-minute periods. On their exercise days, they were asked to use the lightbox for 30 minutes in addition to the 30 minutes of light exposure during exercise. In the gym, the device was mounted on the side panel of the stationary bikes ~18 inches from the patients' nasion. When not at the gym, subjects using the lightboxes were asked to again position them to the side ~18 inches from their face. Subjects randomized to the bright light condition were asked to use the lightboxes only during the hours of 9:00 AM to 2:00 PM to avoid any phase shifting of their circadian rhythms. Subjects in the non-bright light group were exposed to the normal indoor lighting conditions.

Study patients in the exercise-only group were asked to exercise three times per week for 6 weeks but were not given lightboxes. On days that they did not exercise, they kept their normal routine. This group served as a control group. Subjects were asked to consume their normal amounts of food during the 6-week period and to refrain from either dieting or bingeing.

A ruse was presented to study participants to distract them from the true purpose of the study, i.e., the effect of light on exercise and weight loss. Study subjects were told that the study was examining the effects of exercise and bright light treatment on sleep quality and fatigue. At the 6-week visit, the true purpose of the study was explained to both groups of study subjects.

Exercise Program

Study subjects were asked to cycle on one of three identical stationary bicycles (Star Trak Pro, Model 5430 GUSAP0; Star Trak, Irvine, CA) in the same fitness complex for 30 minutes for a period of 6 weeks, three times per week. Study subjects were asked to exercise in the morning or early afternoon, no later than 2:00 PM. The first 5 minutes of the exercise period were for stretching and warm-up, and the last 5 minutes for cool-down and stretches. For 20 minutes, subjects were instructed to cycle on the stationary bikes at a speed that produces a 65% heart rate reserve based on the maximum heart rate (39). For example, if the maximum heart rate is 180 beats per minute for a 40-year-old subject who has a resting heart rate of 80 beats per minute, the calculated exercise heart rate would be $(180 - 80) \times 0.65 = 65 +$ resting heart rate $= 145$ beats per minute. Maintenance of this exercise intensity was verified by a heart rate monitor attached to the exercise equipment. The study coordinator supervised the exercise sessions and checked heart rate readings.

Measurements

Weight, heart rate, blood pressure, BMI, and body fat composition measurements were taken at the initial study visit, at the end of the 6-week exercise program, and at the 3-month follow-up visit. Body fat composition was determined using bioelectrical impedance analysis (Tanita body fat analyzer, model TBF-305; Tanita Corp., Arlington Heights, IL). Study subjects were asked to complete the following subjective scales: mood, Profile of Mood States (POMS) (40) and Centre for Epidemiological Studies in Depression (CES-D) (41); seasonality, Seasonality Pattern Assessment Questionnaire (SPAQ) (29); sleepiness, Epworth Sleepiness Scale (ESS) (42); and fatigue, Fatigue Impact Scale (FIS) (43). The questionnaire battery was administered at the initial visit and at end of the 6-week exercise program.

Outcome Measures

The primary outcome measures were changes in body mass and body composition. Secondary outcome measures were the ratings of mood (POMS, CES-D, and SPAQ questionnaires) and of sleep and fatigue (ESS and FIS questionnaires).

Statistical Analysis

Statistical analysis was carried out using the SAS statistical software (version 8.2 of the SAS system for Windows; SAS Institute, Inc., Cary, NC). Sample means and standard deviation are presented. Univariate paired Student's t test and general linear model were used with variables showing normal distribution (Shapiro-Wilk test); otherwise, the Kruskal-Wallis test was used.

Results

Seventeen male and female subjects were randomized to the bright light group (13 women and 4 men), and 12 subjects (11 women and 1 man) were randomized to the non-bright light group. Twenty-five subjects completed the 6-week exercise program: 14 (10 women and 4 men) in the bright light group and 11 (10 women and 1 man) in the non-bright light group. The study started in late fall around the start of October and ended in early spring, no later than

Table 1. Numbers of subjects

		Start [N]	After 6 weeks [N (%)]	After 3 months [N (%)]	Data at all measurement stages [N (%)]
Weight, BMI, body	Bright light group	17	14 (82%)	8 (47%)	8 (47%)
fat data	Non-bright light group	12	11 (92%)	7 (58%)	7 (58%)
Completed questionnaire	Bright light group	14	8 (57%)	7 (50%)	5 (36%)
	Non-bright light group	12	11 (92%)	6 (50%)	6 (50%)

mid-April. The total numbers of subjects in each group at the various stages of the study are listed in Table 1.

