**Title:** Effort and duration matched 'High Intensity Interval Training' using cycle ergometry compared to leg press resistance training

**Authors:** Marcelo Henrique Silva[1] (silvamarcelo.prof@gmail.com); Cláudio André Barbosa de Lira[1] (andre.claudio@gmail.com); James Steele[2,3] (james.steele@solent.ac.uk); James P. Fisher[2] (james.fisher@solent.ac.uk); João Felipe Mota[4] (jfemota@gmail.com) Aline Corado Gomes[4] (aline2nut@hotmail.com); Paulo Gentil[1] (paulogentil@hotmail.com).

**Institutional Affiliations**: [1]College of Physical Education and Dance, Federal University of Goias, Goiânia, Brazil. [2]School of Sport, Health, and Social Sciences, Solent University, United Kingdom. [3]ukactive Research Institute, London, United Kingdom. [4]Dieterian College Federal University of Goias, Goiânia, Brazil

**Pre-print published on:** 15th April 2019 **DOI:** 10.31236/osf.io/gkxaf

**Citation:** Silva, M. H., de Lira, C. A. B., Steele, J., Fisher, J., Mota, J. F., Gomes, A. C., & Gentil, P. (2019, April 15). Effort and duration matched 'High Intensity Interval Training' using cycle ergometry compared to leg press resistance training. https://doi.org/10.31236/osf.io/gkxaf

**Corresponding author**:

Paulo Gentil (paulogentil@hotmail.com)

FEFD - Faculdade de Educação Física e Dança

Universidade Federal de Goiás - UFG

Campus Samambaia

Avenida Esperança s/n, Campus Samambaia- CEP: 74.690-900

Goiânia - Goiás - Brasil

Phone/Fax: +55 062 3521-1105

**ABSTRACT**

**Purpose**: Exercises for increasing muscle strength and cardiorespiratory fitness are traditionally prescribed separately, based on the different characteristics of the modalities and the adaptations that each typically promotes. This separation has been questioned by recent studies that suggest that the intensity of effort at which the exercise is performed seems to impart greater influence than the equipment involved. Based on this assumption, it has been proposed that 'cardio' training and resistance training might promote similar adaptations as long as effort and duration are equated. The objective of the present study was to compare two 'High Intensity Interval Training' protocols matched for effort and duration using different exercise modalities, leg press (resistance training) and cycle ergometry ('cardio'), upon changes in muscle strength, cardiorespiratory fitness, and lower limb composition in recreationally trained men. **Methods**: Twenty-five trained men (28.9 ± 5.6 years, 6.6 ± 5.6 years of training experience) were randomly divided into two groups. One group performed sprint interval training on a cycle ergometer (4 sets of 30 seconds sprints) and the other performed leg press (4 sets of 10-12 repetitions to momentary failure). Both groups trained three times a week for 5 weeks. Before and after the training period, the participants performed a 10-repetition maximum (10RM) for knee extension, An incremental exercise test on a treadmill for time to exhaustion (TTE) and peak oxygen consumption ($\dot{V}O_{2peak}$), and underwent dual energy X-ray absorptiometry to assess lower limb composition. **Results**: Knee extension 10RM and TTE increased in both groups with no statistically significant between group difference ($p = 0.614$ and $p = 0.210$). There was a statistically significant between group difference for change in $\dot{V}O_{2peak}$ ($p = 0.023$) with only the cycle ergometer group showing a significant within group increase. For all lower limb composition outcomes, changes were minimal. **Conclusion**: The results of the present study suggest that 5 weeks of effort and duration matched 'High Intensity Interval Training' using cycle ergometry 'cardio' or leg press resistance training may produce similar strength and endurance (TTE) adaptations. However, 'cardio' modality training may produce greater increases in cardiorespiratory fitness.

**Key Words***:* Aerobic training, strength training, strength, cardiorespiratory fitness, effort, intensity.

## 1. INTRODUCTION

Physical activity and exercise is associated with reduced risk of all-cause mortality (Nocon et al., 2008) in a seemingly dose-response manner with respect to volume (Lee & Skerrett, 2001; Loprinzi, 2015). As a result, most guidelines for physical activity and exercise are primarily focused upon the accumulation of a minimum volume (Garber et al., 2011). The benefits, however, may result more so from the outcomes of physical activity (i.e. improvements in cardiorespiratory fitness and strength) rather than the behavior per se, and all-cause mortality is associated with both cardiorespiratory fitness (Kodama et al., 2009; Lee et al., 2011), and muscle strength (Dankel, Loenneke, & Loprinzi, 2016). Further, it is argued that greater improvements in these outcomes occur from higher effort physical activity and exercise compared to more moderate physical activity (Steele et al., 2017). Indeed, the intensity of effort of physical activity and exercise seems to be a more impactful moderator of all-cause mortality risk reduction than the amount performed (Lee et al., 2003; Wisloff et al., 2006; Loprinzi & Davies, 2015).

Considering this, and that lack of time is a commonly reported barrier to physical activity and exercise (Arzu, Tuzun, & Eker, 2006; Gómez-López, Gallegos, & Extremera, 2010; Kimm et al., 2006), higher intensity of effort based approaches have been a focus of recent discussion and debate (Biddle and Batterham, 2015; Steele et al., 2017). Indeed, less than 5% of the US population meet guidelines to accumulate at least 30 minutes per day of moderate physical activity (Troiano et al., 2008) and in Brazil surveys report 69.8% of respondents have stated they abandoned exercise due to lack of time (Rossi, Cândido, Sitta, Jabur, & Sanz, 2015). However, it has been argued that conceptualisation of physical activity and exercise from an effort driven model may open up a wider range of options to increase reach to broader and more representative portions of the population, and indeed to some extent can help address the reported barrier of time (Steele et al., 2017). Further, it has been argued that, when considering exercise from the perspective of the intensity of effort required, modality may be of lesser importance in determining the physiological outcomes produced thus also potentially reducing barriers caused by logistical concerns such as lack of specific equipment or facilities (Fisher & Steele, 2014; Steele et al., 2017).

Intensity of effort during exercise can be defined in relation to the current ability to meet the demands of the task being attempted, and for resistance training this is often considered with respect to the proximity to momentary failure (Steele, 2014; Steele et al., 2017); though, this conceptualisation can also be argued to apply to traditional 'cardio' modalities (e.g. cycle ergometry; Phillips & Winett, 2010). Broadly speaking, exercise is often dichotomized into these two primary modalities, 'cardio' (also referred to as 'aerobic training'), and resistance training, with the former primarily thought to stimulate improvements in cardiorespiratory fitness, and the latter primarily stimulating improvements in strength, power, and muscle size. However, some studies evidence that 'cardio' modalities can promote increases in muscle strength and size (Konopka & Harber, 2014; Ozaki, Abe, et al., 2015; Ozaki, Loenneke, Thiebaud, & Abe, 2015; Ozaki, Loenneke, Thiebaud, Stager, & Abe, 2013), especially when training is performed at high intensities of effort (Harber et al., 2009; Lundberg, Fernandez-Gonzalo, Gustafsson, & Tesch, 2013), while on the other hand others suggest high effort resistance training is capable of improving cardiorespiratory fitness (Ozaki, Loenneke, Thiebaud, & Abe, 2013; Steele, Fisher, McGuff, & Bruce-Low, 2012). Despite this, there are relatively few studies directly comparing resistance training and 'cardio' modalities whilst controlling for variable such as intensity of effort and the duration of the exercise bouts.

