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The Effect of Myosync™ Supplementation on Physical Performance in Division II College Football Players

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THE EFFECT OF MYOSYNC™ SUPPLEMENTATION ON PHYSICAL PERFORMANCE IN DIVISION II COLLEGE FOOTBALL PLAYERS

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Table of Contents

List of Figures 5
List of Tables 6
Acknowledgements 7
List of Abbreviations 8
Abstract 9
1. INTRODUCTION 11
1.1. Introduction 11
1.2. Purpose and Hypothesis 14
2. Literature Review 16
2.1. Supplementation and Physical Performance 16
2.2. Muscular Strength and Rate of Force Development 16
2.3. Common Pre-workout Supplements 17
2.4. Choline Supplementation 20
2.5. Myosync ™ 22
3. MATERIALS AND METHODS 26
3.1. Subjects 26
3.2. Experimental Set-up 27
3.2.1. Vertical Jump 27
3.2.2. Dynamometer 28
3.2.3. Electromyography Recordings 29
3.2.4. Electrical Stimulation 30
3.3. Experimental Protocol 31
3.3.1. Baseline Measures 32
3.3.2. Fatiguing Contractions 33
3.3.3. Recovery Measures 33
3.4. Data Analysis 34

3.4.1. Maximum Vertical Jump 34
3.4.2. MVIC 34
3.4.3. Rate of Torque Development 34
3.4.4. Impulse 35
3.4.5. Voluntary Activation 35
3.4.6. Power 36
3.4.7. Surface Electromyography 36
3.5. Statistical Analysis 36
4. RESULTS 38
4.1. Maximum Vertical Jump 38
4.2. MVIC 38
4.3. Rate of Torque Development 39
4.4. Voluntary Activation 40
4.5. Resting Twitch 41
4.6. Impulse 41
4.7. Power 42
4.8. Torque and Power during Fatiguing Contractions 43
4.9. Surface Electromyography 45
5. DISCUSSION 49
5.1. Key Findings 49
5.2. Vertical Jump 49
5.3. Isometric Strength and Rate of Torque Development 50
5.4. Power Measurements 53
5.5. Fatigability 54
5.6. Practical Application 56
5.7. Limitations and Future Direction 56
6. CONCLUSION 58
References 59
Appendix A: Raw data 64
Appendix B: Statistics 76

List of Figures

Figure 1: Experimental Set-Up 28

Figure 2: Electromyography and Electrical Stimulation Electrode Set-up 31

Figure 3: Experimental Protocol 31

Figure 4: Maximum Voluntary Contraction 39

Figure 5: Rate of Torque Development 40

Figure 6: Impulse 42

Figure 7: Power 43

Figure 8: Average Torque During Fatiguing Contractions 44

Figure 9: Average Power During Fatiguing Contractions 45

Figure 10: RMS EMG Activity for Rectus Femoris 46

Figure 11: RMS EMG Activity for Vastus Medialis 47

Figure 12: RMS EMG Activity for Vastus Lateralis 48

List of Tables

Table 1: Review of Literature 18

Table 2: Subject Characteristics.....27

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List of Abbreviations

EMG	Electromyography
MVCC	Maximal Voluntary Concentric Contraction
MVIC	Maximal Voluntary Isometric Contraction
RMS	Root Mean Square
RT	Resting Twitch Torque
RTD	Rate of Torque Development
SIT	Superimposed Twitch Torque
SD	Standard Deviation
Alpha-GPC	Alpha-glycerophosphocholine

Abstract

Previous research relating to Alpha-GPC supplementation and physical performance has been limited to researching Alpha-GPC as a single ingredient supplement. Further research is needed to investigate the effect of Alpha-GPC in combination with other ergogenic ingredients on physical performance. **Purpose:** The purpose of this study was to investigate the acute effect of Myosync™ on physical performance in Division II football players. **Methods**: Fourteen male Division II football players (20.4 ± 1.0 years; 191.4 ± 5.5 cm; 106.9 ± 16.4 kg) participated in a randomized double blind crossover experiment separated by at least seven days. Subjects were given Myosync™ (2 Capsules, 1,076 mg) or a placebo control (2 capsules of fiber) 60 minutes prior to any physical testing measures. Testing consisted of, maximum vertical jumps, maximum voluntary isometric contractions (MVIC), maximal voluntary concentric contractions (MVCC), and fatiguing contractions for the knee extensor muscles. Subjects performed three maximum vertical jumps with one-minute rest between jumps. Three MVICs were performed with the knee extensor muscles while seated on a dynamometer at 90° of hip flexion and knee flexion, with 2-minute rest between trials. Seven sets of two MVCCs at various loads (1 Nm; 10%, 20%, 30%, 40%, 50% and 60% MVIC torque) were completed with 30-seconds of rest between each set. During the fatiguing tasks, 120 MVCCs (4 set x 30 reps) were performed with a load equivalent to 20% MVIC through 60 degree range of motion. Recovery measures were taken 10 minutes post completion of fatiguing task and consisted of one MVIC and MVCCs using the same loads as pre-fatiguing task. **Results:** There was no difference in maximum vertical jump height between control and supplemental sessions (70.8 ± 6.6 vs 70.9 ± 6.2 cm, P = 0.90). MVIC was similar between control and supplemental sessions at

baseline (297.8± 48.4 vs. 296.7 ± 70.5 Nm, respectively, P = 0.34). Rate of torque development (highest slope of torque during the first 400 ms during MVIC was significantly higher throughout the fatiguing task during the supplemental session (P = 0.02). Impulse for all MVIC significantly increased at 200 ms throughout the fatiguing task during the supplemental session (P < 0.001). No significant differences seen between peak power during isotonic contractions as well as fatigability between sessions. **Conclusion:** Maximal strength, power and vertical jump did not improve with Myosync™, however, the significant increases in rate of torque development and impulse could be beneficial for a variety of athletes.

1. INTRODUCTION

1.1.Introduction

With the highly competitive culture in today's athletics, some athletes may look to supplementation as a means of gaining a physical edge on their competition (Lavallee, 2012). Most nutritional ergogenic aids are used to enhance energy metabolism during sport performance by either providing an additional source of energy, or favorably affecting metabolic processes that generate energy (Kanter & Williams, 1995). When discussing the topic of supplementation, many products are included such as, protein, creatine, androstenedione, hormone precursors and other stimulants. Over 500 clients were given a one page questionnaire to assess the use of various supplements (Kanayama, Gruber, Pope, Borowiecki, & Hudson, 2001) and of 334 males that responded, 61% used a protein supplement, 47% used creatine, and 4% admitted to using androstenedione for 6 months or longer.

The regulation of supplementation is the responsibility of the Food and Drug Administration (FDA) as well as the Federal Trade Commission (FTC) (Fomous, Costello, & Coates, 2002). Separate from the FDA and FTC regulations, various governing bodies over athletics such as the NCAA have their own set of banned substances. Every four years the NCAA distributes a survey to student athletes in attempt to evaluate the use of supplementation in college athletics (Green, Uryasz, Petr, & Bray, 2001). Through this 2001 survey, the NCAA was able to determine that the most popular supplement that was used in college athletics was creatine (29%). The study also uncovered that the most common reason for athletes using supplementation was to improve performance and

physical appearance. It is the position of the Academy of Nutrition and Dietetics, Dietitians of Canada, along with the American College of Sports Medicine that performance of, and recovery from sporting activities are enhanced by well-chosen nutrition strategies along with proper supplementation (Thomas, Erdman, & Burke, 2016).

One of the most popular types of supplementation among athletes at the collegiate level are various pre-workout supplements taken with hopes to improve performance in either training sessions or competitions. A main ingredient in many pre-workout supplements is caffeine, due to its ergogenic effect of decreasing the perception of fatigue while exercising (Astorino & Roberson, 2010). Although caffeine, when taken in the proper dose has been shown to provide benefits for exercising, it is also important to note that when too much caffeine is supplemented, adverse side effects such as tremors and increased anxiety and large doses of caffeine can be toxic (Tarnopolsky, 2010). Other common yet often overlooked pre-workout supplements include the various over the counter energy drinks that are used. It was discovered through a survey conducted at a Division I university that the most common nutritional supplement taken by athletes was energy drinks (Froiland, Koszewski, Hingst, & Kopecky, 2004).

Beta-Alanine is another common supplementation taken by athletes before exercise or competition. Beta-Alanine can be used as a single ingredient supplement, or it may be one of many ingredients included in a proprietary blend that makes up a pre-workout supplement. Through a review of the literature pertaining to Beta-Alanine supplementation, Quesnele, Laframboise, Wong, Kim, and Wells (2014) found that Beta-Alanine supplementation was mostly targeted for events that are associated with a high rate of anaerobic glycolysis (i.e., events lasting ~60-240 seconds). It was also found through

the same review that chronic Beta-Alanine supplementation can significantly increase muscle carnosine (Quesnele et al., 2014).

A specific type of supplement that is of interest is choline supplementation. Various studies have investigated the effects of both acute and chronic choline supplementation on physical performance (Bellar, LeBlanc, & Campbell, 2015; P. A. Deuster, Singh, Coll, Hyde, & Becker, 2002; Warber et al., 2000). Studies have investigated the effects of choline supplementation on prolonged exercise (P. A. Deuster et al., 2002; Warber et al., 2000) as well as its effect on muscular strength (Bellar et al., 2015). With the known important role of acetyl-choline (ACh) for muscular contraction, supplementation with various types of choline are intriguing.

One specific type of choline supplementation that has been proven to be a very effective ACh precursor is Alpha-GPC supplementation (Kawamura et al., 2012). Alpha-GPC supplementation has limited previous research with regards to muscular performance (Bellar et al., 2015; Ziegenfuss, 2008). One current limitation concerning Alpha-GPC supplementation is that is has only been investigated as a single ingredient supplement. Myosync™ not only includes Alpha-GPC as its main ingredient, but also several other ingredients to promote the effects of increased ACh.

Due to the importance of lower extremity strength and rate of force development (RFD) in everyday life as well as athletics, various research methods have been used to assess these measures (Aagaard, Simonsen, Andersen, Magnusson, & Dyhre-Poulsen, 2002; Andersen & Aagaard, 2006; Young et al., 2005). The method of testing used to assess strength and RFD can depend on many variables such as subject population as well as equipment available to researchers. A common method that has been used previously in

research the utilization of a dynamometer such as a Biodex. Using this method, researchers can assess various aspects of strength (isometric, dynamic, eccentric) while also getting sufficient data relating to RFD. Previous researchers have used various time points at the start of the isometric MVC (0-10, 0-20, 0-30, 0-250 ms) and assessed the slope of the torque-time curve to determine RFD. (Aagaard et al., 2002). This is a good way to isolate the knee extensor muscle group and gather information regarding an individual's MVC.

1.2.Purpose and Hypothesis

Athletic performance is very important to many individuals from the high-school level all the way to the professional levels. One main interest for many athletes is the topic of supplementation as stated by Lavallee (2012) but unfortunately the research to support effects of various supplements is lacking. Gaining an understanding of the benefits that supplements provide, along with proper usage of these supplements can lead to a great understanding in regard to improving physical performance. Furthermore, many supplements contain multiple ingredients and stimulants that are designed to enhance some aspect of physical performance. With the mixed results concerning the effect of Alpha-GPC to increase strength or power (Bellar et al., 2015; Ziegenfuss, 2008) the additional ingredients contained in Myosync™ could lead to significant results. The purpose of this study is to examine the effects of a supplement, Myosync™ on physical performance in Division II collegiate football players using both practical and laboratory based testing measures. To the author's knowledge, this is the first study to investigate the effects of Myosync™ on physical performance. Based off previous literature conducted by Bellar et al. (2015), it was hypothesized that subjects would show an increase in physical

performance as measured by vertical jump height, maximal isometric strength as well as maximal dynamic strength and power with supplementation of Myosync™.

2. Literature Review

2.1.Supplementation and Physical Performance

One aspect of performance that athletes are continuously trying to improve is maximal strength and rate of force development due to its importance in a variety of athletic movements (Andersen & Aagaard, 2006). Throughout the recent history of studying athletic performance; supplementation has been an area of interest for researchers. Supplements are used to improve energy metabolism through either increasing energy sources available or improving metabolic processes that generate those energy sources (Kanter & Williams, 1995). Various types of pre-workout supplements have been available for athletes to use but further research is necessary to assess the efficacy of these supplements.

2.2.Muscular Strength and Rate of Force Development

Muscular strength has previously been defined as the muscles ability to exert force on an external object or resistance (Suchomel, Nimphius, & Stone, 2016) . Similarly, Aagaard et al. have defined Rate of Force Development (RFD) as the rise in force over a change in time (Aagaard et al., 2002). With today's high level of competition in athletics, athletes are required in many sports to exert a very high amount of force over a very short period of time. Because athletes are required to produce maximal amounts of force within 50-250 ms (Andersen & Aagaard, 2006), RFD has become a very important aspect of training for many athletes. Some various examples of skills in athletics that demonstrate an athletes need for a high RFD are, sprinting, jumping, and change of direction (COD).

Limited research exists related to the supplementation of Alpha-GPC and isometric strength (Bellar et al., 2015) which concluded that an acute dose of Alpha-GPC did not significantly improve isometric strength. However, after six days of 600 mg Alpha-GPC, significant increases in lower body isometric strength were observed. Furthermore, an additional study testing the effects of choline ingestion on various aspects of physical performance and saw no improvements in hand grip strength or lower body strength (Patricia A. Deuster, 2002). One possible limitation with the previously mentioned studies could be the testing protocol used to assess lower body strength. Although the testing protocol utilized by Bellar et al. (2015) included an isometric mid-thigh pull, which is a common weight training exercise, the amount of technique that is required to properly execute the exercise and produce maximal results could require experience that not all subjects may have had. The measurement for strength in the study conducted by P. A. Deuster et al. (2002) was a load carry test. Although this type of test can give great insight into other muscular factors such as muscular endurance, it is difficult to quantify maximal strength with this particular test. With the importance of isometric strength and RFD seen throughout athletics, testing protocols for these qualities need to be improved and standardized to ensure consistent measurements.

2.3. Common Pre-workout Supplements

Caffeine is one of the most commonly used supplements due to its effectiveness at stimulating the central nervous system resulting in increased alertness and focus (Astorino & Roberson, 2010). Through a study conducted in 2008 to assess the effect of caffeine ingestion (5 mg/kg body mass) on repeat sprint ability, it was found that caffeine has

ergogenic properties that improve not only single sprint time but also times in multiple sprints (Glaister et al., 2008). A study looking into the effects of supplementing with 400 mg of caffeine (approximately 4.9 mg/kg/body weight) in 21 untrained males showed no effect on either upper or lower body strength as well as no effect on endurance cycling performance (Hendrix et al., 2010).

In addition to caffeine supplementation, another common pre workout supplement is beta-alanine. In a study looking at the effect of beta-alanine supplementation in trained sprinters, it determined that oral supplementation was able to significantly increase the muscle carnosine levels as well as attenuate fatigue (Derave et al., 2007). A summary of previous supplementation studies is presented below in Table 1.

Due to the large amount of pre-workout supplements available on the market today, it is important that both positive and negative effects of supplements are well-known to not only the researchers but the consumers as well.

Table 1. Review of Literature

Study	Subjects	Supplement	Measurements	Outcome
Bellar et al. (2015)	13 college aged males.	Alpha-GPC (600 mg/day)	Upper and lower body isometric strength	No acute effects of Alpha GPC supplementation. Six days of supplementation increased lower body force production.
Claudino et al. (2014)	14 Brazilian elite soccer players	Creatine (20 g/day 1 week; 5 g/day 6 weeks)	Lower body power (counter movement jump)	Creatine supplementation prevented loss in lower limb muscle power throughout pre-season training.

