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Single Exposure to Prolonged Sitting Prior to Exercise Does not Impact Athletic Performance

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Abstract **Background:** The effects of sitting, and benefits of breaking up sitting time, have been extensively researched in regard to cardiometabolic dysregulation; however, the effect of long periods of not moving prior to athletic performance are unclear. Despite this, the belief that periods of intermittent light exercise to break up sitting prior to exercise performance persists. **Objectives**: To examine the effect of prolonged sitting time, as well as one common and one novel intervention to break up sitting, on subsequent exercise. **Methods:** 30 healthy individuals in ≥80th percentile of age and gender matched fitness participated in three conditions: 1) 5hr of uninterrupted sitting, 2) 5hr of interrupted sitting with 5 min walking bouts at 4.8 km/h every 30min, 3) 5hr of sitting with passive blood flow restriction and transcutaneous electrical muscle stimulation (BFR+TEMS) every 60min. A baseline assessment of maximal leg power generation and an incremental exercise protocol using a stationary cycle ergometer were conducted prior to the sitting protocol. Primary outcomes after 5hr of sitting included maximal leg power and time to exhaustion during incremental cycle ergometery to voluntary fatigue. **Results:** 5hr of uninterrupted sitting did not significantly alter leg power relative to baseline (Δ= -80± 998 W), nor did BFR+TEMS (Δ= 7 ±1252 W), or WALK (Δ= 53± 547 W) interventions (all p>0.05). Prolonged sitting was not detrimental to time to exhaustion (Δ= - 10 sec 95% CI -7 sec, 27 sec). Analysis of the BFR+TEMS (Δ= 23 sec, 95% CI -74 sec, 28 sec) and WALK (Δ= 14 sec, 95% CI -90 sec, 62 sec) groups, compared to corresponding controls, indicated that there were no additional ergogenic effects of either intervention strategy. **Conclusions:** Considering explosive leg power and aerobic cycling to exhaustion, uninterrupted sitting for 5 hours prior to exercise had no negative effect on performance, and neither intermittent walking nor blood flow restriction with electrical stimulation further improved performance.

Keywords Sedentary, Blood flow restriction, Exercise, Aerobic power, Anaerobic power

1. Introduction

It is well established that prolonged siting time is closely associated with alterations in metabolic control, [1] reductions in vascular shear stress, and dysregulated endothelial function [21,22]. Previous work has indicated that as little as three hours of uninterrupted sitting results in a significant impairment of blood flow and endothelial function, even in young and healthy individuals [3]. Short bouts of light to moderate physical activity, performed intermittently throughout sedentary time, is an effective strategy for regulating blood sugar [4], maintaining blood flow and preserving vascular function [10,12,15,22]. Despite the body of evidence suggesting a relationship between breaks in sitting and improved vascular function, little is known as to whether exposure to prolonged sedentary time negatively impacts an individual's maximal exercise capabilities, such as the ability to generate maximal leg power or sustain prolonged incremental exercise. This is important, given that exercise performance and prolonged sitting are frequently paired temporally. As one, non-exclusive example, both professional and amateur athletes regularly travel by land or air to arrive at the site of competition and this usually entails a period of forced immobilization. For many non-elite athletes, traveling by a team bus is the most economical solution to reach venues, and cost savings are realized by travelling in close proximity to competition to avoid further accommodation costs. If prolonged sitting results in a deleterious impact on sport performance, this would be extremely relevant for athletes in a number of scenarios, including travel to and from competition and training, or in situations wherein there is unavoidable sedentary time preceding competition – such as waiting in the stands for one's own event class . Owing to the intuitive nature of the belief that extended sitting may affect subsequent performance, anecdotally; many teams already have strategies in an effort to keep players "fresh".

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While it is likely of a lower concern for high-caliber athletes who participate in relatively high levels of moderate to vigorous physical activity on a routine basis, past work has shown cumulative sedentary time is independently associated with negative health outcomes [2,7].

The current study used a model of forced sitting preceding exercise to understand if sedentary time prior to competition could negatively affect performance, and if breaking up sitting with light physical activity was advantageous. Previous work examining the effect of decreasing occupational sitting time has demonstrated intermittent low intensity exercise, such as walking, to be an effective method of improving health outcomes [1,16,23]. To provide an alternative to walking for situations of limited space, we further attempted a novel strategy to offset sitting using repeated bouts of blood flow restriction (BFR) in conjunction with transcutaneous electrical muscle stimulation (TEMS). This was included as an intervention that could be applied in a chair, without the need to stand and ambulate.

