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ORIGINAL RESEARCH

HIGH INTENSITY INTERVAL CYCLING IMPROVES PHYSICAL FITNESS IN TRAINED ADULTS

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ABSTRACT

Introduction: High intensity interval training (HIIT) is a specific type of vigorous intensity exercise characterised by periods of work over 85% maximum heart rate (HR_{max}). Numerous past studies have documented significant cardiovascular, metabolic, musculoskeletal, and body composition improvements with this type of training, traditionally with cycling Wingate tests. However, popular HIIT sessions outside of research typically incorporate weight-bearing impact, which limits large segments of the population from participating. Thus, a low-impact alternative in a practical format with parallel benefits is an imperative option that requires testing.

Methods: Thirty-six trained adults were randomly assigned to one of two groups: Group HIIT or Group FIT. Group HIIT participants replaced a single 60-minute cardiovascular training session with 2, 30-minute high intensity indoor cycling sessions for 6 weeks. Group FIT maintained their current training routine. We measured blood pressure, peak oxygen consumption, fasting blood profile, body composition, and leg strength.

Results: The HIIT intervention significantly improved all variables ($p<0.05$) except HDL cholesterol. Peak oxygen consumption and leg strength increased significantly for the HIIT group (+9.7% and 11.9% respectively) but not the FIT group. There were significant decreases in the HIIT group for blood pressure (-9.9%), fasting blood glucose (-7.0%), total cholesterol (-6.0%), LDL cholesterol (-7.8%), triglycerides (-16.3%) and fat mass (-1.1%).

Conclusion: Adding high intensity interval cycling to the routine of trained adults improved physical fitness. Our results suggest that replacing one bout of moderate intensity exercise with two 30-minute bouts of cycling HIIT is an effective, low impact option to improve cardiovascular, metabolic and musculoskeletal fitness, as well as body composition.

Keywords: exercise, intervention, cardiovascular, metabolic, musculoskeletal

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INTRODUCTION

Vigorous intensity exercise lowers cardiovascular disease risk and can even extend lifespan by 22% in men and 31% in women[1-5]. High intensity interval training (HIIT) is a specific type of vigorous intensity exercise characterised by periods of work over 85% maximum heart rate (HR_{max}) followed by periods of active recovery or rest[6]. One type of HIIT training, sprint interval training (SIT) is typically performed in a laboratory on a cycle ergometer with repeated low-volume Wingate tests; 10-30 seconds of maximum effort followed by rest[7-9]. These protocols increased maximal oxygen consumption (VO_{2max}) by 5.5-9.3% depending on the interval to rest ratios. Additionally, Burgomaster et al.[10] studied the oxidative capacity and skeletal muscle adaptations in response to low-volume repeated Wingate sprint tests and endurance training. After 6 weeks, VO_{2max} increased by 7.3% for sprint training and 9.8% for endurance training. Therefore, low-volume HIIT cycling using repeated Wingate tests has the potential to stimulate significant changes in oxidative capacity similar to those of moderate-intensity training. While these protocols are efficient for highly trained individuals, they are difficult to generalise to the rest of the population and disseminate to the community.

Physical fitness consists of cardiovascular, metabolic, and musculoskeletal fitness, as well as body composition. One of the key indicators of improvements in cardiovascular fitness is a change in VO_{2max} as previously described in laboratory SIT protocols. In untrained or moderately trained adults, Helgerud et al.[11] and Nybo et al.[12], reported that HIIT running at 90-95% HR_{max} increased VO_{2max} more than endurance or strength training. Gottschall et al.[13] found that replacing just one 60-minute bout of moderate-intensity exercise with 2, 30-minute weight-bearing HIIT classes per week, in trained adults significantly improved cardiorespiratory, metabolic, musculoskeletal, and body composition measures more than maintaining a moderate-intensity training program.

Despite the positive findings in cardiovascular fitness, there is not yet a consensus on the effects of HIIT or SIT on other aspects of physical fitness. In general, long-term studies involving at least 6 weeks of HIIT have shown decreases in total cholesterol (TC) and low density lipoprotein (LDL-C)[13-15], while shorter term studies have shown no changes in cholesterol[16-18]. Likewise, musculoskeletal fitness and body composition changes with SIT cycling are conflicting. While most studies show a decrease in body fat percentage, the magnitude of these changes range from 0.6% for protocols of at least 12 weeks to 11.2% for protocols over 15 weeks[19-21]. Many studies have evaluated the effects of HIIT or SIT on anaerobic power, however few have studied leg strength, specifically isometric leg strength. In summary, the effects produced by HIIT cycling on metabolic and musculoskeletal fitness, as well as body composition, require further investigation.