Derave et al. (2007)	15 male athletes	Beta-alanine (4.8 g/day for 4 weeks)	5 sets of 30 maximal knee extensions; 400- m sprint time	Supplementation improved torque during 4^{th} and 5^{th} sets of knee extension. No effect on 400-m sprint time.
Patricia A. Deuster (2002)	13 males	Choline (50mg/kg body weight)	Upper and lower body strength and endurance measures	Supplementation did not have any effect on physical performance.
Glaister et al. (2008)	21 physically active males	Caffeine (5 mg/kg body weight)	Repeat Sprints (12 x 30 m at 35 second intervals)	Resulted in 1.4% decrease in fastest sprint time; 1.2% increase in fatigue
Hendrix et al. (2010)	21 untrained males	Supplement containing 400 mg caffeine	1 RM bench press and leg extension; Time to exhaustion at 80% VO_2 peak cycling.	Results showed no effect on 1 RM bench press, leg extension or time to exhaustion.
Kawamura et al. (2012)	8 healthy males	Alpha-GPC (1000 mg)	Plasma choline levels; Plasma growth hormone levels.	Increase in plasma free choline levels at 60 minutes with supplementation. Increase in plasma growth hormone secretion.
Scholey et al. (2010)	32 healthy young adults	Cereboost (100, 200, 400 mg trials)	Mood, cognitive function, and blood glucose (1, 3 and 6 hrs following supplement-ation)	Supplementation showed significant improvement in working memory across all doses and time points.
Warber et al. (2000)	14	Choline Citrate (8.425 g)	4 hour load carriage treadmill test (Load 34.1 kg)	Choline levels increased 128% with supplementation, but did not deplete during placebo. No performance changes during test.

Ziegenfuss (2008)	7 males	Alpha-GPC (600 mg)	6 sets of 10 reps of Smith machine squats at 70% 1RM; 3 sets of bench press throws at 50% 1RM	Supplementation increased peak bench press force; No effect on peak power or rate of force development.

2.4.Choline Supplementation

Choline was first officially recognized by the Institute of Medicine as an essential nutrient in 1998 (Zeisel & da Costa, 2009), and can be found naturally in eggs, red meat, milk, and fish (Cho et al., 2006). Choline supplementation is a well-known method used as an Acetyl Choline (ACh) precursor that has been researched in both the medical and physical performance disciplines (Conlay, Sabounjian, & Wurtman, 1992; Costa, 2009; Lavallee, 2012). Supplementation with ACh precursors has focused on both physical/physiological effects as well as effects on cognitive function in individuals. Specifically, Alpha-GPC has been shown to be a highly effective precursor for ACh (Kawamura et al., 2012). With the majority of the research surrounding choline supplementation pertaining to neurodegenerative disorders such as Alzheimer's disease (da Rocha et al., 2011; Zeisel & da Costa, 2009) there are still many questions about its ability to increase physical performance.

The majority of previous research assessing the effect of Alpha-GPC or other various forms of choline supplementation have focused on endurance athlete performance (Conlay et al., 1992; Warber et al., 2000). Previously, research has investigated the effect of prolonged exercise on plasma choline levels. One of the findings from previous research

states that after completing the Boston Marathon, runners showed a 40% reduction in plasma choline levels (Conlay, Sabounjian et al. 1992). With depeleted levels of plasma choline, one could infer that acteylcholine release could be inhibited or decreased at the neuromuscular junction level. Because the previously mentioned study did not investigate the effect of choline supplementation on levels of plasma choline, it is difficult to come to any conclusions other than prolonged aerobic exercise has been shown to deplete levels of plasma choline. Other previous studies have investigated the effect of elevating plasma choline levels above their basal levels with aims at investigating if the elevated plasma choline levels had any effect on performance in endurance exercises (Patricia A. Deuster, 2002; Warber et al., 2000).

The study conducted by Warber et al. (2000) examined physical performance in a battery of tests including a four hour load carriage test on a treadmill, run time-to-exhaustion test, along with squat testing. This study found that with supplementation of choline citrate (8 grams) it was possible to increase plasma choline levels by 128%, but failed to find any change in levels of plasma choline when subjects ingested the placebo beverage. It is important to note that there were no observed increases in physical performance with choline supplementation and elevated levels of plasma choline. Based on the results indicating no depletion of plasma choline during the placebo trial, it is reasonable to conclude that the exercise protocol may not have been sufficient enough to show similar decreases in plasma choline as previously shown by (Conlay et al., 1992). Similar to the previously mentioned study, Patricia A. Deuster (2002) investigated the effect of choline supplementation during a timed load carriage test. It was concluded that

choline supplementation was successful in elevating plasma choline levels; however, it did not show any improvements in the time to fatigue during the load carriage test.

It has been known that weakened impulse transmission along with impaired skeletal muscle performance have been associated with reduced concentrations of free choline during exercise (Conlay et al., 1992). When plasma choline levels have been shown to decrease during intense physical activities, short term choline supplementation (10 days) has shown improvements in exercise capacity during high intensity cycling and intermittent running (Jäger, Purpura, & Kingsley, 2007).

As it has been shown, choline supplementation has been studied for many years concerning performance in various activities involving prolonged exercise. One area that is just beginning to gain interest is choline supplementation with regards to maximum strength and explosive exercise. Due to the known importance of ACh for muscular performance, further research is necessary to investigate these effects.

2.5.Myosync ™

Previous research has been focused on the supplementation of the individual ingredient Alpha-GPC (Bellar et al., 2015; Ziegenfuss, 2008) or other various forms of supplementation (Buchman, Jenden, & Roch, 1999; Penry & Manore, 2008). The current product Myosync ™ not only includes Alpha-Size Alpha-GPC, to serve as an acetylcholine precursor, it also includes other ingredients that are aimed to promote and enhance the effect of the main ingredient, Alpha-GPC. Ingredients included in the Neuromuscular response Matrix include: Alphasize® 50% Alpha-Glyceryl Phosphoryl Choline, Panax

quinquefolius extract, Vinpocetine, Huperzia serrata, Rosmarinus officinalis extract and Bioperine® black pepper extract.

Alpha-GPC: Alpha-GPC is a putative acetyl choline precursor that has the potential to increase growth hormone (GH) secretion via acetyl-choline stimulated catecholamine (Kawamura et al., 2012). As previously stated, Alpha-GPC has been studied previously alone as a single ingredient supplement. One previous study conducted by Bellar et al. (2015) was the first study to investigate the effect of Alpha-GPC supplementation on isometric strength. Bellar et al. (2015) found no acute effect with regards to an increase in isometric strength, however they did find after 6 days of supplementation isometric strength was increased. It was also observed in a separate study that a single dose of 1000 mg of Alpha-GPC was shown to increase the plasma GH levels significantly after 60 minutes of ingestion when compared to a placebo (Kawamura et al., 2012).

Panax Quinquefolius Extract: Also known as American Ginseng has been studied recently and has shown promising effects on improving aspects of human cognitive function. A 2010 study looked into the effects of 3 different doses of the supplement Cereboost™ which contained panax quinquefolius extract standardized to 10.65% ginsenosides. This study found great improvements in working memory as well as reaction time through the different doses associated with panax quinquefolius (Scholey et al., 2010). Furthermore, an additional study looking into the effectiveness of panax quinquefolius extract in treating Alzheimer disease found that after a 12 week period of daily supplementation of 4.5g/d, patients began to show improvements in various cognitive function assessments (Lee, Chu, Sim, Heo, & Kim, 2008).

Huperzia Serrata: Huperzine A is an alkaloid that can be isolated from the Chinese herb Huperzia serrata, is a very effective and highly specific inhibitor of acetylocholinesterase (AChE) (Wang, Yan, & Tang, 2006). AChE is an enzyme that is responsible for the removal of ACh, by inhibiting this enzyme, the neurotransmitter ACh will remain longer in the neuromuscular junction. When studied in rats, compared with the other AChE inhibitors Donepezil, Tacrine, Rivastigmine and Physostigmine, Huperzine A was shown to have a much greater effect on AChE (Zhao & Tang, 2002).

Vinpocetine: A large amount of the previous research involving vinpocetine has pertained to cerebrovascular disease as well as cognitive disorders such as dementia and Alzheimer's (Patyar, Prakash, Modi, & Medhi, 2011; Szapáry et al., 2012). It was shown in the study conducted by Balestreri, Fontana, and Astengo (1987) that vinpocetine supplementation three times daily was able to improve scores on a variety of cognitive assessments.

Rosmarinus officinalis extract: Rsomarinus officinalis extract has been shown to have the potential to serve as an agent to aide in the prevention of various human neurodegenerative disorders caused by oxidative stress (Park, Kim, Sapkota, & Kim, 2010).

Bioperine® black pepper extract: Bioperine black pepper extract has been one of various ingredients contained in thermogenic dietary supplements (Outlaw et al., 2013). Previously it has been found that supplementation of coenzyme Q10 with an additional 5 mg of Bioperine® increased plasma levels of coenzyme Q10 more so than supplementation with coenzyme Q10 alone (Badmaev, Majeed, & Prakash, 2000). The increase in plasma levels of coenzyme Q10 observed in the study conducted by Badmaev et al. (2000) could

indicate that Bioperine® supplementation may increase the bioavailability of other nutrients.

With the addition of the various previously studied ingredients just discussed, Myosync™ could provide better improvements in physical performance than seen previously with Alpha-GPC supplementation.

3. MATERIALS AND METHODS

3.1.Subjects

Following a reading of the testing procedures along with the benefits and risks associated with the study, written consent was obtained by each individual before their participation began. This study was approved by the Michigan Technological University's Institutional Review Board for the protection of human subjects.

Fourteen Division II college football players volunteered to participate in the study. Subjects were free from musculoskeletal disorders that would impair their ability to exercise. Subject characteristics are summarized in **Table 2**.

All subjects attended a familiarization session that involved completing a physical activity questionnaire (Kriska & Bennett, 1992), handedness questionnaire (Oldfield, 1971), collection of subject characteristics and vitals, habituation of the electrical-stimulation to the vastus lateralis, vastus medialis, rectus femoris muscles and practice of maximal voluntary isometric contractions (MVIC). The experiment was designed as a double blind randomized crossover experiment with subjects participating in two experimental sessions (placebo control and supplemental), each separated by seven days. Subjects were asked to refrain from strenuous exercise for 24 hours prior to each of the two experimental sessions to insure the quality of performance during each testing session.

Table 2. Subject characteristics

Variables	Value (n = 14)
Age (years)	20.4 ± 1.0
Height (cm)	191.4 ± 5.5
Weight (kg)	106.9 ± 16.4
Body fat (%)	17.7 ± 5.4
Physical activity (MET h/wk)	139.2 ± 55.9
Handedness (a.u)	40.7 ± 65.4
BMI (kg/m^2)	29.1 ± 3.8

3.2.Experimental Set-up

Experimental sessions included a variety of physical and muscle function testing. The testing consisted of several baseline measures including maximal vertical jumps, MVICs , and maximal voluntary concentric contractions. Fatiguing contractions were then completed followed by reassessment of baseline measures 10 minutes post completion of fatiguing task. All muscle function testing began one hour after subject ingested either two capsules of a control (Fiber) or two capsules of Myosync™ (1,076 mg/capsule).

3.2.1. Vertical Jump

A Vertec vertical jump tester (Vertec, JumpUSA, Sunnyvale, Ca. USA) was used to measure vertical jump height. The Vertec device was placed directly over the subject as seen in **Figure 1** and the subject was instructed to hit the Vertec at the peak of their jump height.

Figure 1. Subject walks under the Vertec with both arms extended overhead to asses standing reach (left). Subject prepares for maximal countermovement jump (right).

3.2.2. Dynamometer

A Biodex multi-joint dynamometer (System 4 Pro; Biodex Medical System, Shirley, NY, USA) was used for testing. This particular dynamometer has been shown to perform with acceptable trial-to-trial and day-to-day mechanical reliability and validity for testing angle, torque and velocity measures using various muscle groups (Drouin, Valovich-mcLeod, Shultz, Gansneder, & Perrin, 2004). Each participant was seated in a slightly reclined position with the hip and knee angle at 95° and 90°, respectively. Participant's shank was strapped to the distal end of the Biodex arm, with the lateral epicondyle of the femur aligned with the axis of rotation of the dynamometer.

All voluntary isometric contractions were performed at 90 degrees of flexion (0 degrees being horizontal). The angle of 90 degrees was chosen based on results from pilot testing and previous literature De Ruiter, Kooistra, Paalman, and de Haan (2004) indicating it to be an effective position for torque development and muscle activation. Shortening contractions began at 90 degrees of flexion and moved through to 30 degrees of flexion. Therefore, all dynamic contractions moved through a 60 degree range of motion. Torque, angle, and angular velocity data were sampled at a rate of 2000 Hz using a micro 1401 AD converter and Spike 2 software (Version 8, Cambridge Electronics Design, Cambridge, UK). Torque signal was displayed on a 70-in TV monitor (Sharp Electronics, NJ, USA) located 2.5 m in front of the subject.

3.2.3. Electromyography Recordings

Surface electromyography (EMG) system (Bagnoli 16; Delsys, Natick, MA., USA) was used to record activity of the knee extensor muscles, including the rectus femoris, vastus lateralis and vastus medialis throughout the testing. Electrode placement (see **Figure 2**) was determined according to recommendations by the Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM Project) (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). The ground electrode was positioned over the patella. The skin was thoroughly scrubbed with alcohol soaked cleansing cloths before electrode placement, and location was marked via a permanent pen to ensure placement was consistent for the entirety of the testing sessions. The EMG signal was sampled at a rate of 2000 Hz using a micro 1401 AD converter and Spike 2 software (Version 8, Cambridge Electronics Design, Cambridge, UK).

3.2.4. Electrical Stimulation

Electrical pulse (singlet, square wave, 100-μs duration) was applied using a computer-controlled stimulator (D185; Digitimer, Welwyn Garden City, UK) and a pair of self-adhesive surface electrodes (6.98 x 12.7 cm, Dura-Stick plus DJO Brands). The exact electrode positions were marked with a permanent pen, which allowed the investigator to replicate positioning of electrode pads for subsequent trials. The cathode electrode was place distally in relation to the anode electrode. The superior aspect of the proximal electrode was positioned at the height of the greater femoral trochanter with the midpoint of the electrode horizontally aligned with the anterior-superior iliac spine (Pietrosimone, Selkow, Ingersoll, Hart, & Saliba, 2011). The distal electrode was positioned so that the inferior aspect of the electrode sat approximately 3 cm superior to the patella, with the medial border of the electrode aligned with the midline of the patella (Pietrosimone et al., 2011). See Figure 2 for electrode placement. At the start of each testing session, the stimulation voltage was increased until the twitch torque response leveled off, and it was assumed that at that point, all of the knee extensor muscle fibers were fully activated. To ensure full activation of all motor units by supramaximal stimulation, voltage was further increased by an additional 20%. This supramaximal voltage intensity (120%) was used for all electrically evoked contractions for the remainder of the testing session for each individual.

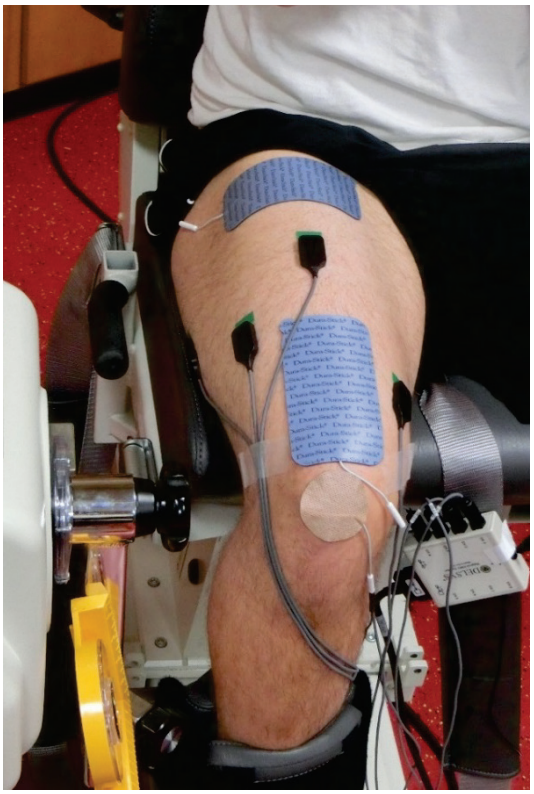

Figure 2. Electromyography and Electrical Stimulation Electrode Set-up. EMG electrodes (black). Electrical Stimulation electrodes (blue). The ground electrode (beige) is positioned over patella.