Acute studies that have matched conditions by effort and duration have found similar physiological responses between resistance training and 'cardio' modalities (Steele et al., 2018; Vilaça-Alves et al., 2016). Steele et al. (2018) examined the effect of modality upon acute physiological response during high intensity of effort interval based exercises; leg press exercise (4 x 12RM using 2 seconds concentric and 3 seconds eccentric repetition durations thus meaning each set lasted ~ 60 seconds), and cycle ergometry (4x 60 seconds bouts using resistance level permitting 80 – 100 rpm but culminating with being unable to sustain the minimum cadence for the final 5 – 10 seconds). $\dot{V}O_2$, respiratory exchange ratio, blood lactate accumulation, estimated energy expenditure, muscle swelling, electromyographic activity and perceptual responses were evaluated in both conditions and there were no significant effects by condition in any physiological responses examined. Thus, the acute responses suggest that there might be similarity in the physiological responses to different forms of exercise when the effort and duration is matched.

However, studies comparing resistance training and 'cardio' modalities with respect to chronic adaptations show contrasting results. When comparing resistance training and 'cardio' approaches, though some studies suggest no significant differences for changes in cardiorespiratory fitness (Messier and Dill, 1985; Hepple et al., 1997; Sawczyn et al., 2015), the majority suggest that 'cardio' type approaches favour cardiorespiratory fitness increases (Goldberg et al., 1994; Poelhman et al., 2000; Ferrara et al., 2006; Wilkinson et al., 2008; Silanpaa et al., 2008; Athianen et al., 2009). Similarly, for strength changes, though there are exceptions (Messier and Dill, 1985), the majority of research suggests that resistance training produces greater increases in strength than 'cardio' type training (Goldberg et al., 1994; Poelhman et al., 2000; Ferrara et al., 2006; Wilkinson et al., 2008; Silanpaa et al., 2008; Athianen et al., 2009). Furthermore, a recent meta-analysis has also shown that resistance training produces more favorable changes in muscle hypertrophy compared to 'cardio' type approaches (Grgic et al., 2018). Though, none of these studies matched effort or duration of exercise and thus comparisons were for two different *patterns* of exercise behaviour and not necessarily between modalities per se. As noted, the intensity of effort may be of importance when drawing comparisons between modalities and where studies have matched these the adaptations produced seem to be largely similar (Androulakis-Korakakis et al., 2017; Álvarez et al., 2017; Gil-Sotomayor et al., 2018).

If it is possible to improve both cardiorespiratory fitness and muscle strength using a single modality (resistance training or 'cardio'), then it would be possible to design exercise programs and provide physical activity recommendations that bring many functional benefits while reducing time commitment, which could be valuable to increase adherence. At present, guidelines recommend that both modalities be engaged in (Garber et al., 2011). Yet if outcomes were found to be similar, this would allow practitioners and individuals to choose among many possible activities, according to personal preference, equipment availability and logistics. However, there is still limited research examining exercise modality from the perspective of an effort-based paradigm. Therefore, the purpose of the present study was to compare two 'High Intensity Interval Training' protocols matched for effort and duration using different exercise modalities, leg press (resistance training) and cycle ergometry ('cardio'), upon changes in muscle strength, cardiorespiratory fitness, and lower limb composition in recreationally trained men.

## 2. METHODS

### *Participants*

Eighty-four healthy men were initially recruited through social media and word of mouth. Eligibility criteria for entering the study included being at least 18 years old, having at least 12 months of previous resistance training experience, having been engaged in resistance training uninterruptedly for the previous 6 months, and being free of clinical problems that could be aggravated by the study procedures. Participants reported having previous experience of 'cardio' training but this was not an inclusion criteria. Twenty-five were excluded during the pre-test period and 59 were randomized in cycle ergometer (Bike) and leg press groups. All completed a Physical Activity Readiness Questionnaire (PAR-Q) to evaluate general health status. Thirty-four volunteers did not complete the study for several reasons (figure 1); 15 of them claimed that the intensity of effort and associated discomfort was too high and 19 dropped out for personal reasons. All 25 participants (28.9 ± 5.6 years; 178.8 ± 7.6 cm; 80.4 ± 12.7 kg; 6.6 ± 5.6 years of training) that concluded the study had a history of training 3 – 4 times per week performing both resistance training and 'cardio', with the performance of 229.6 ± 59.5 minutes of exercise per week in the previous 6 months. At the end of the study 25 subjects met all criteria to be included in data analysis (Table 1). The participants were all notified of the research procedures, requirements, benefits and risks before providing written informed consent prior to participation in the study, and all the experimental protocols of the present study were approved by Ethics Committee of the Federal University of Goiás (CAAE: 56907716.5.0000.5083).

### *Knee extension 10 repetition maximum (10 RM)*

Tests were conducted using a knee extension machine (*Rocha's equipment* Goiânia, Brazil). This exercise was chosen to avoid the possible influences of learning (Gentil, Del

Vecchio, Paoli, Schoenfeld, & Bottaro, 2017), as neither training group performed it during the study interventions. At baseline prior to the intervention, the 10RM load for each participant was assessed twice on separate days at least 72 hours apart according to the procedures reported by Gentil, Oliveira & Bottaro, (2006). Technical error of measurement was calculated using Hopkins (2015) spreadsheets as 2.11 kg [95%CI 1.65 to 2.94]. Prior to the tests, participants performed specific warm-ups with 30% of their usual training load, performing three sets of 15 repetitions with two-minutes of rest intervals between sets. After the warm up, the 10RM test was performed. To minimize errors, all subjects were instructed regarding test procedures and correct exercise technique. All tests were supervised by professionals with experience in this type of procedure, who were blinded to group allocation. The participants were verbally encouraged to exert maximum efforts during the tests. Repetitions were performed using a duration of 2 seconds for concentric and 2 seconds for eccentric muscle actions, without pause in the transition between phases. However, due to fatigue the repetition duration necessarily lengthened as momentary failure was approached. A 5-minute interval was given between each attempt with loads being adjusted $\geq$2kg between attempts. No more than five attempts were necessary for any participant.

*Maximal graded exercise testing.*

Graded exercise testing (GXT) was administrated to determine peak oxygen uptake ($\dot{V}O_{2peak}$). Prior to performing GXT, participants were given a standardized set of instructions explaining the test. On completion of these preliminary procedures each participant underwent incremental maximal exercise test on a motorized treadmill (ATL, Inbramed Porto Alegre, Brazil) with 0% incline. The test consisted of a 5 min warmup at 7 km.h$^{-1}$, and the initial speed was progressively increased by 1 km.h$^{-1}$ every 1 minute until exhaustion (de Lira et al., 2013). All tests were supervised by the lead investigator with experience in this type of procedure, who was not blinded to group allocation. During the GXT participants were verbally encouraged to exercise for as long as possible and give a maximal effort. Respiratory gas samples of oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$) were analysed by a metabolic gas collection system (VO2000, MedGraphics, Saint Paul USA) averaged over 10 second periods. Prior to testing, the metabolic system was calibrated according to the manufacturer's instructions. After exhaustion the load was reduced to 3.0 $Km.h^{-1}$ to perform a recovery of a 2 min. The $\dot{V}O_{2peak}$ was determined by the highest 10 second average $\dot{V}O_2$ during the test. Heart rate was continuously monitored using a cardiac monitor (Polar Finland RS-800 Kempele, Finland) and RPE was evaluated every minute using the 6-20 Borg, (1982) scale.

*DXA (Dual X-ray Densitometry)*

Body composition was measured at baseline and after 5 weeks of intervention by dual energy X- ray absorptiometry (DXA), using a DPX NT densitometry equipment (General Electric Medical Systems Lunar, Madison, EUA) with Encore 2011 software (version 13.60, GE Healthcare). Participants were instructed not to exercise in the 24 hours before the test, and all tests were conducted at the same time of the day (between 7 a.m. and 12 noon); During the tests, the participants were barefoot and wearing light clothing. All tests were supervised by professionals with experience in this type of procedure, who were blinded to group allocation. The same operator performed all the measures and calibrations. The coefficient of variation for the DXA tests of lean and fat mass were 0.75% and 1.03%, respectively.

