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Performing 30 second weight training bouts for five weeks decreases 2000 m ergometer times in collegiate rowers

Andre Beven Pelletier, *The University of Western Ontario*

Supervisor: Belfry, Glen R., *The University of Western Ontario*

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Abstract

This study investigated the effects of performing 30 second weight training bouts (30 s) on peak aerobic power, 2000 m time and peak and mean 1 min power output, compared to those of a low repetition strength training program (LoRep), in pre-conditioned well-trained male and female collegiate rowers while concurrently performing a high volume of endurance training over an identical five week period. The 30 s group mean 2000 m time was significantly reduced pre-to-post training by 1.0% (±1.3) (30 s: pre = 6:45.3 (±35.3), post = 6:41.2 (±32.7), $P \leq 0.05$) while LoRep group mean 2000 m time was reduced by 0.9% (±1.4) (LoRep: pre = 6:51.6 (±36.1), post = 6:47.7 (±34.5)), which was not significant ($P \geq 0.05$). The 30 s group had a significant 2.9% (±4.1) increase in peak power (30 s: pre = 608 watts (W) (±155), post = 624 W (±150), $P \leq 0.05$) whereas the 0.7% (±4.7) increase in the LoRep was not significant (LoRep: pre = 639 W (±143), post = 642 W (±138), $P \geq 0.05$). However, both the 30 s and LoRep groups improved mean 1 min power by 4.0% (±3.5) and 4.2% (±3.6) respectively, (30 s: pre = 545 W (±139), post = 564 W (±133), $P \leq 0.05$; LoRep: pre = 552 W (±128), post = 575 W (±132), $P \leq 0.05$). No change in cycling peak aerobic power was found in either group (30 s: pre = 414 W (±90), post = 421 W (±88), $P \geq 0.05$; LoRep: pre = 416 W (±90), post = 415 W (±78), $P \geq 0.05$). The 30 s group was found to have reduced post-ramp blood lactate post-training (pre-training; post-ramp = 13.7 $mmol \cdot L^{-1}$ (±2.3); post-training; post-ramp = 12.0 $mmol \cdot L^{-1}$ (±2.0), $P \leq 0.05$). These findings demonstrate that five weeks of 30 s weight training bouts improved rowing ergometer performance whereas low-repetition strength training did not when performed concurrently with a high volume of endurance training in well-trained collegiate rowers.

Keywords: 30 second training, strength training, endurance performance, concurrent training, rowing

Co-Authorship Statement

This study was designed by G. R. Belfry and A. B. Pelletier with input from V. Nolte. A.B. Pelletier collected and analyzed the data and wrote the original manuscript with guidance from G. R. Belfry.

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List of Abbreviations

30 s – 30 second training group

AMP- Adenosine monophosphate

AMPK – AMP-activated protein kinase

AMRAP – As many repetitions as possible

ATP-PCr – Adenosine triphosphate – phosphocreatine

BPM – Beats per minute

C (C1 to C6) – Category of training intensity

CK – Creatine kinase

CO_2 – Carbon Dioxide

CP – Critical Power

HR – Heart rate

km – Kilometer

L – Liters

$L_{O2}\cdot min^{-1}$ – Liters of oxygen per minute

LoRep – Low-repetition training group

LW – Lightweight rowing class

m – Meters

min – Minutes

$mmol\cdot L^{-1}$ – millimol per liter

mRNA – Messenger ribonucleic acid

mTORC1 – Mammalian target of rapamycin complex 1

NC(M) – National collegiate and or club competitor medalist

O – Open weight rowing class

O_2 – Oxygen

PAP – Peak aerobic power

PDC – Provincial development championship competitor

PC(M) – Provincial collegiate championship medalist

PCr – Phosphocreatine

PGC-1 α – Peroxisome proliferator-activated receptor- γ coactivator-1α

RAMP- Incremental ramp test to exhaustion

RPE – Rate of perceived exertion

s – Seconds

SIT – Sprint interval training

SPM – Strokes per minute

SR – Stroke rate

Supp – Supplementary

$\dot{V}_{O2Max}$ – Maximal oxygen uptake $\dot{V}_{O2Max}$

$\dot{V}_{O2peak}$ – Peak oxygen uptake

$V_{\dot{V}O2peak}$ – velocity at peak oxygen uptake

W (W1 to W5) – Weeks of training

W – Watts

W' – Anaerobic work capacity

$W \cdot min^{-1}$ – Watts per minute

WJRC – World Junior Rowing Championship competitor

WU23RC – World Under-23 Rowing Championship competitor

Chapter 1

1 Review of Literature

1.1 Introduction

In an Olympic rowing race, athletes must initially generate maximal power outputs in the start before sustaining a lower power output in the proximity of peak aerobic power for the middle of the race[1]. As the races are 5 – 8 minutes (min) in duration[2] and 70% of the energy required originates from aerobic metabolism [3], the primary focus of rowing training is to develop aerobic capacity to ensure that the high work rate can be sustained[4]. However, the significant anaerobic contributions as well as the high force and power outputs seen in rowing suggest that it is necessary to develop the maximal force and power capabilities[1,3]. Moreover, maximal force and power are found to correlate as highly as maximal aerobic capacity and peak aerobic power with 2000 m indoor rowing performance in elite rowers[5].

Rowing coaches often choose to incorporate strength training into their training program[4], but literature on the subject is limited[6]. Training to develop the endurance and strength capacities simultaneously is referred to as concurrent training, which has been suggested to hinder the development of strength compared to strength training alone[7,8]. The effect of concurrent training on rowing performance has not been thoroughly investigated in rowers[9]. However, the addition of strength training to a largely aerobic exercise prescription has improved endurance performance and peak power in athletes in other sports [10]. Concurrent training has also increased peak aerobic power (PAP) to a greater extent than endurance training alone but without a concomitant increase in $\dot{V}_{O2Max}$[11].

30 s Sprint interval training (SIT), an alternative means of developing peak power, has also been shown to simultaneously increase $\dot{V}_{O2Max}$ [12,13]. Modified 30 s training, with intervals at 130-

175% of PAP, has shown greater performance improvements in endurance athletes compared to long duration continuous aerobic training[14,15]. Further, adapted use of 30 s intervals for set duration in weight training has shown promise at improving power as well as endurance performance[16].

Determining the effects of 30 s weight training bouts on rowing performance requires an objective performance measure, such as rowing ergometer testing[17]. A 2000 m time trial on the Concept 2 rowing ergometer imposes a physiological demand similar to on-water rowing and is regularly used by rowing coaches to track training progress[18,19]. The cycle ergometer was also used in the present study to perform an incremental ramp test to determine PAP.

The present study investigated and compared the effects of a concurrent 30 s weight training program performed by pre-conditioned well-trained rowers, to a control group composed of a similar cohort of rowers performing a coach prescribed, low-repetition (LoRep) strength training regime over an identical five week period on peak aerobic power, 2000 m time and a 1 min “all-out” test on rowing ergometers.

This chapter will review the background literature of rowing performance, endurance and strength training, concurrent training, 30 s training and rowing and cycle ergometer testing.

1.2 Physiological and Performance Parameters associated with Rowing Success

The most studied endurance events are distance running and endurance cycling, owing to the ease at which sport specific testing can be performed in the laboratory[20]. Though the components of endurance performance such as lactate threshold and $\dot{V}_{O2Max}$ are common between different types of endurance athletes, the relative importance of these different physiological variables depends on the duration of the competitive event[21]. For events such as distance running and cycling, the physiological emphasis is on the lactate threshold, which constitutes the oxygen uptake and power output above which aerobic energy production is supplemented with anaerobic sources[22,23]. Rowing performance however, with competitive events lasting from 5 to 8 min[2], has a stronger relationship with $\dot{V}_{O2Max}$ (r = 0.88) and PAP (r = 0.95), as well as maximal force (r = 0.95). and peak power (r = 0.95) [5].

Maximal Aerobic Capacity – $\dot{V}_{O2Max}$

Elite rowers have been found to have higher absolute maximal aerobic capacities when compared to other elite endurance athletes due to their greater lean muscle mass[24] . $\dot{V}_{O2Max}$ is the greatest volume of oxygen that can be consumed during exercise. It is determined through exercising at incrementally higher work rates (RAMP) until exhaustion and then confirmed with a fatiguing ride post-RAMP at a fractionally higher work rate[25]. The mechanisms underlying $\dot{V}_{O2Max}$ can be separated into oxygen transport and oxygen utilization. The oxygen transport factors include stroke volume, blood volume and hemoglobin content[26,27,28]. Factors of oxygen utilization include capillarization and oxidative enzyme concentration and activity[29].

Peak Aerobic Power – PAP

Peak aerobic power (PAP) is the power output corresponding to obtainment of $\dot{V}_{O2Max}$ on an incremental ramp or step test[5,30]. PAP is primarily influenced by $\dot{V}_{O2Max}$ and exercise economy. Other factors include anaerobic capacity, muscle power and neuromuscular recruitment at high speeds[11,31,32].

Maximal Force

The development of maximal force involves an individual attempting to recruit as many fibers in a muscle as possible for the purpose of applying force[33]. The muscles performing a movement are made of many motor units. A motor unit consists of the motor neuron, its motor axone and the many muscle fibers it innervates[34]. Muscle fibers are made up of series of contractile units, called sarcomeres, containing longitudinal thick and thin filaments[35]. The ratios of different isoforms of these muscle filaments are the basis for distinguishing muscle fiber types. These filaments split ATP to "climb" along each other, creating a shortening of the sarcomere[35]. Different fiber types are capable of contracting at different rates, with Type II or "fast twitch" fibers contracting in 40–90 milliseconds, twice as fast as Type I "slow twitch" fibers that contract in 90–140 milliseconds. The shortening of these units generates force[35]. In rowing, the highest force outputs are generated in the initial strokes, in which the rowers must overcome the inertia of their own body weight and the boat to propel themselves out of the starting gates[1].

Peak Power

Power can be defined as "the rate of transformation of energy to work"(Knuttgen & Kraemer, 1987) [33]. Power can be calculated through the following equation,

$$Power = Force \times Velocity$$

where "Force" is the force generated by the muscle contraction, and "Velocity" is the distance of the movement per unit time in the direction of the force applied[33].

The rate of muscle shortening is determined by the type of muscle fiber and the number of sarcomeres in series[36]. Rate of force development, the ability to develop force rapidly, is also subject to neuromuscular factors such as the firing rate of the motor neuron[37]. Peak power output in a rowing race occurs in the start, similar to maximal force[1]. Different race strategies may require bouts of higher power output throughout the rowing race and in the sprint finish[1].