Body Weight, BMI, and Body Fat Composition

No difference was found between body weight ($p = 0.816$) either initially or after the exercise in the bright light and non-bright light subject groups. Body weight decreased significantly from the start to the end of the 6-week program ($p = 0.033$) in both study groups, but the group (bright light vs. non-bright light) by time (start vs. after 6 weeks) interaction was not statistically significant (Table 2). Similar results were found with BMI, which was not significantly different in the bright light and non-bright light subjects at the outset. BMI decreased significantly after 6 weeks of exercise ($p = 0.031$) in both groups, but there was no significant difference in the changes in BMI between the two groups (Table 2). At the 3-month follow-up visit, after the bright light treatment was withdrawn, mean BMI increased from 30.2 ± 3.6 to 31.4 ± 3.7 kg/m^2 in the bright light group and decreased from 30.3 ± 4.2 to 29.1 ± 3.5 kg/m^2 in the control subjects; however, the number of the participants was too small, strongly limiting any further analysis.

Body fat composition was initially similar for both groups, but after the 6-week period, a difference was found in the bright light and non-bright light groups ($p = 0.034$). There was a significant effect of the interaction of group by time on body fat composition ($F = 5.11$, df = 1, $p < 0.034$). Univariate paired Student's t test analyses revealed that, for those in the bright light group, body fat declined significantly from 41.3 ± 12.6% to 39.2 ± 11.9% ($p = 0.03$) with exercise, whereas no changes occurred with exercise in the non-bright light group (42.3 ± 4.7% to 42.9 ± 6.4%; Table 2; Figure 1A). Limiting the key body fat change interaction to women did not alter the results. For women in the bright light group ($n = 13$), total body fat decreased from 44.5 ±

Table 2. Body weight, BMI, and body fat composition

	Bright light group	Non-bright light group	ANOVA
Body weight (kg)			$F = 5.15$, df = 1/23, $p = 0.033$
Start	81.0 ± 10.7	81.7 ± 11.3	
After 6 weeks	79.9 ± 10.7	81.2 ± 11.7	
After 3 months	80.0 ± 7.5	79.0 ± 8.2	
Time-bright light interaction	$F = 0.79$, df = 1, $p = 0.38$		
BMI (kg/m^2)			$F = 0.79$, df = 1/23, $p = 0.031$
Start	30.6 ± 3.7	30.5 ± 4.2	
After 6 weeks	30.2 ± 3.6	30.3 ± 4.2	
After 3 months	31.4 ± 3.7	29.1 ± 3.5	
Time-bright light interaction	$F = 0.66$ df = 1 $p = 0.42$		
Body fat composition (%)			$F = 1.43$, df = 1/23, $p = 0.247$
Start	41.3 ± 12.6	42.3 ± 4.7	
After 6 weeks	39.2 ± 11.9	42.9 ± 6.4	
After 3 months	40.1 ± 14.1	43.3 ± 8.9	
Time-bright light interaction	$F = 5.11$, df = 1, $p = 0.034$		