The rationale underlying this novel intervention strategy was to increase blood flow to the muscle via manipulation of shear stress mediated reactive hyperaemia, and through ascending vasodilation from the metabolic, hypoxic and rhythmic exercise stimuli generated at the tissue level via BFR related muscle contraction [20]. Further, the application of TEMS has been shown previously to increase blood flow when applied repeatedly at submaximal intensity in short bursts [13]. Recent work has confirmed the efficacy of repeated shear stress challenges as a method to elicit improved microvascular reactivity and endothelial function [8]. It is also possible that exposure to stimuli that limit decreases in blood flow and vascular reactivity, could help to offset decrements (or even lead to improvements) in athletic performance. The allure of promoting blood flow in this way is that it is thought to provide an alternative to walking that could be completed in situations of prolonged sitting wherein standing and exercising was logistically challenging or implausible, such as when traveling.

For athletes and others in physically demanding occupations (e.g., first responders, military), the ability to perform at one's optimal physical capacity after prolonged sitting could have important consequences. In addition to the improvements in blood delivery associated with shear change during the reactive hyperemic phase of BFR, the repeated bouts of reduced blood supply and hypoxia prior to exercise, commonly referred to as ischemic pre-conditioning (IPC), may also act as an ergogenic aid to improve endurance performance [15]. Previous work has demonstrated small improvements in VO_2 max and peak power output after exposure to IPC prior to a similar exercise protocol [16]. Research examining the mechanistic properties of IPC have suggested multiple potential pathways, but it appears the commonality for improved performance is a result of a hormonal cascade, which acts to mediate cell injury and remodeling during times of low oxygen [11,17,5,9].

The purpose of the current study was to explore changes in athletic performance (i.e., muscle power and endurance) after a single bout of uninterrupted prolonged sitting, compared to interruption by walking or BFR+TEMS. Given that acute sedentary time negatively impacts endothelial function, it was hypothesized that small but meaningful decrements in athletic performance would occur following uninterrupted sitting compared to both intermittent walking and BFR+TEMS.

2. Methods

2.1. Participants

Healthy, active individuals (n=30) volunteered to participate in a multi-site randomized controlled trial. Participants were recreationally trained with an average maximal aerobic capacity of 51.5±7 $ml \cdot kg^{-1} min^{-1}$. All were non-smokers who habitually participated in sport, aerobic, and resistance training. All participants completed a medical history questionnaire (Physical Activity Readiness Questionnaire (PAR-Q+) and were free from medical conditions or medications. Prior to participation, subjects were informed of testing procedures and gave written informed consent in accord with the declaration of Helsinki and the local research ethics boards at The University of Guelph and University of New Brunswick, who reviewed and approved this project.

2.2. Protocol and Measurements

Participants refrained from alcohol, caffeine and vigorous physical activity for at least 24 hours prior to testing sessions. All participants were instructed to maintain similar dietary patterns the night prior to testing and to arrive at the lab following overnight fast. Upon arrival all participants were measured for weight (kg) using a digital scale (Tanita, BC-554) and height (cm). All tests were performed in controlled laboratory conditions with a temperature between 20-22℃.

Each subject was randomly assigned to one of two experimental groups (n=10 WALK, n=10 BFR+TEMS) or the control group (n=10 CON). At baseline, participants underwent an incremental maximal exercise test on a Velotron cycle ergometer, followed by two separate testing sessions separated by 5-7 days. The baseline incremental exercise test was used to determine if participants met the studies inclusion criteria. In one of the experimental sessions, participants sat uninterrupted for 5hr. In the other experimental session, participant's sitting time was broken up with intermittent activity breaks throughout the five hours. The order of uninterrupted sitting or sitting with intermittent activity was assigned in random order. The progression of the baseline incremental exercise test was individually tailored to the participant to ensure the loading procedure matched their cycling experience and ability, and would lead to test termination between 8-12 minutes.