1.3 Endurance Training

The energy demand of a 2000 m rowing race is thought to be met with 70-75% contributions supplied by oxidative phosphorylation, with the remaining 25-30% supplied by anaerobic glycolysis and high energy-phosphates[3]. As such, rowing training involves a high volume of aerobic training, characterized by long, low intensity continuous rowing and cross-training[4]. This type of training promotes improvements in blood volume and erythrocyte mass[27,28]. Furthermore, eccentric stress on the left ventricle, increased blood pressure and hormonal responses during exercise stimulate myocardial hypertrophy and contractility, that increases stroke volume[38,39,40]. Data collected over several decades shows an increase in low-intensity training volume coinciding with increased $\dot{V}_{O2Max}$ and improved performance in elite rowers [4]. Other beneficial adaptations of this type of endurance training include increased glycogen storage and reduced glycogen depletion as fat oxidation increases [41,42]. Furthermore, this endurance training elicits increases in skeletal oxidative enzymes concentration and activity thus reducing lactate production at submaximal work rates[43,44].

The anaerobic contribution to the energy supply in an endurance performance comes from the breakdown of glycogen, phosphocreatine and adenosine triphosphate [45]. Supramaximal training can increase the storage of glycogen and phosphocreatine, as well as the activity and concentrations of their respective enzymes, phosphofructokinase and creatine kinase [46,47,48]. This improved anaerobic capacity (*W'*) increases an athlete's ability to work above their highest sustainable aerobic work rate, critical power (CP) [49]. The *W'* could be used to supplement CP throughout the race distance to maintain an elevated pace, or it could be applied intermittently in a powerful sprint at the start and finish, as seen in rowing[1,49].

1.4 Strength Training

Strength training refers to resisted movement undertaken to develop a large force output and subsequently increase maximal force, maximal force at a given velocity and or maximal power[33]. Multiple periodization models exist to develop these characteristics, adjusting variables such as frequency, volume and intensity[50]. These include, but are not limited to, strength-power periodization and undulating periodization[50]. Strength-power periodization involves steadily increasing intensity while concomitantly decreasing volume, converging for a peaking phase. Undulating periodization involves the bi-weekly, weekly or daily manipulation of intensity and volume. Further elements of individual exercise sessions subject to manipulation include exercise selection, number of sets, number of repetitions, tempo or movement velocity and rest between sets[51]. The best practice of resistance training to achieve specific physiological goals is still being debated [51,52]. However, there are concrete physiological changes that must take place to improve performance in these domains that will be discussed below.

Adaptations to Increase Muscle Force

Increases in muscle filament proteins, often estimated based on changes in cross section diameter of the muscle fiber, result in increased force development[36]. Cellular hypertrophy can increase pennation angle, contributing to the increases in force beyond what might be attributable to changes in cross sectional area[53]. Neural adaptations that enable greater force production include increased motor unit firing frequency of the agonist muscle, as well as optimized activation of the antagonistic and synergistic muscles.[37]

Adaptations to Increase Muscle Power

Since power is a product of the force applied and the velocity of the movement, improvements in force will increase power production if the velocity (distance per unit time) remains unchanged. Though muscle fiber type does not influence maximal static force[35], selective hypertrophy of Type II fibers can occur with training[54] thus decreasing the contraction time of the muscle and increasing the velocity of the movement, thereby increasing power [35]. Neural adaptations measured by electromyography such as increased motor unit activation and increased rate of motor unit activation have been found in conjunction with improved rate of force development[55].

Effect of Concurrent Training on Strength Development

Performing endurance training concurrently with strength training can diminish strength adaptations compared to performing strength training alone[8]. The prominent theory of the cause behind this mitigation to adaptations of strength training is conflicting cellular signaling pathways. Mammalian target of rapamycin complex 1 (mTORC1) is a key step in the anabolic response pathway, sensitive to nutrients, insulin, insulin-like growth factors and resistance exercise[56]. mTORC1 activation is suppressed by AMP-activated protein kinase (AMPK), a cellular energy sensor that accumulates with fasting or endurance exercise[56,57]. While increased AMPK upregulates peroxisome proliferator-activated receptor- ɣ coactivator-1α (PGC-1 α; discussed in greater detail below) which is important for oxidative adaptations, the suppressed mTORC1 activation results in decreased strength adaptations[58,59].

Alternate theories to explain the blunted strength adaptations include sub-optimal strength training conditions stemming from concurrent endurance training, such as residual neuromuscular fatigue[60] or low glycogen levels[61]. Neuromuscular fatigue has been demonstrated via reduced isometric muscular twitch and reduced muscle activation, which are caused by impaired action potential transmission and decreased excitability of the muscle fiber plasmolemma[60]. Furthermore, the high volume of training typical of rowing[4] depletes glycogen concentrations[62] which has been implicated in the control of mTORC-1 activation separately from AMPK[61].

1.5 Effects of Concurrent Training on Power and Performance

Endurance performance can be enhanced by supplementing aerobic training with strength training[10]. Rowing training often involves a regimen of weight training to supplement on water rowing and cross-training[4,6]. However, investigations into strength training interventions in rowers often lack control or randomization of participants[6]. Concurrently performing two resistance training sessions of either high- or low-load with endurance training for 8 weeks did not result in greater 2000 m performance than solely endurance-trained controls in moderately-trained collegiate rowers[9]. However, the large discrepancies in mean 2000-m times and years of experience between training groups brings the randomization process into question. Furthermore, the quantity and intensity of the endurance training performed concurrently was not described and the conclusions were based on the sole performance measure without any accompanying physiological investigation to explicate their results[9].

The addition of resistance training to an endurance training program to improve endurance performance has been better studied in other athletic populations. In “traditional rowers” (fixed-seat, open-water, 13 man boat rowing), adding two resistance training sessions to ~8 h/week of aerobic activity for 8 weeks increased not only maximal strength and peak power, but also power output on a 20 min test[63]. However, there was not a physiological explanation for the improved performance.

In other endurance athletes, the addition of strength training to their endurance training has led to gains in maximal force, such as 1-repetition maximums[11,10, 64,65] or maximal voluntary contractions[66]. Indices of maximum power, such as rate of force development [64,66] and peak power in a cycling Wingate test[10,11] have also seen greater improvement with combined strength and endurance training than endurance training alone. Similarly, including strength training allowed triathletes to maintain 10 s repeated maximal hopping power better than endurance training alone[65]. As described earlier, maximum force can be attributed to muscle size, and as such can be used as a simplified measure of the amount of muscle filaments present in the tissue, and thus the capacity for force production[36]. This has also been posited to explain differences in peak power [67,68]. Indeed, several concurrent training studies have observed increases in cross sectional area [10] and lean mass[11]. However, endurance training has been shown to blunt hypertrophic responses to strength training[69]. Accordingly, endurance athletes performing strength training have increased rate of force development and 45 min endurance cycling performance without concomitant increases in cross sectional area and lean mass[66]. This implicates changes in neurological function, though this has not been directly evaluated in endurance athletes.

Though improvements in strength and power are to be expected from regular strength training, the addition of strength training to endurance training has led to improvements in endurance performance as well[1,4,10,11, 66]. After a period of heavy weight training, cyclists have been found to have increased power output in 40-45 min trials compared to cyclists who only completed endurance training[10,11,66]. Power output at 2 and 4 mmol·L^{-1} blood lactate, potent indicators of endurance performance, have also been increased to a greater degree by concurrent strength and endurance training than endurance training alone [10,11]. Several mechanisms have been proposed to explain these phenomena. Increased power and rate of force development, leading to an earlier peak torque within the pedal stroke[11,64], have been suggested to increase endurance performance by lengthening the relaxation time of each movement cycle and thus improving blood flow[70]. Other researchers have proposed that an increased force capacity of Type I fibers delays the activation of the less economic Type II fibers, leading to increased performance[10,11]. This is supported by previous findings that stronger individuals have less muscle activation at the same relative intensity than weaker individuals[71]. In the case of elite triathletes, improved economy was linked to the improved performance [65] . This was attributed to a reduction in fatigue-induced alteration in leg stiffness regulation and storage-recoil of energy[72].

Changes in economy have also been suggested as the explanation for greater PAP and time to exhaustion at PAP after concurrent strength and endurance training [64,65]. Though PAP is primarily influenced by $\dot{V}_{O2Max}$ and exercise economy, it also incorporates the individual's anaerobic capacity and neuromuscular characteristics[31]. Accordingly, increases in muscle activation and rate of force development have been found alongside improvements in PAP following concurrent training[73]. Furthermore, fiber type transitions from Type IIB/X to Type II A, thus increasing the oxidative capacity of skeletal muscle, and delayed activation of Type II fibers have also been cited for the increase in PAP seen after concurrent strength and endurance training[11,65]. However, despite the high correlation between PAP and $\dot{V}_{O2Max}$[74], no concurrent strength and endurance training studies observed any improvement in the $\dot{V}_{O2Max}$ of the athletes greater than that seen in the group performing endurance training alone.

1.6 SIT and 30 s Training

Short bouts of supramaximal exercise, such as sprint interval training (SIT) have been found to increase both PAP and $\dot{V}_{O2Max}$, while also improving anaerobic performance[13,75]. SIT is characterized by maximal effort 30 s bouts, separated by several min of rest [76,77]. Despite a singular bout relying predominantly on anaerobic energy supply[78,79,80], repeated bouts can elicit near-maximal (90% of $\dot{V}_{O2peak}$) oxygen uptake[81]. This aerobic demand stimulates increased mRNA expression of peroxisome proliferator-activated receptor- ɣ coactivator-1α (PGC-1α), increasing the concentration of skeletal muscle oxidative enzymes[82,83]. This greater oxidative enzyme concentration [76] has been suggested to explain, in part, the improvements in time trial performance and time to exhaustion seen after SIT[75]. SIT has increased both short (<10min) [12,77,84] and long (>10min)[76,77,85] time trial performance. These improvements are often similar or greater than those experienced by endurance-trained controls, despite a much lower volume of work[77,84,86]. Notably, SIT has also increased $\dot{V}_{O2Max}$[12,13,85,86,87,] and PAP [88,89,90]. In conjunction with the improvements in aerobic parameters, SIT is known to increase measures of anaerobic power such as peak [75] and mean power output[12,13,88,90,91] in a 30 s Wingate test.

Similar to SIT, repeated 30 s bouts of training at intensities greater than PAP have also led to improved performance in endurance athletes. In cyclists, 12 x 30 s at 175% of PAP with 4.5 min rest, performed twice a week for 4 weeks led to increased PAP and $\dot{V}_{O2Max}$, as well as improved 40 km time trial performance and ventilatory threshold [14,92]. In runners, 12 x 30 s bouts at 130% of PAP with 4.5 min rest increased $\dot{V}_{O2Max}$ and PAP as well as time to exhaustion at PAP and 3000m time trial performance[15]. Thus far, investigations into the effect of 30 s training on anaerobic adaptation in trained participants are limited. One study in cyclists found that anaerobic capacity, as determined by maximally accumulated oxygen debt, was increased after

30 s training [92]. Despite the abundance of evidence in less-trained populations, further investigations are required to elucidate any anaerobic adaptation in response to 30 s training in well-trained populations.