A HIIT cycling program that can be implemented in the community would provide a low-impact alternative to laboratory SIT protocols and weight-bearing HIIT programs. We hypothesise that a 6-week intervention where trained individuals replace one 60-minute bout of cardiovascular training with two 30-minute bouts of HIIT cycling, will improve health and fitness more than maintaining their moderate-intensity cardiovascular exercise routine. More specifically, we expect to see an increase in peak oxygen consumption, leg strength and high density lipoprotein cholesterol (HDL-C), with accompanying decreases in blood pressure (BP), triglycerides (TRG), cholesterol (TC and LDL-C), blood glucose (GLU), and body fat percentage.

MATERIALS AND METHODS

Experimental Approach to the Problem

We measured blood pressure, peak oxygen consumption, fasting blood profile, body composition, and leg strength in two randomly designated groups of trained adults. One group was assigned to replace one of their current 60-minute cardiovascular training sessions with 2, 30-minute high intensity cycling sessions.

Table 1: Participant Initial Characteristics. Groups did not differ significantly in age, height, weight, fat mass and estimated maximal oxygen consumption. Measures are reported as mean (standard deviation).

	Age (yrs)	Height (m)	Weight (kg)	Fat Mass (kg)	VO_{2peak} (ml/kg/min)
Group FIT	41 (11)	1.71 (0.10)	73.18 (15.01)	42.65 (16.63)	39.37 (5.55)
Group HIIT	41 (11)	1.68 (0.09)	73.51 (16.39)	44.23 (23.98)	41.11 (4.50)

Participants

We recruited 36 healthy, trained adults (Table 1; 8 men, 41 ± 11 years). The participants were exceeding current physical fitness recommendations prior to the start of the study[22]. They were involved in regular cardiovascular activity more than 3 times per week and full-body strength training 2 times per week for at least 60 minutes per bout of exercise. Furthermore, participants all had experience cycling either outdoors or on a stationary bike in the last 6 months. All of the participants gave written informed consent that followed the guidelines of The Pennsylvania State University Institutional Review Board. Individuals with cardiovascular risk factors or chronic medical conditions were not included.

Procedures

We collected data at initial (Week 0) and final (Week 6) points of the study on the same day of the week and the same time of day. The following physiological variables were measured: blood pressure, estimated maximal oxygen consumption, fasting blood profile, leg strength and body composition. We conducted a submaximal oxygen consumption cycle ergometer test using the Astrand-Rhyming protocol. The participant warmed up for 10 minutes cycling at 60 rpm until their heart rate reached 130-160 bpm. They maintained their heart rate in this range for 6 minutes pedaling at 60 rpm, adjusting the wattage accordingly as instructed by the study team. We then calculated VO_{2peak} from the participants' final work rate wattages. Additionally, following a 12-hour food, alcohol and exercise fast, the following variables were measured with a finger prick blood draw: TC, TRG, HDL-C, LDL-C, and GLU (Cholestech LDX). Previous studies have shown coefficients of variation less than 9% between and within measurement tests. We measured musculoskeletal strength through a maximal leg strength deadlift test using a dynamometer (Initial Evaluation Instruments). With maximum effort, participants pulled upward on the dynamometer with feet shoulder-width apart, knees flexed to 110 degrees, and arms fully extended. Verbal encouragement was given and participants performed three trials. The average and maximum readings were recorded. Lastly, body composition variables were also measured at initial and final: height, total mass, fat mass, and fat-free mass. We used the BodPod (COSMED), a dual chamber air displacement plethysmograph, to measure the participant's body composition (fat and fat-free mass). The calculated coefficient of variation of the BodPod was 0.8% body fat. All the testing procedures as well as training sessions were completed at a temperature controlled group fitness studio.