3.3.Experimental Protocol

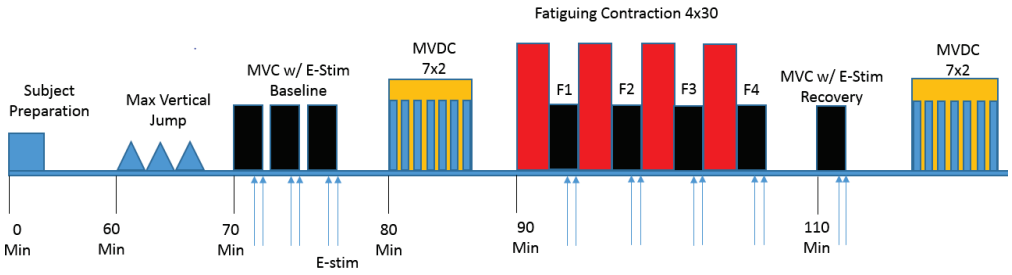

Figure 3. Experimental protocol for both control and supplemental sessions. Subjects ingested either control or supplement (random order) at the 0-minute mark of each testing session.

3.3.1. Baseline Measures

Maximum Vertical Jump. The subject was asked to walk under the Vertec with both arms fully extended overhead in order to obtain the subject's standing reach. Subjects were instructed to walk back and forth until they were no longer able to reach any of the veins on the Vertec. This measurement was then used as the subject's standing reach. After the standing reach was determined, the subject was instructed to stand in the center of the force plate with the Vertec positioned directly over their head. They then performed three maximum vertical jumps separated by one minute each. With each jump the subject was instructed to keep their knees fully extended in the air, while reaching to slap the highest vein possible at the peak of their vertical jump.

Maximal Voluntary Isometric Contractions (MVICs). Three MVICs were performed each with a contraction time of 3-5 seconds. 120 seconds were given as a rest period in between contractions to ensure adequate recovery. If at least two of the three MVIC values were not within 5% of each other, a fourth trial was done. Visual feedback of the live torque-time tracing were given to the subjects on a 70-inch TV monitor, as well as verbal encouragement to ensure maximal effort during all MVICs. Subjects were instructed to attempt to extend their knee as fast and as hard as possible while electrical stimulation was applied to at the peak torque level during MVIC. An additional twitch was triggered upon relaxation (approximately 1 s) following the MVIC.

Maximal Voluntary Concentric Contractions (MVCCs). Seven sets of isotonic contractions at various pre-determined resistance loads were performed, including 1 Nm, 10%, 20%, 30%, 40%, 50%, and 60% of MVIC. These loads were in randomized order, and stayed in the same randomized order for the duration of the testing procedures per individual.

Subjects were instructed to move the resistance load as "fast and hard" as possible throughout the full 60° range of motion. Subjects were provided with verbal encouragement and real-time torque feedback displayed on a TV monitor to encourage a maximal effort (maximal velocity) (Campenella, Mattacola, & Kimura, 2000). Two consecutive repetitions at each resistance were performed to improve the chances that true maximal velocity was reached. Thirty seconds of rest were allotted in-between sets. The peak velocity reached at each resistance load was used to establish baseline values for angular velocity at each of the seven resistance loads, with the peak angular velocity (obtained at 1 Nm) considered the maximal shortening velocity. Power was calculated across each of the seven resistance loads, with the peak power being the highest product of torque and velocity at any given time-point during the contraction.

3.3.2. Fatiguing Contractions

Subjects performed four sets of 30 repetitions of a dynamic leg extension at a constant load. The load used for these contractions was set to 20% of the subject's MVIC torque value. Similar to the MVCCs, subjects were instructed to extend their leg as fast and as hard as possible throughout the entire 60 degree range of motion. After each extension, the Biodex returned the subjects' leg passively to 90 degrees in order to perform the next contraction. In between each set of 30 repetitions, subjects performed one MVIC (F1, F2, F3, and F4) with electrical stimulation in order to assess the subject's voluntary activation level.

3.3.3. Recovery Measures

MVIC and MVCC measurements were performed at 10 minutes post completion of the fatiguing task.

3.4.Data Analysis

Spike 2 software was used offline to determine maximum vertical jump, velocity, torque, power and EMG as follows.

3.4.1. Maximum Vertical Jump

Prior to each testing session subjects had their standing reach assessed by walking underneath a Vertec with both arms fully extended overhead. Subjects were asked to walk back and forth underneath the Vertec until they were no longer able to make contact with any of the measurement veins. This value was used as the "Standing Reach" value and was subtracted from the total height the subject was able to reach during each maximal jump.

3.4.2. MVIC

Maximal voluntary isometric contraction (MVIC) torque was quantified as the average torque of 0.1 s duration prior the event of electrical stimulation during MVIC. When the electrical stimulation was not applied at the peak torque, MVIC torque was quantified as the average torque value over a period of 0.1 s that was centered about the peak torque. During baseline measurements where 3-4 MVICs were measured, the greatest torque amplitude amongst all of the trials was recorded and used for analysis.

3.4.3. Rate of Torque Development

Rate of torque development during the MVICs was calculated as the peak tangential torque using a moving mean method of the torque-time curve over the first 400 ms from the onset of contraction (Aagaard et al., 2002).

3.4.4. Impulse

Impulse during each MVIC was calculated as the total area under the torque-time curve at specified time points. Impulse was assessed at 200 ms during each MVIC.

3.4.5. Voluntary Activation

Voluntary activation (VA) was assessed by measuring the torque response in knee extensor electrical stimulation. Both the peak amplitude of the superimposed twitch (SIT) and the resting twitch torque (RT) were used in the following formula (Equation 1) to assess voluntary activation:

Equation 1:

$$\textit{Voluntary Activation (\%)} = 100 \times (1\text{-}SIT/RT) \textit{ (Merton, 1954).}$$

Additionally, formula was also used to calculate VA as a supplement, because it has the additional correction factor (D) to take into account potential differences between the true maximal voluntary torque and the torque value directly prior to the electrical stimulation (See Equation 2):

Equation 2:

$$VA_{corrected} \textit{ (\%)} = 100 - (D \times (SIT/\ MVIC\ )/RT \times 100) \textit{ (Strojnik \& Komi, 2000).}$$

Equation 2 with the correction factor has previously been shown to be beneficial when subjects did not receive the electrical stimulation at their peak maximal voluntary torque (Strojnik & Komi, 2000). Values were reported using the Equation 2 (Strojnik & Komi,

2000) formula for voluntary activation. This was decided because there was a considerable difference between the voluntary activation values for our data using this formula, versus Equation 1 (Merton, 1954)

3.4.6. Power

Knee extensor power was represented in Watts and was calculated as the product of torque (Nm) and angular velocity (rad/s). Peak power was determined for each of the 7 predetermined loads based off of the subjects highest baseline value for MVIC.

3.4.7. Surface Electromyography

The EMG signal was amplified (x100) and bandpass filtered (10-450 Hz) using a micro 1401 AD converter and Spike 2 software. EMG of the knee extensor muscles was determined as the root mean squared (RMS) value over a 0.1 s interval, which was time interval equivalent to the MVC torque measurement. All subsequent MVIC RMS values were normalized to the level obtained during baseline.

3.5.Statistical Analysis

Data were reported as means ± SD within the text and displayed as means ± SE in the figures. Normality and homogeneity were tested using Shapiro-Wilk and Levene tests, respectively. Baseline variables including MVIC, RTD, impulse, EMG, and vertical jump, were analyzed using a paired t-test to compare between control and supplemental sessions. Two-way Analysis of Variance (ANOVA) with repeated measures was used to compare dependent variables between sessions (control, supplement) and across time points (Baseline, F1, F2, F3, F4; F4, recovery; for fatigue and recovery respectively). The

variables include MVIC, RTD, impulse, power, and EMG. For each ANOVA the sphericity of data was verified with Mauchly's test and technical corrections were performed whenever necessary. Statistical Package for the Social Sciences (SPSS) software (ver. 21, IBM, Armonk, New York, USA) was used for all statistical analysis. An alpha value of $P < 0.05$ was used to identify statistical significance.

4. RESULTS

4.1.Maximum Vertical Jump

Maximum vertical jump showed no significant difference in jump height between control and supplemental sessions (70.8 ± 6.6 vs 70.9 ± 6.2 cm, $t_{13} = -0.135$, $P = 0.895$).

4.2.MVIC

Maximal voluntary isometric contraction (MVIC) torque at baseline was similar between control and supplemental sessions (297.8 ± 48.4 vs. 296.7 ± 70.5 Nm; $t_{13} = 0.088$, $P = 0.931$). MVIC torque decreased during the fatiguing contractions (fatigue effect; $F_{1.6, 20.3} = 45.5$, $P < 0.001$, $\eta^2p = 0.778$), and the decline was similar throughout the testing protocol between both sessions (fatigue × session; $F_{4, 52} = 0.356$, $P = 0.839$, $\eta^2p = 0.027$). After 10 min of recovery, MVIC torque significantly increased (recovery effect; $F_{1, 13} = 47.31$, $P < 0.001$, $\eta^2p = 0.784$), and the relative increase was similar between sessions (recovery × session; $F_{1, 13} = 0.064$, $P = 0.804$, $\eta^2p = 0.005$). See **Figure 4**.

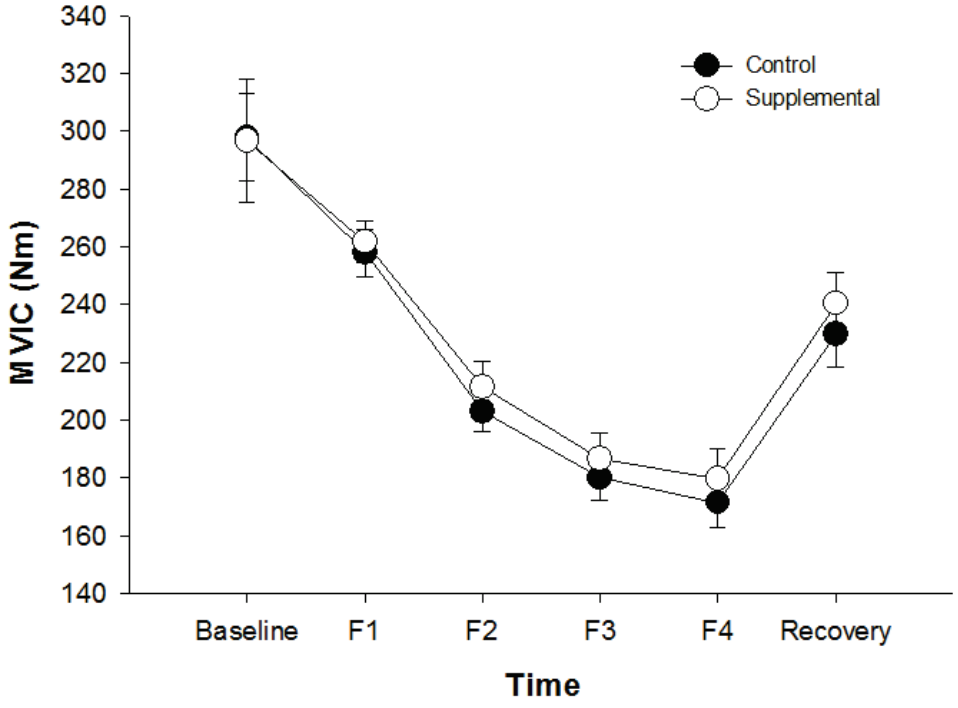

Figure 4. MVIC measurements for control and supplemental sessions were similar at baseline (297.8 ± 48.4 vs. 296.7 ± 70.5 Nm, P = 0.931) and showed similar decrease during fatiguing contractions (P = 0.839) and similar recovery at 10 minutes post completion of fatiguing task (P = 0.784).

4.3.Rate of Torque Development

Rate of torque development (RTD) at baseline was similar between control and supplemental sessions (2171.2 ± 564.4 vs. 2156.0 ± 566.6 Nm/s; $t_{13} = 0.140$, P = 0.891). RTD decreased during the fatiguing contractions (fatigue effect; $F_{2.0,\ 26.6} = 27.0$, $P < 0.001$, $\eta^2p = 0.675$), and the decline was similar throughout the testing protocol for both sessions (fatigue × session; $F_{4,\ 52} = 2.23$, P = 0.079, $\eta^2p = 0.146$). Despite the similar decrease in both sessions, RTD was significantly higher in supplemental session compared to control session (1772.7 ± 82.6 vs 1584.9 ± 79.3 Nm/s; session effect; $F_{1.0,\ 13.0} = 7.40$, P = 0.018, $\eta^2p = 0.363$). After 10 min of recovery,

RTD significantly increased (recovery effect; $F_{1, 13} = 54.37$, $P < 0.001$, $\eta^2p = 0.807$), and the relative increase was similar between sessions (recovery × session; $F_{1, 13} = 1.96$, $P = 0.216$, $\eta^2p = 0.115$). See **figure 5**.

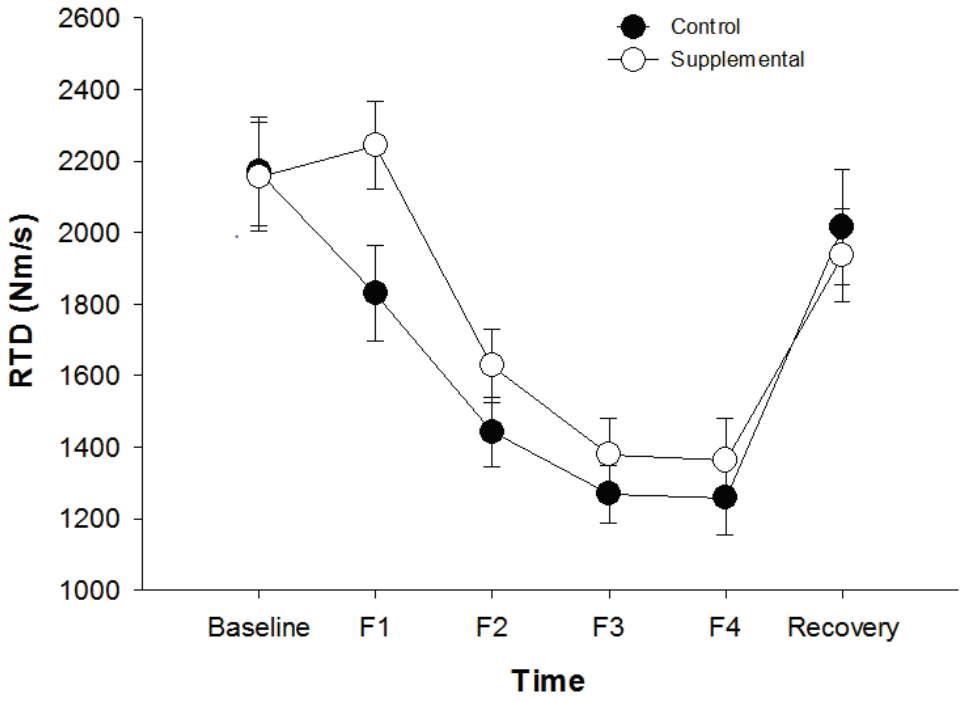

Figure 5. RTD was similar at baseline ($P = 0.891$) and decreased during the fatiguing contractions similarly in both sessions. Despite the similar decrease through fatiguing contractions, RTD was greater during the supplemental session throughout the fatiguing task (session effect; $F = 7.40$, $P = 0.018$).

4.4.Voluntary Activation

Voluntary activation was similar between control and supplemental sessions during baseline measurements (99.24 ± 1.10 vs. 98.85 ± 1.72 %; $t_{13} = 1.15$, $P = 0.270$). Throughout the fatiguing contractions, voluntary activation remained similar between both control and supplemental sessions, (session effect; $F_{1, 13} = 2.01$, $P = 0.180$, $\eta^2p = .134$). After 10

minutes of recovery, voluntary activation was similar between sessions, (recovery x session; $F_{1, 13} = 0.163$, $P = 0.693$, $\eta^2p = 0.012$).

4.5.Resting Twitch

Resting twitch torque was similar between control and supplemental sessions during baseline measurements (75.03 ± 13.55 vs. 75.59 ± 15.36 Nm; $t_{13} = -0.162$, $P = 0.874$). Throughout the fatiguing contractions, resting twitch decreased (fatigue effect; $F_{4, 52} = 164.07$, $P < 0.001$, $\eta^2p = .927$) and the decrease was similar between both control and supplemental sessions, (fatigue x session; $F_{4, 52} = 0.838$, $P = 0.507$, $\eta^2p = 0.061$). After 10 minutes of recovery, resting twitch increased significantly (recovery effect; $F_{1, 13} = 87.62$, $P < 0.001$, $\eta^2p = .871$) and the increase was similar between sessions (recovery x session; $F_{1, 13} = .932$, $P = .352$, $\eta^2p = 0.067$).