A novel foray into 30 s training is its use in weight training. 2 x 30 s of weighted exercises specific to swimming musculature increased performance in both 50- and 200-yrd swims[16]. This intervention was performed 3 times per week for 6 weeks and participants were instructed to perform 20 repetitions in 30 s with a regular tempo (4 repetitions in 6 seconds (s)). Weight was increased once 20 repetitions were attained. The increase in weight lifted and the increased skeletal muscle oxidative enzymes indicate improvements in both aerobic and anaerobic capacity contributed to the improvements in swimming performance[16].

1.7 Rowing and Cycle Ergometer Testing

Rowing Ergometry

The Concept 2 rowing ergometer (Concept 2, Morrisville, VT, USA) is used as an objective measure of rowing performance that is not affected by the variability of external elements such as environmental conditions and event venue[93]. Kinematic comparison of on-water rowing and ergometer rowing show that the movements are similar, with only slight differences in the motion of the arms owing to the coordination required in on-water rowing for the blade to enter and exit the water[94]. Despite rowers being able to complete the 2000 m trial faster on the ergometer than on-water, the physiological demands are similar[18]. 2000 m indoor rowing performance has strong correlations with on-water performance in elite rowers, though the strength of the relationship varies between boat classes[95,96]. Rowing Canada Aviron uses a combination of regular rowing ergometer tests and on-water assessments to track athlete performance[19]. The 1 min test is an “all out” un-paced effort used as a test of anaerobic capacity[97]. Since the rower is expected to apply and maintain maximal power to the best of their ability, peak power can be measured from the test as well.

Cycle Ergometer Testing

In this study, incremental ramp testing was performed on an electromagnetically braked cycle ergometer (Velotron Pro, Seattle, WA, USA). The cycle ergometer ramp test protocol included a 4 min baseline at 20 watts (W) before work rate increased until exhaustion at a rate of 25 or 30 W per min for women and men respectively [98,99].

1.8 Study Rationale

The current concurrent training literature lacks comparisons between similar highly-trained cohorts of rowers[9], as 30 s training has only been evaluated in sedentary populations or on athletes performing other modalities[14,76]. At present the use of 30 s weight training has been limited to recreational swimmers that were not concurrently performing endurance training[16].

Therefore, the main purpose of this study was to investigate and compare the effects of a concurrent 30 s weight training program performed by pre-conditioned well-trained collegiate rowers ranging from novice to international caliber, to a similar cohort of rowers performing a low-repetition strength training regime over an identical 5 week period on peak aerobic power, 2000 m time and peak and mean 1 min power output on the rowing ergometer while performing a high volume of endurance training. The results will provide insight into the use of 30 s weight training by rowers and compare its effects to the low-repetition strength training regime currently used by rowers.

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Chapter 2

Performing 30 second weight training bouts for five weeks decreases 2000 m ergometer times in collegiate rowers

2.1 Introduction

Rowing is a full-body cyclical exercise demanding aerobic energy pathway contributions of 70-75%, with the remainder coming from the anaerobic energy system (25-30%) [1]. Moreover, strong correlations between rowing success and maximal oxygen uptake ($\dot{V}_{O2Max}$), peak aerobic power (PAP), maximal force output (strength) and peak power output have been observed[2].

Despite the relationship between strength and power, and rowing success, there is a lack of literature investigating the effects of strength training on rowing performance. However, the effects of added strength training performed concurrently with endurance training have been evaluated in "traditional style" (fixed-seat, open-water, 13 man boat) rowers. Increases in 1-repetition maximum (1-RM), 10-stroke power, and mean power output on a 20-min test compared to a non-strength training control were observed[3]. However, no physiological mechanisms were studied that could account for the enhanced endurance performance and no testing was executed over Olympic rowing durations (5-8 min) [3,4]. Further investigation into physiological adaptations and Olympic rowing performance enhancement in response to concurrent strength and endurance training is warranted.

Research on elite cyclists has identified several adaptations responsible for improvements in endurance performance after concurrent strength and endurance training. Aagaard et al. have postulated that performing aerobic training with an added strength training program, that increased type IIA fiber cross sectional area at the expense of type IIX muscle fibers, was responsible for improved 45 min trial performances compared to the aerobic training only group[5]. A similar concurrent training study in elite cyclists found increased PAP and mean power output on a 40 min trial following this training[6]. The improvements in endurance performance in this study were attributed to an earlier occurrence of peak torque in each pedal stroke. Both of these concurrent protocols increased peak power and strength, however, no change in peak oxygen uptake ($\dot{V}_{O2peak}$) was observed in either study[5,6]. Since $\dot{V}_{O2peak}$, PAP and peak power output all correlate similarly with rowing success, a single intervention that increased all of these characteristics would improve rowing performance[2].

As a case in point, $\dot{V}_{O2peak}$, PAP, peak power output and endurance performance have all been shown to increase following 30 s sprint interval training (SIT) [7,8]. This SIT incorporated 30 s of maximal effort, high muscle contraction/relaxation frequency (115 per/min) bouts, separated by several min of rest[9,10]. The energy cost of a singular 30 s sprint interval is largely met by the anaerobic ATP-PCr and glycolytic energy pathways [11,12,13]. However, repeated 30 s maximal effort exercise bouts have been shown to elicit near-maximal (90%) $\dot{V}_{O2peak}$ [14]. This SIT research has identified increased mRNA expression of peroxisome proliferator-activated receptor-ɣ coactivator-1α (PGC-1α) as the mechanism by which oxidative phosphorylation increases [15,16]. It is suggested that a 30 s high intensity weight training regime encompassing the specific Olympic rowing movement would improve peak, anaerobic and peak aerobic power, as well as Olympic-style rowing 2000 m performances compared to a traditional low repetition strength training regime.

Much of the work in 30 s training has been conducted with sedentary or recreationally active participants [9,10,17,18]. However, a few studies of 30 s training have found improved $\dot{V}_{O2peak}$ and velocity at $\dot{V}_{O2peak}$ ($V_{\dot{V}O2peak}$) in runners [19] and cyclists [20,21], though the results have been equivocal and have lacked a whole-body predominantly aerobic performance measure comparable to a 2000 m rowing ergometer test. Furthermore, these investigations were not performed by preconditioned collegiate rowers ranging from novice to international caliber, while undertaking a concurrent high volume of aerobic training prescribed by an internationally recognized rowing coach. Consequently, further investigation is warranted into the effects of a 30 s weight training program on indices of rowing performance and associated physiological parameters performed by well-trained rowers.

The purpose of the present study was to investigate and compare the effects of a 5 week 30 s weight training program performed by pre-conditioned well-trained rowers, to a control group composed of a similar cohort of rowers performing a low-repetition strength training regime. Both groups performed concurrent high volume, predominantly low-intensity endurance training designed by an internationally acclaimed coach. Pre- and post-training measures of peak aerobic power on the cycle ergometer, and 2000 m and 1 min performances on rowing ergometers were carried out. It was hypothesized that the 30 s intervention would improve the 30 s group's peak aerobic power, 2000 m time and peak and mean 1 min power output on the rowing ergometer compared to the low-repetition group.

2.2 Methods

Experimental Approach to the Problem

The objective of this study was to compare the effects of a rowing specific low-repetition strength training program (e.g. 3 sets of 5 repetitions) to a rowing specific 30 s weight training program (5 sets of 30 s bouts), performed three times per week for 5 weeks by collegiate rowers.

The 5 week intervention period was imbedded in the seasonal training plan of the collegiate team's head coach, who has had the distinction of being named to the Canadian coaching staff for several Olympics.Both weight training programs were performed concurrently with the participants' predominantly aerobic rowing ergometer training (11-14 hours per week) after an initial 7 week early season rowing training period. Participants were paired based on performance on an incremental ramp (RAMP) test before being randomly allocated by the flip of a coin to either the low-repetition strength training group (LoRep) or 30 s interval group (30 s). Rowers completed a RAMP test on a cycle ergometer, as well as 1 min and 2000 m tests on a rowing ergometer before and after training.

Participants

Twenty-one collegiate rowers were recruited for the present study, comprising of 7 females and 14 males from 18-23 years of age and including a continuum of ability typical of a collegiate program, ranging from novice rowers who competed at the Ontario provincial development championships to varsity rowers who had competed for Canada at the under 23 World Rowing Championships. Participants were informed of the benefits and risks of this investigation and gave written informed consent to participate in this study. All procedures were approved by The University of Western Ontario Research Ethics Board for Health Sciences Research Involving Human Subjects and conformed to the declaration of Helsinki. The participants were healthy non-smokers who presented no musculoskeletal or cardiopulmonary issues and completed individual Physical Activity Readiness Questionnaires (PAR-Q) prior to the start of pre-training testing[22].

Testing Procedures

Peak Aerobic Power (PAP) Test with Blood Lactate Testing

Participants were asked to abstain from exercise within 4 hours and avoid consumption of a large meal within 2 hours of their scheduled test. Participants were instructed to take the elevator prior to entering the lab to reduce any possible lactate buildup from taking the stairs. Participants were seated for 3 to 5 min while they read and signed the letter of information and PAR-Q. Blood lactate was measured 5 min before and between 15 and 30 s after the RAMP protocol. Rubbing alcohol was used to sterilize the left index finger and then a blood sample was collected using the ACCU-CHEK Safe-T-Pro Plus sterile single-use lancing device. The blood lactate was measured using a Lactate SCOUT blood lactate analyzer, with a reported accuracy within ±0.2 $mmol \cdot L^{-1}$ (SensLab GmbH, Leipzig, Germany).

PAP was determined using an incremental ramp test to volitional fatigue on a Velotron electronic cycle ergometer (Velotron Pro, Seattle, WA, USA). After a 4 min baseline at 20 W, power output increased at a rate of 25 $W \cdot min^{-1}$ for women [23] and 30 $W \cdot min^{-1}$ for men [24]. PAP was defined as the work rate at which the participant could no longer maintain a pedal frequency of 70 revolutions per min.