*Assessment of nutritional habits*

In the first and last weeks of the study, dietary intake was assessed using the 24-h dietary recall method. The participants were instructed to record their daily dietary intake for 3 days, including a weekend day. The volunteers were instructed to not change their nutritional habits during the study period, all of them verbally confirmed that they maintained their diet throughout the trial period, and no relevant change was reported. Dietary caloric intakes and macronutrient values was performed by Dietpro software (version 5.8, Minas Gerais, Viçosa, Brazil). All participants were instructed to maintain a habitual diet and water intake *ad libitum.*

*Training Program*

Training classes were offered every hour at the University Training facilities. Participants chose the training schedules that best met their routine, to facilitate their adherence to the research. Then, the classes were randomly divided into the two possible training interventions; a resistance training intervention using the leg press, and a 'cardio' condition using the cycle ergometer.

The training protocols were performed a circuit model, with one-and-a-half-minute passive interval between each exercise in the sequence described in Table 2. Both conditions performed the same supplementary exercises including chest press, lat pulldown, knee flexion, and trunk flexion using resistance machines interspersed between the leg press or cycle ergometer sets matched for effort by training to momentary failure as described below. Considering the importance of supervision during training ( Gentil & Bottaro, 2010), participants were supervised by at last one trainer during each session. During the first training session participants were instructed to report their perceived effort and perceived discomfort for the leg press or cycle ergometer on two separate 0-10 scales designed to differentiate the two perceptual responses (Steele et al., 2017).

The leg press condition involved participants performing 4 sets of ~10 RM in the 45° leg press (Rotech, RS SP) culminating in participants reaching momentary failure at the $10^{th}$ repetition. Repetitions were performed using a 1 s concentric and 2 s eccentric repetition duration. Thus, each set lasted ~ 30 s in total. If participants could not perform all 10 repetitions, the load was decreased for the next set by 10%. If the participants were able to exceed all 10 repetitions they were still encouraged to continue until momentary failure, as previously defined

(Steele, Fisher, Giessing, & Gentil, 2017), and based on the number of repetitions the load was adjusted for the next set by 5-10%.

The cycle ergometer condition involved participants performing 4 sets of 30 seconds sprints using a stationary cycle ergometer (Evolution SR, Schwinn, EUA). At the beginning of the intervention all participants started with the same resistance level on the cycle ergometer and were encouraged to maintain the highest revolutions per minute possible (i.e. give a maximal effort) at that resistance for the duration of each set. If participants were able to maintain a similar cadence throughout then the resistance was increased by a one quarter turn of the resistance setting on the cycle ergometer for the next set or session. If the volunteer lost the ability to move the pedal before 30 seconds (i.e. reached momentary failure), the time was recorded, and the resistance reduced by one quarter turn of the resistance setting on the cycle ergometer for the next set or session.

*Statistical analysis*

The independent variable was 'group' (leg press or bike) and the dependent variables were the absolute change (post- minus pre-test) in knee extension 10RM, $\dot{V}O_{2peak}$ and time to exhaustion (TTE) during the GXT, and total lower limb mass, lower limb lean mass, and lower limb fat mass determined from DXA. Analysis of Covariance (ANCOVA) was used to compare absolute change for each outcome variable between groups with pre-test values used as covariates for each analysis. Acute perceptual responses for effort and discomfort were examined for effects by 'group' and 'set number' (i.e. set 1 to set 4) using a two way repeated measured Analysis of Variance (ANOVA; a Greenhouse-Geisser correction was applied where assumptions of sphericity were found to be violated using Mauchly's test). Analysis was conducted using R and the 'jamovi' package (version 3.5.2; R Core Development Team, https://www.r-project.org/). An $\alpha$ for statistical significance was set at 0.05. Further, estimated marginal means with 95% confidence intervals (CI) were calculated and plotted with fitted values from the ANCOVA model for visualisation of results.

## RESULTS

### *Knee extension 10RM*

There was no statistically significant between group effect for change in knee extension 10RM ($F_{(1,22)} = 0.261$, $p = 0.614$). Both groups appeared to improve as evidenced by 95%CIs not containing zero. Changes appear similar for both bike and leg press groups and figure 1a shows estimated marginal means with 95%CIs and fitted values from the ANCOVA model.

### *Time to Exhaustion in IXT*

There was no statistically significant between group effect for change in TTE for the IXT ($F_{(1,22)} = 1.665$, $p = 0.210$). Both groups appeared to improve as evidenced by 95%CIs not containing zero and, though not significantly different, improvements appeared slightly greater for the bike group. Figure 1b shows estimated marginal means with 95%CIs and fitted values from the ANCOVA model.

### $\dot{V}O_{2peak}$ *(Peak oxygen consumption)*

There was a statistically significant between group effect for change in $\dot{V}O_{2peak}$ ($F_{(1,22)} = 5.93$, $p = 0.023$). The bike group appeared to improve as evidenced by 95%CIs not containing zero, whereas the 95%CIs for change in the leg press group overlapped zero. Figure 1c shows estimated marginal means with 95%CIs and fitted values from the ANCOVA model.

### *Lower Limb Composition*

There was no statistically significant between group effect for change in total lower limb mass ($F_{(1,22)} = 1.589$, $p = 0.221$), lower limb lean mass ($F_{(1,22)} = 0.491$, $p = 0.491$), or lower limb fat mass ($F_{(1,22)} = 1.238$, $p = 0.278$). Though not significantly different, for all measures the leg press group appeared to increase as evidenced by 95%CIs not containing zero, whereas the 95%CIs for change in the bike group overlapped zero. Figures 3a, 3b, and 3c show estimated marginal means with 95%CIs and fitted values from the ANCOVA model.

*Perceptual Responses*

Two way repeated measures ANOVA revealed no significant effects by ‘group’ for effort ($F_{(1,23)} = 1.69$, $p = 0.206$) or discomfort ($F_{(1,23)} = 3.40$, $p = 0.078$). There was a significant effect by ‘set number’ with both effort ($F_{(3,69)} = 67.05$, $p < 0.001$) and discomfort ($F_{(3,69)} = 51.21$, $p < 0.001$) increasing across sets. There was no significant interaction effect for either effort ($F_{(2.24,51.45)} = 1.54$, $p = 0.223$) or discomfort ($F_{(1.82,41.88)} = 1.23$, $p = 0.301$). Estimated marginal means and 95% confidence intervals for both effort and discomfort between groups and across sets are shown in Figure 4a and 4b respectively.

*Dietary intake*

There were not any meaningful changes in dietary patterns in either the bike or leg press groups. Daily caloric intake, percentage of calories derived from proteins, carbohydrates and total fat from the pre-training period are shown in Table 3.

## 3. DISCUSSION

The present study compared the effects of different modalities of training whilst matching effort and duration of exercise upon strength, cardiorespiratory fitness, and lower limb composition in recreationally trained men. Resistance training was performed using a leg press and 'cardio' training was performed using a cycle ergometer. The primary findings of the present study were that, after 5 weeks of training, strength and endurance (TTE) adaptations may be similar, 'cardio' modality training appeared to produce greater increases in cardiorespiratory fitness. For both training interventions though, lower limb composition changes were trivial.

A number of previous studies comparing resistance training with 'cardio' training modalities have reported that resistance training produces greater increases in strength than 'cardio' type training (Goldberg et al., 1994; Poelhman et al., 2000; Ferrara et al., 2006; Wilkinson et al., 2008; Silanpaa et al., 2008; Athianen et al., 2009) though there are exceptions (Messier and Dill, 1985). As noted though, few studies have compared modalities whilst matching effort or duration of exercise. In addition, and a particular issue for strength outcome testing (Buckner et al., 2017; Gentil, 2017), studies have often tested their outcomes in manners that might favour particular interventions (i.e. strength was tested using the exercise for which the resistance training intervention was specifically trained). Where studies have matched effort and duration, but used testing outcomes favouring the resistance training intervention there seems to be greater strength changes for resistance training compared to 'cardio' (Álvarez et al., 2017). Yet, similarly to the findings reported here, where effort and duration have been matched but the testing outcome was independent of either intervention, strength changes appear to be largely similar (Androulakis-Korakakis et al., 2017).