The participants were randomly assigned to one of two groups: group HIIT or group FIT. Group HIIT participants replaced a single 60-minute cardiovascular training session with 2, 30-minute high intensity LES MILLS SPRINT™ indoor cycling sessions on 2 non-consecutive days. Group FIT participants served as controls and maintained their current physical fitness routine of 3 cardiovascular sessions and 2 full-body strength training sessions. The groups were matched for age, gender, physical activity level and VO_{2peak}. The intensity of the HIIT sessions was 85-95% HR_{max} for 20 of the 30 minutes while the intensity of the cardiovascular sessions was 70-85% HR_{max} for 40 of the 60 minutes.

Each HIIT session was 30-minutes with a similar average workload to 60-minutes of cardiovascular training sessions. The HIIT sessions started with a 5-minute accelerated warm-up and continued with 3 or 4, 5-10 minute blocks for speed and power conditioning. The intervals in a block varied and consisted of work to rest ratios of 1:2, 2:1, and 3:2 with the total duration of work equal in each 30-minute session. The shortest work time period was 20 s and and the longest was 120 s.

Statistical Analysis

Data were presented as mean ± standard deviation and analyzed using StatPlus Version 6 (AnalystSoft, Inc). We completed independent t-tests to evaluate differences in descriptive characteristics between the groups. Two-way analysis of variance with repeated measures was used to examine the differences in cardiovascular, metabolic, and musculoskeletal fitness as well as body composition variables, with time (initial vs final) as a within-subjects factor and group (HIIT vs FIT) as a between-subjects factor. Tukey's post hoc test was used to detect differences between means with a resulting significant F ratio. Significance was defined at $p<0.05$.

RESULTS

There were no statistically significant time or group main effects. There were time x group main effects for all measured variables ($p<0.05$) with the six weeks of HIIT training, except HDL cholesterol. Maximal oxygen consumption and leg strength increased significantly ($p<0.05$) for the HIIT group, but not for the FIT group. There were significant ($p<0.05$) decreases in the HIIT group for blood pressure, GLU, TC, LDL, TRG, and fat mass.

Systolic blood pressure was significantly ($p<0.05$) higher for Group HIIT than Group FIT at initial (131 mmHg HIIT, 119 mmHg FIT). Other initial measures did not vary significantly between groups. Systolic and diastolic blood pressure were significantly ($p<0.05$) less after the intervention for Group HIIT. Systolic blood pressure decreased by 11 mmHg (8.4%, $p<0.01$) and diastolic decreased by 8 mmHg (9.9%, $p<0.01$). Blood pressure did not change significantly for Group FIT, nor did final values differ significantly between intervention groups.

In summary, there were multiple significant differences between initial and final cardiovascular, metabolic, and musculoskeletal fitness as well as body composition measurements in the HIIT group. First, estimated maximal oxygen consumption increased significantly ($p<0.01$) for the HIIT group from 41.1 ml/kg/min to 45.1 ml/kg/min (9.7%) and did not change significantly for the FIT group (Figure 1).