4.6.Impulse

Impulse during the first 200 ms of MVIC at baseline were similar between control and supplemental sessions (27.18 ± 6.55 vs. 28.51 ± 7.10 N/s; $t_{13} = -1.14$, $P = 0.276$). Impulse decreased throughout the fatiguing contractions, (fatigue effect; $F_{1.92, 24.90} = 38.7$, $P < 0.001$, $\eta^2p = 0.749$), and the decline was similar throughout the testing protocol for both sessions (fatigue x session; $F_{4, 52} = 0.623$, $P = 0.648$, $\eta^2p = 0.046$). Despite the similar decrease for impulse throughout the fatiguing protocol, impulse was greater for subjects during the supplemental session when compared to the control session throughout the fatiguing contractions (20.30 ± 0.87 vs. 18.33 ± 0.93 Nms; session effect; $F_{1.0, 13.0} = 28.94$, $P < 0.001$, $\eta^2p = 0.690$). After 10 min of recovery, impulse increased significantly (recovery effect; $F_{1,13} = 48.06$, $P < 0.001$, $\eta^2p = 0.787$), and the relative increase was similar

between sessions (recovery x session; $F_{1,13} = 0.240$, $P = 0.633$, $\eta^2p = 0.018$). See **Figure 6.**

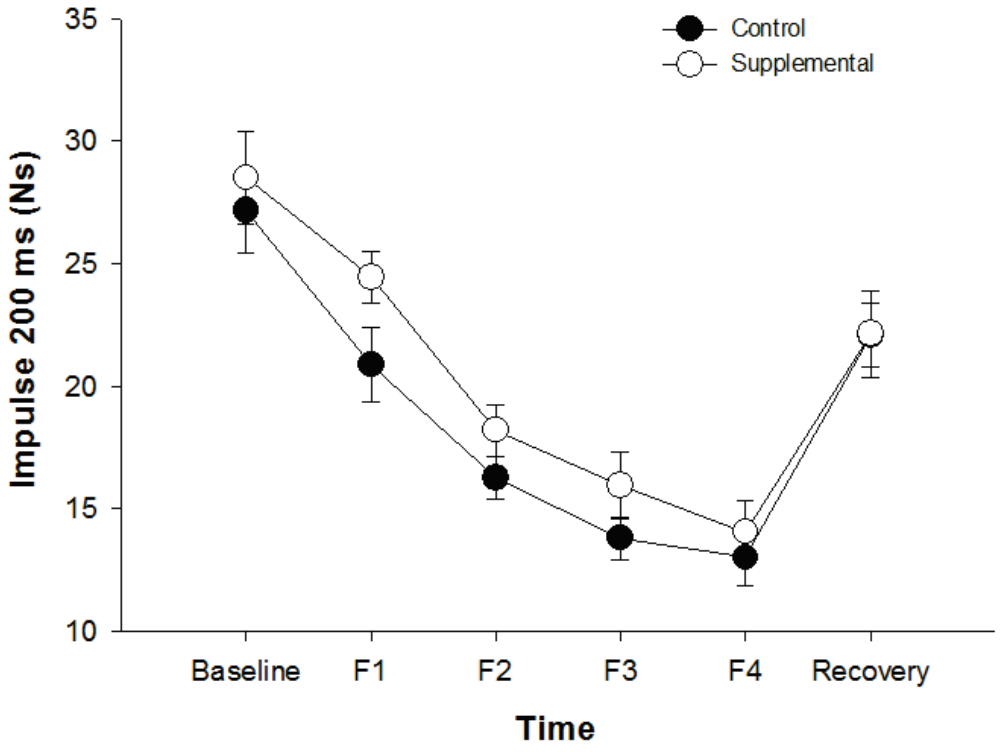

Figure 6. Impulse was similar at baseline and decreased similarly throughout the fatiguing contractions. Despite the similar decrease through fatiguing contractions, impulse at 200 ms was greater during the supplemental session (session effect; $F = 28.94$, $P < 0.001$).

4.7.Power

Knee extensor power showed no significant differences across all loads between control and supplemental sessions ($F_{1,13} = 3.77$, $P = 0.074$, $\eta^2p = 0.225$). Knee extensor power decreased significantly from baseline to after fatigue (time effect; $F_{1,13} = 19.87$, $P = 0.001$, $\eta^2p = 0.604$) and the decrease between sessions were similar (session x time; $F_{1,13} = 0.099$, $P = 0.758$, $\eta^2p = 0.008$). The decrease across all loads was similar from baseline to recovery

for all load conditions (session × intensity × time; $F_{6, 78} = 0.551$, $P = 0.767$, $\eta^2p = 0.041$). See **Figure 7.**

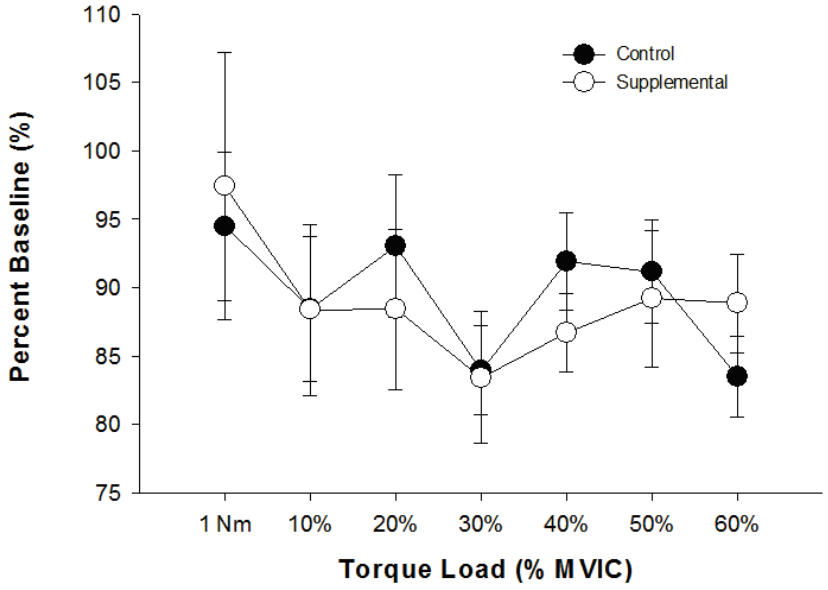

Figure 7. Peak power decreased after fatiguing contractions for all load conditions similarly between control and supplemental sessions.

4.8.Torque and Power during Fatiguing Contractions

Average torque through the fatiguing contractions decreased similarly between control and supplemental sessions ($F_{1, 13} = 0.002$, $P = 0.961$, $\eta^2p < 0.001$). Average torque decreased throughout the sets of fatiguing contractions (time effect; $F_{7, 91} = 93.8$, $P < 0.001$, $\eta^2p = 0.878$) and the decrease was similar between control and supplemental sessions (session × time; $F_{7, 91} = 0.878$, $P = 0.527$, $\eta^2p = 0.063$). See **Figure 8**.

Average power through the fatiguing contractions decreased similarly between control and supplemental sessions ($F_{1, 13} = 1.37$, $P = 0.263$, $\eta^2p = 0.095$). Average power

decreased throughout the sets of fatiguing contractions (time effect; $F_{7, 91} = 170.0$, $P < 0.001$, $\eta^2p = 0.929$) and the decrease was similar between control and supplemental sessions (session × time; $F_{7, 91} = 1.45$, $P = 0.194$, $\eta^2p = 0.101$). See **Figure 9**.

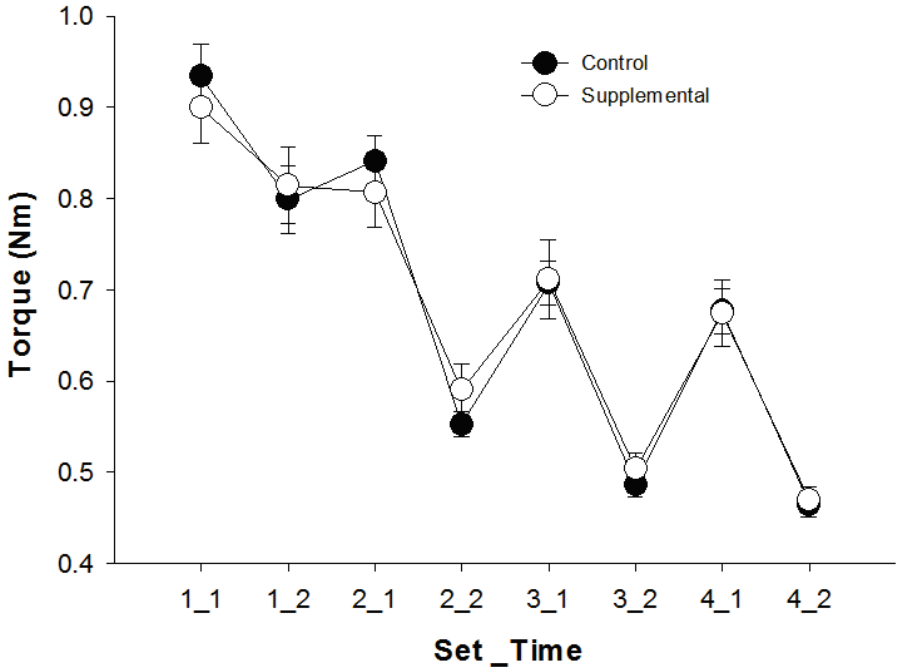

Figure 8. Average torque from first and last 5 repetitions of each set during the fatiguing contractions. Average torque decreased similarly throughout the fatiguing contractions for both control and supplemental sessions.

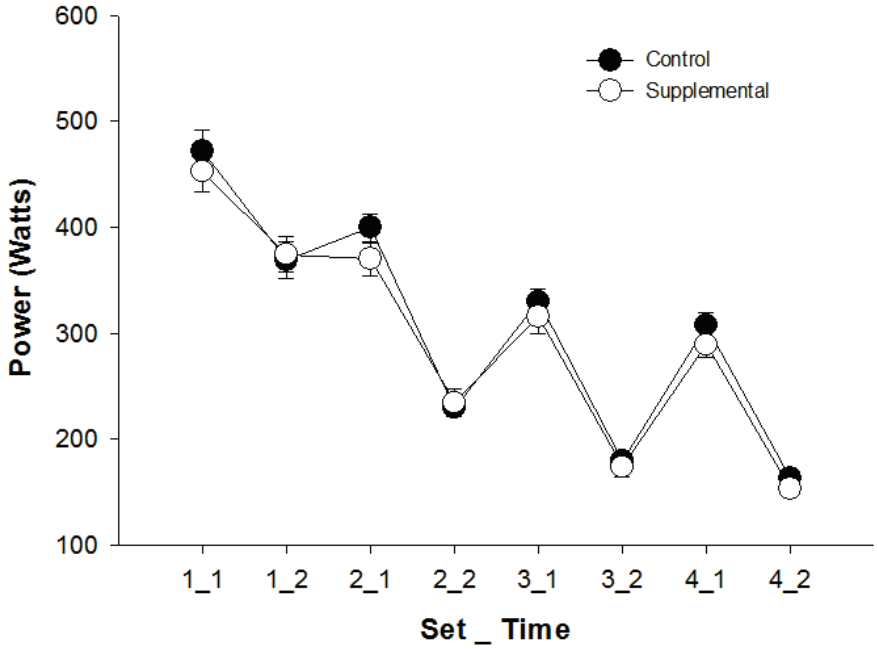

Figure 9. Average power from first and last 5 repetitions of each set during the fatiguing contractions. Average power decreased similarly throughout the fatiguing contractions for both control and supplemental sessions.

4.9.Surface Electromyography

Electromyography activity was examined during the MVIC contractions for the following knee extensor muscles: rectus femoris, vastus medialis, and vastus lateralis. EMG decreased from baseline through the fatiguing contractions similarly between control and supplemental sessions, for rectus femoris (session effect, $F_{1,13} = 0.981$, $P = 0.340$, $\eta^2p = 0.070$) (See **Figure 10**), vastus medialis (session effect, $F_{1,13} = 0.023$, $P = 0.881$, $\eta^2p = 0.002$) (See **Figure 11**), and for vastus lateralis (session effect, $F_{1,13} = 0.377$, $P = 0.550$, $\eta^2p = 0.028$) (See **Figure 12**). EMG activity showed similar recovery between sessions, for rectus femoris (session effect, $F_{1,13} = 4.46$, $P = 0.055$, $\eta^2p = 0.255$), vastus medialis

(session effect, $F_{1,13} = 0.371$, $P = 0.553$, $\eta^2p = 0.028$), and for vastus lateralis (session effect, $F_{1,13} = 0.719$, $P = 0.412$, $\eta^2p = 0.052$).

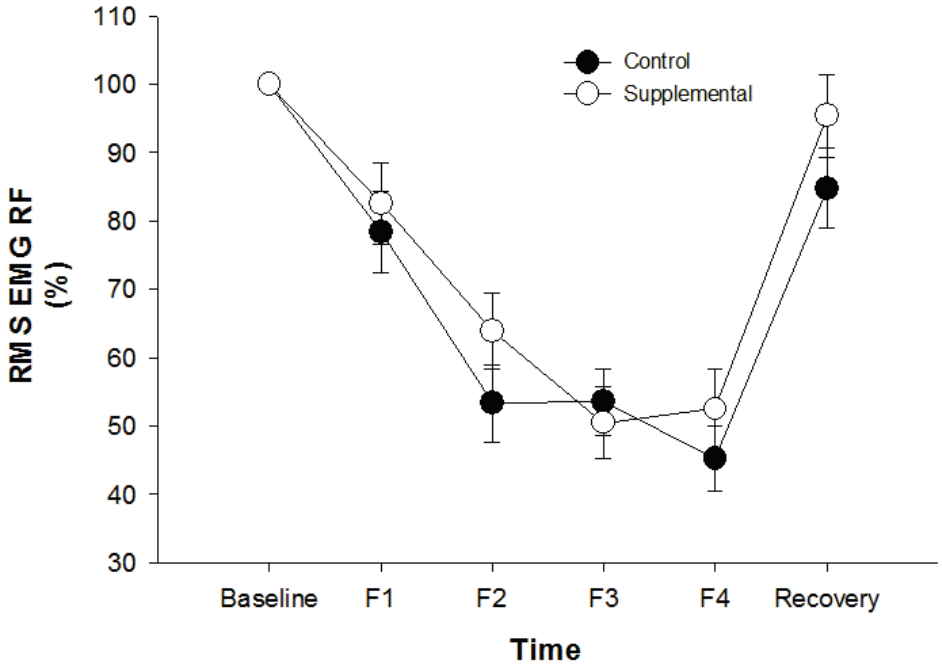

Figure 10. Rectus femoris EMG measured during each MVIC shows similar decreases between control and supplemental sessions.

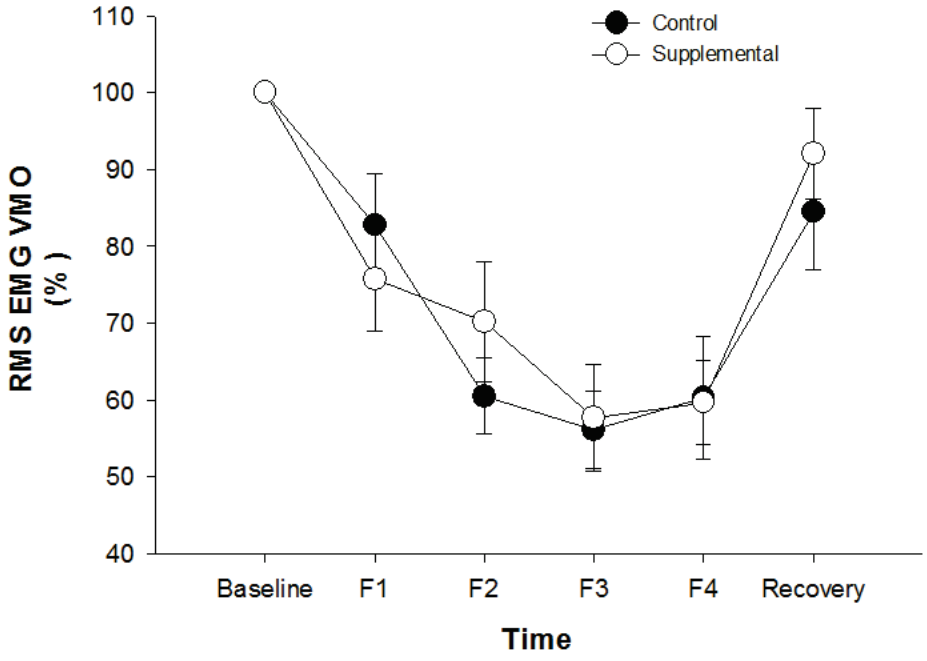

Figure 11. Vastus medialis EMG measured during each MVIC shows similar decrease between control and supplemental sessions.