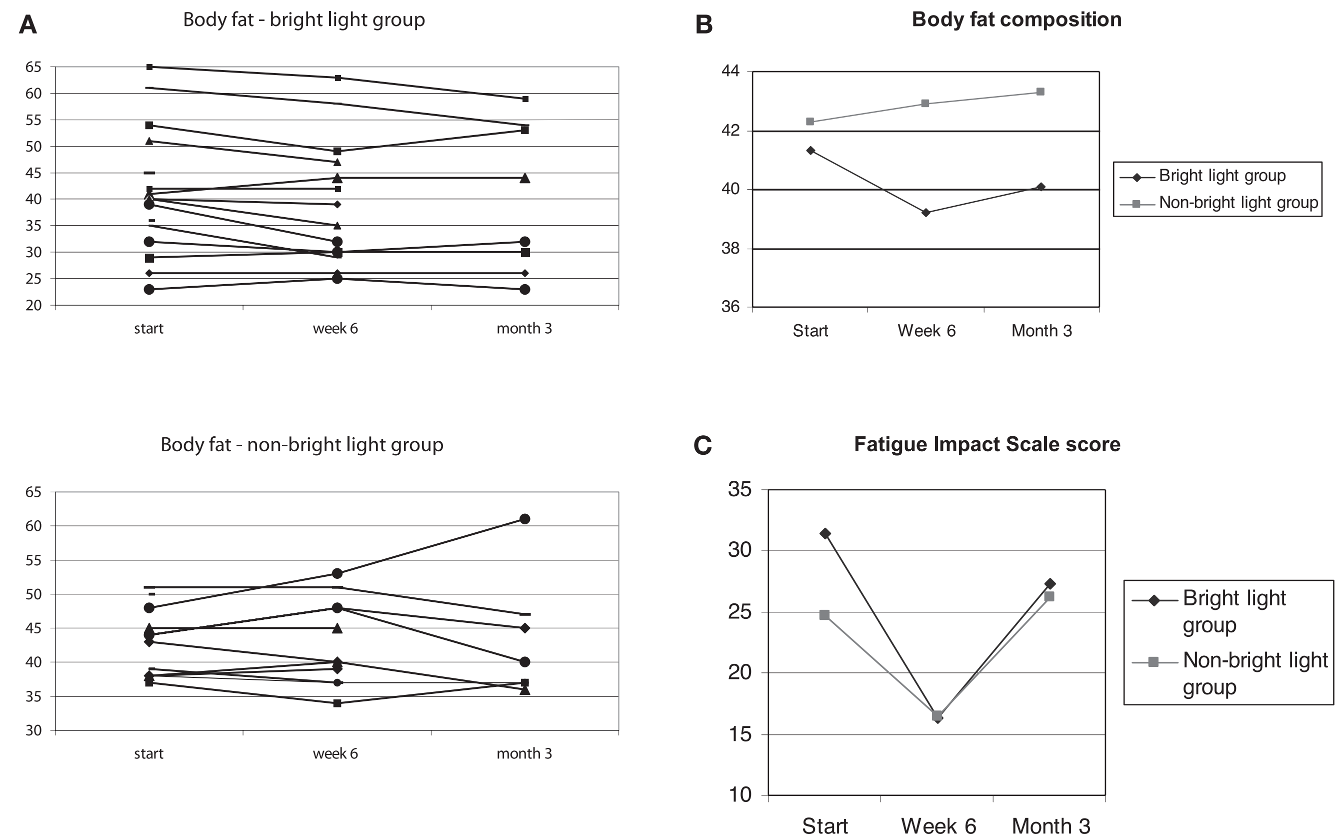

Figure 1: (A) Changes in individual measurements of body fat composition at baseline and after 6 weeks and 3 months. (B) Body fat composition in the bright light group and the non-bright light group at baseline and after 6 weeks and 3 months (time-light interaction: $F = 5.11$, df = 1, $p < 0.034$). (C) FIS score in the bright light group and the non-bright light group at start and after 6 weeks and 3 months (time-light interaction: $F = 0.01$, df = 1, $p = 0.93$.

10.4 to 43.6 ± 11.2 kg ($p < 0.03$), whereas those in the non-bright light group ($n = 11$) did not show a significant change (43.3 ± 5.0 to 43.5 ± 6.4 kg).

Mood and Sleep

Analysis of ratings of mood showed significant changes in the CES-D and SPAQ scores with exercise and exposure to bright light. The CES-D score dropped significantly after 6 weeks in the bright light group (from 15.6 to 8.8; mean difference, 4.3; $p = 0.03$), whereas there was no comparable change in the non-bright light group (0 weeks: 9.7; 6 week: 13.6; Table 3). There is no significant correlation between the change in CES-D scores and change in body fat at 6 weeks. In addition, there were no significant changes found using the POMS scores.