Concept 2 Rowing Ergometer Tests

Participants completed all rowing performance tests on Concept 2 Model D rowing ergometers (Concept 2, Morrisville, VT, USA). Participants were accustomed to the rowing ergometer tests, which are regularly scheduled as part of the collegiate and national team selection criteria. Tests were performed, as scheduled by coaches, within a competitive team environment to promote best performance. Rowers performed their preferred individual warm up, which varied between individuals and rowing ergometer test. A typical 2000 m test warm up included 10 to 20 min of lighter intensity continuous rowing (C5-C6; see Table 1) followed by three to five 30-45 s bouts at race pace or above with active recovery in between bursts. A typical 1 min test warm up included five to ten min of C5-C6 followed by two to four 15-30 s maximal bouts with active recovery in between. Rowers finished their warm up and were ready to start the test for the coach-assigned start time. Teammates, coaches and one researcher gave vocal encouragement to enhance motivation. Time to completion, average power output and average split per 500 m were collected from the 2000 m test. All 1 min tests were digitally recorded as to discern individual stroke power output and stroke rate. Mean power output and stroke rate per 10 s were calculated. Peak power output was defined as the best 10 s mean power output from the 1 min test.

Common Rowing Training Program

Rowers completed 7 weeks of predominantly long duration endurance training (10-12 hours per week) prior to the study period, with one higher-intensity interval session and one higher-intensity continuous long duration session per week. Volume and intensity were increased progressively throughout this pre-conditioning period. The intensity of a session was prescribed relative to the intensity of each rower's 2000 m race pace using a categorical scale developed by Fritsch and Nolte [25] (Table 1). This preconditioning period was followed by the 5 week intervention period. Both LoRep and 30 s groups adhered to a coach-prescribed rowing ergometer training program during this phase (See Table 2). Table 2 describes the minimum training requirement to prepare an athlete for racing. An additional 4 - 6 hours a week of steady state (Category 6) rowing or cross-training was recommended above this minimum required training to all members of the rowing team and thus all participants.

Low-Repetition Strength Training Program

The training frequency of the LoRep group is shown in Table 3, while the prescribed strength program is shown in Table 4. Training took place in a competitive environment with supervision from the rowing strength coaches. The weight moved for each exercise was a function of the participants' performance level as well as the number of repetitions performed, where an exercise with fewer repetitions would have a greater weight moved. For the 7 weeks prior to the beginning of the study period, both groups performed a common low-repetition strength training program similar to that shown in Table 4.

Thirty Second Training Program

The 30 s group performed a warm up consisting of light cycling and dynamic stretching as well as a warm up set consisting of 10 repetitions using 50-75% of the weight used for the prescribed sets before commencing the dumbbell deadlifts. In a standing position, the dumbbells were gripped in forearm pronation in front of the body, before flexing sequentially at the hip and then the knee to lower the dumbbells to the lowest possible depth that would not cause a rounding of the lower back. The participant would then immediately extend their knees, then their hips to return to the standing start position. Participants performed five 30 s sets of dumbbell deadlift at a regular tempo between 1 repetition every 2 s and 2 repetitions in 3 seconds, completing 15 - 20 repetitions in each set. Each 30 s set was followed by 3.5 min of rest. Participants increased the dumbbells weight by 1 kg (women) or 2.2 kg (men) on achievement of 20 repetitions in 30 s with a constant cadence or if they reported a rate of perceived exertion (RPE) of less than "8" (< very hard) [26]. This was followed by the dumbbell benchpulls. These were performed with a similar tempo and progression format as the dumbbell deadlifts. Participants straddled an incline bench with a dumbbell elevating their body off the seat so that their hands would not reach the floor when hanging on both sides of the bench and also so that they could see a timer placed on the floor in front of them. Participants assumed a pronated grip on the dumbbells and lifted them by flexing at the elbow and extending the shoulders until the dumbbells touched the bench, before lowering the weights back to the start position. A researcher certified in personal training was present at all sessions to record weight lifted and number of repetitions performed, while also monitoring exercise form and providing positive feedback to enhance motivation. Two participants performed the 30 s training in the laboratory for gas exchange analysis and blood lactate analysis. Blood lactate was assessed (with similar methods as described above) at baseline and 2.5-3 min after the termination of each first and fifth set of dumbbell deadlift and dumbbell benchpull.

The training sessions were performed on Tuesdays, Thursdays and Saturdays. The intervention period including pre- and post-testing is shown in Table 3.

Oxygen Uptake Measurements

Participants performing the 30 s training in the laboratory wore a nose clip and breathed through a mouthpiece attached to a headset for breath-by-breath gas-exchange analysis. Volumes of inspired and expired air and flow rates were measured using a low dead space bidirectional turbine (Alpha Technologies, VMM 110) and pneumotach (Hans Rudolph, Model 4813) secured to the mouthpiece. The total apparatus dead space was 150 mL. Expired air was sampled continuously at the mouth and analyzed by mass spectrometry (Innovision, AMIS 2000, Lindvedvej, Denmark) for fractional concentrations of O_2 and CO_2. The volume turbine was calibrated before each test using a 3 L syringe at multiple flow rates. Gas concentrations were calibrated with gases of known concentration. The time delay between instantaneous, square-wave changes in fractional gas concentration at the sampling inlet was measured electronically using the computer. Respiratory volumes, flow rates and gas concentrations were recorded in real time and were used to digitally build and display a profile of each breath. The algorithms of Swanson [27] were used to calculate alveolar gas exchange breath by breath.

Statistical Analyses

All statistical analyses were calculated using SigmaPlot 12.3 (Systat Software Inc., San Jose, CA, USA). Statistical significance was accepted at an alpha level of $P \leq 0.05$. Pre- and post-training group mean 2000 m time, peak power, mean power and peak stroke rate in the 1 min test and PAP were compared using paired-t tests. Two way repeated measure ANOVA's (2WayRM ANOVA) were used to determine differences in power output throughout the 1 min test as well as baseline and post-RAMP blood lactate concentrations within groups pre- to post-training. Data is reported as mean ± standard deviation.

2.3 Results

Eighteen participants performed all pre- and post- training tests. One participant from the 30 s group chose not to continue with the study prior to the start of the training period so that they could perform a higher volume of strength training. Two participants from the Low-repetition group were not able to complete the post-training tests, missing either the 2000 m or cycle RAMP test, due to injury. The data sets of the participant who did not complete their respective training protocol and of a participant who was determined to be an outlier (2000 m time 2 standard deviations off of group mean time) were expunged. The data sets of the participants who completed the training protocol but did not complete all post-training tests were included, but the pre-training tests lacking a post-training value were excluded from statistical calculations.

Both groups completed a high volume (11-14 hr per week) of predominantly low-intensity rowing ergometer training during the 5 week intervention period (Table 2). There were 10 opportunities to perform the rowing coach-prescribed strength training (see Table 3). Number of sets increased throughout the program before decreasing in the final week.

There were 13 opportunities to complete the 30 s training protocol (Table 3). The mean number of sessions attended was 10.9 (± 1.8). Dumbbell deadlift mean weight increased by 29.7% (±15.1) from 23.23 kg (±4.06) to 30.18 kg (±6.46) ($P \leq 0.05$). Dumbbell benchpull mean weight increased by 26.9% (±10.5) from 20.46 kg (±6.98) to 25.51 kg (±7.28) ($P \leq 0.05$).

Mean O_2 uptake during the 30 s training in two exemplar participants is shown in Figures 1 and 2. Blood lactate concentration increased with subsequent sets (baseline = 1.8 $mmol{\cdot}L^{-1}$ (±0.3), dumbbell deadlift, post-set 1 = 2.9 $mmol{\cdot}L^{-1}$ (±0.1), post-set 5 = 4.8 $mmol{\cdot}L^{-1}$ (±0.5); dumbbell benchpull, post-set 1 = 5.5 $mmol{\cdot}L^{-1}$ (±0.2), post-set 5 = 5.6 $mmol{\cdot}L^{-1}$ (±0.9).

The 30 s group mean 2000 m time was reduced by 1.0% (±1.3) ($P \leq 0.05$) from pre- to post-training. The LoRep group mean 2000 m time was reduced by 0.9% (±1.4) which was not significant ($P \geq 0.05$). Individual and mean pre- and post-training 2000 m times are shown in Table 5.

Peak power output in the 1 min test was achieved between 10 s and 20 s in both LoRep and 30 s during Pre- and Post-training tests (see Figures 3 and 4). The 30 s group increased peak power by 2.9% (±4.1; $P \leq 0.05$) whereas the 0.7% increase (±4.7) in the LoRep group was not significant ($P \geq 0.05$). The 30 s and LoRep groups both increased 1 min mean power output pre- to post-training by 4.0% (± 3.5) and 4.2% (± 3.6) respectively (30 s: $P \leq 0.05$, Figure 3; LoRep: $P \leq 0.05$, Figure 4). The percent increase in 1 min mean power output was also similar between groups ($P \geq 0.05$).

No change in PAP was observed in either 30 s or LoRep groups pre- to post-training, as seen in Figures 5 and 6, respectively. Pre- and post-training blood lactate concentrations for the 30 s and LoRep groups are shown in Figures 7 and 8 respectively. The 30 s group had a reduction of post-RAMP lactate by 11.2% (± 15.2) ($P \leq 0.05$).

Table 1: Category system of training intensities used in common rowing training program

Intensity Category	Approximate Heart Rate (bpm)	Duration of One Bout (min)	Practical Examples with Stroke Rates (spm)	Ergometer Splits (estimate based on 2000 m test)	Lactate Level (mmol·L^{-1})
1	Maximum HR i.e. 180 – 200	0.5 – 1.5	- 1 – 6 x 500 m (with start) - Interval training (short bouts):series of 30 – 60 strokes or 1 – 2 min SR: > 2 km SR	Maximum Speed	> 10
2	Maximum HR i.e. 180 – 200	2 – 7	-Race over 1500 – 2000 m -6 x 2 min -3 x 1000 m -5 x 750 m SR: 2 km SR	Average Split per 500 m for 2 km	8 – 14
3	Maximum HR i.e. 180 – 200	6 – 10	-4 x 7 min -3 x 2000 m constant speed -5 x 5 min SR: 2 – 4 < 2 km SR	2 km Split + 5 s	5 – 8
4	165 – 175	10 – 45	-2 x 20 min with SR change -3 x 5 km time-control -10 km head race -3 x 12 min SR: 3 – 6 < 2 km SR	2 km Split + 10 s	~ 4
5	150 – 165	30 – 90	-30 – 90 min steady state SR: 10 – 12 < 2 km SR	2 km split + 15 s	~ 3
6	135 - 150	> 45	-45 – 120 min steady state at low intensity SR: 12 – 18 < 2 km SR (approximately 18 – 24 spm)	2 km split + 20 s	< 2

Nolte & Fritsch[24]. HR = Heart Rate; Bpm = beats per min; min = minutes; SR = stroke rate; spm = strokes per min; 2 km = 2000 m rowing ergometer test; mmol·L^{-1} = millimoles per liter of blood.