Stronger cyclists (by self report and training history) used a loading protocol that increased at 0.5W per second increments from 100W to fatigue whereas less experienced participants used a more moderate ramp that increased from 100W at 0.33W per second increments. This method of incremental aerobic fitness evaluation allowed for a more accurate representation of aerobic capacity with minimal influence from muscular fatigue.

Participants were to complete one 5hr bout of prolonged uninterrupted sitting and one with the inclusion of either bouts of walking or BFR+TEMS interventions, followed by the same maximal exercise test. Participants in the control group completed the incremental exercise test to exhaustion without any sitting prior and after 5hr of uninterrupted sitting. If, during the sitting period, a subject needed to use the bathroom or otherwise move from the testing area, a researcher would assist by wheeling the subject in a moveable chair to avoid ambulation not included in the sitting protocol.

Participants who completed the walking or BFR+TEMS conditions also completed three maximal effort vertical jumps, to determine if sitting impacted explosive leg power, by comparing jumps before sitting, directly after sitting, and after the cessation of exercise, respectively. Participants were instructed to complete counter movement jumps, from the standing position with both feet fully planted to the floor. If during the counter movement phase of the jump, a participant's feet partially or fully left the ground prior to the measured jump, the attempt was void. Vertical jump was measured to the nearest 0.5 inch and leg power was calculated using Sayers's formula (W= (60.7 x cm) + (45.3 x kg)- 2055) [20].

Subjects who were placed in the intermittent walking group (WALK) were asked to walk every 30 minutes at 4.8 km/h (3 mph), 0% for 5 minutes throughout the 5hr of seated time. This intensity equates to an approximate equivalent of 3 METS, which is generally accepted as light to moderate physical exercise. A 5min duration was selected as a reasonable break from seated travel in a non-simulated traveling environment. The other experimental group consisted of hourly bi-lateral arterial occlusion using an automated tourniquet device (Delfi, PTS, Vancouver, Canada) set at the lowest effective occlusion pressure for each individual, in conjunction with low intensity transcutaneous electrical muscle stimulation (BFR+TEMS, n=10). The lowest effective occlusion pressure was measured automatically using Doppler sensor technology built directly in to the automated tourniquet devices. This allowed for the participants limb occlusion pressure and lowest effective occlusion pressure measurement to be administered by the same piece of equipment, thus minimizing variance caused by human interference and variation between equipment sensors.

Subjects in the BFR+TEMS group were exposed to three bouts of 5min of occlusion (185±29 mmHg) followed by 5min of reperfusion (total time per hourly cycle, 25 min). TEMS was applied using a commercially available muscle stimulator (Compex, California, USA) with a pulse length of 400μs, delivered at a stimulation frequency ranging from 50-100Hz, which was set at the highest tolerable intensity, as indicated by the research subject. Upon completion of the sitting protocol, subjects in both groups completed the same incremental exercise test on the bicycle ergometer. An illustration of the exercise protocol is presented in Figure 1. The protocol consisted of 4min stages starting at 50W, increasing by 50W until 150W, then increasing by 20W each minute until voluntary exhaustion or until they were no longer able to maintain >60RPM. This alternative incremental exercise protocol provides increased duration at submaximal intensity and has been used to demonstrate improvements of exercise capacity after bi-lateral limb ischemic preconditioning [16].