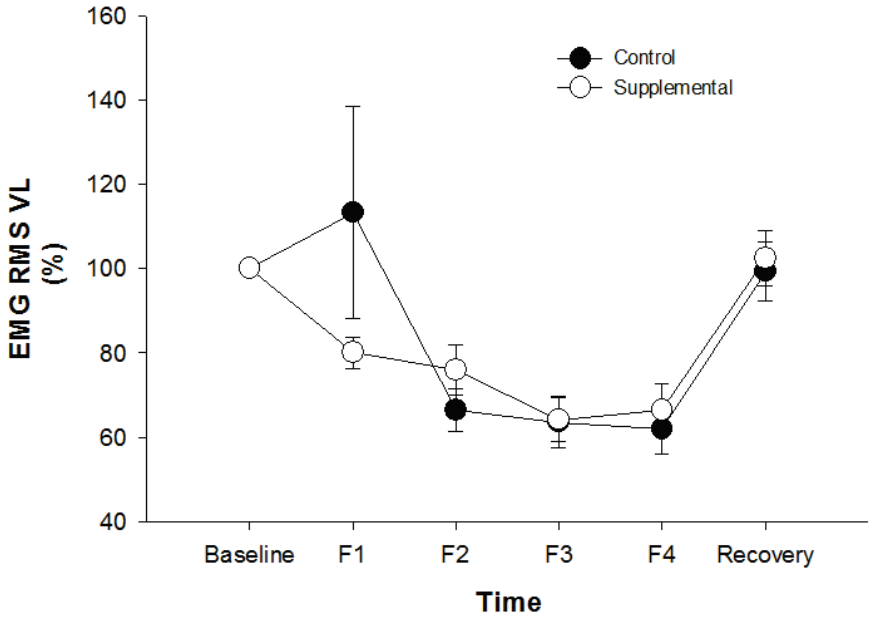

Figure 12. Vastus lateralis EMG activity measured during each MVIC shows similar decreases between control and supplemental sessions.

5. DISCUSSION

5.1.Key Findings

The current study tested the acute effect of supplementing Myosync™ on physical performance in Division II football players. The study compared physical and muscle function testing results between a supplemental and control session in a double blind cross-over procedure. Contrary to the hypothesis, supplementation with Myosync™ did not show improvements in vertical jump height or maximum isometric strength.

The new findings from the current study are, 1) Acute supplementation with Myosync™ does not have an effect on vertical jump height; 2) Acute supplementation with Myosync™ showed no significant improvements in MVIC strength or dynamic power; 3) Acute supplementation with Myosync™ did show significant improvements in rate of torque development and impulse; 4) Acute supplementation with Myosync™ showed no effect on fatigue. Given that maximal strength has previously been significantly correlated with voluntary RFD (Mirkov, Nedeljkovic, Milanovic, & Jaric, 2004) increases in the current study for RFD and not maximal strength are intriguing. The results of the current study suggest that it is possible to improve RFD without improvements in maximal strength, which could be an area of interest for many athletes and coaches.

5.2.Vertical Jump

To the author's knowledge, this is the first study to investigate the effect of Myosync™ supplementation on practical measures of athletic performance such as the vertical jump height. The results of the current study indicated no change in vertical jump height which agree with previous research involving supplementation and vertical jump height (Bunn,

Crossley, & Timiney, 2017; Claudino et al., 2014). Previously, Bunn et al. (2017) concluded that 500 mg Alpha-GPC supplementation showed no improvements in vertical jump height when tested against a placebo. Claudino et al. (2014) found that creatine supplementation for professional soccer players failed to reach statistical significance when comparing vertical jump performance against a placebo. It has been shown that ten weeks of barbell deadlift training increased RFD along with vertical jump in novice weight lifters (Thompson et al., 2015). The increases in both RFD and vertical jump that were seen in the novice subjects were likely due to the early training adaptations that occurred over the ten-week period of training. It has previously been shown that individuals who are untrained will make better adaptations to training then previously trained individuals during a 21-week supervised training regimen (Ahtiainen, Pakarinen, Alen, Kraemer, & Häkkinen, 2003). Many times there is a disconnect between researchers and sport coaches or players, and that disconnect can lead to a lack of respect for research from athletes or coaches. Future research pertaining to athletic performance should attempt to include both practical assessments such as vertical jump and sprint time, along with laboratory measurements to support those practical measures.

5.3. Isometric Strength and Rate of Torque Development

Maximal strength is a very important aspect of athletics across a wide variety of sports. Depending on the nature of the sport, athletes typically have to generate large amounts of strength in very short amounts of times. Previously, it has been found that increases in maximal strength lead to improvements in RFD (Aagaard et al., 2002). Currently, to the

authors' knowledge, no other studies have yet to compare the effect of Myosync™ on muscle strength and performance.

Based on the results of the current study, it was found that supplementation with two capsules of Mysoync™ did not show significant improvements in maximal isometric strength. A similar study conducted by Bellar et al. (2015) found no difference in isometric lower body strength when looking at the effects of acute supplementation with Alpha-GPC supplementation; however they found a significant increase in lower body isometric strength after a six day loading phase of Alpha-GPC supplementation. One possible explanation for not finding increases in isometric strength during the current study could be because the subjects were not given enough dosage of Myosync™. The recommended dosage by the manufacturer states athletes may need anywhere between two and four capsules for supplementation based on the level and training year of the athletes. Another possible explanation for the lack of improvement in isometric strength that would agree with the findings of Bellar et al. (2015) is that the current study involved no loading phase of the supplement.

Furthermore, maximal strength has recently been a topic of discussion when training athletes. It is well known that increases in strength have been shown lead to improvements in sport performance, resulting in better performance while sprinting, jumping, and change of direction (Suchomel et al., 2016). More recently, the question has shifted towards, how much strength is necessary, and when should the athletes training emphasis shift towards speed and power production. This question has led many researchers to investigate the association between strength improvements and changes in sport performance.

It has been previously stated that given the unpredictable nature of athletics, athletes have to generate as much force as possible between 50-250 ms which is not enough time to generate maximal strength (Andersen & Aagaard, 2006). Because of this, many researchers and coaches have placed equal if not more importance on the RFD. The results of the current study indicate that RFD during MVICs showed significant improvement during the supplemental session. Results from previous research conducted by Andersen and Aagaard (2006) showed that at time intervals later than 90ms from the onset of contraction, maximal strength could account for 52-81% of the variance in voluntary RFD. Contrary to the results of Andersen and Aagaard (2006) the current study measured RFD at a time of 400 ms from the onset of contraction showing no increase in maximal strength but an increase in RFD. A previous review of the literature has investigated various mechanisms that influence RFD including neural and peripheral mechanisms (Maffiuletti et al., 2016). One of the major influences on RFD especially early in a voluntary contraction is motor unit recruitment and discharge rate. It has been shown by Desmedt and Godaux (1977) that contrary to slow contractions, which have a progressively increasing motor unit discharge rate, faster contractions generally have a high initial discharge rate that decreases over the length of the contraction. With the results showing no significant difference in voluntary activation, but a reduction in resting twitch torque, it can be concluded that the peripheral mechanism of fatigue contributed significantly to MVIC and consequently RFD. Muscle size is another mechanism that has been shown to improve RFD, showing increases in muscle size and cross sectional area have led to improved RFD (Andersen & Aagaard, 2006). The increases seen in RFD through the current study could be a result of the motor

unit discharge rate not decreasing as rapidly during the voluntary contractions with supplementation of Myosync™.

The current study was not able to measure the amount of acetylcholine present in the neuromuscular junction but it seems logical to assume that an increased amount of acetylcholine present would allow for better recruitment of motor units within a shorter amount of time. Because an increase in maximum strength would involve activating more muscle fibers, the idea of being able to activate the muscle fibers available faster would seem more logical when discussing supplementation for athletes. These findings suggest that it is possible to increase the RFD with supplementation. Based on the results of increased RFD, athletes could potentially improve performance in their sport by supplementing with Myosync™.

5.4.Power Measurements

With power being defined as the product of torque and velocity, investigation of performance during dynamic contractions can have strong implications for various sports. Similar to isometric strength, limited research has been conducted investigating the effect of Alpha-GPC supplementation on dynamic power. Furthermore, to the authors' knowledge, no research has examined the effects of supplementation with Myosync™ on dynamic power.

The current study measured power using dynamic contractions with various loads based of the individuals MVIC value (1nm, 10, 20, 30, 40, 50, and 60%). With results showing no difference in the baseline or recovery power values between sessions, it can be concluded that supplementation with Myosync™ provided no benefit in increasing power

throughout the dynamic contractions. Because there were no differences overall with regards to isometric strength, subjects were moving similar resistances during both sessions. With the load being relatively consistent between sessions, one can conclude that in order to show increases in power, subjects would have had to increase the velocity of the contraction.

The current study was unable to detect in power production through a dynamic contraction with supplementation, it is important to note that the majority of research pertaining to Alpha-GPC supplementation has been conducted using isometric muscle testing. One pilot study conducted by Ziegenfuss (2008) showed a 14% increase in peak bench press force by supplementing with an Alpha-GPC supplement. More research is necessary to investigate the role of Alpha-GPC supplementation during dynamic contractions to investigate the effects on dynamic strength and power.

5.5.Fatigability

Fatigue is a reduction in muscle force or power production. The protocol used in the current study to induce muscle fatigue was chosen in an attempt to mimic the demands of athletics. For the purpose of the current study, muscle fatigue was analyzed in multiple ways such as reduction in MVIC, reduction in resting twitch torque production, reduction in voluntary activation, as well as monitoring torque and power production throughout the 120 fatiguing contractions.

Previous research has assessed the effect of choline supplementation on performance during prolonged exercise such as load carriage tasks and cycling (Spector et al., 1995; Warber et al., 2000). Similar to the results found in the current study, Spector et

al. (1995) found that choline supplementation did not improve performance in supramaximal brief or prolonged submaximal cycling, It is important to note that the previously mentioned study did not notice significant levels of choline depletion during either testing condition (Spector et al., 1995). Similarly, Warber et al. (2000) showed no improvements in prolonged exercise performance with choline supplementation.

Due to the fact that reductions in MVIC were seen immediately after the first set of 30 fatiguing contractions and those reductions were similar between both sessions, it is fair to conclude that supplementation did not have an impact on preserving isometric strength throughout the testing protocol. It is still important to acknowledge that although MVIC strength decreased similarly between sessions, rate of torque development did not decrease as much during the MVIC throughout the fatiguing protocol for the supplemental session.

The decrease in torque and power through each set of fatiguing contractions was also used to quantify the amount of muscle fatigue. By analyzing the first and last five contractions of each set of 30 of fatiguing contractions, it was shown that the rate of fatigue was similar between both sessions. The smallest decrease in both torque and power occurred during the first set of fatiguing contractions, with larger and more significant decreases occurring during sets two, three, and four.

To the author's knowledge, this is the first study to assess neuromuscular fatigue while assessing the effect of an Alpha-GPC supplement on muscular strength and fatigability. With electrical stimulation, the authors assessed resting twitch torque and voluntary activation which are variables others researching this area were not able to use. Using the corrected voluntary activation equation described previously, there was no change observed in voluntary activation throughout any of the MVICs across both sessions.

This shows that although isometric strength was decreased and fatigue was observed, the fatigue was not likely due to central fatigue. Unlike voluntary activation, the resting twitch elicited by electrical stimulation did show decreases progressively throughout the fatiguing contractions. Although the decreases were similar between sessions, it can still be concluded that the fatigue exhibited can be contributed to the peripheral mechanisms of fatigue. Further research and more advanced protocols are needed in order to truly assess the mechanisms of fatigue and the effect that supplementation with an Alpha-GPC supplement can have on fatigue.

5.6.Practical Application

These findings suggest that it is possible to increase RFD with supplementation while not improving overall maximum strength. Athletes across a wide variety of team sports (ex. football, basketball, and hockey) could see improvements in performance by supplementation with Myosync™. Specifically, improved RFD will allow athletes to better withstand the unpredictable nature of sports such as being hit or having to change directions quickly. In addition to improving sports performance, athletes who are able to generate more force quickly could be at less risk of suffering a contact related injury.

5.7.Limitations and Future Direction

One potential limitation with the current study is that no measurements of the amount of free choline levels in the subjects were taken during the control and experimental sessions. As mentioned before, many of the previous studies involving choline supplementation measured the amount of free choline to investigate if the supplement was effective at the

most basic level. Future research investigating the effect of Myosync™ or any form of choline supplementation would benefit from this measurement.

Another possible limitation within the current study is with the dosage of the supplement Myosync™. The manufacturers of Myosync™ recommend a dosage of two to four capsules, depending on the training level of the individual. For the simplicity of the current study, all subjects received only two capsules of Myosync™, which seemed to show improvements for some individuals while showing no effect for others. Future research involving supplementation and performance should take into effect dosage amounts for individual subjects as well as taking consideration of responders and non-responders to the supplement.

Assessing voluntary activation using electrical stimulation was difficult for both the experimenter as well as the subject. A possible better alternative method to assess voluntary activation going forward would be the use of magnetic stimulation. Magnetic stimulation is a less painful technique and could provide more accurate data concerning the integrity of the neuromuscular junction. In the future, using magnetic stimulation, which is generally a less painful technique, could be a good alternative for research regarding voluntary activation.

The current research provides various implications for not only researchers and sports scientist, but also coaches and athletes as well. Many studies involving athletic performance have a major limitation within their subject pool. When investigating athletic performance it is important to test trained athletes, and many studies involve "trained" college subjects. Based on the results of the current study, improvements in RFD can be seen with acute supplementation and are not only improved via strength

training. The current research involved many laboratory measurements that are not commonly utilized when studying athletic performance. In the future, it is imperative that athletes, coaches, and researchers work together when studying athletic performance to assess both practical measures and other more detailed measures assessed in a laboratory.

6. CONCLUSION

Acute supplementation with Myosync™ did not have a significant effect on either maximal vertical jump height or maximal isometric strength of the knee extensor muscles. However, supplementation with Myosync™ maintained RFD and impulse during MVIC measurements throughout the fatiguing protocol. These results indicate that athletes across many team sports can benefit from supplementation of Myosync™.