Table 2: Common rowing ergometer training program during five week training period

Training Category	C1 (min)	C2 (min)	C3 (min)	C4 (min)	C5 (min)	C6 (min)	Supp (hours)	
Week								Total Time (hours)
W1	70			60	140	160	4 - 6	11.2 - 13.2
W2			70	60	80	260	4 - 6	11.8 - 13.8
W3	50	80			80	305	4 - 6	12.6 - 14.6
W4		80		60	100	260	4 - 6	12.3 - 14.3
W5	50				160	290	4 - 6	12.3 - 14.3

W1 - W5 = weeks 1 - 5 of the intervention; C1 - C6 = category 1 - 6, in min; Supp = the supplementary C6 training expected of competitive rowers, in hours. Training volume by category is shown in minutes and includes warm-ups and cool-downs. See Table 1 for category descriptions.

Table 3: 5 week training period with pre- and post-training tests and 30 s and LoRep group training days

Week	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
pre-test 1	2 km		RAMP	RAMP	RAMP	RAMP	RAMP
pre-test 2	RAMP	RAMP	RAMP	1 min			
Reading Week							
W1			30 s or LoRep		30 s or LoRep		30 s
W2			30 s or LoRep		30 s or LoRep		30 s
W3			30 s or LoRep		30 s or LoRep		30 s
W4			30 s or LoRep		30 s or LoRep		30 s
W5			30 s or LoRep				
post-test 1					1 min	2 km	
post-test 2		RAMP	RAMP	RAMP	RAMP	RAMP	

2 km = 2000 m rowing ergometer test; 30 s = 30 s interval training; LoRep = Low-repetition strength training; RAMP = Incremental Ramp test; 1 min = 1 min rowing ergometer test, W = week. 30 s participants performed five sets in weeks 1 through 4 and three sets in week 5. Weight lifted was reduced by 10% in week 5 to recover for ergometer and RAMP testing in the following two weeks.

Table 4: Low-repetition strength training program

	Phase 1					Phase 2						
Session A					**Session A**							
Exercise	w1	w2	*Tempo	**Rest	Exercise	w1	w2	w3	w4	Tempo	Rest	
A Squat	5 x 3-5	5 x 3-5	3010	180 s	A Squat	4 x 2-4	5 x 2-4	6 x 2-4	3 x 2-4	3010	180 s	
B Dumbbell Step-Up	5 x 4-6/side	5 x 4-6/side	2010	120 s	B Leg Press	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	4010	90 s	
C1 Bench Press	5 x 4-6/side	5 x 4-6/side	4010	60 s	C1 Incline Bench Press	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	4010	60 s	
C2 Dumbell Row	5 x 4-6/side	5 x 4-6/side	4010	60 s	C2 Reverse EZ Bar Curl	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	4010	60 s	
D1 EZ Bar Curl	2 x 15	2 x 15	2020	0 s	D1 Hanging Knee Raises	3 x 15	3 x 15	3 x 15	3 x 15	2020	0 s	
D2 Pushups	2 x AMRAP	2 x AMRAP	2020	30 s	D2 Knee-to-Elbow Plank	3 x 15/side	3 x 15/side	3 x 15/side	3 x 15/side	2020	60 s	
E Hanging Knee Raises	3 x 15-20	3 x 15-20	2020	30 s								
Session B					**Session B**							
A Trap Bar Dead Lift	6 x 2-4	6 x 2-4	2010	180 s	A Wide Grip Deadlift	4 x 2-4	5 x 2-4	6 x 2-4	3 x 2-4	2010	180s	
B Step Forward Lunge	4 x 6-8/side	4 x 6-8/side	2010	120 s	B1 Dumbell Step-Up	4 x 5-7/side	5 x 5-7/side	5 x 5-7/side	4 x 5-7/side	2010	60 s	
C Leg Press	4 x 12-15	4 x 12-15	3010	60 s	B2 Leg Curl	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	5010	60 s	
D1 Chin Up	4 x 6-8	4 x 6-8	3010	60 s	C1 Barbell Upright Row	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	4010	60 s	
D2 Incline Dumbbell Bench Press	4 x 6-8	4 x 6-8	3010	60 s	C2 Pull Up (Add weight if needed)	4 x 5-7	5 x 5-7	5 x 5-7	4 x 5-7	4010	60 s	
E V-Ups	3 x 15-20	3 x 15-20	2020	30 s	D1 Ab Rollout	3 x 15	3 x 15	3 x 15	3 x 15	2020	0s	
					D2 Froggers	3 x 30 s	3 x 30 s	3 x 30s	3 x 30 s	1010	60 s	

Squat = with a barbell on shoulders, squat until femur reaches parrallel with floor; Dumbbell Step-Up = with dumbbells in each hand, step forward up onto a box or bench, lower back down, alternate legs; Bench Press = with a barbell in hands and back on a bench, lower the bar to chest, then press up to lockout; Dumbell Row = one knee and one arm supported by bench or box, dumbell in other hand, pull dumbbell to touch ribcage; EZ Bar Curl = while standing with elbows extended, grip the angular EZ bar with palms facing away from body and flex the elbow to bring the bar to collarbone; Pushups = on the floor, arms fully extended vertically below shoulders, legs straight with torso, lower body to ground by flexing at elbows and extending shoulder, press back up to start position; Hanging Knee Raises = with elbows in hanging straps, suspend body weight, bring knees to chest; Trap Bar Dead Lift = standing in trap bar (hexagon shaped bar), grip handles, extend hips and knees to a standing position; Step Forward Lunge = with dumbbells in hands, step forwards, lower trailing knee to touch floor, press up to bring leg forward to standing, alternate legs; Leg Press = in leg press machine, with feet on foot plates, extend hips and knees to lift the weight carriage; Chin Up = with palms facing body, grip bar arms reach above body, pull elbows down to ribcage to lift head above bar; Incline Dumbbell Bench Press = on an incline bench, dumbbells in hands, press dumbbells towards ceiling by extending elbows and flexing the shoulders; V-Ups = supine on floor, flex at hips keeping torso rigid and legs straight to form a "V"; Incline Bench Press = on an incline bench, barbell in hands, press barbell towards ceiling by extending elbows and flexing the shoulders; Reverse EZ Bar Curl = while standing with elbows extended, grip the angular EZ bar with palms facing body and flex the elbow to bring the bar to collarbone; Knee-to-Elbow Plank = hands and feet on floor, torso and legs straight and elevated, bring knee to elbow of same side arm; Wide Grip Deadlift = hands on the outer ring of the barbell, extend knees and hips to bring bar up the body to a standing position; Leg Curl = kneel on opposite knee in leg curl machine, bring heel to glutes by flexing knee; Barbell Upright Row = with barbell in hands, palms facing body, flex elbows and shoulders laterally to bring the bar up to the upper chest; Pull Up = with palms facing away from body, grip bar arms-reach above body, pull elbows down to ribcage to lift head above bar; Ab Rollout = grip handles on ab wheel, knees on the floor, extend arms out in front of body, lowering body towards floor, pressing back to start position; Froggers = with hands and feet on floor, torso and legs straight and elevated, hop feet simultaneously to the outside of each hand, hop back. Phase 1 workouts were completed in weeks one and two of the intervention period. Phase 2 workouts were completed for weeks three through five. Sessions A and B were performed on either Tuesday or Thursday, with the Men's and Women's teams performing the same plan on opposite days. w1-w4 = the week of that phase of programming; *Tempo = time spent in the eccentric, isometric and concentric parts of the exercise as well as the time between repetitions. Squatting with the "3010" tempo entails a 3 second eccentric, 0 second isometric and 1 second concentric, with 0 seconds between repetitions; **Rest = time in seconds between sets. Exercises with the same letter and a number preceding their name are meant to be done back to back with the time between exercises indicated in the rest. The notation indicates the number of sets then the number of repetitions or range of repetitions i.e. the notation "5 x 3-5" indicates five sets of three to five repetitions. EZ bar = an angular bar used to change the grip angle; AMRAP = as many repetitions as possible.

Table 5: 2000 m rowing ergometer results, participant competition history and pre- and post-training cycling peak aerobic power

Group	Sex	Category	Pre-Training 2 km (min:s)	Post-Training 2 km (min:s)	Level of Competition Achieved
LoRep	♀	O	7:31.8	7:25.2 *	WJRC
	♀	O	7:38.1 †	7:32.6 *	PDC
	♀	LW	7:39.7 †	7:33.0 *	PDC
	♂	O	6:18.0		WJRC
	♂	O	6:19.9	6:09.3 *	NC(M)
	♂	O	6:07.9 †	6:07.0 *	NC(M)
	♂	O	6:26.0	6:21.8 *	NC(M)
	♂	LW	6:25.2	6:33.9	NC(M)
	♂	LW	6:49.6 †	6:45.0 *	PDC
	♂	LW	6:45.9	6:42.0	NC(M)
	Group Mean (±Standard Deviation)		**6:51.6 (±36.1)**	**6:47.7 (±35.5)**	
30 s	♀	O	7:23.5	7:12.8 *	PC(M)
	♀	LW	7:42.7 †	7:37.0 *	PC(M)
	♀	LW	7:20.9	7:12.4 *	NC(M)
	♂	O	6:09.5	6:03.0	WU23RC
	♂	O	6:30.9	6:27.7	PDC
	♂	O	6:30.0	6:23.4	NC(M)
	♂	O	6:13.9	6:20.7	PC(M)
	♂	O	6:10.3	6:08.7 *	NC(M)
	♂	LW	6:45.7 †	6:44.9 *	PDC
	Group Mean (±Standard Deviation)		**6:45.3 (±35.3)**	**6:41.2 α (±32.7)**	

LoRep: Low-repetition weight training group; 30 s: 30 s interval training group; 2 km: 2000 m rowing ergometer test time; O: Open weight class; LW: Lightweight class, males = 72.5 kg, females = 59.0 kg; WJRC: participant competed at the World Junior Rowing Championships; PDC: participant competed at the provincial development championships; PC(M): participant has medalled at the provincial collegiate championships; NC(M): participant has medalled at the national collegiate and or club championships; WU23RC: participant has competed at the World Under-23 Rowing Championships; $L_{O2}\cdot min^{-1}$ **:** Liters of oxygen per min; min:s: minutes:seconds; W: watts; ♂: male participant; ♀: female participant;†: participant achieved a personal best in Pre-Training; *: participant achieved a personal best in Post-Training; α: statistically significant reduction of mean 2000 m time