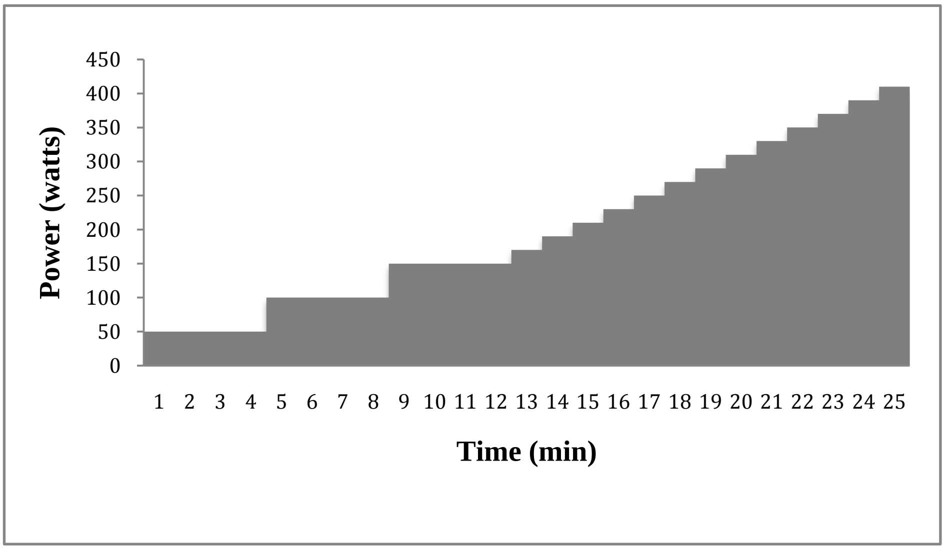


Figure 1. Illustration of the cycling protocol used after 5hr of sitting

2.3. Statistical Analysis

Statistical analyses were performed using SPSS Statistical software (SPSS, V.24, Chicago IL). Changes in leg power were assessed and compared at baseline, after the uninterrupted condition, and after the respective interrupted condition in all participants who completed the walk or BFR+TEMS conditions (n=20) using repeated measures ANOVA. If a statistically significant change occurred between groups or conditions within the data set, then post-hoc evaluations were conducted. Statistical significance was considered to be P=0.05. To examine the effect of sitting on incremental exercise to fatigue, an independent measures ANOVA was conducted to compare the results of the exercise test without prior sitting and after 5hr of uninterrupted sitting in the control group. This was similarly used to determine if BFR+TEMS or WALK intervention strategies had any impact on individual exercise performance by comparing interrupted sitting results on the cycling test to their corresponding 5hr uninterrupted sitting condition.

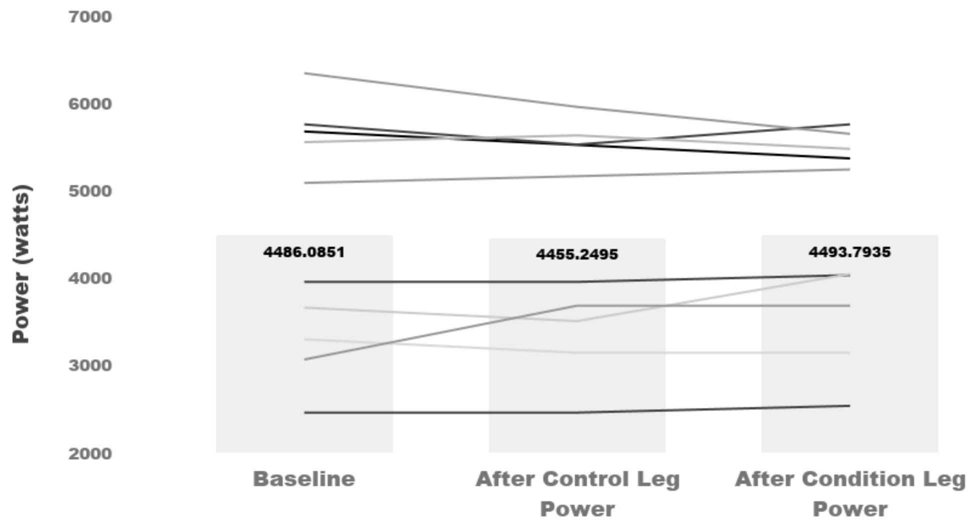
3. Results

Descriptive participant characteristics for each group are summarized in Table 1. Leg power was not impacted by 5hr of uninterrupted sitting (Δ= -80± 988W, P=0.3). Individual analysis of the 20 participants (n=10 from WALK, n=10 BFR+TEM) that completed vertical jumps at baseline, after uninterrupted sitting and after their respective intervention revealed that 15 individuals experienced decreased leg power compared to their own baseline, while only five individual's jumps improved after uninterrupted sitting (Figure 2). A comparison of the effects of BFR+TEMS and WALK on leg power after 5hr of sitting revealed no significant benefit of either intervention (BFR+TEMS Δ= 7± 1252 W; WALK Δ= 53± 547W; p=0.5).