The comparative strength adaptations may result from similar neuromuscular stimulus in both modalities when effort and duration are analogous. Both Steele et al. (2018) and Kuznetsov et al. (2011) have reported findings suggesting that motor unit recruitment may be similar between modalities and indeed effort has been argued to arise from the central motor command required to drive the musculature to perform the task being attempted (Marcora, 2009; Pageaux et al., 2016). Thus, it is thought that effort, both that required and perceived, is likely intrinsically linked to motor command and motor unit recruitment (de Morree et al., 2012; Guo et al., 2017) and possibly due to Henneman's size principle (Potvin and Fuglevand, 2017). Indeed, both high effort resistance training (Nuzzo et al., 2017) and 'cardio' based high intensity interval training (Kinnunen et al., 2019) have been shown to strength likely due to neurmuscular adaptations.

Regarding cardiorespiratory fitness, both groups improved in time to exhaustion (though this appeared slightly greater for the 'cardio' group) which may have been facilitated to some degree by the improvements in strength. Indeed, Álvarez et al. (2017) reported endurance performance tested as 2 km walking test improved in both resistance training and 'cardio' effort and duration matched 'high intensity interval training' with no statistically significant differences between them (both improving by ~2 minutes; $p$ = 0.284).

For change in $\dot{V}O_{2peakh}$ however, there was a significant difference between groups for with only the 'cardio' group seemingly improving. Though this finding is in agreement with a number of previous studies suggesting 'cardio' type approaches favor cardiorespiratory fitness increases (Goldberg et al., 1994; Poelhman et al., 2000; Ferrara et al., 2006; Wilkinson et al., 2008; Silanpaa et al., 2008; Athianen et al., 2009), it contradicts the findings of studies where modalities have been compared with effort and duration matched (Álvarez et al., 2017; Gil-Sotomayor et al., 2018). This may be due to the fact that participants were already trained as both groups had multiple years previous training experience. Indeed, it is well known that the magnitude of changes in cardiorespiratory fitness along with many other variables diminishes with training experience. However, training experience was similarly long between groups and it might be expected that any ceiling effect would thus be similar. Further, some previous effort and duration matched modality comparisons have been in highly trained populations (i.e. powerlifters and strongmen) and found similar changes in cardiorespiratory fitness (Androulakis-Korakakis et al., 2017). Though it should be noted that (Androulakis-Korakakis et al., 2017) indirectly measured cardiorespiratory fitness using a step test whereas in the present study $\dot{V}O_{2peak}$ was measured directly. In the present study though there was considerable variation in maximal criteria from the incremental treadmill protocol with none of the participants reaching a respiratory exchange ratio >1.15 and also a number of participants showing differences in end of test max heart rate (>10 beats.min$^{-1}$) between pre- and post-tests suggesting that truly maximal efforts may not have occurred during this testing. Thus, though $\dot{V}O_{2peak}$ changes may be similar in untrained participants (Álvarez et al., 2017; Gil-Sotomayor et al., 2018) and may rise from similarity in acute physiological responses (Steele et al., 2018), it is at present not wholly clear whether $\dot{V}O_{2peak}$ changes similarly when comparing effort and duration matched modalities in trained participants.

Changes in lower limb composition where minimal for both groups. Changes in muscle mass are relatively minimal following the initial training period (Counts et al., 2017) which may explain the minimal changes reported here. However, though there were no statistically significant difference between groups, only the resistance training group saw significant within group changes in both lean and fat mass contributing to an increase in total lower limb mass. It is not clear the degree to which this is meaningful, nor why both lean and fat mass might have increased. This may merely reflect variation in the measurement over the duration of the study. A recent meta-analysis has shown that resistance training produces more favourable changes in muscle hypertrophy compared to ‘cardio’ type approaches (Grgic et al., 2018) though the included studies were not effort and duration matched. Gil-Sotomayor et al. (2018) however reported in untrained persons performing effort and duration matched resistance training or ‘cardio’ that changes in lean mass were minor ($g$ = -0.07 to 0.00). Thus, it would seem that changes in lean mass are likely minimal with either training modality.

Acute perceptual responses did not differ significantly between groups suggesting that the two were succesfully matched in terms of effort, but both perceievd effort and discomfort increased with set number. These findings are similar to the acute findings reported by Steele et al. (2018) using the same scales and again, presumably these increases occurred across sets as a function of accumulated fatigue. However, in the present study participants were encouraged to exercise maximally in both conditions (i.e. to momentary failure on the leg press and to sprint maximally on the cycle ergometer) from set 1, yet maximal ratings of perceievd effort did not near maximal values for most participants until the final set. On average the ratings of perceived effort reported in the present study were around ~1 point lower than those reported by Steele et al. (2018), though in their study the exercise protocols were designed to be high, but not necessarily maximal. Despite this, in the present study participants perceptions of discomfort were around ~2-3 points higher than those reported by Steele et al. (2018). This suggests the possibility of an exponential increase in discomfort when efforts are near maximal in both exercise modailities, but that this response may be similar between them. Participants in the present study were encouraged to provide maximal efforts in both groups and yet our data suggest that they may not have perceived themselves to be doing so. This may have been due to some element of pacing as participants were aware they had to complete multiple sets of the exercises. Indeed, pacing strategies have been shown even in maximal effort voluntary contractions (Halperin et al., 2014). Whether or not a lower volume appraoch utilising a single set of either condition might enable participants to be able to give a maximal effort straight away and also elicit similar adaptations is not clear. Some studies have suggested that both lower volume single set resistance training (Marshall et al., 2011), and single sprint cycle ergometry (Tjonna et al., 2013) may be able to elicit strength and cardiorespiratory fitness increases respectively. Considering the time efficiency of ‘High Intensity Interval Training’ type aproaches, and the evidence here that this might be accomplished with a variety of modalities, this might be an interesting area of future research.

The limitations of the present study should be aknowledged. The duration of the study was relatively short and it is not possible to confirm if the results would be simlar over longer durations, or whether adaptations from either modality might exceed the other for certain outcomes. Morever, we experienced a number of dropouts during the study. Although many where due to personal reasons, the intensity of effort and associated perceived discomfort was very high for both interventions, which 15 participants claimed was the reasons for their dropout from the study (~25%  percent of the initial sample). Therefore, though these appraoches may demonstrate some degree of comparative efficacy, it could be argued that their effectiveness requires further investigation and consideration for how to reduce associated perceievd discomfort, and thus dropout rates. Lastly, we selected two common exercise types representative of the two broad modalities we were interested in comparsing (resistance training = leg press, 'cardio' = cycle ergometer). Future work should look to test the effects of differentes types of exercise (e.g,. elliptical, running) in addition to upper body exercise (e.g. bench press, arm ergometry) and whether these may produce similar adaptations, since it as been suggested that the exercise type used for 'High Intensity Interval Training' may influence adaptation (Viana et al., 2018).

## 4. CONCLUSION

The results of the present study suggest that 5 weeks of effort and duration matched 'High Intensity Interval Training' using cycle ergometry 'cardio' or leg press resistance training may produce similar strength and endurance (TTE) adaptations. However, 'cardio' modality training may produce greater increases in cardiorespiratory fitness. For both training interventions though, lower limb composition changes (total lower limb mass, lower limb lean mass, and lower limb fat mass) are minimal as might be expected in trained participants. This suggests that there may be more flexibility in choice of exercise modality when using a high intensity of effort which potentially expands the options available to persons seeking to improve health and fitness.

## 5. ACKNOWLEDGEMENTS.

MS would like to thank National Council for the Improvement of Higher Education (CAPES) for receiving a graduate student grant. The study has no external financial support. The authors declare no conflict of interest.

**6. REFERENCES.**

Ahtiainen JP, Hulmi JJ, Kraemer WJ, et al. Strength, endurance or combined training elicit diverse skeletal muscle myosin heavy chain isoform proportion but unaltered androgen receptor concentration in older men. Int J Sports Med. 2009;30(12):879–87.