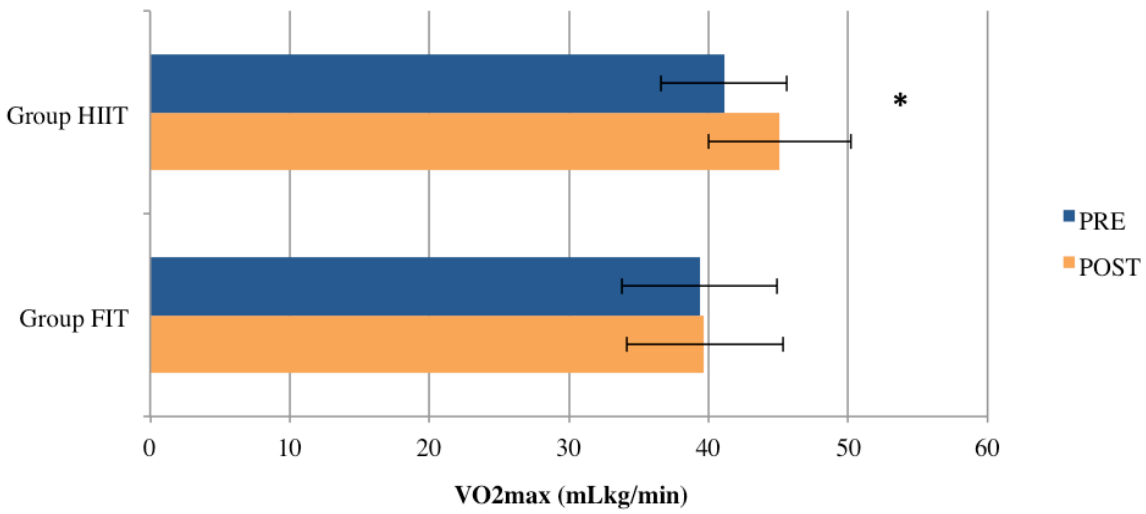

Figure 1: Estimated maximal oxygen consumption for Group FIT and Group HIIT. VO_{2peak} increased significantly ($p<0.05$) for Group HIIT, but not Group FIT. Similarly, there was a significant ($p<0.05$) difference between post-intervention VO_{2peak} for Group HIIT and Group FIT. (* = significant difference between initial and final measurements)

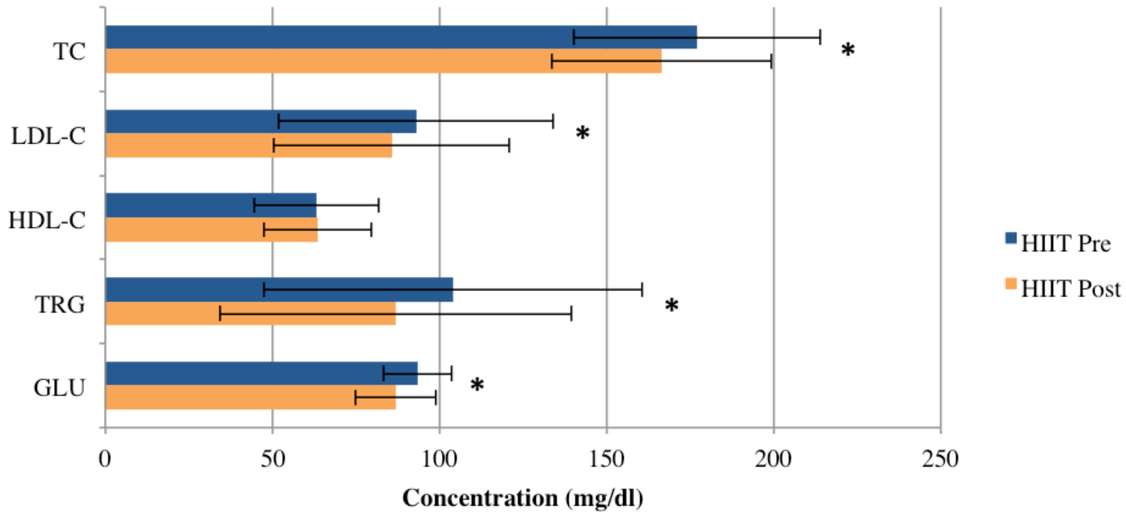

Figure 2: Blood panel profile measures pre- and post intervention. Total cholesterol (TC), low density lipoprotein cholesterol (LDL-C), triglycerides (TRG), and glucose (GLU), decreased significantly (p<0.05) for Group HIIT from initial to final. High density lipoprotein cholesterol (HDL-C) is the only variable that did not change for the HIIT intervention group. (* = significant difference between initial and final measurements)