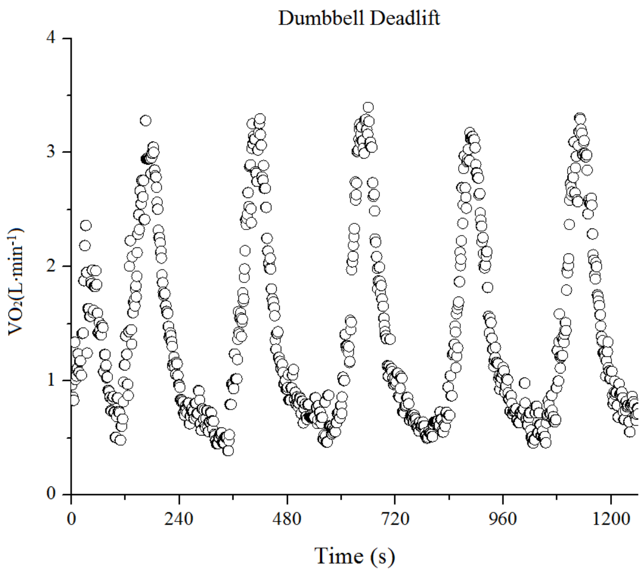

Figure 1: Oxygen uptake during dumbbell deadlift. 10 repetition warm up set with 50-75% of working weight followed by 5 sets of 30 s with 3.5 min rest. V_{O2}(L·min^{-1}) = oxygen uptake in liters per min; s = seconds

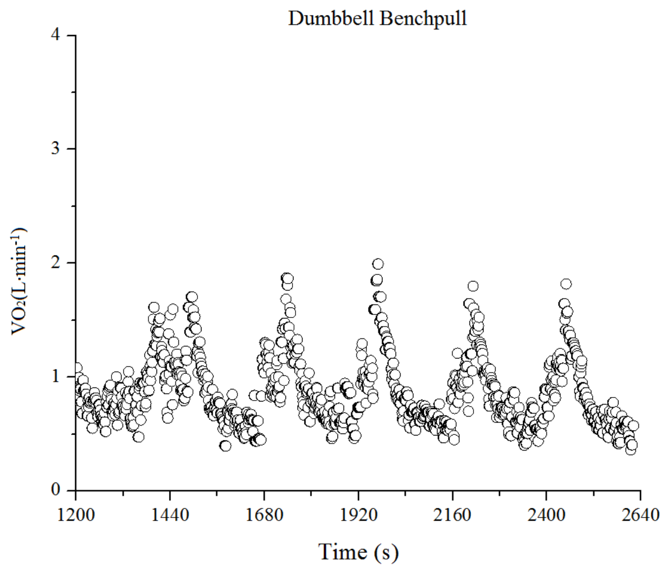

Figure 2: Oxygen uptake during dumbbell benchpull. 10 repetition warm up set with 50-75% of working weight followed by 5 sets of 30 s with 3.5 min rest. V_{O2}(L·min^{-1}) = oxygen uptake in liters per min; s = seconds

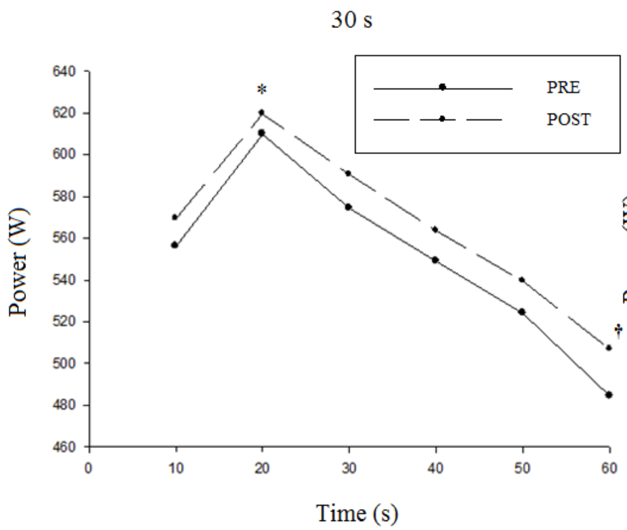

Figure 3: 30 s Group 1 Minute Test 10 second Power Averages. W = watts; s = seconds; * = significant increase in power in a 10 s average; † = significant increase in mean power output. Mean power output: Pre-training = 545 W (±139); Post-training = 564 W (±133). Peak power output: Pre-training = 608 W (±155); Post-training = 624 W (±150) (* = Paired-t test: P ≤ 0.05). Peak average stroke rate: Pre-training = 49 strokes per min (spm)(±3); Post-training = 50 spm (±7) (P ≥ 0.05).

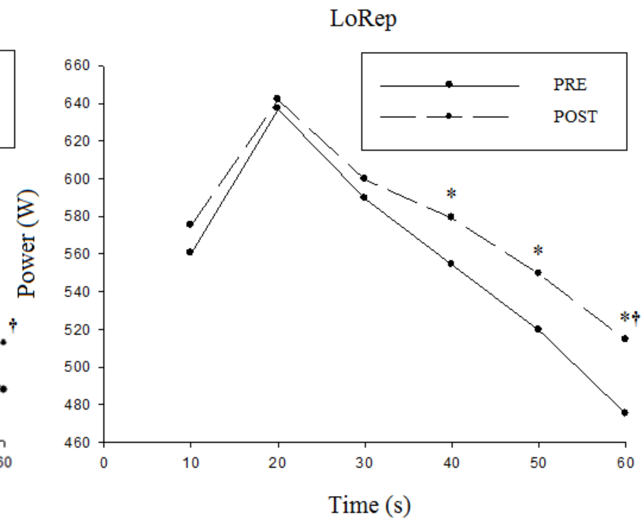

Figure 4: Low-Repetition Group 1 Minute Test 10 second Power Averages. W = watts; s = seconds; * = significant increase in power in a 10 s average; † = significant increase in mean power output. Mean power output: Pre-training = 552 W (±128); Post-training = 575 W (±132). Peak power output: Pre-training = 639 W (±143); Post-training = 642 W (±138). Peak average stroke rate: Pre-training = 54 strokes per min (spm)(±5); Post-training = 53 spm (±6) (P ≥ 0.05).

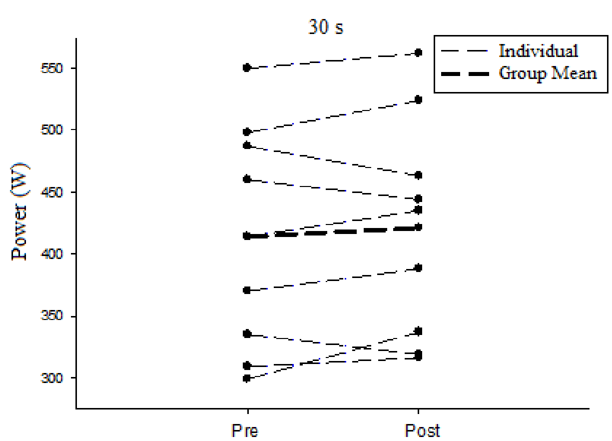

Figure 5:30 s Group RAMP Test Peak Aerobic Power (PAP). PAP: Pre-training = 414 W (±90); Post-training = 421 W (±88), P ≥ 0.05.

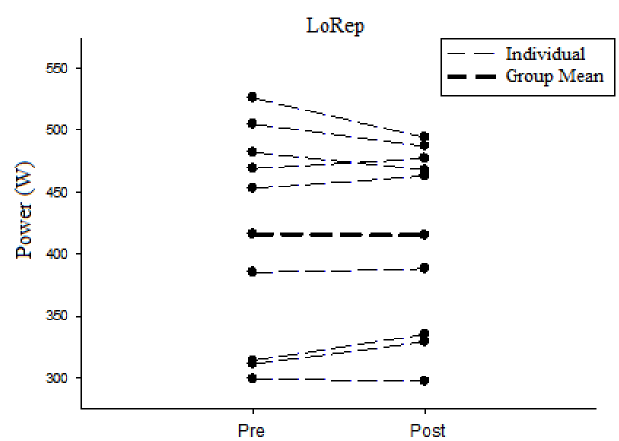

Figure 6: LoRep Group RAMP Test Peak Aerobic Power (PAP). PAP: Pre-training = 416 W (±90); Post-training = 415 (±88), P ≥ 0.05.

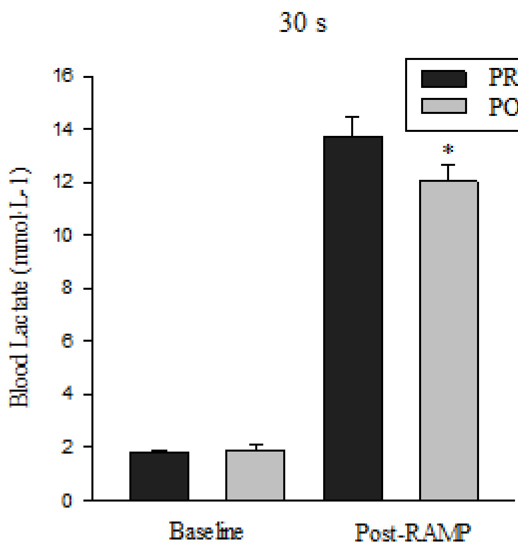

Figure 8: 30 s Group RAMP Test Blood Lactate Analysis. Baseline = 5 min prior to RAMP test start; Post-RAMP = 15-30 seconds after RAMP termination; mmol·L^{-1} = millimoles per liter; * = significant decrease in blood lactate concentration. PAP: Pre-training = 414 W (±90); Post-training = 421 W (±88), P ≥ 0.05.

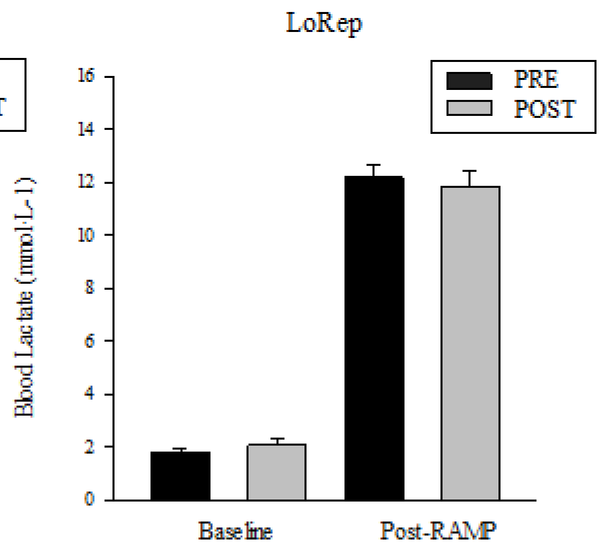

Figure 7: LoRep Group RAMP Test Blood Lactate Analysis. Baseline = 5 min prior to RAMP test start; Post-RAMP = 15-30 seconds after RAMP termination; mmol·L^{-1} = millimoles per liter. PAP: Pre-training = 416 W (±90); Post-training = 415 (±88), P ≥ 0.05.

2.4 Discussion

The present study investigated the effects of a five week 30 s weight training program performed three times per week concurrently with a high volume of endurance training in pre-conditioned collegiate rowers ranging from novice to international caliber. These findings were compared to the results of a control group composed of a similar cohort of rowers who performed a coach prescribed low-repetition strength training regime over an identical five week period on peak aerobic power, and 2000 m and 1 min rowing ergometer performance. It was hypothesized that the 30 s intervention would improve their peak aerobic power, 2000 m time and their peak and mean 1 min power output on the rowing ergometer compared to the low-repetition group.