Álvarez C, Ramirez-Campillo R, Ramirez-Vèlez R, Izquierdo M. Effects and prevalence of nonresponders after 12 weeks of high-intensity interval of resistance training in women with insulin resistance: a randomized trial. J Apply Physiol. 2017;122(4):985-996

Androulakis-Korakakis P, Langdown L, Lewis A, Fisher JP, Gentil P, Paoli A, Steele J. Effects of exercise modality during additional "high-intensity interval training" on aerobic fitness and strength in powerlifting and strongman athletes. J Strength Cond Res. 2018;32(2):450-457

Arzu, D., Tuzun, E. H., & Eker, L. (2006). Perceived barriers to physical activity in university students. *Journal of Sports Science & Medicine*, *5*(4), 615–20. Retrieved from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3861763&tool=pmcentrez&rendertype=abstract

Biddle, S.J.H., & Batterham, A.M. (2015). High-intensity intrval exercise training for pubic health: a big HIT or shall we HIT it on the head? *International Journal of Behavioural Nutrition and Physical Activity*, 12, 95

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine and Science in Sports and Exercise, 14*(5), 377–81. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/7154893

Buckner, S.L., Jessee, M.B., Mattocks, K.T., Mouser, J.G., Counts, B.R., Dankel, S.J., & Loenneke, J.P. (2017). Determining strength: A case for multiple methods of measurement. *Sports Medicine, 47(2)*, 193-195

Counts, B.R., Buckner, S.L., Mouser, J.G., Dankel, S.J., Jessee, M.B., Mattocks, K.T., & Loenneke, J.P. (2017). Muscle growth: To infinity and beyond? *Muscle and Nerve, 56(6)*, 1022-1030

Dankel, S. J., Loenneke, J. P., & Loprinzi, P. D. (2016). Determining the Importance of Meeting Muscle-Strengthening Activity Guidelines: Is the Behavior or the Outcome of the Behavior (Strength) a More Important Determinant of All-Cause Mortality? *Mayo Clinic Proceedings*, *91*(2), 166–74. http://doi.org/10.1016/j.mayocp.2015.10.017

de Lira, C. A. B., Peixinho-Pena, L. F., Vancini, R. L., de Freitas Guina Fachina, R. J., de Almeida, A. A., Andrade, M. D. S., & da Silva, A. C. (2013). Heart rate response during a simulated Olympic boxing match is predominantly above ventilatory threshold 2: a cross sectional study. *Open Access Journal of Sports Medicine*, *4*, 175–82. http://doi.org/10.2147/OAJSM.S44807

de Morree HM, Klein C, Marcora S. Perception of effort reflects central motor command during movement execution. Psychophysiology. 2012;49(9):1242-1253

Ferrara CM, Goldberg AP, Ortmeyer HK, et al. Effects of aerobic and resistive exercise training on glucose disposal and skeletal muscle metabolism in older men. J Gerontol A Biol Sci Med Sci. 2006;61(5):480–7.

Fisher, J., & Steele, J. (2014). Questioning the Resistance/Aerobic Training Dichotomy: A commentary on physiological adaptations determined by effort rather than exercise modality. *Journal of Human Kinetics*, *44*, 137–42. http://doi.org/10.2478/hukin-2014-0119

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I.-M., … American College of Sports Medicine. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine and Science in Sports and Exercise*, *43*(7), 1334–59. http://doi.org/10.1249/MSS.0b013e318213fefb

Gentil, P. (2017). Comment on: "Determining strength: A case for multiple methods of measurement." *Sports Medicine, 47(9)*, 1901-1902

Gentil, P., & Bottaro, M. (2010). Influence of supervision ratio on muscle adaptations to resistance training in nontrained subjects. *Journal of Strength and Conditioning Research*, *24*(3), 639–43. http://doi.org/10.1519/JSC.0b013e3181ad3373

Gentil, P., Del Vecchio, F. B., Paoli, A., Schoenfeld, B. J., & Bottaro, M. (2017). Isokinetic Dynamometry and 1RM Tests Produce Conflicting Results for Assessing Alterations in Muscle Strength. *Journal of Human Kinetics*, *56*(1). http://doi.org/10.1515/hukin-2017-0019

Gentil, P., Oliveira, E., & Bottaro, M. (2006). Time under tension and blood lactate response during four different resistance training methods. *Journal of Physiological Anthropology*, *25*(5), 339–44. http://doi.org/10.2114/jpa2.25.339

Gil-Sotomayor A, Williden M, Zinn C, Borotkanics R, Plank L, Kilding A, Harris N. The effect of high intensity interval training or resistance training, both with low-carbohydrate high-fat nutrition on fitness and fat loss in low-active overweight adults. In: Abstract book for the ISBNPA 2018 Annual Meeting in Hong Kong, China, June 3-6

Goldberg L, Elliot DL, Keuhl KS. A comparison of the cardiovascular effects of running and weight training. J Strength Cond Res. 1994;8:219-224

Gómez-López, M., Gallegos, A. G., & Extremera, A. B. (2010). Perceived barriers by university students in the practice of physical activities. *Journal of Sports Science & Medicine*, *9*(3), 374–81. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/24149629

Guo F, Sun YJ, Zhang RH. Perceived exertion during muscle fatigue as reflected in movement-related cortical potentials: an event-related potential study. Neuroreport. 2017; 28(3):115-122

Halperin, I., Aboodarda, S.J., Basset, F.A., Byrne, J.M., & Behm, D.G. (2014). Pacing strategies during repeated maximal voluntary contractions. *European Journal of Applied Physiology, 114(7),* 1413-1420

Harber, M. P., Konopka, A. R., Douglass, M. D., Minchev, K., Kaminsky, L. A., Trappe, T. A., & Trappe, S. (2009). Aerobic exercise training improves whole muscle and single myofiber size and function in older women. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology*, *297*(5), R1452-9. http://doi.org/10.1152/ajpregu.00354.2009

Hepple RT, Mackinnon SL, Goodman JM, Thomas SG, Plyley MJ. Resistance and aerobic training in older men: effects on VO2peak and the capillary supple to skeletal muscle. J Apply Physiol. 1997;82(4):1305-1310

Hopkins, W.G. (2015). Spreadsheets for analysis of validity and reliability. *Sportscience, 19,* 36-42.

Kimm, S. Y. S., Glynn, N. W., Mcmahon, R. P., Voorhees, C. C., Striegel-Moore, R. H., & Daniels, S. R. (2006). Self-perceived barriers to activity participation among sedentary adolescent girls. *Medicine and Science in Sports and Exercise*, *38*(3), 534–540.

Kinnunen, J.V., Pitulainen, H., & Piirainen, J.M. (2019). Neuromuscular adaptations to short-term high-intensity interval training in female ice-hockey players. *Journal of Strength and Conditioning Research, 33(2),* 479-485

Kodama, S., Saito, K., Tanaka, S., Maki, M., Yachi, Y., Asumi, M., … Sone, H. (2009). Cardiorespiratory fitness as a quantitative predictor of all-cause mortality and cardiovascular events in healthy men and women: a meta-analysis. *JAMA*, *301*(19), 2024–35. http://doi.org/10.1001/jama.2009.681

Konopka, A. R., & Harber, M. P. (2014). Skeletal Muscle Hypertrophy After Aerobic Exercise Training. *Exercise and Sport Sciences Reviews*, *42*(2), 53–61. http://doi.org/10.1249/JES.0000000000000007

Kuznetsov SY, Popov DV, Borovik AS, Vinogradova OL. Wavelet analysis of the m. vastus lateralis surface electromyogram activity in incremental tests until exhaustion using bicycle and knee extension exercises. Hum Physiol. 2011;37:629-635