SPAQ scores, a measure of seasonality, were different after 6 weeks of exercise between the bright light and non-bright light group ($p = 0.03$; Table 3). Correlating the sleep items on the SPAQ (i.e., the six subitems that address changes in sleep length, social activity) with percentage change in total body fat did not show a significant correlation of change on the SPAQ (total score or individual subitems) with changes in body fat levels.

Analysis of the ratings of sleep on the ESS questionnaires revealed no difference between the two groups after 6 weeks. The FIS score decreased after 6 weeks in both groups, with no significant time-bright light interaction ($p = 0.93$). With regard to the FIS subscores (FIS cognitive, FIS physical, FIS social), bright light treatment resulted in no significant interaction (Table 4; Figure 1B).

Discussion

This randomized, controlled study is the first to show that bright light treatment during exercise impacted body composition by significantly reducing body fat after only a 6-week period. There was also a trend toward a greater reduction in body weight in the bright light treatment group, but this did not reach significance. The change in body fat mass is of particular importance because visceral fat has been particularly implicated as a major factor in the development of the metabolic syndrome (44). This observation is an important step toward addressing the problem of overweight and obesity in the study population. It has been shown that a moderate weight loss can improve insulin

Table 3. Mood and sleep

	Bright light group	Non-bright light group	ANOVA
CES-D			$F = 0.01$, df = 1/17, $p = 0.924$
Start	15.6 ± 8.7	9.7 ± 6.1	
After 6 weeks	8.8 ± 7.4	13.6 ± 12.1	
After 3 months	16.1 ± 7.7	9.5 ± 8.5	
Time-bright light interaction	$F = 3.24$, df = 1, $p = 0.091$		
SPAQ			$F = 0.46$, df = 1/17, $p = 0.509$
Start	8.9 ± 8.8	8.5 ± 6.7	
After 6 weeks	5.1 ± 5.2	11.0 ± 5.4	
After 3 months	7.4 ± 4.8	10.2 ± 7.0	
Time-bright light interaction	$F = 0.46$, df = 1, $p = 0.51$		
POMS			$F = 0.3$, df = 1/11, $p = 0.592$
Start	20.3 ± 32.1	21.1 ± 27.6	
After 6 weeks	7.7 ± 20.3	6.3 ± 25.6	
After 3 months	20.7 ± 30.2	10.6 ± 30.3	
Time-bright light interaction	$F = 0.3$, df = 1, $p = 0.592$		
ESS			$F = 0.58$, df = 1/17, $p = 0.455$
Start	7.4 ± 4.99	7.3 ± 3.0	
After 6 weeks	7.5 ± 6.4	6.9 ± 2.3	
After 3 months	5.6 ± 5.4	5.5 ± 1.6	
Time-bright light interaction	$F = 0.58$, df = 1, $p = 0.46$		

CES-D, Centre for Epidemiological Studies in Depression; SPAQ, Seasonality Pattern Assessment Questionnaire; POMS, Profile of Mood States; ESS, Epworth Sleepiness Scale.

sensitivity, lower blood pressure, and improve triglyceride levels (3). One limitation of this preliminary study is that more detailed anthropometric measures including changes in waist circumference and waist-to-hip ratio were not collected.

Our finding that body fat composition was reduced, whereas body weight was not significantly altered by bright light therapy dovetails with the study of Tsai et al. (45), who concluded that, although food restriction is effective in promoting weight loss, exercise has greater impact on body fat composition, leading to a better and longer-term effect on lipid profile. In this study, it was the combination of exercise and bright light that had the greater impact on body fat levels. It was remarkable that in this study, the relatively short exercise period was effective in those subjects in the bright light therapy group. In this study, blood profiles for glucose and lipid levels were not conducted. Future studies in this area are warranted to investigate the effect of light in combination with exercise over a longer period on metabolic parameters.