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Appendix A: Raw data

Table 3. Maximum Vertical Jump Height (inches)

Session	Subject	Jump 1	Jump 2	Jump 3
Control	1	21.5	23	24
	2	26.5	26.5	26.0
	3	25.5	25.5	26.5
	4	28.0	28.5	29.0
	5	28.5	29.0	29.0
	6	26.0	26.0	26.0
	7	28.5	30.0	32.5
	8	27.5	29.0	29.5
	9	23.0	24.5	24.5
	10	29.5	28.0	28.0
	11	26.5	26.5	27.5
	12	25.5	26.0	26.0
	13	32.0	32.5	30.5
	14	27.5	25.0	27.0
Supplemental	1	23.5	23.5	24.0
	2	28.5	28.0	28.5
	3	25.5	27.0	27.0
	4	27.0	25.5	29.0
	5	28.0	29.0	29.0
	6	28	27.5	27.5
	7	30.5	32.5	33.5
	8	29.0	26.0	25.5
	9	22.0	22.5	24.0
	10	28.5	27.0	28.5
	11	26.0	26.5	27.0
	12	23.5	25.0	25.5
	13	31.0	30.5	30.5
	14	27.5	27.5	26.0

Table 4. MVIC during baseline, fatigue, and recovery (Nm)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	323.3	303.51	250.99	235.94	238.44	295.59
	2	274.67	278.14	201.63	163.08	147.94	206.07
	3	305.35	267.69	223.65	213.64	210.88	280.56
	4	302.74	271.77	205.78	183.68	159.39	233.87
	5	254.32	210.82	205.21	179.55	142.33	210.28
	6	316.01	220.11	204.21	149.74	182.55	212.99
	7	337.83	222.68	167.00	148.95	147.10	242.95
	8	321.47	265.87	218.24	205.35	170.71	250.61
	9	263.24	304.27	233.22	185.12	139.03	150.97
	10	315.45	257.11	191.97	173.39	181.99	283.11
	11	201.58	222.17	171.38	172.96	165.77	217.67
	12	308.75	287.07	224.68	212.65	214.01	207.28
	13	401.78	253.84	156.53	151.46	127.18	251.21
	14	242.48	246.12	185.77	142.38	170.94	170.93
Supplemental	1	310.03	280.05	237.12	249.32	262.60	286.93
	2	320.74	332.53	257.03	228.08	212.03	260.36
	3	297.33	261.03	235.89	229.33	220.04	257.46
	4	312.29	268.73	192.44	177.83	170.35	237.07
	5	274.05	256.25	208.76	168.46	143.30	215.05
	6	340.30	245.14	218.31	181.27	199.79	232.49
	7	304.62	236.11	186.09	184.14	192.52	250.18
	8	291.47	259.93	210.43	172.68	176.52	287.82
	9	184.47	266.58	122.36	125.82	110.26	153.22
	10	283.35	241.84	195.48	188.56	130.72	269.99
	11	199.12	262.88	197.50	150.16	169.52	183.17
	12	252.70	275.00	230.16	207.58	186.15	229.68
	13	488.88	265.95	243.92	165.18	189.97	287.35
	14	294.94	211.01	221.45	184.15	151.95	213.63

Table 5. Rate of Torque Development during baseline, fatigue and recovery (Nm/s)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	1843.40	1662.30	1246.30	1534.60	1390.30	2271.60
	2	2710.90	2487.20	1879.40	1453.60	1320.60	2787.90
	3	2743.20	2029.00	1656.00	1783.20	1739.30	3349.90
	4	2509.40	1601.00	1238.60	1013.40	880.90	1977.20
	5	916.50	1189.00	1323.50	871.70	1033.00	1517.40
	6	2938.20	2600.10	1998.90	857.50	1747.60	1736.70
	7	2433.90	1421.30	1101.20	1263.10	724.40	1560.40
	8	2108.50	1814.40	1585.90	1280.40	846.60	1644.50
	9	2039.30	2048.20	1897.40	1617.00	1008.10	1836.20
	10	2197.40	1456.90	1608.80	1010.40	1112.10	2237.20
	11	1711.90	1610.90	1134.40	1195.40	946.30	1893.90
	12	2157.60	2681.30	1744.80	1536.20	1298.80	1741.90
	13	2676.90	1289.10	860.30	911.10	502.80	1057.40
	14	1409.50	1993.10	1540.70	1434.50	1530.70	1008.20
Supplemental	1	1954.20	2029.20	1416.40	1420.20	1856.80	1892.70
	2	2355.70	2921.20	1775.90	1965.60	2017.20	1899.30
	3	2204.20	2622.70	2305.10	2019.90	2242.50	2446.90
	4	2954.40	2166.40	1121.90	1079.60	1123.70	2149.60
	5	1059.20	1838.80	1231.50	1024.50	762.80	800.40
	6	2501.70	2980.20	1702.50	1839.80	1568.80	1980.90
	7	2047.60	1988.40	1470.40	1526.30	2182.60	2613.70
	8	1441.20	1814.70	2349.40	1193.30	1482.20	1900.60
	9	2157.50	2572.10	1823.90	1737.30	1450.60	2106.90
	10	2525.30	1590.60	1161.10	1193.90	1127.50	2493.10
	11	1804.90	2583.20	1409.10	1061.60	1186.70	1152.00
	12	2017.70	1624.80	1458.20	947.30	959.50	1860.20
	13	3276.50	2391.60	1987.90	950.10	1181.70	1776.60
	14	1883.40	2299.60	1573.20	1359.00	1233.50	2044.80

Table 6. Impulse 200 ms data at baseline, throughout fatigue, and recovery. (N/s)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	26.80	22.55	18.26	18.27	13.44	25.13
	2	32.39	34.54	19.70	17.02	14.42	19.99
	3	33.68	24.99	21.95	20.38	18.13	34.62
	4	31.56	20.06	10.90	16.26	12.88	26.20
	5	13.87	11.48	15.16	11.91	1.79	21.42
	6	25.94	23.68	19.98	9.59	16.77	18.71
	7	30.27	21.73	11.32	13.46	11.08	19.48
	8	28.12	23.05	18.96	17.61	13.78	21.60
	9	24.88	15.49	17.28	11.91	12.26	18.28
	10	28.60	13.87	14.43	8.90	15.22	26.88
	11	19.95	15.63	16.19	15.45	15.98	23.79
	12	31.03	25.79	14.25	11.72	14.63	23.27
	13	36.84	19.64	12.64	12.81	6.50	18.17
	14	16.59	21.22	18.37	11.94	15.52	14.43
Supplemental	1	29.31	24.89	16.36	19.20	17.64	25.68
	2	28.81	35.31	23.82	23.81	19.22	16.34
	3	30.21	28.70	25.39	25.40	23.72	31.52
	4	36.75	24.20	15.42	13.15	14.91	29.28
	5	14.45	20.35	12.52	13.41	9.67	7.88
	6	31.45	25.34	19.22	15.65	16.91	20.14
	7	28.53	25.14	14.99	19.07	3.77	29.59
	8	23.42	23.08	22.12	19.11	17.94	24.23
	9	25.30	24.49	16.79	16.36	13.00	20.75
	10	30.58	21.53	11.35	6.15	11.05	28.37
	11	22.03	25.13	18.61	9.26	12.05	14.96
	12	28.05	23.20	18.54	14.16	14.48	21.69
	13	45.28	20.33	17.76	13.53	15.91	25.04
	14	24.90	20.93	20.13	17.84	9.70	17.56

Table 7. Resting twitch torque data at baseline, throughout fatigue, and recovery. (Nm)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	89.11	76.21	50.73	45.96	46.96	71.48
	2	108.45	67.78	41.21	37.52	34.39	95.12
	3	72.33	45.1	28.26	21.75	27.04	59.33
	4	72.69	40.65	29.99	24.5	20.02	40.44
	5	52.77	37.12	23.25	17.91	13.12	34.8
	6	73	60.95	46.46	42.89	41.05	53.89
	7	74.39	39.28	26.29	30.73	29.44	50.53
	8	73.71	44.26	34.25	29.62	28.45	51.73
	9	72.47	64.05	34.91	31.3	25.23	44.57
	10	56.61	21.22	16.4	14.83	18.98	38.61
	11	82.2	55.36	40.44	37.61	29.07	62.86
	12	83.89	53.72	21.17	19.17	13.39	47.24
	13	72.43	39.23	18.82	18.02	29.22	42.22
	14	66.33	48.46	32.24	21.99	22.45	45.85
Supplemental	1	82.75	59.29	48.74	43.1	56.56	76
	2	106.95	62.34	41.32	51.91	38.98	89.03
	3	74.41	50.15	37.67	41.38	33.47	42.44
	4	56.88	38.12	21.04	18.66	19.03	35.07
	5	68.84	34.94	28.05	20.81	14.83	36.84
	6	88.95	60.85	38.3	34.37	37.58	55.76
	7	82.79	55.57	41	32.79	28.9	56.67
	8	68.02	46.97	44.74	52.02	37.26	50.63
	9	67	62.78	43.9	36.66	32.6	49.93
	10	67.62	28.92	18.23	17.19	16.78	43.3
	11	77.08	65.65	56.09	41.53	35.99	56.55
	12	69.81	39.34	21.35	16.96	19.49	47.29
	13	97.73	41.31	26.63	23.41	22.48	53.09
	14	49.46	38.53	29.9	18.53	15.71	40.08

Table 8. Voluntary Activation data at baseline, throughout fatigue, and recovery. (%)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	91.28	92.8	92.13	91.03	88.94	86.58
	2	82.76	99.06	96.82	93.16	90.49	80.73
	3	79.61	100	94.11	99.99	99.99	85.48
	4	96.77	95.59	74.22	93.94	99.99	100
	5	100	71.45	87.92	86.53	74.47	100
	6	88.21	93.52	75.1	74.38	79.94	69.09
	7	100	73.88	83.27	91.38	93.53	88.42
	8	95.56	97.32	88.34	99.99	84.08	85.9
	9	79.92	100	62.94	100	99.99	83.42
	10	100	86.9	99.71	86.07	97.13	68.5
	11	68.37	95.28	82.92	100	99.99	66.62
	12	86.53	98.31	97.45	99.99	95.53	86.41
	13	100	84.8	77.28	88.73	54.93	84.62
	14	89.48	93.99	100	99.44	88.26	100
Supplemental	1	88.43	91.42	95.3	100	87.08	72.88
	2	81.82	96	92.52	78.33	79.69	84.57
	3	95.19	85.51	100	99.43	96.36	85.27
	4	87.03	97.58	87.86	78.6	85.95	100
	5	95.1	100	90.75	77.9	99.99	71.51
	6	84.09	88.05	92.91	77.52	91.99	89.79
	7	93.9	79.38	83.49	73.52	78.51	92.49
	8	88.45	87.31	93.91	70.51	81.27	97.34
	9	67.16	86.37	86.11	77.79	70.96	64.12
	10	84.21	99.99	99.99	99.99	99.49	96.41
	11	70.84	95.24	91.63	56.58	86.29	82.5
	12	80.48	100	94.66	99.99	99.99	79.98
	13	100	65.94	91.04	89.23	75.31	93.86
	14	100	85.98	-16.12	83.39	9.49	69.55

Table 9. Corrected Voluntary Activation data at baseline, throughout fatigue, and recovery. (%)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	99.8	99.89	99.55	99.86	99.77	99.25
	2	98.43	99.89	99.47	98.47	98.81	96.81
	3	98.77	100	99.04	100	100	99.6
	4	99.96	99.97	99.06	99.92	100	100
	5	100	96.82	98.17	99.07	98.58	100
	6	99.52	99.11	94.67	95.18	94.67	91.84
	7	100	98.82	99.59	99.72	99.91	99.74
	8	99.89	99.81	99.51	100	97.13	98.7
	9	97.94	100	93.38	100	100	96.9
	10	100	98.2	99.96	99.51	99.28	92.16
	11	96.2	99.59	97.68	100	100	90.27
	12	99.13	99.94	99.88	100	99.89	97.5
	13	100	99.73	99.05	99.32	95.58	99.67
	14	99.69	99.49	100	99.95	98.29	100
Supplemental	1	99.65	99.59	99.84	100	98.18	97.67
	2	98.99	99.69	99.58	97.54	97.93	98.51
	3	99.66	99.66	100	99.98	99.88	98.02
	4	99.71	99.99	99.87	99.56	99.84	100
	5	99.94	100	99.05	99.03	100	98.7
	6	99.35	98.7	98.99	99.14	99.81	99.77
	7	99.83	98.78	98.79	98.85	96.75	99.39
	8	99.4	98.06	99.14	90.32	97.77	99.73
	9	93.69	95.73	97.14	93.04	87.05	91.13
	10	98.38	100	100	100	99.91	99.72
	11	96.83	98.8	98.78	93.81	95.81	95.81
	12	98.41	100	99.94	100	100	94.55
	13	100	98.34	99.88	99.19	98.96	99.55
	14	100	99.32	70.17	99.72	91.83	96.82

Table 10. Peak Isotonic Power Baseline. (Watts)

Session	Subject	1 Nm	10%	20%	30%	40%	50%	60%
Control	1	418.1	609.1	533.8	499.1	442.6	451.9	482.9
	2	561.1	699.2	551.3	727	654.7	688.3	718.9
	3	707.3	523.2	559.2	537.2	534.1	489.6	438.8
	4	667.3	689.1	451.4	674.5	631.7	548.5	653.9
	5	449.5	511.8	591	534.4	507.9	408.8	632.8
	6	496.1	710.6	639.6	572.5	589.6	646.3	495.5
	7	628.4	412	637.4	656.7	501.7	563.7	476.7
	8	523.1	456.3	515.4	546.4	579.6	620.5	582.8
	9	497.7	479.2	423.6	630.8	470.8	594.2	554.7
	10	584.2	493.5	562.1	541.7	529.2	590	628.2
	11	604.4	600.1	510.7	561.6	600.6	625.3	685.4
	12	613.1	562.7	581.7	569.1	580.3	472.6	510.8
	13	458.9	738.2	723.6	735.1	703.1	738.9	643.6
	14	562.2	470.5	425.6	576.3	556.7	562.2	631.1
Supplemental	1	316.2	527.3	430.2	494	496.3	515.2	496.6
	2	755.7	632.9	593.7	711.3	642.2	623.1	671.4
	3	693.4	607.2	590.4	487.4	624.2	630.1	544.6
	4	636.2	599.7	655.4	599	642.1	614.9	522.4
	5	470.9	444.1	427.3	514.4	430.8	445.9	456.2
	6	657.9	807.1	785.9	613.4	490.9	501.7	396.9
	7	558.5	443.1	450.7	567	522.1	560	521.6
	8	373.5	405.6	413	525	452.8	495	519
	9	585.5	444.8	589.6	650.8	513.2	626.2	509
	10	503.1	542.4	516.6	585.6	585.4	536	606
	11	589.9	605.5	395.9	473.2	525.4	510.2	567.4
	12	349.1	446	488	444.8	431.3	413.2	436.2
	13	819.5	726.8	718.3	647	672.5	770	589.6
	14	417.6	466.8	457.2	644.5	611.7	605.8	603.6

Table 11. Peak Isotonic Power Recovery. (Watts)

Session	Subject	1 Nm	10%	20%	30%	40%	50%	60%
Control	1	536.5	477.2	518.2	491.6	383.7	416.8	413.6
	2	662.5	525.1	628.2	663.4	615.7	595.8	626.2
	3	713.6	510.9	619.7	483	553.8	554.6	444.6
	4	520.1	463	530.2	477.6	525.7	541	503.6
	5	402.3	340.4	550.2	446.3	463	470.3	472.4
	6	468.7	555.7	440.1	557.7	478.4	484.7	388.7
	7	612.4	537.4	634.1	589.3	499	576.5	523.4
	8	414.5	474.5	601.7	466	479.7	587.5	486.2
	9	277	432.5	378.2	398.1	395.3	402.1	422.7
	10	530.8	400.1	458.2	520.2	565.8	561.2	534
	11	546.4	576.8	371.8	514.5	626	503.7	492.3
	12	458.7	436.8	340.3	343.5	367.7	412.8	351.1
	13	587.5	531.5	540.6	605.6	637.1	542.7	519.9
	14	546.2	581.2	461.3	435.8	641.8	531.6	560.4
Supplemental	1	603.6	489	407.3	453.6	408.9	521.9	492.9
	2	734	596.3	502	602.3	584.4	559.8	600.6
	3	626.4	505.8	514.6	609.9	544	538.6	529.9
	4	384.1	499.3	487.6	568	561.9	492.6	553.3
	5	490.5	461	389.4	474.5	481.9	501	497.1
	6	477.6	420.8	642.3	473.6	402.4	378.8	325.2
	7	500.5	401.6	346.2	409.1	461.1	489.4	433.6
	8	246.9	274.7	275.6	288	464.6	524.3	372.5
	9	485.3	484.7	443.1	370.7	436.9	383.4	492.6
	10	530.3	523	429	479.2	530.3	545.1	529.6
	11	626.6	553.6	586.2	485.6	442.6	616	545.5
	12	404.9	361.2	429.7	334.2	313.8	374.1	337.4
	13	351.5	358.4	468.4	545.6	491.6	402.4	352.3
	14	581.2	664.3	553.2	476.3	459.2	510.6	536.1