Lee, D.-C., Sui, X., Ortega, F. B., Kim, Y.-S., Church, T. S., Winett, R. A., … Blair, S. N. (2011). Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. *British Journal of Sports Medicine*, *45*(6), 504–510. http://doi.org/10.1136/bjsm.2009.066209

Lee, I. M., & Skerrett, P. J. (2001). Physical activity and all-cause mortality: what is the dose-response relation? *Medicine and Science in Sports and Exercise*, *33*(6 Suppl), 2024–2035. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11427772

Lee, I., Sesso, H.D., Oguma, Y., & Paffenbarger, R.S. (2003). Relative intensity of physical activity and risk of coronary heart disease. *Circulation*, *107*, 1110-1116

Loprinzi, P. D. (2015). Dose-response association of moderate-to-vigorous physical activity with cardiovascular biomarkers and all-cause mortality: Considerations by individual sports, exercise and recreational physical activities. *Preventive Medicine*, *81*, 73–7. http://doi.org/10.1016/j.ypmed.2015.08.014

Loprinzi, P.D. & Davies, R.E. (2015). Effects of individual, combined, and isolated physical activity behaviours on all-cause mortality and CVD-specific mortality: prospective cohort study among U.S. adults. *Physiology and Behaviour, 151,* 355-359

Lundberg, T. R., Fernandez-Gonzalo, R., Gustafsson, T., & Tesch, P. A. (2013). Aerobic exercise does not compromise muscle hypertrophy response to short-term resistance training. *Journal of Applied Physiology (Bethesda, Md. : 1985)*, *114*(1), 81–9. http://doi.org/10.1152/japplphysiol.01013.2012

Marcora S. Perception of effort during exercise is independent of afferent feedback from skeletal muscles, heart, and lungs. J Appl Physiol. 2009;106(6):2060-2062

Marshall, P.W., McEwen, M., & Robbins, D.W. (2011). Strength and neuromuscular adaptation following one, four, and eight sets of high intensity resistance exercise in trained males. *European Journal of Applied Physiology, 111(12),* 3007-3016

Messier SP, Dill ME. Alterations in strength and maximal oxygen uptake consequent to nautilus circuit weight training. Res Q Exerc Sport. 1985;56:345-351

Nocon, M., Hiemann, T., Müller-Riemenschneider, F., Thalau, F., Roll, S., & Willich, S. N. (2008). Association of physical activity with all-cause and cardiovascular mortality: a systematic review and meta-analysis. *European Journal of Cardiovascular Prevention and*

*Rehabilitation : Official Journal of the European Society of Cardiology, Working Groups on Epidemiology & Prevention and Cardiac Rehabilitation and Exercise Physiology*, *15*(3), 239–46. http://doi.org/10.1097/HJR.0b013e3282f55e09

Nuzzo, J.L., Barry, B.K., Jones, M.D., Gandevia, S.C., & Taylor, J.L. (2017). Effects of four weeks of strength training on the corticomotoneuronal pathway. *Medicine and Science in Sports and Exercise, 49(11)*, 2286-2296

Ozaki, H., Abe, T., Mikesky, A. E., Sakamoto, A., Machida, S., & Naito, H. (2015). Physiological stimuli necessary for muscle hypertrophy. *The Journal of Physical Fitness and Sports Medicine*, *4*(1), 43–51. http://doi.org/10.7600/jpfsm.4.43

Ozaki, H., Loenneke, J. P., Thiebaud, R. S., & Abe, T. (2013). Resistance training induced increase in VO2max in young and older subjects. *European Review of Aging and Physical Activity*, *10*(2), 107–116. http://doi.org/10.1007/s11556-013-0120-1

Ozaki, H., Loenneke, J. P., Thiebaud, R. S., & Abe, T. (2015). Cycle training induces muscle hypertrophy and strength gain: strategies and mechanisms. *Acta Physiologica Hungarica*, *102*(1), 1–22. http://doi.org/10.1556/APhysiol.102.2015.1.1

Ozaki, H., Loenneke, J. P., Thiebaud, R. S., Stager, J. M., & Abe, T. (2013). Possibility of leg muscle hypertrophy by ambulation in older adults: a brief review. *Clinical Interventions in Aging*, *8*, 369–75. http://doi.org/10.2147/CIA.S43837

Pageaux B. Perception of effort in exercise science: Definition, measurement and perspectives. Eur J Sport Sci. 2016;16(8):885-894

Phillips, S.M., & Winett, R.A. (2010). Uncomplicated resistance training and health-related outcomes: evidence for a public health mandate. *Current Sports Medicine Reports*, *9*, 208-

213

Poehlman ET, Dvorak RV, DeNino WF, et al. Effects of resistance training and endurance training on insulin sensitivity in nonobese, young women: a controlled randomized trial. J Clin Endocrinol Metab. 2000;85(7):2463–8.

Potvin, J. R., & Fuglevand, A. J. (2017). A motor unit-based model of muscle fatigue. *PLOS Computational Biology*, *13*(6), e1005581. http://doi.org/10.1371/journal.pcbi.1005581

Rossi, P., Cândido, C. E., Sitta, T., Jabur, A. clara, & Sanz, C. (2015). Diagnóstico Nacional do Esporte: DIESPORTE. Retrieved October 30, 2017, from http://www.esporte.gov.br/diesporte/diesporte_grafica.pdf

Sawczyn S, Mischenko V, Moska W, Sawczyn M, Jagiello M, Kuehne T, Kostrewa-Nowak D, Nowak R, Cięszczyk P. Strength and aerobic training in overweight females in Gdansk, Poland. Open Med. 2015;10:152-162

Sillanpaa E, Hakkinen A, Nyman K, et al. Body composition and fitness during strength and/or endurance training in older men. Med Sci Sports Exerc. 2008;40(5):950–8.

Steele, J., Butler, A., Comerford, Z., Dyer, J., Lloyd, N., Ward, J., … Ozaki, H. (2018). Similar acute physiological responses from effort and duration matched leg press and recumbent cycling tasks. *PeerJ*, *6*, e4403. http://doi.org/10.7717/peerj.4403

Steele, J., Fisher, J., Giessing, J., & Gentil, P. (2017). Clarity in reporting terminology and definitions of set endpoints in resistance training. *Muscle & Nerve*, *56*(3), 368–374. http://doi.org/10.1002/mus.25557

Steele, J., Fisher, J., McGuff, D., & Bruce-Low, S. (2012). Resistance Training to Momentary Muscular Failure Improves Cardiovascular Fitness in Humans: A Review of Acute

Physiological Responses and Chronic Physiological Adaptations. *Journal of Exercise Physiology*, *15*, 53–80.

Steele, J., Fisher, J., Skivington, M., Dunn, C., Arnold, J., … Tew, G. (2017). A higher effort-based paradigm in physical activity and exercise for public health: making the case for a greater emphasis on resistance training. *BMC Public Health, 17,* 300

Tionna, A.E., Leinan, I.M., Bartnes, A.T., Jenssen, B.M., Gibala, M.J., Winett, R.A., & Wisloff, U. (2013). Low- and high-volume of intensive endurance training significnatly improves maximal oxygen upatek after 10-weeks of training in healthy men. *PLoS One, 8(5),* e65382

Troiano, R. P., Berrigan, D., Dodd, K. W., Mâsse, L. C., Tilert, T., & Mc Dowell, M. (2008). Physical Activity in the United States Measured by Accelerometer. *Medicine & Science in Sports & Exercise*, *40*(1), 181–188. http://doi.org/10.1249/mss.0b013e31815a51b3

Vilaça-Alves, J., Freitas, N. M., Saavedra, F. J., Scott, C. B., dos Reis, V. M., Simão, R., & Garrido, N. (2016). Comparison of oxygen uptake during and after the execution of resistance exercises and exercises performed on ergometers, matched for intensity. *Journal of Human Kinetics*, *53*(1). http://doi.org/10.1515/hukin-2016-0021

Wilkinson SB, Phillips SM, Atherton PJ, et al. Differential effects of resistance and endurance exercise in the fed state on signalling molecule phosphorylation and protein synthesis in human muscle. J Physiol. 2008;586(Pt 15):3701–17.