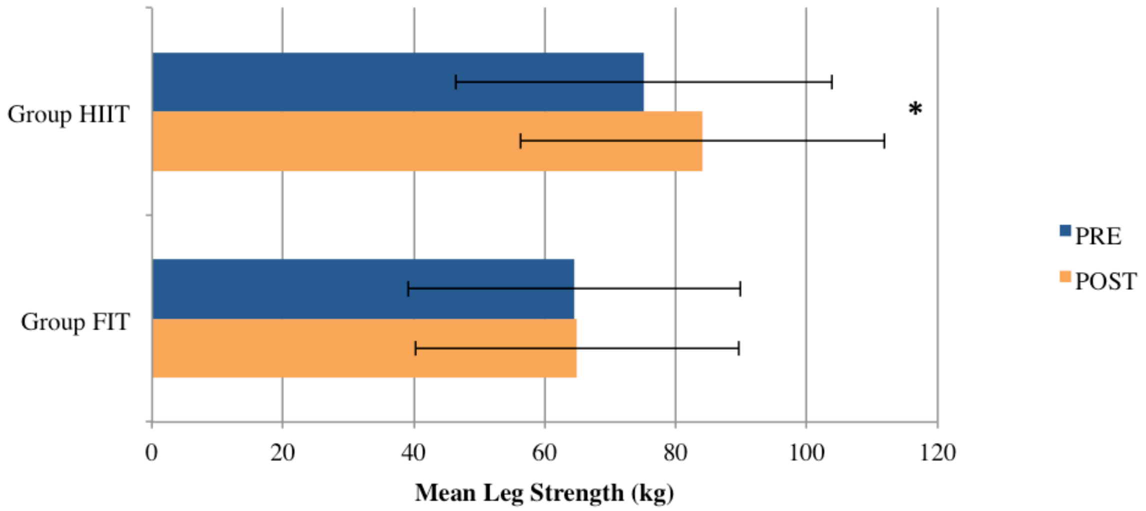

Figure 3: Changes in mean leg strength for Group HIIT and Group FIT. There were significant (p<0.05)differences between pre- and post-intervention for Group HIIT, and the final measurements for Group HIIT were significantly (p<0.05) larger than Group FIT. (* = significant difference between initial and final measurements)

Second, for the HIIT intervention group, all of the blood cholesterol concentrations (except HDL-C) and fasting blood glucose decreased significantly (p<0.05) throughout the intervention (Figure 2); TC decreased by 11 mg/dL (6.0%), LDL-C by 7 mg/dL (7.8%), TRG by 17 mg/dL (16.3%), and glucose by 7 mg/dL (7.0%). Third, mean leg strength increased significantly (p<0.05) by 9.0 kg for the HIIT group from initial to final (11.9%). Group FIT showed no change in mean leg strength (Figure 3). Fourth, body fat percentage decreased significantly (p<0.05) by 1.1% for the HIIT group through the 6-week intervention. Group FIT body fat percentage did not change significantly from initial to final. In addition, mass decreased significantly (p<0.01) by 0.9 kg for the HIIT group (1.1%), but not for the FIT group.

DISCUSSION

Incorporating high intensity interval training cycling to the routine of active adults improved physical fitness. Our results suggest that replacing one bout of moderate intensity exercise with two 30-minute bouts of HIIT is an effective way to improve cardiovascular (VO_{2peak} and blood pressure) metabolic (blood profiles) and musculoskeletal (strength) fitness as well as body composition (fat and lean mass).

The substantial increase in peak oxygen consumption (9.7%) for the HIIT intervention resembled the previous VO_{2max} data using repeated Wingate tests (5.5-7.3%) in both untrained and trained adults[8-10]. While both protocols use high intensity intervals, the Wingate tests are 10-30 seconds of maximum effort, whereas this study uses high intensity intervals up to 120 seconds. The longer intervals in the current study likely contributed to the increases in VO_{2peak}. As expected, past studies with inactive participants had larger improvements in oxygen consumption than seen in this study. SIT cycling increased VO_{2max} by 11.1% after 2 weeks, 15.2% after 12 weeks, and 23.8% after 15 weeks in untrained adults[20, 23-24]. Based on previous literature and the results of this study, untrained individuals may attain gains in VO_{2max} without the impact involved in weight-bearing HIIT.

In comparison to weight-bearing HIIT protocols, VO_{2peak} gains were similar in this intervention. Studies with similar protocols that replaced or added HIIT to previous physical activity regimens found that VO_{2peak} increased by 6.4-6.9% with HIIT versus 1.8-2.7% with maintaining their previous physical activity routine[13,25]. In recreationally active adults, weight-bearing HIIT increases of VO_{2peak} by 4.9% and 10.3%[14,26]. In summary, the improvements in cardiovascular fitness closely match the improvements in trained and recreationally active adults with either low-volume SIT cycling or weight-bearing HIIT protocols.