Uninterrupted sitting was also not significantly detrimental to cycling performance (Table 2.) (Δ= - 10 sec, 95% CI -7 sec, 27 sec; p=0.2). As prolonged sitting time did not appear to impact cycling performance ability in and of itself, a comparison of BFR+TEMS and WALK interventions was conducted relative to the uninterrupted control using a paired one-way ANOVA, which considered the change in time to fatigue after no sitting, uninterrupted sitting and both interrupted conditions, respectively (p=0.6). The results revealed no significant change using BFR+TEMS (Δ= 23 sec, 95% CI -74 sec, 27 sec) or WALK (Δ= 14 sec, 95% CI -90 sec, 62 sec) intervention strategies over their respective uninterrupted sitting exercise performances (Figure 3.).

Table 1. Summary of participant characteristics (n=30). Group 1, Control group (no sitting and uninterrupted sitting); Group 2, Walking (sitting uninterrupted and sitting with intermittent walking); Group 3, BFR+TEMS (sitting uninterrupted and sitting with repeated blood flow restriction and electrical muscle stimulation)

Subject Characteristic	Group Mean	Male	Female
Group 1			
Sex	8m, 2f	-	-
Age	24.2±2.3	24.3±2.3	23.5±3.5
Height (cm)	166.7±32.3	165.5±36.4	171±4.2
Weight (kg)	75.7±15.0	80.1±13.1	58±5.6
VO_2 (ml·kg^{-1}min^{-1})	47.5±4.9	47.3±4.8	48.1±7.0
Group 2			
Sex	5m, 5f	-	-
Age	24.9±3.3	24.8±0.4	25±4.8
Height (cm)	172.1±7.8	178.7±2.1	165.5±4.6
Weight (kg)	71.4±12.7	82.7±4.9	60±3.9
VO_2 (ml.kg.-1min-1)	52.0±8.6	48.6±3.1	55.4±11.2
Group 3			
Sex	8m, 2f	-	-
Age	23.5±4	23.3±4.5	24±1.4
Height (cm)	176.4±7.1	178.5±3.2	167.5±13.4
Weight (kg)	77.1±8.7	80±6.9	65.1±5.3
VO_2 (ml.kg.-1min-1)	55.1±5.5	56.3±5.3	49.9±0.9



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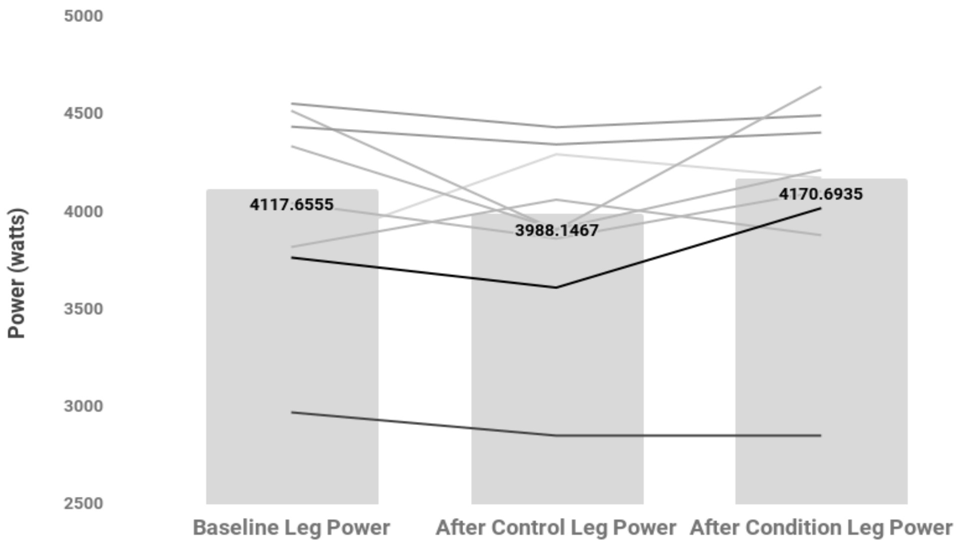

b

Figure 2. Leg power measurements at baseline visit, after 5hr of uninterrupted sitting and after 5hr of sitting with (a.) blood flow restriction and transcutaneous electrical muscle stimulation (BFR+TEMS, n=10) and (b.) walking (WALK, n=10). Leg power was not measured in the exercise protocol control group

Table 2. Outcome measurements for vertical jump (a.) and the incremental exercise protocol (b.). Leg power was measured to the nearest .5 inch and then converted to watts by mathematical formula. Exercise time to fatigue is expressed as minutes completed and percentage of subsequent minute completed

a.