Wisloff, U., Nilsen, T.I., Droyvold, W.B., Morkved, S., Slordahl, S.A., Vatten, L.J. (2006). A single wqeekly bout of exercise may reduce cardiovascular mortality: how little pain for cardiac gain? The HUNT study, Norway. *European Journal of Cadriovascular Prevention and Rehabilitation, 13(5),* 798-804

**Table 1:** Participant demographics

| | Leg Press (n = 12) | Bike (n = 13) |
|---|---|---|
| Age (years) | 28.5 ± 6.8 | 29.3 ± 4.5 |
| Height (cm) | 179.7 ± 9 | 178.0 ± 6.2 |
| Training experience (years) | 8.1 ± 6.8 | 5.1 ± 4.1 |
| Weekly training | 4.0 ± 0.2 | 4.0 ± 0.3 |
| Minutes per week of exercise | 210.8 ±13.2 | 246.9 ± 18.5 |
| Total body mass (kg) | 78.0 ± 1.0 | 82.7 ± 13.4 |
| Lean mass (kg) | 58.3 ± 7.5 | 60.5 ± 5.9 |
| Fat mass (kg) | 19.7 ± 8.2 | 21.9 ± 9.7 |
| % Body fat | 23.7 ± 7.0 | 24.8 ± 8 |
| BMI ($kg/m^2$) | 24.2 ± 3.9 | 26.0 ± 3.8 |
| $\dot{V}O_{2peak}$ ($mL.kg^{-1}.min^{-1}$) | 56.6 ± 6.9 | 56.1± 9.5 |
| 10 Maximum repetition (kg) | 45.4 ± 8.6 | 50.0 ± 9.5 |

Data are expressed as mean ± standard deviation;

Abbreviations: $\dot{V}O_{2peak.}$ Peak Oxygen consumption; 10RM, 10 Repetition Maximum

**Table 2:** Training routine

| Leg Press | Bike |
|---|---|
| Chest Press (~10 reps to MF) | Chest Press (~10 reps to MF) |
| Leg Press 45º (~10 reps to MF) | Cycle Ergometer (30s sprint) |
| Chest Press (~10 reps to MF) | Chest Press (~10 reps to MF) |
| Leg Press 45º (~10 reps to MF) | Cycle Ergometer (30s sprint) |
| Lat Pull Down (~10 reps to MF) | Lat Pull Down (~10 reps to MF) |
| Leg Press 45º (~10 reps to MF) | Cycle Ergometer (30s sprint) |
| Lat Pull Down (~10 reps to MF) | Lat Pull Down (~10 reps to MF) |
| Leg Press 45º (~10 reps to MF) | Cycle Ergometer (30s sprint) |
| Knee Flexor (~10 reps to MF) | Knee Flexor (~10 reps to MF) |
| Trunk flexion (~15 reps to MF) | Trunk flexion (~15 reps to MF) |
| Knee Flexor (~10 reps to MF) | Knee Flexor (~10 reps to MF) |
| Trunk flexion (~15 reps to MF) | Trunk flexion (~15 reps to MF) |

Abbreviations: MF: Momentary failure; Rep: Repetition

**Table 3:** Change in dietary intake after training protocol

| | Leg Press (n=12) | | Bike (n = 13) | | Between group | |
|---|---|---|---|---|---|---|
| | Baseline | Post | Baseline | Post | ES | *p* |
| Energy (kcal) | 2432.7 ± 390.7 | 2348.6 ± 710.7 | 2004.2 ± 330.7 | 1891.9 ± 406.1 | 0.37 | 0.91 |
| Protein (%) | 21.1 ± 6.1 | 21.6 ± 8.4 | 23.8 ± 7.8 | 26.0 ± 12.6 | 0.20 | 0.72 |
| Carbohydrate (%) | 46.9 ± 14.8 | 52.2 ± 20.2 | 54.5 ± 5.7 | 53.6 ± 6.9 | 0.05 | 0.53 |
| Total fat (%) | 23.7± 5.9 | 23.9 ± 7.7 | 32.4 ± 6.9 | 37.4 ± 10.2 | 0.59 | 0.40 |

Values are presented as mean ± standard deviation; 95% CI; ES = Cohen's. ES: *effect size.* Comparison of post test effects of between group training, *p* value obtained by ANCOVA – using pre values as covariates

**Table 4.** Estimated marginal means and 95%CIs for perceived effort and discomfort.

| | Set 1 | Set 2 | Set 3 | Set 4 |
|---|---|---|---|---|
| Effort | | | | |
| Bike | 7.6 [7.2 to 8.0] | 8.8 [8.5 to 9.2] | 9.8 [9.4 to 10.2] | 9.9 [9.5 to 10.3] |
| Leg Press | 8.2 [7.9 to 8.6] | 9.1 [8.7 to 9.5] | 9.8 [9.4 to 10.2] | 10.0 [9.6 to 1.4] |
| Discomfort | | | | |
| Bike | 8.0 [7.5 to 8.5] | 9.2 [8.7 to 9.8] | 9.8 [9.3 to 10.4] | 9.9 [9.4 to 10.5] |
| Leg Press | 7.4 [6.9 to 7.9] | 8.4 [7.9 to 8.9] | 9.3 [8.8 to 9.8] | 9.8 [9.2 to 10.3] |

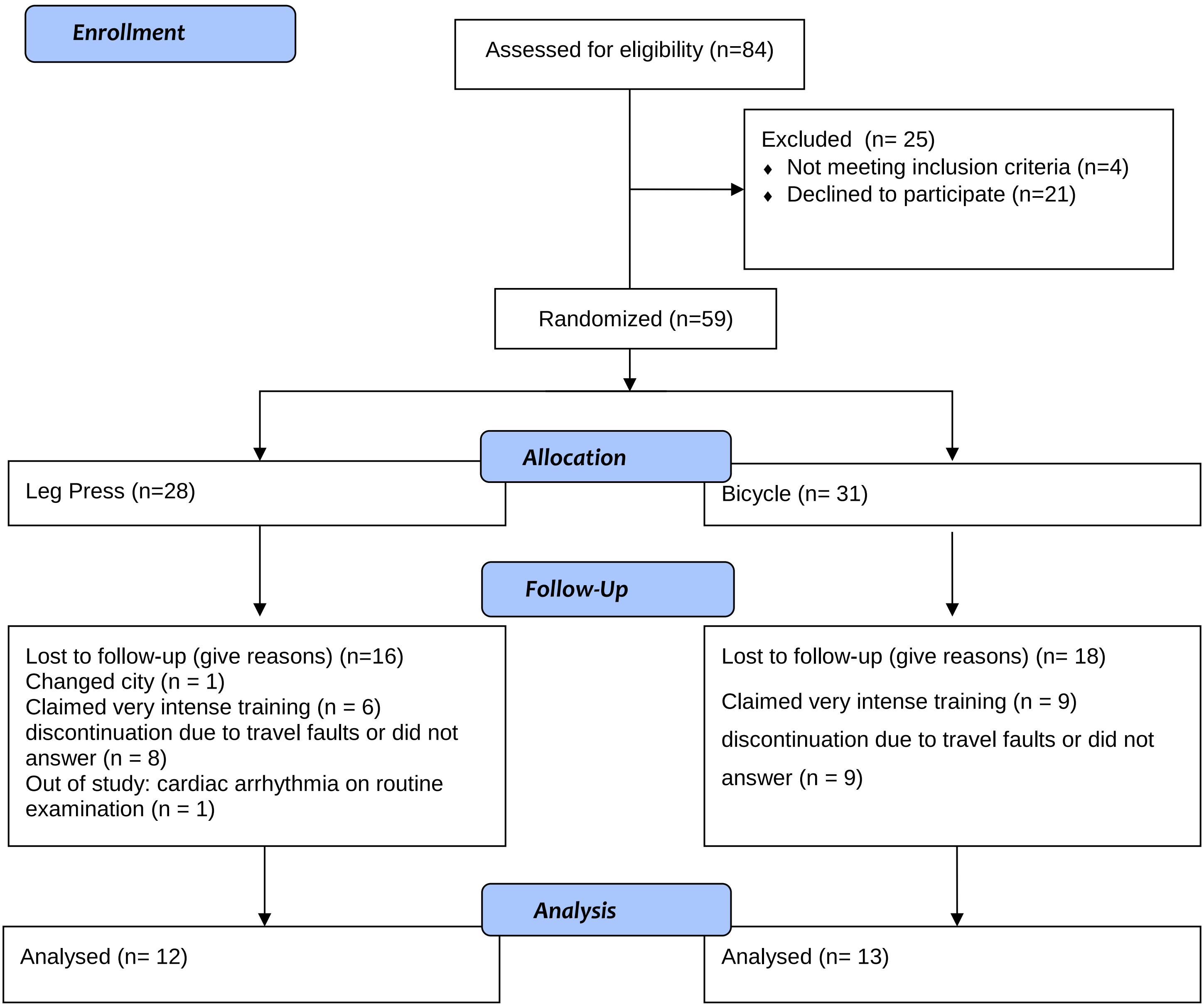
Figure 1. CONSORT flow diagram.