Table 12. RMS EMG Activity during MVIC Rectus Femoris (mv)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	0.196	0.170	0.141	0.151	0.108	0.163
	2	0.203	0.147	0.078	0.074	0.056	0.116
	3	0.530	0.399	0.192	0.204	0.186	0.594
	4	0.346	0.389	0.324	0.159	0.190	0.323
	5	0.432	0.265	0.172	0.214	0.211	0.274
	6	0.355	0.179	0.178	0.188	0.115	0.346
	7	0.485	0.552	0.332	0.254	0.386	0.527
	8	0.331	0.258	0.292	0.205	0.092	0.345
	9	0.173	0.137	0.071	0.064	0.051	0.080
	10	0.672	0.313	0.240	0.600	0.198	0.487
	11	0.208	0.122	0.075	0.099	0.110	0.156
	12	0.302	0.330	0.151	0.255	0.228	0.188
	13	0.550	0.327	0.158	0.179	0.175	0.596
	14	0.275	0.258	0.187	0.120	0.148	0.284
Supplemental	1	0.2066	0.1645	0.1593	0.1358	0.1289	0.2823
	2	0.2321	0.1713	0.1425	0.0825	0.0892	0.1657
	3	0.4235	0.5155	0.433	0.3437	0.3699	0.5306
	4	0.3216	0.3365	0.2936	0.1868	0.2631	0.3636
	5	0.4492	0.2912	0.1732	0.1488	0.1203	0.4244
	6	0.4071	0.2815	0.2108	0.3232	0.2825	0.4563
	7	0.5877	0.5839	0.3865	0.4106	0.4439	0.4529
	8	0.4024	0.4419	0.1324	0.0712	0.1257	0.4097
	9	0.1085	0.0704	0.0424	0.0464	0.0428	0.0751
	10	0.4808	0.2285	0.2459	0.2154	0.0671	0.5351
	11	0.1661	0.1768	0.1196	0.0846	0.0683	0.1705
	12	0.2021	0.1691	0.1619	0.0909	0.0971	0.1393
	13	0.6404	0.4559	0.3342	0.1536	0.3329	0.467
	14	0.3474	0.2023	0.2735	0.2033	0.234	0.2725

Table 13. RMS EMG Activity during MVIC for Vastus Medialis (mv)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	0.4072	0.4068	0.317	0.3496	0.4975	0.4623
	2	0.2038	0.1403	0.087	0.1044	0.0853	0.194
	3	0.8389	0.7634	0.3975	0.3806	0.4489	0.8736
	4	1.062	1.5294	1.0989	0.85	1.0266	1.4813
	5	0.8764	0.5594	0.6972	0.6661	0.7421	0.8067
	6	1.3143	0.5156	0.6558	0.4083	0.4883	0.6525
	7	1.5485	1.0857	1.0493	0.6794	1.1146	1.5501
	8	1.0782	0.7497	0.7075	0.5432	0.4101	0.6545
	9	0.5373	0.4553	0.2905	0.1713	0.136	0.1321
	10	1.0194	0.6895	0.4019	0.568	0.274	0.8017
	11	0.2984	0.2409	0.2067	0.167	0.1947	0.2755
	12	0.5591	0.5872	0.3503	0.4746	0.5229	0.4921
	13	1.3506	0.9204	0.4918	0.463	0.4857	0.957
	14	0.5003	0.5289	0.2535	0.2936	0.2537	0.3697
Supplemental	1	0.2598	0.2266	0.2661	0.2291	0.1397	0.2602
	2	0.4672	0.4141	0.3122	0.2188	0.3271	0.3565
	3	0.8707	1.2121	1.0129	0.9384	0.9645	0.856
	4	0.7138	0.6291	0.6897	0.4852	0.4349	0.8279
	5	1.0031	0.7064	0.5153	0.5025	0.3962	1.4412
	6	1.1999	0.6137	0.3308	0.5511	0.7103	0.9509
	7	1.1529	1.2531	0.9384	0.8674	0.8049	1.1198
	8	0.595	0.35	0.2446	0.1042	0.2853	0.4715
	9	0.4927	0.259	0.113	0.1071	0.19	0.2729
	10	1.0618	0.4856	0.4637	0.5679	0.2494	1.0387
	11	0.2471	0.1684	0.1641	0.1503	0.1786	0.2323
	12	0.2844	0.2253	0.2753	0.2109	0.158	0.2258
	13	1.4552	0.9085	1.2874	0.3736	0.9528	0.9753
	14	0.673	0.4016	0.5475	0.4845	0.4546	0.7038

Table 14. RMS EMG Activity during MVIC for Vastus Lateralis. (mv)

Session	Subject	Baseline	Fatigue 1	Fatigue 2	Fatigue 3	Fatigue 4	Recovery (10 min)
Control	1	0.2552	0.2591	0.2137	0.2127	0.1908	0.2049
	2	0.3181	0.3427	0.163	0.107	0.1199	0.2759
	3	0.7823	0.67	0.3911	0.32	0.5021	1.0797
	4	0.7076	0.8082	0.8125	0.4731	0.7096	0.8188
	5	0.5433	0.4509	0.4559	0.4181	0.2831	0.4721
	6	0.5059	0.2854	0.284	0.2712	0.2271	0.3763
	7	1.0916	0.843	0.6535	0.7347	0.7758	1.2286
	8	0.3222	0.257	0.2649	0.2208	0.1489	0.3604
	9	0.19	0.1661	0.0949	0.0674	0.0642	0.0942
	10	0.8357	0.5699	0.3841	0.6039	0.2866	0.7278
	11	0.1183	0.5137	0.0832	0.0736	0.0931	0.1213
	12	0.2513	0.2823	0.1485	0.3058	0.2439	0.2005
	13	0.5909	0.4786	0.3478	0.3829	0.3111	0.8001
	14	0.4691	0.456	0.3025	0.1989	0.3693	0.61
Supplemental	1	0.3608	0.3078	0.3182	0.2456	0.2417	0.3038
	2	0.2155	0.1754	0.1513	0.1415	0.1224	0.2549
	3	0.4276	0.4162	0.3153	0.3193	0.3878	0.3805
	4	0.6449	0.6146	0.641	0.4856	0.5689	0.9615
	5	0.5978	0.4987	0.3923	0.4558	0.3446	0.4573
	6	0.4661	0.2612	0.2586	0.3189	0.3878	0.5926
	7	0.7191	0.7304	0.5651	0.6646	0.7469	0.808
	8	0.3822	0.2687	0.2627	0.0954	0.2043	0.4378
	9	0.1615	0.0942	0.0413	0.0478	0.0451	0.107
	10	0.7787	0.6322	0.5259	0.4785	0.1656	0.575
	11	0.2854	0.1991	0.229	0.2005	0.1638	0.3155
	12	0.3651	0.3323	0.4556	0.2729	0.2404	0.2982
	13	0.8795	0.7199	0.654	0.3467	0.5784	0.8779
	14	0.6618	0.4511	0.6007	0.5067	0.5988	0.8687

Appendix B: Statistics

Table 15. Mean data for MVIC Measures (Nm).

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	297.79	56.56	15.12
	Supplemental	14	296.73	79.14	21.15
Fatigue 1	Control	14	257.94	30.58	8.17
	Supplemental	14	261.65	27.10	7.24
Fatigue 2	Control	14	202.88	26.65	7.12
	Supplemental	14	211.21	33.15	8.86
Fatigue 3	Control	14	179.85	28.42	7.59
	Supplemental	14	186.61	32.87	8.78
Fatigue 4	Control	14	171.30	31.95	8.54
	Supplemental	14	179.69	39.00	10.42
Recovery (10 min)	Control	14	229.58	41.50	11.09
	Supplemental	14	240.32	39.91	10.67

Table 16. T-test for Baseline MVIC

	Paired Differences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	*Upper*			
Baseline Control vs Supplemental Session	1.05	44.84	11.98	-24.84	26.94	.088	13	.931

Table 17. Repeated Measure Tests of Within-Subjects Effects MVIC during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	956.515	1	956.515	.426	.525	.032
	Greenhouse-Geisser	956.515	1	956.515	.426	.525	.032
	Huynh-Feldt	956.515	1	956.515	.426	.525	.032
	Lower-bound	956.515	1	956.515	.426	.525	.032
Session*Rep	Sphericity Assumed	446.339	4	111.585	.356	.839	.027
	Greenhouse-Geisser	446.339	1.565	134.436	.356	.805	.027
	Huynh-Feldt	446.339	1.741	111.585	.356	.839	.027
	Lower-bound	446.339	1.000	446.339	.356	.561	.027
Error(Session*Rep)	Sphericity Assumed	16317.564	52	317.799			
	Greenhouse-Geisser	16317.564	43.161	378.061			
	Huynh-Feldt	16317.564	52.000	313.799			
	Lower-bound	16317.564	13.000	1255.197			

Table 18. Repeated Measure Tests of Within-Subjects Effects MVIC Recovery (fatigue 4 vs. recovery; control vs. supplemental).

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	1280.371	1	1280.371	2.100	.171	.139
	Greenhouse-Geisser	1280.371	1	1280.371	2.100	.171	.139
	Huynh-Feldt	1280.371	1	1280.371	2.100	.171	.139
	Lower-bound	1280.371	1	1280.371	2.100	.171	.139
Session*Rep	Sphericity Assumed	19.270	1	19.270	.064	0.804	.005
	Greenhouse-Geisser	19.270	1	19.270	.064	0.804	.005
	Huynh-Feldt	19.270	1	19.270	.064	0.804	.005
	Lower-bound	19.270	1	19.270	.064	0.804	.005
Error(Session*Rep)	Sphericity Assumed	3895.923	13	299.686			
	Greenhouse-Geisser	3895.923	13	299.686			
	Huynh-Feldt	3895.923	13	299.686			
	Lower-bound	3895.923	13	299.686			

Table 19. Mean Data for RTD (Nm/s)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	2171.19	564.39	150.84
	Supplemental	14	2155.96	566.65	151.44
Fatigue 1	Control	14	1848.84	480.15	128.32
	Supplemental	14	2244.54	453.02	121.07
Fatigue 2	Control	14	1486.87	341.86	91.37
	Supplemental	14	1627.61	387.79	103.64
Fatigue 3	Control	14	1268.72	301.53	80.59
	Supplemental	14	1379.89	379.72	101.49
Fatigue 4	Control	14	1148.68	372.05	99.44
	Supplemental	14	1455.44	462.29	123.55
Recovery (10 min)	Control	14	1901.46	622.42	166.35
	Supplemental	14	1936.98	485.10	129.65

Table 20. T-test for Baseline RTD

	Paired Differences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	*Upper*			
Baseline Control vs Supplemental Session	15.22	407.90	109.02	-220.29	250.74	.140	13	.891

Table 21. Repeated Measure Tests of Within-Subjects Effects RTD during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	1234747	1	1234747	7.392	.018	.363
	Greenhouse-Geisser	1234747	1.000	1234747	7.392	.018	.363
	Huynh-Feldt	1234747	1.000	1234747	7.392	.018	.363
	Lower-bound	1234747	1.000	1234747	7.392	.018	.363
Session*Rep	Sphericity Assumed	746732.1	4	186683.0	2.226	.079	.146
	Greenhouse-Geisser	746732.1	3.154	236754.7	2.226	.079	.146
	Huynh-Feldt	746732.1	4.000	186683.0	2.226	.079	.146
	Lower-bound	746732.1	1.000	746732.1	2.226	.079	.146
Error(Session*Rep)	Sphericity Assumed	4361355	52	83872.2			
	Greenhouse-Geisser	4361355	41.002	106368.2			
	Huynh-Feldt	4361355	52.000	83872.2			
	Lower-bound	4361355	13.000	335488.9			

Table 22. Repeated Measure Tests of Within-Subjects Effects RTD during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	410041.2	1	410041.2	2.090	.172	.138
	Greenhouse-Geisser	410041.2	1.000	410041.2	2.090	.172	.138
	Huynh-Feldt	410041.2	1.000	410041.2	2.090	.172	.138
	Lower-bound	410041.2	1.000	410041.2	2.090	.172	.138
Session*Rep	Sphericity Assumed	257490.8	1	257490.8	1.693	.216	.115
	Greenhouse-Geisser	257490.8	1.000	257490.8	1.693	.216	.115
	Huynh-Feldt	257490.8	1.000	257490.8	1.693	.216	.115
	Lower-bound	257490.8	1.000	257490.8	1.693	.216	.115
Error(Session*Rep)	Sphericity Assumed	1977197	13	152092.1			
	Greenhouse-Geisser	1977197	13.000	152092.1			
	Huynh-Feldt	1977197	13.000	152092.1			
	Lower-bound	1977197	13.000	152092.1			

Table 23. Mean Data for Impulse 200 ms (Ns)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	27.18	5.79	1.75
	Supplemental	14	26.13	6.74	1.80
Fatigue 1	Control	14	20.76	5.79	1.55
	Supplemental	14	25.10	4.67	1.25
Fatigue 2	Control	14	16.68	3.51	0.94
	Supplemental	14	18.20	4.13	1.10
Fatigue 3	Control	14	14.41	2.96	0.79
	Supplemental	14	16.69	5.15	1.38
Fatigue 4	Control	14	13.83	3.92	1.05
	Supplemental	14	14.51	4.69	1.25
Recovery (10 min)	Control	14	22.53	4.82	1.29
	Supplemental	14	23.21	5.97	1.59

Table 24. T-test for Baseline Impulse 200 ms

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig.(2-tailed)
				Lower	*Upper*			
Baseline Control vs Supplemental Session	-1.32	4.36	1.16	-3.84	1.19	-1.14	13	0.276

Table 25. Repeated Measure Tests of Within-Subjects Effects Impulse during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	135.08	1	135.08	28.94	.000	.690
	Greenhouse-Geisser	135.08	1	135.08	28.94	.000	.690
	Huynh-Feldt	135.08	1	135.08	28.94	.000	.690
	Lower-bound	135.08	1	135.08	28.94	.000	.690
Session*Rep	Sphericity Assumed	23.34	4	5.84	0.623	0.648	0.046
	Greenhouse-Geisser	23.34	3.541	6.59	0.623	0.629	0.046
	Huynh-Feldt	23.34	4.000	5.84	0.623	0.648	0.046
	Lower-bound	23.34	1.000	23.34	0.623	0.444	0.046
Error(Session*Rep)	Sphericity Assumed	486.94	52	9.36			
	Greenhouse-Geisser	486.94	46.03	10.58			
	Huynh-Feldt	486.94	52.00	9.36			
	Lower-bound	486.94	13.000	37.48			

Table 26. Repeated Measure Tests of Within-Subjects Effects Impulse during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	6.20	1	6.20	0.56	0.468	0.041
	Greenhouse-Geisser	6.20	1	6.20	0.56	0.468	0.041
	Huynh-Feldt	6.20	1	6.20	0.56	0.468	0.041
	Lower-bound	6.20	1	6.20	0.56	0.468	0.041
Session*Rep	Sphericity Assumed	4.87	1	4.87	0.24	0.63	.115
	Greenhouse-Geisser	4.87	1	4.87	0.24	0.63	.115
	Huynh-Feldt	4.87	1	4.87	0.24	0.63	.115
	Lower-bound	4.87	1	4.87	0.24	0.63	.115
Error(Session*Rep)	Sphericity Assumed	1977197	13	152092.1			
	Greenhouse-Geisser	1977197	13.000	152092.1			
	Huynh-Feldt	1977197	13.000	152092.1			
	Lower-bound	1977197	13.000	152092.1			

Table 27. Mean Data for Resting Twitch Torque (Nm)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	75.03	13.55	3.62
	Supplemental	14	75.59	15.36	4.10
Fatigue 1	Control	14	49.53	14.50	3.87
	Supplemental	14	48.91	12.16	3.25
Fatigue 2	Control	14	31.74	10.34	2.76
	Supplemental	14	35.50	11.45	3.10
Fatigue 3	Control	14	28.13	9.95	2.66
	Supplemental	14	32.09	12.80	3.42
Fatigue 4	Control	14	27.06	9.54	2.55
	Supplemental	14	29.26	11.90	3.18
Recovery (10 min)	Control	14	52.76	15.76	4.21
	Supplemental	14	52.33	14.83	3.96

Table 28. T-test for Baseline Resting Twitch

	Paired Differences							
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig.(2-tailed)
				Lower	*Upper*			
Baseline Control vs Supplemental Session	-0.57	13.03	3.48	-8.09	6.96	-0.16	13	0.874

Table 29. Repeated Measure Tests of Within-Subjects Effects Resting Twitch Torque during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	136.40	1	136.40	1.64	0.22	0.11
	Greenhouse-Geisser	136.40	1	136.40	1.64	0.22	0.11
	Huynh-Feldt	136.40	1	136.40	1.64	0.22	0.11
	Lower-bound	136.40	1	136.40	1.64	0.22	0.11
Session*Rep	Sphericity Assumed	111.16	4	27.79	0.84	0.51	0.06
	Greenhouse-Geisser	111.16	2.30	48.45	0.84	0.46	0.06
	Huynh-Feldt	111.16	2.81	39.50	0.84	0.48	0.06
	Lower-bound	111.16	1	111.16	0.84	0.38	0.06
Error(Session*Rep)	Sphericity Assumed	1723.90	52	33.15			
	Greenhouse-Geisser	1723.90	29.83	57.78			
	Huynh-Feldt	1723.90	36.59	47.12			
	Lower-bound	1723.90	13	132.61			