Metabolic fitness improved substantially with HIIT cycling. The decreases in total cholesterol, triglycerides, and LDL-C confirm our hypothesis and mimic the results of Ouerghi et al.[25]. After 12 weeks of HIIT training, TC decreased by 3 mg/dL, LDL-C by 2 mg/dL, TRG by 7 mg/dL in trained male soccer players. However, their results were not statistically significant possibly due to the small sample size (n=8 in each intervention). The decreases in triglycerides (17mg/dL) and LDL-C (7mg/dL) from the current study were similar to previous findings in 6-12 week protocols[13-15]. HDL-C concentrations did not change for our intervention, which match some previous findings with HIIT, both cycling and weight-bearing[15,27] but not all[13]. It is possible that HDL-C did not change in the current study since the participants were already trained. Overall, these varying results in metabolic fitness are likely due to differences in type of HIIT (weight-bearing versus cycling) and the physical activity level of the participants. Additional studies on HIIT cycling in trained adults are necessary to corroborate an effect on metabolic fitness.

Another measure of metabolic fitness is fasting blood glucose, which decreased 7mg/dL in this intervention. This supported our hypothesis and mimics the ranges, but not the magnitude of changes reported in previous long-term studies with untrained adults. Sandvei et al.[14] found that 8 weeks of HIIT decreased fasting blood glucose by 3.6 mg/dL. After 12 weeks of HIIT, Nybo et al.[12] determined that HIIT decreased fasting blood glucose by 9.0 mg/dL. With trained adults, our results do not support the findings of studies over 2-3 weeks, in which HIIT did not change fasting blood glucose[16-18]. These results suggest that longer HIIT cycling interventions and studies with untrained individuals have greater benefits for blood glucose control. Changes in fasting blood glucose may be a response to increased adrenaline associated with HIIT, which regulates glucose metabolism, as well as changes in body composition favoring higher post-exercise metabolism[28-29].

In support of our hypothesis, body composition improved significantly with HIIT. Comparatively, decreases in body fat percentage in this study were similar to results from treadmill running HIIT studies. We reported a body fat percentage decrease of 1.1% while previous studies in untrained adults found decreases in body fat percentage ranging from 0.6% after 12 weeks of HIIT to 11.2% after 15 weeks of HIIT[19-20,30]. While the literature with untrained adults shows improvements of varying magnitude in body composition, 2-3 weeks of HIIT cycling did not elicit significant changes in body fat with trained adults[9,18]. For 6 weeks of a weight-bearing HIIT intervention, however, body fat percentage decreased by 2.1% in 6 weeks in trained adults[13] and by 12.4% in 6 weeks in active, younger adults[26]. The reduction in body fat percentage in the current study follows the general trend of HIIT in trained adults over a period of 6 weeks. The lack of change with only 2-3 weeks seems to indicate that at least 6 weeks are necessary to achieve improvements in body composition. Thus, a longer duration intervention may be more effective in eliciting these changes in trained adults.

LIMITATIONS AND FUTURE STUDIES

There were several limitations to this study. While our primary goal was to evaluate a practical alternative that can be performed by a greater segment of the population, this allows less control over environmental and lifestyle factors. For example, we asked that the participants not change their diet, however we did not strictly measure their nutritional intake over the 6 weeks. A secondary goal was to utilise methods that could be utilised in non-research settings for future comparisons. For this reason, we elected to use a heart rate based estimate of maximal oxygen consumption instead of indirect calorimetry and the portable dynamometer instead of weight machines. Obviously these procedures reduce accuracy in this single study but will hopefully encourage reports in facilities around the globe. Additionally, for the HIIT sessions, participants were asked to follow the cadence and resistance guidelines of the instructor but we did not analyse the specific wattages for each participant. Future studies could investigate heart rate data on this protocol in order to determine the high intensity to recovery time ratios that elicit the greatest improvements in physical fitness.

CONCLUSIONS AND PRACTICAL APPLICATIONS

Together, the results of this study and previous studies demonstrate the benefits of improving physical fitness (cardiovascular, metabolic, and musculoskeletal fitness, as well as body composition) with HIIT or SIT cycling. More specifically, these results suggest that replacing a bout of moderate-intensity exercise with 2-30 minute bouts of HIIT cycling bouts is an effective way to improve physical fitness. This data is beneficial to professionals including physicians, personal trainers, and exercise instructors in an effort to advise patients and clients on how to incorporate low impact, high intensity training into their current routine to maximise physical fitness.

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POTENTIAL CONFLICT OF INTEREST

Jinger S. Gottschall is a co-owner and founder of FITOLOGY, LLC, the studio where the participants completed the classes. Les Mills International was supportive of the present study but they did not have access to the data for analyses.

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