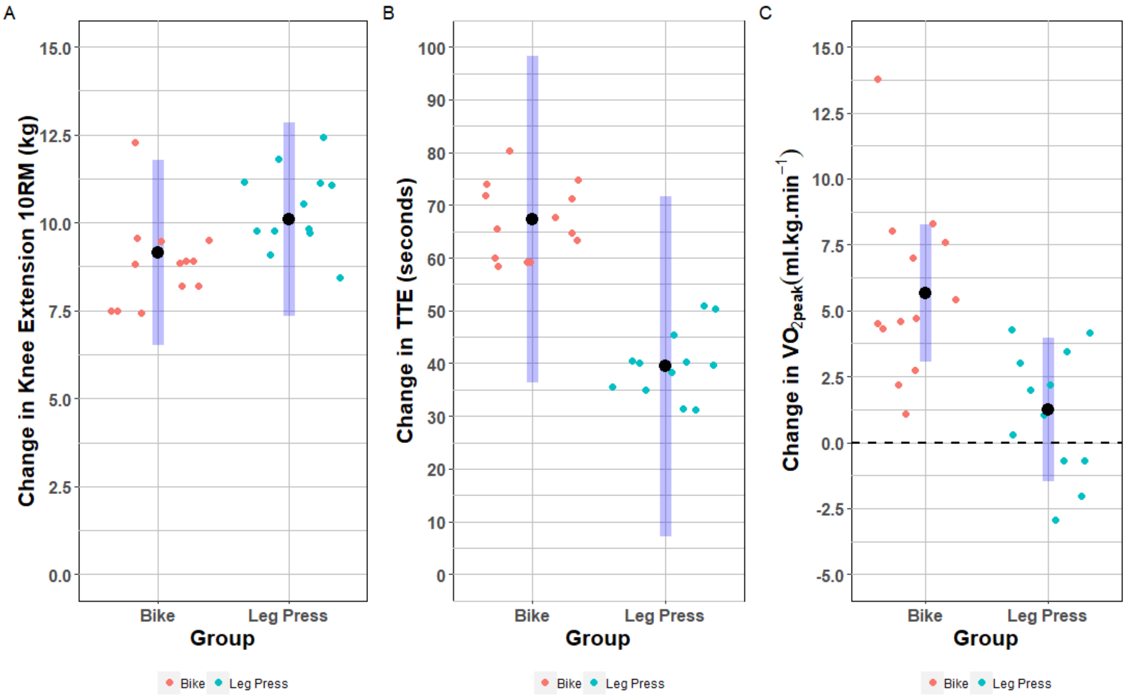
Figure 2. Estimated marginal means, 95%CIs, and fitted individual values from ANCOVA model for changes in a) knee extension 1RM, b) time to exhaustion, and c) $VO_{2peak}$.

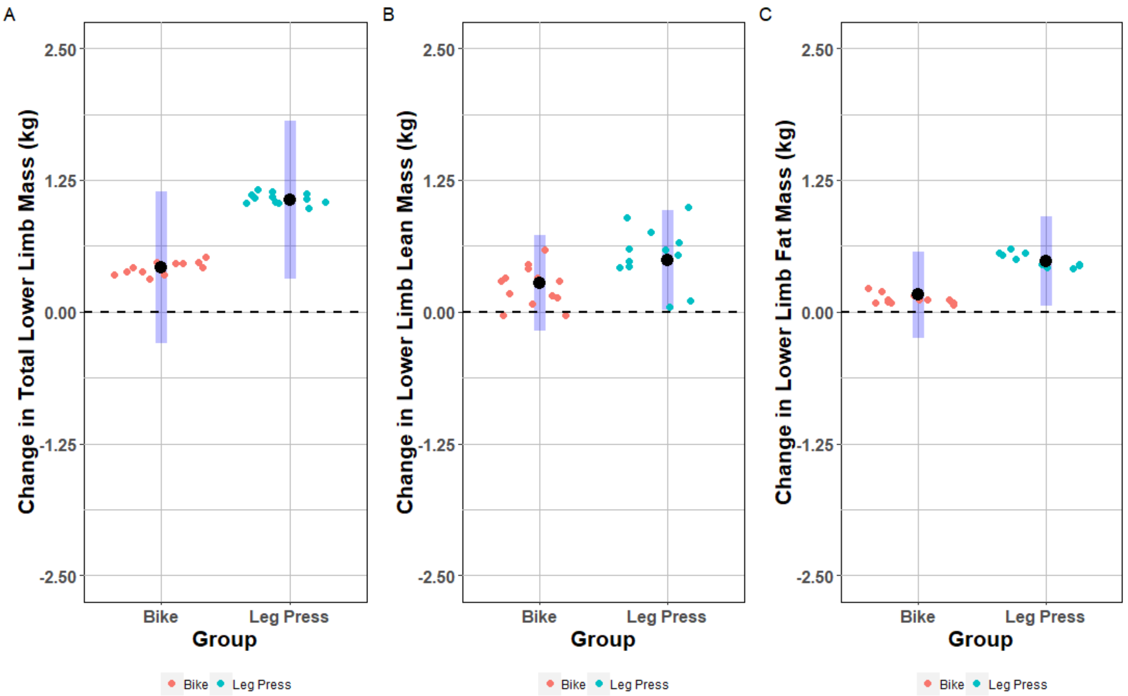
Figure 3. Estimated marginal means, 95%CIs, and fitted individual values from ANCOVA model for changes in a) total lower limb mass, b) lower limb lean mass, and c) lower limb fat mass.

CONSORT
TRANSPARENT REPORTING of TRIALS

## CONSORT 2010 Flow Diagram




A
Change in Knee Extension 10RM (kg)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Bike
Leg Press
Group
Bike Leg Press
B
Change in TTE (seconds)
100
90
80
70
60
50
40
30
20
10
0
Bike
Leg Press
Group
Bike Leg Press
C
Change in $VO_{2peak}$ ($ml.kg.min^{-1}$)
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
-5.0
Bike
Leg Press
Group
Bike Leg Press


A
Change in Total Lower Limb Mass (kg)
2.50
1.25
0.00
-1.25
-2.50
Bike
Leg Press
Group
Bike Leg Press
B
Change in Lower Limb Lean Mass (kg)
2.50
1.25
0.00
-1.25
-2.50
Bike
Leg Press
Group
Bike Leg Press
C
Change in Lower Limb Fat Mass (kg)
2.50
1.25
0.00
-1.25
-2.50
Bike
Leg Press
Group
Bike Leg Press