Table 30. Repeated Measure Tests of Within-Subjects Effects Resting Twitch Torque during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	11.04	1	11.04	0.72	0.41	0.05
	Greenhouse-Geisser	11.04	1	11.04	0.72	0.41	0.05
	Huynh-Feldt	11.04	1	11.04	0.72	0.41	0.05
	Lower-bound	11.04	1	11.04	0.72	0.41	0.05
Session*Rep	Sphericity Assumed	24.24	1	24.24	0.93	0.35	0.07
	Greenhouse-Geisser	24.24	1	24.24	0.93	0.35	0.07
	Huynh-Feldt	24.24	1	24.24	0.93	0.35	0.07
	Lower-bound	24.24	1	24.24	0.93	0.35	0.07
Error(Session*Rep)	Sphericity Assumed	337.90	13	25.99			
	Greenhouse-Geisser	337.90	13	25.99			
	Huynh-Feldt	337.90	13	25.99			
	Lower-bound	337.90	13	25.99			

Table 31. Mean Data for Corrected Voluntary Activation (%)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	99.24	1.10	0.29
	Supplemental	14	98.85	1.72	0.46
Fatigue 1	Control	14	99.38	1.28	0.24
	Supplemental	14	99.05	1.16	0.31
Fatigue 2	Control	14	98.50	2.02	0.54
	Supplemental	14	97.23	7.83	2.09
Fatigue 3	Control	14	99.36	1.28	0.34
	Supplemental	14	97.87	3.12	0.84
Fatigue 4	Control	14	98.71	1.75	0.47
	Supplemental	14	97.41	3.74	1.00
Recovery (10 min)	Control	14	97.32	3.40	0.91
	Supplemental	14	97.81	2.53	0.68

Table 32. T-test for Baseline Corrected Voluntary Activation

	Paired Differences					t	df	Sig.(2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	*Upper*			
Baseline Control vs Supplemental Session	0.39	1.27	0.34	-0.34	1.13	1.15	13	0.27

Table 33. Repeated Measure Tests of Within-Subjects Effects Corrected Voluntary Activation during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	32.01	1.00	32.01	2.01	0.18	0.13
	Greenhouse-Geisser	32.01	1.00	32.01	2.01	0.18	0.13
	Huynh-Feldt	32.01	1.00	32.01	2.01	0.18	0.13
	Lower-bound	32.01	1.00	32.01	2.01	0.18	0.13
Session*Rep	Sphericity Assumed	8.49	4.00	2.12	0.23	0.92	0.02
	Greenhouse-Geisser	8.49	1.57	5.42	0.23	0.75	0.02
	Huynh-Feldt	8.49	1.74	4.87	0.23	0.77	0.02
	Lower-bound	8.49	1.00	8.49	0.23	0.64	0.02
Error(Session*Rep)	Sphericity Assumed	486.25	52.00	9.35			
	Greenhouse-Geisser	486.25	20.37	23.87			
	Huynh-Feldt	486.25	22.67	21.45			
	Lower-bound	486.25	13.00	37.40			

Table 34. Repeated Measure Tests of Within-Subjects Effects Corrected Voluntary Activation during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	2.26	1.00	2.26	0.16	0.69	0.01
	Greenhouse-Geisser	2.26	1.00	2.26	0.16	0.69	0.01
	Huynh-Feldt	2.26	1.00	2.26	0.16	0.69	0.01
	Lower-bound	2.26	1.00	2.26	0.16	0.69	0.01
Session*Rep	Sphericity Assumed	11.27	1.00	11.27	2.74	0.12	0.17
	Greenhouse-Geisser	11.27	1.00	11.27	2.74	0.12	0.17
	Huynh-Feldt	11.27	1.00	11.27	2.74	0.12	0.17
	Lower-bound	11.27	1.00	11.27	2.74	0.12	0.17
Error(Session*Rep)	Sphericity Assumed	53.40	13.00	4.11			
	Greenhouse-Geisser	53.40	13.00	4.11			
	Huynh-Feldt	53.40	13.00	4.11			
	Lower-bound	53.40	13.00	4.11			

Table 35. Mean Data for Peak Isotonic Power Baseline Measurements (Watts)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
1 Nm	Control	14	555.10	85.41	22.83
	Supplemental	14	551.93	154.33	41.25
10%	Control	14	568.25	107.00	28.60
	Supplemental	14	549.95	119.59	31.96
20%	Control	14	550.46	84.53	22.59
	Supplemental	14	536.59	121.85	32.57
30%	Control	14	597.31	74.65	19.95
	Supplemental	14	568.39	80.23	21.44
40%	Control	14	563.04	71.93	19.22
	Supplemental	14	545.78	82.82	22.13
50%	Control	14	571.49	92.55	24.74
	Supplemental	14	560.52	91.88	24.56
60%	Control	14	581.15	87.80	23.47
	Supplemental	14	531.46	73.43	19.62

Table 36. Mean Data for Peak Isotonic Power Recovery Measurements (Watts)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
1 Nm	Control	14	519.80	112.00	29.93
	Supplemental	14	503.10	128.38	34.31
10%	Control	14	488.79	69.90	18.68
	Supplemental	14	470.98	102.21	27.32
20%	Control	14	505.20	99.12	26.49
	Supplemental	14	462.47	96.16	25.70
30%	Control	14	499.47	84.88	22.69
	Supplemental	14	469.33	95.35	25.48
40%	Control	14	516.62	94.63	25.29
	Supplemental	14	470.26	71.27	19.05
50%	Control	14	512.95	66.10	17.67
	Supplemental	14	488.43	75.29	20.12
60%	Control	14	481.36	72.80	19.46
	Supplemental	14	471.33	90.38	24.15

Table 37. Repeated Measures test of Within Subjects Effects for Peak Isotonic Power baseline and recovery.

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	54612.76	1.00	54612.76	3.77	0.07	0.23
	Greenhouse-Geisser	54612.76	1.00	54612.76	3.77	0.07	0.23
	Huynh-Feldt	54612.76	1.00	54612.76	3.77	0.07	0.23
	Lower-bound	54612.76	1.00	54612.76	3.77	0.07	0.23
Session*Intensity	Sphericity Assumed	5820.30	6.00	970.05	0.22	0.97	0.02
	Greenhouse-Geisser	5820.30	2.55	2286.60	0.22	0.85	0.02
	Huynh-Feldt	5820.30	3.22	1809.07	0.22	0.89	0.02
	Lower-bound	5820.30	1.00	5820.30	0.22	0.64	0.02
Error(Session*Intensity)	Sphericity Assumed	338080.75	78.00	4334.37			
	Greenhouse-Geisser	338080.75	33.09	10216.97			
	Huynh-Feldt	338080.75	41.83	8083.26			
	Lower-bound	338080.75	13.00	26006.21			
Session*Intensity*Time	Sphericity Assumed	11607.09	6.00	1934.52	0.55	0.77	0.04
	Greenhouse-Geisser	11607.09	3.68	3154.75	0.55	0.69	0.04
	Huynh-Feldt	11607.09	5.31	2185.18	0.55	0.75	0.04
	Lower-bound	11607.09	1.00	11607.09	0.55	0.47	0.04
Error(Session*Intensity*Time)	Sphericity Assumed	273610.07	78.00	3507.82			
	Greenhouse-Geisser	273610.07	47.83	5720.45			
	Huynh-Feldt	273610.07	69.05	3962.34			
	Lower-bound	273610.07	13.00	21046.93			

Table 38. Mean Data for EMG RMS Rectus Femoris (mv)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	0.36	0.15	0.04
	Supplemental	14	0.36	0.16	0.04
Fatigue 1	Control	14	0.27	0.12	0.03
	Supplemental	14	0.29	0.15	0.04
Fatigue 2	Control	14	0.19	0.09	0.02
	Supplemental	14	0.22	0.11	0.03
Fatigue 3	Control	14	0.20	0.13	0.03
	Supplemental	14	0.18	0.11	0.03
Fatigue 4	Control	14	0.16	0.09	0.02
	Supplemental	14	0.19	0.13	0.03
Recovery (10 min)	Control	14	0.32	0.17	0.05
	Supplemental	14	0.34	0.15	0.04

Table 39. Repeated Measure Tests of Within-Subjects Effects EMG Rectus Femoris during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	501.28	1.00	501.28	0.98	0.34	0.07
	Greenhouse-Geisser	501.28	1.00	501.28	0.98	0.34	0.07
	Huynh-Feldt	501.28	1.00	501.28	0.98	0.34	0.07
	Lower-bound	501.28	1.00	501.28	0.98	0.34	0.07
Session*Rep	Sphericity Assumed	836.28	4.00	209.07	1.08	0.38	0.08
	Greenhouse-Geisser	836.28	3.10	269.76	1.08	0.37	0.08
	Huynh-Feldt	836.28	4.00	209.07	1.08	0.38	0.08
	Lower-bound	836.28	1.00	836.28	1.08	0.32	0.08
Error(Session*Rep)	Sphericity Assumed	10074.88	52.00	193.75			
	Greenhouse-Geisser	10074.88	40.30	249.99			
	Huynh-Feldt	10074.88	52.00	193.75			
	Lower-bound	10074.88	13.00	774.99			

Table 40. Repeated Measure Tests of Within-Subjects Effects EMG Rectus Femoris during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	1119.38	1.00	1119.38	4.46	0.06	0.26
	Greenhouse-Geisser	1119.38	1.00	1119.38	4.46	0.06	0.26
	Huynh-Feldt	1119.38	1.00	1119.38	4.46	0.06	0.26
	Lower-bound	1119.38	1.00	1119.38	4.46	0.06	0.26
Session*Rep	Sphericity Assumed	39.22	1.00	39.22	0.11	0.74	0.01
	Greenhouse-Geisser	39.22	1.00	39.22	0.11	0.74	0.01
	Huynh-Feldt	39.22	1.00	39.22	0.11	0.74	0.01
	Lower-bound	39.22	1.00	39.22	0.11	0.74	0.01
Error(Session*Rep)	Sphericity Assumed	4512.12	13.00	347.09			
	Greenhouse-Geisser	4512.12	13.00	347.09			
	Huynh-Feldt	4512.12	13.00	347.09			
	Lower-bound	4512.12	13.00	347.09			

Table 41. Mean Data for EMG RMS Vastus Medialis. (mv)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	0.83	0.42	0.11
	Supplemental	14	0.75	0.38	0.10
Fatigue 1	Control	14	0.66	0.35	0.09
	Supplemental	14	0.56	0.35	0.09
Fatigue 2	Control	14	0.50	0.30	0.08
	Supplemental	14	0.51	0.35	0.09
Fatigue 3	Control	14	0.44	0.21	0.06
	Supplemental	14	0.41	0.27	0.07
Fatigue 4	Control	14	0.48	0.31	0.08
	Supplemental	14	0.45	0.29	0.08
Recovery (10 min)	Control	14	0.69	0.43	0.12
	Supplemental	14	0.69	0.39	0.11

Table 42. Repeated Measure Tests of Within-Subjects Effects EMG Vastus Medialis during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	18.95	1.00	18.95	0.02	0.88	0.00
	Greenhouse-Geisser	18.95	1.00	18.95	0.02	0.88	0.00
	Huynh-Feldt	18.95	1.00	18.95	0.02	0.88	0.00
	Lower-bound	18.95	1.00	18.95	0.02	0.88	0.00
Session*Rep	Sphericity Assumed	1013.23	4.00	253.31	1.01	0.41	0.07
	Greenhouse-Geisser	1013.23	3.35	302.63	1.01	0.40	0.07
	Huynh-Feldt	1013.23	4.00	253.31	1.01	0.41	0.07
	Lower-bound	1013.23	1.00	1013.23	1.01	0.33	0.07
Error(Session*Rep)	Sphericity Assumed	13003.57	52.00	250.07			
	Greenhouse-Geisser	13003.57	43.53	298.76			
	Huynh-Feldt	13003.57	52.00	250.07			
	Lower-bound	13003.57	13.00	1000.28			

Table 43. Repeated Measure Tests of Within-Subjects Effects EMG Vastus Medialis during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	165.50	1.00	165.50	0.37	0.55	0.03
	Greenhouse-Geisser	165.50	1.00	165.50	0.37	0.55	0.03
	Huynh-Feldt	165.50	1.00	165.50	0.37	0.55	0.03
	Lower-bound	165.50	1.00	165.50	0.37	0.55	0.03
Session*Rep	Sphericity Assumed	231.81	1.00	231.81	0.58	0.46	0.04
	Greenhouse-Geisser	231.81	1.00	231.81	0.58	0.46	0.04
	Huynh-Feldt	231.81	1.00	231.81	0.58	0.46	0.04
	Lower-bound	231.81	1.00	231.81	0.58	0.46	0.04
Error(Session*Rep)	Sphericity Assumed	5239.60	13.00	403.05			
	Greenhouse-Geisser	5239.60	13.00	403.05			
	Huynh-Feldt	5239.60	13.00	403.05			
	Lower-bound	5239.60	13.00	403.05			

Table 44. Mean Data for EMG RMS Vastus Lateralis. (mv)

MVIC	Session	N	Mean	Std. Dev.	Std. Error
Baseline	Control	14	0.50	0.28	0.08
	Supplemental	14	0.50	0.22	0.06
Fatigue 1	Control	14	0.46	0.21	0.06
	Supplemental	14	0.41	0.21	0.06
Fatigue 2	Control	14	0.33	0.21	0.06
	Supplemental	14	0.39	0.19	0.05
Fatigue 3	Control	14	0.31	0.20	0.05
	Supplemental	14	0.33	0.18	0.05
Fatigue 4	Control	14	0.31	0.22	0.06
	Supplemental	14	0.34	0.21	0.06
Recovery (10 min)	Control	14	0.53	0.36	0.10
	Supplemental	14	0.52	0.27	0.07

Table 45. Repeated Measure Tests of Within-Subjects Effects EMG Vastus Lateralis during fatiguing task (control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	488.06	1.00	488.06	0.38	0.55	0.03
	Greenhouse-Geisser	488.06	1.00	488.06	0.38	0.55	0.03
	Huynh-Feldt	488.06	1.00	488.06	0.38	0.55	0.03
	Lower-bound	488.06	1.00	488.06	0.38	0.55	0.03
Session*Rep	Sphericity Assumed	8004.35	4.00	2001.09	1.89	0.13	0.13
	Greenhouse-Geisser	8004.35	1.31	6130.91	1.89	0.19	0.13
	Huynh-Feldt	8004.35	1.39	5750.47	1.89	0.19	0.13
	Lower-bound	8004.35	1.00	8004.35	1.89	0.19	0.13
Error(Session*Rep)	Sphericity Assumed	55211.91	52.00	1061.77			
	Greenhouse-Geisser	55211.91	16.97	3253.03			
	Huynh-Feldt	55211.91	18.10	3051.17			
	Lower-bound	55211.91	13.00	4247.07			

Table 46. Repeated Measure Tests of Within-Subjects Effects EMG Rectus Lateralis during Recovery (fatigue 4 vs. recovery; control-supplemental session)

		Type III SS	df	MS	F	Sig.	η^2p
Session	Sphericity Assumed	203.54	1.00	203.54	0.72	0.41	0.05
	Greenhouse-Geisser	203.54	1.00	203.54	0.72	0.41	0.05
	Huynh-Feldt	203.54	1.00	203.54	0.72	0.41	0.05
	Lower-bound	203.54	1.00	203.54	0.72	0.41	0.05
Session*Rep	Sphericity Assumed	6.78	1.00	6.78	0.02	0.88	0.00
	Greenhouse-Geisser	6.78	1.00	6.78	0.02	0.88	0.00
	Huynh-Feldt	6.78	1.00	6.78	0.02	0.88	0.00
	Lower-bound	6.78	1.00	6.78	0.02	0.88	0.00
Error(Session*Rep)	Sphericity Assumed	3638.28	13.00	279.87			
	Greenhouse-Geisser	3638.28	13.00	279.87			
	Huynh-Feldt	3638.28	13.00	279.87			
	Lower-bound	3638.28	13.00	279.87			