The major findings of this study were that the 30 s training group decreased their 2000 m time and had an increase in peak power during their 1 min test ($P \leq 0.05$) while the low-repetition group did not ($P \geq 0.05$).

The metabolic cost of a 2000 m rowing race is predominantly met by aerobic metabolism, providing 70-75% of the overall energy cost, whereas 25-30% is met by anaerobic glycolysis and high energy phosphates[1]. Due to the sizeable aerobic contribution to a 2000 m race, the improved 2000 m performance by the 30 s group in the present study is consistent with the improved endurance performances previously seen after 30 s training in runners and cyclists,[19,21]. Esfarjani & Laursen [19] worked with moderately-trained runners who completed 10 weeks of a maximum of 12 x 30 s bouts at 130% of the velocity at $\dot{V}_{O2peak,}$ ($V_{\dot{V}O2peak}$; similar to the PAP of the present study) with 4.5 min rest in between bouts. This protocol was performed twice a week with an additional 2 long light intensity (75% of $V_{\dot{V}O2peak}$) runs compared to a control group who performed 4 long light-intensity runs per week. They found that 3000 m run time decreased and $\dot{V}_{O2peak}$ and V $\dot{V}_{O2peak}$ increased [19]. However, the present study did not observe changes in PAP, whereas Esfarjani & Laursen observed a 7.8% improvement in V $\dot{V}_{O2peak}$ [19]. This is likely due to the lower performance level of the runners, as exhibited by their low training volume (4 hours per week) and non-competitive 3000 m performance times[28], whereas the participants in the present study were completing a high volume of training (11-14 hours per week) and many had been competitive on the national stage within their home country (Table 5). Though Esfarjani & Laursen did not evaluate the metabolic demand of their 30 s protocol, the aerobic stimulus was evidently substantial enough to cause an increase in $\dot{V}_{O2peak}$ and V $\dot{V}_{O2peak}$. This suggests an intensity of 90% of $\dot{V}_{O2peak}$ or greater, similar to values seen during SIT[14], which has been shown to be conducive to improvements in $\dot{V}_{O2Max}$ and PAP [29,30].

Peak oxygen measures obtained during the dumbbell deadlift and dumbbell bench pull were 3.4 $L_{O2}\cdot min^{-1}$ and 2.0 $L_{O2}\cdot min^{-1}$ respectively, which constitute 61.8 and 36.4% of the mean $\dot{V}_{O2Max}$ of the two participants who completed the training protocol in the lab. It is therefore likely that the present study protocol did not sufficiently challenge the cardiovascular system to provoke an adaptive response in $\dot{V}_{O2Max}$ and thus PAP [31]. It should be noted that the present 30 s protocol was intended to be near-maximal, rather than maximal, as to avoid inducing repetition failure and mitigate risk of injury, particularly during the dumbbell deadlifts. It is likely that this distinction in intensities contributed to the lack of change in PAP compared to previous work in runners and cyclists[19,21]

Interestingly, there were also no changes shown in the PAP of the LoRep group. This contrasts with the findings of Rønnestad et al. [6], where the addition of low repetition strength training led to a significant 3% increase in PAP in highly-trained cyclists whereas the endurance only group experienced a non-significant decrement. However, the length of said intervention was 25 weeks long, five times the duration of the present protocol. Indeed, studies in athletes showing the benefits of performing strength and endurance training concurrently typically involve a longer intervention period (8+ weeks [3,5,32]) or a greater weekly volume (3-4 sessions per week[33,34]). This may also reflect the influence of the concurrent training effect [35], necessitating a longer intervention period or higher volume of strength training to show significant improvements in endurance athletes. Though the present protocol may not have shown improvements in PAP, other potential mechanisms such as reduced blood lactate accumulation and increased PCr concentration and activity could account for the significant improvement in 2000 m time of the 30 s group.

Blood lactate analysis conducted during a representative training session of the present study indicated that anaerobic glycolysis was supplementing oxidative phosphorylation and the ATP-PCr system, with blood lactate ranging from 2.9 to 5.6 $mmol \cdot L^{-1}$ over the course of the 30 s exercise protocol. Though the activation of PGC-1α was not investigated in this study, lactate accumulation has been found to coincide with the metabolic signalling cascade leading to an increased expression of oxidative enzymes after 30 s training[15,16]. PGC-1α has also been shown to attenuate lactate production and increase the capacity for lactate transport [36,37]. The changes in monocarboxylate lactate transporter 1 (MCT 1), PGC-1α, and oxidative enzymes have been shown to occur in shorter time periods (i.e. 5-6 weeks), comparable to the 5 week intervention in the present study [15,16,38,39]. In line with these findings, the 30 s group was found to have a reduced post-ramp blood lactate concentration post-training, despite obtaining a similar power output to their pre-training PAP. This is similar to previous findings where lactate accumulation has been reduced after 30 s sprint interval training [9]. These adaptations have been shown to translate into improved tolerance of high intensity exercise and improved endurance performance[8,10,38].

Increased phosphocreatine (PCr) stores and creatine kinase (CK) activity may also have contributed to the improvements in 2000m performance. Intramuscular PCr concentrations and CK activity have been shown to increase by 31 and 44%, respectively, after 14 SIT sessions[40]. The PCr system, along with energy derived from anaerobic glycolysis, make up the anaerobic work capacity (*W'*). *W'* quantifies the work performed above critical power (CP). CP has been defined as the highest power output capable of being wholly sustained by oxidative phosphorylation[41]. Continued exercise above CP results in a gradual increase in oxygen uptake until $\dot{V}_{O2Max}$ is reached[41], which has been shown to occur in a 2000 m rowing ergometer test[42]. Consequently, an increase in the ability to work above CP would improve the mean power output of a 2000 m rowing ergometer test.

Though PCr and CK activity and or concentrations were not assessed in the present study, the improvement in 10 s peak power observed only in the 30 s group is indicative of greater PCr system activity. PCr kinetics during repeated sprint intervals reveal that PCr content is related to the ability to generate peak power[11,12,43]. Additionally, the weight used to perform the dumbbell deadlifts and dumbbell bench pull improved significantly with training, indicating an ability to sustain higher power outputs over repeated 30 s bouts, which has also been shown to be related to PCr concentrations[43]. Resistance training consisting of fewer repetitions and higher force outputs, such as the strength program followed by the LoRep group, have not been found to increase PCr concentrations.[44] Accordingly, the LoRep group did not have a significant increase in peak power.

This lack of improvement in peak power contrasts with previous strength training studies in elite endurance athletes such as Rønnestad et al [45] where 12 weeks of strength training increased peak power in a Wingate test by 120 W, whereas a non-significant decrement was seen in the endurance only group. However, participants in said study were instructed to perform the concentric phase of their strength training as quickly as possible, whereas the participants in the LoRep group had a prescribed tempo which was not imposed actively by the coaches. Intended movement velocity has been shown to determine the velocity specificity of training adaptation, which suggests that the neuromuscular adaptations to the LoRep training would not transfer to the significantly higher movement velocities seen during the 1 min test[46]. Furthermore, the participants in the Rønnestad et al [45] study had not been strength training for the preceding 6 months, whereas the participants of the present study had been performing strength training for a minimum of 7 weeks prior to the investigation, reducing the novelty of the stimulus and diminishing the likelihood of significant changes over a 5 week period[47].

Both groups increased mean power output during the 1 min test. However, the post-training improvements in power output over the pre-test occurred in the last 30 s of the test in the LoRep group. Conversely, elite cyclists have been found to have a greater reduction in power throughout a 30 s Wingate test after performing concurrent strength and endurance training, compared to a similar cohort performing endurance training only [6,45]. As previously described, the absence of improvement in peak power in the LoRep group may be reflective of the slower intended movement velocity of their strength training, the shorter intervention period or greater familiarity with - and therefore reduced sensitivity to - strength training compared to previous concurrent training work in cyclists[6,45]. The improved ability to sustain a supramaximal power output, as seen in the last 30 s of the LoRep group 1 min test, is reflective of the high volume endurance training program performed by both groups, which was designed to improve CP and $\dot{V}_{O2peak}$ and would thus increase the ability to sustain a supramaximal power output [48,49].

However, this improved ability to sustain supramaximal power was not observed in the 30 s group. It may that the 30 s group had exhausted their PCr system earlier in the exercise bout, as studies in sprinters have found that faster sprinters are able to deplete their PCr stores more completely and more quickly than slower sprinters [50]. Exhausting the PCr system earlier in the exercise bout would diminish power output in the remainder of the bout, since the participant could no longer supplement their oxidative metabolism with that particular anaerobic source[11,51]. However, mean power output in the 1 min test improved similarly in both groups.

To the researchers' knowledge, this was the first study to compare the effects of 30 s interval weight training to low-repetition strength training in pre-conditioned collegiate rowers ranging from novice to international caliber, performed concurrently with a large volume of endurance training. This intervention was imbedded within the training plan of an internationally recognized rowing coach with performance tests that are included in the criteria for Canadian national team selection.. The improvement in 2000 m time and peak power indicate that 30 s weight training can lead to performance enhancement in well-trained rowers over a 5 week period when performed concurrently with a high volume of endurance training. The effectiveness of the 30 s protocol is emphasized by the improvements seen in the top two participants in this group, who improved both their peak aerobic power and 2000 m time from pre- to post-training. Both of these participants are national championship medalists, and one had participated in the World Under-23 Rowing Championships.

Conclusions

Five weeks of 30 s weight training performed three times per week improved 2000 m performance and peak power whereas low-repetition strength training did not when performed concurrently with a high volume of endurance training in well-trained, pre-conditioned, male and female collegiate rowers ranging from novice to international caliber during their training season.

Practical Applications

It is recommended that rowing coaches include this 30 s weight training program within their yearly resistance training program after their initial aerobic conditioning and strength development phase. This will lead to greater improvements in performance in relatively short periods (5 weeks) than those seen with only low-repetition strength training.

Acknowledgements

This study could not have been conducted without the participation of the collegiate rowers of Western University. The dedication and curiosity of the athletes and coaches allowed this project to materialize. Further thanks must be extended to the staff of the Western Student Recreation Center and the Micheal Kirkley Varsity Training Center for the use of their space and equipment.

We would also like to express our gratitude to Dr. J.M. Kowalchuk for access to the cardiorespiratory lab at the University of Western Ontario’s Canadian Center for Activity and

Aging research facility and to Prof. P.A. Robbins, University of Oxford, for providing the End-tidal Forcing software for breath-by-breath pulmonary oxygen uptake measurement, and to Brad Hansen for his technical expertise.