Study subjects were asked not to diet or binge throughout the study, but food diaries detailing food preference and intake were not recorded, so it is not known whether changes in amounts consumed or eating pattern among those treated with the bright light accounted for the change in body fat mass. If the bright light treatment in this study was acting through serotonergic mechanisms, based on numerous animal models, serotonin has been shown to be a modulator of carbohydrate metabolism (46–48). In humans, the impact of serotonergic agents on carbohydrate intake is less clear, but serotonin reuptake inhibitors have been shown to result in better glycemic control in diabetic subjects (49). Other studies have proposed that serotonergic pathways may also play a role in fat intake, and this may provide one explanation for the findings of this study. Serotonergic agonists (50,51) and stimulation of serotonergic receptors (52) have been shown to preferentially reduce fat intake in rats. In humans, body fat levels are reduced by treatment with sibutramine, a new serotonin and noradrenaline reuptake inhibitor (53). However, this is speculation, because this study did not measure serotonin levels; therefore, it is not possible to determine whether serotonergic mechanisms were involved with the changes in body fat with bright light therapy. To date, only one study has reported an increase in blood

Table 4. Fatigue Impact Scale score

	Bright light group	Non-bright light group	ANOVA
FIS total			$F = 4.57$, df = 1/16, $p = 0.048$
Start	31.4 ± 20.0	24.7 ± 22.5	
After 6 weeks	16.3 ± 13.6	16.5 ± 14.5	
After 3 months	27.3 ± 26.6	26.2 ± 22.2	
Time-bright light interaction	$F = 0.01$, df = 1, $p = 0.93$		
FIS cognitive			$F = 6.15$, df = 1/17, $p = 0.024$
Start	12.6 ± 10.4	6.7 ± 7.8	
After 6 weeks	7.4 ± 7.7	3.3 ± 2.6	
After 3 months	8.4 ± 8.5	10.0 ± 8.7	
Time-bright light interaction	$F = 0.03$, df = 1, $p = 0.87$		
FIS physical			$F = 0.68$, df = 1/16, $p = 0.421$
Start	6.0 ± 5.1	6.7 ± 6.3	
After 6 weeks	3.3 ± 3.7	5.0 ± 7.1	
After 3 months	7.6 ± 6.8	6.2 ± 5.6	
Time-bright light interaction	$F = 0.17$, df = 1, $p = 0.69$		
FIS social			$F = 3.02$, df = 1/15, $p = 0.103$
Start	12.8 ± 9.3	11.7 ± 11.0	
After 6 weeks	6.4 ± 5.2	8.8 ± 8.6	
After 3 months	11.3 ± 11.9	10.0 ± 10.8	
Time-bright light interaction	$F = 0.3$, df = 1, $p = 0.99$		

FIS, Fatigue Impact Scale.

serotonin with bright light therapy (8); hence, more research will be needed to determine whether changes in blood serotonin levels occur with bright light therapy and how these relate to brain serotonin levels.

Changes in energy expenditure may also have accounted for the findings in this study. All subjects were required to exercise at the same level (i.e., at a 65% heart rate reserve) and all subjects used identical stationary bicycles, but those in the bright light group may have been more active outside of the exercise period than those in the other study group. Future studies using 24-hour actigraphy measurements are needed to test this hypothesis. Leptin measurements in studies of this nature may also prove useful as leptin is an endogenous appetite suppressor, and it is possible that any change in food intake induced by bright light treatment may also involve leptin. Administration of leptin in the obese mouse model is shown to increase activity levels, reduce body fat, and reduce food intake to levels observed in lean controls (54). Although largely still unexplored, there seems to be a connection between the serotonergic system and leptin secretion, and administration of 5-hydroxytryptophan in mice has been shown to increase serum leptin levels (55). There are no known effects of bright light therapy on leptin levels, but leptin receptor immunoreactivity is highly colocalized with serotonin in the raphe system (56).

It was observed that mood scores as measured by the CES-D scale improved in the bright light group only. It should be emphasized that these subjects were not depressed and were screened carefully before starting the study. An improvement in mood is known to occur with exercise, but it is noteworthy that, in the case of this study, this was true only for those subjects undergoing bright light therapy. Although not examined in this preliminary study, it would be of interest to see the impact of the mood-elevating properties of bright light on compliance to a longer-term exercise program.

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