Group	Baseline (watts)	Uninterrupted (watts)	Treatment Condition (watts)	Effect of Condition	Condition Group Interaction
Walk	4118±556	3988±502	4171±559	0.194	0.481
BFR+TEMS	4486±1354	4455±1242	4494±1153	0.194	0.481

b.

Group	Baseline (min)	Uninterrupted (min)	Treatment Condition (min)	Effect of Condition
Walk	-	19.29±1.74	19.52±2.29	0.687
BFR+TEMS	-	18.79±1.90	19.17±2.19	0.33
Control	18.43±3.03	18.27±3.05		0.221

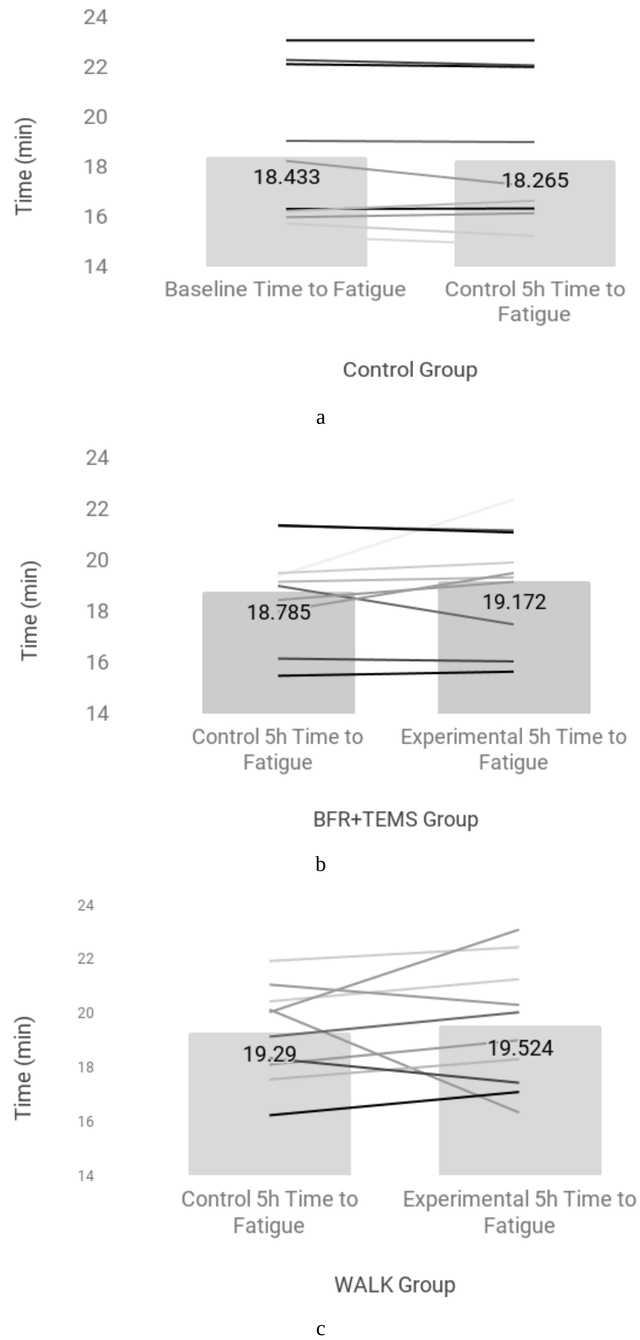

Figure 3. Individual participant cycling protocol results. The control group (b, n=10) was measured without any sitting prior to exercise and with 5hr of sitting prior. Experimental groups (b, n=10; c, n=10) were measured after 5hr of uninterrupted sitting and after 5hr with BFR+TEMS (b) or walking (c)

4. Discussion

The primary novel finding of the current study was that prolonged sitting did not impact post-sitting performance in tests of cycling to exhaustion or vertical jump. The inclusion of intermittent physical activity as a method of breaking up prolonged sitting did not appear to have additional benefits to performance.

Evidence suggests that a reduction in shear rate occurs in healthy adults after only a few hours of uninterrupted sitting [3], thus, it was initially hypothesized that prolonged sitting might produce moderate decrements in athletic performance due to impairments in local blood flow and endothelial function. There was no significant change in cycling time to exhaustion or explosive leg power after uninterrupted sitting, suggesting that neither the aerobic nor anaerobic systems were greatly affected.

While mechanisms of blood flow and homeostasis may be affected by prolonged inactivity, as is evidenced in the extensive literature [13,18,21], this does not appear to translate in a more applied setting and is, thus, likely of little concern to athletes or other populations for whom physically demanding exercise follows forced sitting. It is possible that moderate decrements in performance may have occurred during the initial stages of exercise; however, maximal cycling is a relatively large stimulus, and therefore even the initial exposure to this stimulus may have outweighed any impact of sitting. Presumably, a high quality dynamic warm-up prior to competition would mitigate any potential decrements that may be visible at a submaximal intensity. As such, we must reject our hypotheses that prolonged sitting would affect exercise capacity, and that decrements could be offset with a simple walking intervention, which was thus a non-issue.

It was speculated that BFR+TEMS might produce a small ergogenic effect as a result of the potential ischemic preconditioning effects caused by repeated mechanical manipulation of muscle perfusion. Recent evidence, from our group and others [21–23], does suggest that IPC can have an effect on subsequent exercise performance, and in fact the addition of both walking and TEMS has been shown to augment this affect [24], though, it was not observed in the current study. It is important to note, however, that none of this previous work has specifically been used in conjunction with forced sitting, De Groot et al. demonstrated increased aerobic capacity and peak power output [16] using the same exercise protocol after a single dose of IPC (cycles of 5 minutes of occlusion, 5 minutes of reperfusion using a standardized 220 mmHg cuff pressure); however, in the current study these potential performance enhancements did not translate to either increased time to exhaustion, or changes in the ability to generate maximal leg power, either as peak watts during the cycling protocol or the vertical jump. Why this ischemic preconditioning effect appears to work in some settings but not others [15] is an area that requires further investigation; this has been suggested to be related to factors including the intensity and modality of exercise, the period of time from treatment to performance, or the fitness of the participants. As such, it is certainly conceivable that the current model, which induced prolonged sitting, had the effect of blunting this response.

As with any study, there are limitations that need to be highlighted and should be considered in the interpretation of the data. The current study was exploratory in nature and thus expected effect sizes and *a priori* statistical power calculations were unavailable. It should also be noted that the current study was not gender balanced. The authors are however, not aware of any research suggesting that male and female participants may behave differently in the experimental procedures used in this study. The exercise protocol was selected based on previous blood flow restriction research [16], and employment of the vertical jump test as method of evaluating explosive power. Future work examining a predominantly anaerobic glycolysis driven exercise might be of merit. One interesting limitation of employing TEMS was the inability to control for electrical stimulation intensity, due to the unique pain sensitivity of each participant. We used a commercially available Compex muscle stimulator, which participants were allowed to control, but were encouraged to use the highest tolerable intensity throughout each testing session. Previous work has indicated that blood flow only increases at >10% MVC repeated contractions [13], so in order to account for intensity indirectly, participants were required to have visible muscle contractions. In this study, we did not measure maximal oxygen uptake or flow mediated dilation via ultrasound after prolonged sitting, as the intention was to examine applied performance. It is possible that even though alterations were not observed in performance variables that, at a more mechanistic level, alterations in metabolism, blood flow, and exercise efficiency may have still occurred. The current study used a randomized design where both the groups (BFR+TEMS or walking) and the order of exposure (uninterrupted or interrupted) to sitting were random. This method of experimental design helped to eliminate experimental bias and also allow for a smaller time commitment for participants.

5. Conclusions

The purpose of this study was to explore the effect of prolonged sitting prior to athletic performance. As a majority of published research focuses on breaking-up chronic occupational sitting time, the goal of the current study was to examine how an acute bout of sitting might impact one's ability to perform maximally during staged "competition." In the performance variables tested herein, it does not appear that acute prolonged sitting is detrimental to athletic performance. Further research is of merit to determine if sitting impacts other performance variables. Although BFR+TEMS was not a successful method of producing ergogenic effects currently, future research may consider examining different avenues of BFR+TEMS as a possible method for improving other areas of health and performance.

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