2.5 Future Directions and Limitations

Future Directions

The present study compared the effects of a 30 s weight training program with those of a low-repetition strength training program in a group of well-trained male and female collegiate rowers ranging from novice to international caliber. Similar investigations should be performed with more female participants or athletes of lower levels of experience to see if these results can be generalized to a wider population of rowers. Furthermore, neuromuscular testing, histochemical and Western blot analysis are warranted to determine the physiological mechanism of performance enhancement.

Limitations

Attendance was only taken in two weekly sessions of the high volume of rowing training that was performed concurrently with each of the protocols, allowing a degree of individual variability that could influence training adaptations. Additionally, the strength and conditioning coaches who ensured motivation and proper technique in the participants who were in the low-repetition group were also responsible for a number of other athletes during the same training period, diminishing their time per participant compared to the researcher only coaching the 30 s group. This could have reduced the feedback given to each participant, thus influencing the quality of each training session. [52]

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Appendix: Letter of Information

Western
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LETTER OF INFORMATION

The effect of 30 s weight training bouts on selected physiological variables and performance in varsity rowers.

Principal Investigator: Glen Belfry PhD
Co-investigator: Andre Pelletier MSc candidate

Purpose of Study:

You are being invited to participate in a study that will determine whether your muscles will see a greater improvement in their ability to use oxygen, as well as produce energy for physical work, by performing either a traditional strength training regime (control group) or a perform novel 30 s bouts of a weight training regime (30 s training group) over a six week period.

Both of these groups of rowers will also be performing the regularly scheduled dryland rowing machine (rowing ergometer) training sessions as designed by your Head Coach.

Participation in this study involves visits to the laboratory of the Canadian Centre for Activity and Aging on two different occasions. These visits will require about 60 minutes of your time.

This laboratory is located at the University of Western Ontario, in the Health Science Building, room 313. This room is located on the third floor.

A total of 20 healthy male or female members of the rowing team will be invited to participate in this study. In order to participate you must be between 18-35 years of age. You will not be able to participate in the study if you have been diagnosed previously with any respiratory, cardiovascular, metabolic, neurological or musculoskeletal disease; or you are currently on medication; or you are a smoker; or you respond to the exercise protocol in an irregular manner or cannot tolerate the exercise or exercise training protocol.

If you decide to participate you will be then "randomized" into the control group or the 30 s bouts of weight training group. Randomization means that you are put into a group by chance (we will flip a coin). There is no way to predict which group you will be assigned to. There will be an equal chance you will assigned to either group. Neither you, nor the study investigators can choose what group you will be in.

Your first task, if you decide to participate, will be to complete the Physical Activity Readiness Questionnaire (PAR-Q) designed for adults ages 15-69 years of age. This questionnaire “will tell you if you should check with your doctor before you start this study”.
You will be randomly assigned to either 1) the 30 s weight training group or 2) the control group for the following six week period. You will be informed of your group assignment one week after test completion.

If you are pregnant at this time or become pregnant during the study you will also be excluded from participating in this study.

Research Testing Protocol:
During the first visit to the laboratory you will complete a ramp incremental exercise test until you are unable to continue because the exercise intensity is either too high or too uncomfortable. This exercise test will be performed on a stationary bicycle (cycling ergometer). The test will begin with the exercise intensity being very light and easy (very little resistance). After a few minutes the exercise intensity will gradually and continuously increase until you are unable to continue because of fatigue, or until you wish to stop.

This visit will last approximately 1 hour. Seven weeks later you will return to the lab to perform these identical tests.

Research Procedures:
During the ramp incremental tests you will be required to wear a nose-clip (to prevent you from breathing through your nose) and a rubber mouthpiece (similar to breathing through a snorkel or diving mask). These will be washed and sterilized between users. This will enable us to measure the volume of air that you breathe in and out, and measure the oxygen and carbon dioxide levels in that air. You may experience some initial discomfort from wearing the nose-clip and mouthpiece.

Before and after the ramp incremental test a pin prick will be administered to your left index finger and a drop of blood will be used to measure the muscle byproducts (lactic acid) of high intensity exercise.

Weight Training Programs:
The control group will perform your coach prescribed weight training program during your regularly scheduled weight training sessions on Tuesdays and Thursdays during your regularly scheduled rowing team weight training sessions for six weeks.

The 30 s weight training group will perform 15 repetitions, within 30 s, of both the “bench pull” and “deadlift” exercises, with dumb bells. This program will be followed for six weeks.

You will perform three sets of this protocol during week's one, three, and five, and five sets of this protocol during week's two, four and six, on Tuesdays and Thursdays during your regularly scheduled Western rowing team's weight training sessions.

The 30 s training group will perform an additional three sets of this 30 s protocol on Saturdays after your regular scheduled rowing ergometer training session. All weight training sessions for both groups will take place at the Western varsity weight training centre (Kirkley Centre) at TD Waterhouse Stadium.

A certified strength and conditioning coach will be present at all training sessions of both groups to ensure that the exercises are performed safely and with correct technique.

You will be familiar with both the "bench pull" (Figure A) and "deadlift" (Figure B) exercises as you will have been exposed to them throughout your rowing career here at Western. See pictures below.

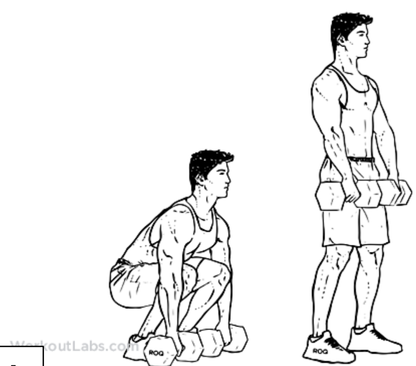

Figure A

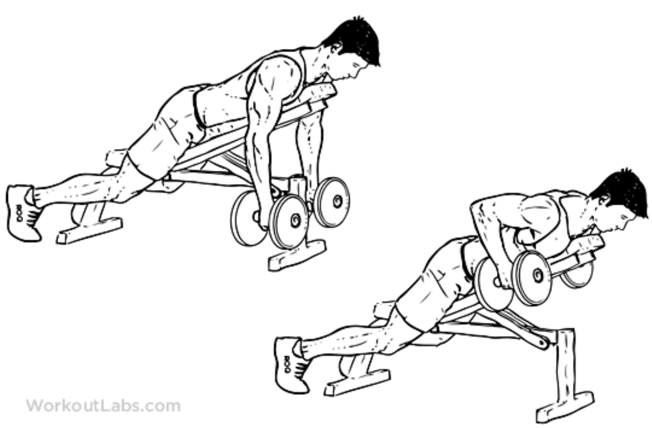

Figure B

Possible Risks and Discomforts:

Any exercise carries a slight risk of heart attack or may be uncomfortable if you are unfit or not used to exercise. The risk, as stated by American College of Sports Medicine, is 6 in 10,000 for adverse outcome in people at higher risk – these risks would be much lower in healthy young adult athletes, who have no signs or symptoms which may contraindicate exercise. There is no reason to expect any harmful effects of exercise in healthy young individuals such as your-self.

There will be discomfort during the exercise testing. You may experience increased awareness of breathing, muscle pain and/or fatigue, increased sweating, or a general feeling of fatigue or nausea, all of which are not unexpected consequences of exercise.

Benefits of Participation:
This is a basic physiology study and, as such, there will be no direct benefits received as a consequence of participating in the study. However, due to the nature of the exercise training there may be some beneficial cardiovascular adaptations (increased fitness) and strength; however these may be only temporary and disappear within a few weeks of the completion of the study. If you are interested, the rationale for conducting the research and theory and significance of each of the tests will be explained, as will your individual results from each of the tests. You will also have the opportunity to learn about and better understand your physiological response to these exercise situations.

Confidentiality
Records from this Canadian Centre for Activity and Aging facility are confidential and will be stored securely at the testing venue. Your records are listed according to an identification number rather than by your name. Published reports resulting from this study will not identify you by name. Representatives of the University of Western Ontario Health Sciences Research Ethics Board may require access to your study-related records or follow-up with you to monitor the conduct of this research.

Voluntary Participation:
Participation in the study is voluntary. You may refuse to participate, refuse to answer any questions and withdraw from the study at any time with no effect on your academic or employment status or status as a varsity athlete.
If you no longer want your data to be used in this research, you should tell the researcher who is present during training and /or testing (Andre Pelletier), who will ensure this data is deleted and no further testing will be done and your participation in the study will be discontinued.

Identifiable information will be stored on a pass word protected computer in the lab (HSB room 313) and will limited to your name and email for purposes of contacting you about study related questions or suggestions.
As per University policy information collected from this study will be kept for 5 years.

If you sustain and injury from this study you will be treated by the Medical and Physical Therapy staff at the Fowler-Kennedy Athletic Injuries Clinic located in the 3 M building on the Western University campus.

You will be given a copy of this letter of information and consent form to sign. You do not waive any legal rights by signing the consent form.

Questions:

If you have any questions regarding this study please contact Glen Belfry at ####-#### extension ##### (____@uwo.ca) or Andre Pelletier (_____@uwo.ca). If you have any questions about the conduct of this study or your rights as a research participant you may contact the Office of Human Research Ethics, The University of Western Ontario, ###-###-#### (###@uwo.ca).

Appendix: Letter of Informed Consent

LETTER OF INFORMED CONSENT

⇒ **The effect of a 30 s weight training bouts on selected physiological variables and performance in varsity rowers**

Principal investigator: Dr Glen Belfry PhD
Co-investigator: Andre Pelletier

I have read the Letter of Information and have had the nature of the study explained to me and I agree to participate. All questions have been answered to my satisfaction.

Participant:

____________________________ ____________________________
Name (please print) Signature

____
Date

Investigator (Person Responsible for Obtaining Informed Consent):

____________________________ ____________________________
Name (please print) Signature

____
Date

Appendix: PAR-Q

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	**Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2.	**Do you feel pain in your chest when you do physical activity?**
☐	☐	3.	**In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4.	**Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5.	**Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6.	**Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7.	**Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ______________________

SIGNATURE ______________________ DATE ______________________

SIGNATURE OF PARENT ______________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Curriculum Vitae
Name: André Beven Pelletier

Post-Secondary Education and Degrees:

MSc, Integrative Biosciences in Kinesiology, 2018, Western University, London On

BA with Honors, Specialization in Fitness and Exercise Prescription, 2016, Western University, London On

Honours and Awards:

Western Graduate Research Scholarship Recipient, 2016-2018, Western University

Dean's list and Athlete Scholar, 2015-2017, Western University

Bronze W 2016, Western University

Purple Blanket 2018, Western University

Related Work Experience: Graduate Teaching Assistant in Coca Cola Exercise Physiology Laboratory 2016-2018, Western University, London On

Publications: