Assessing the effect of psychological priming techniques on salivary hormones and physical performance markers

Collins, J.M.

Assessing the effect of psychological priming techniques on salivary hormones and physical performance markers

James M. Collins, MSc, MSc, BSc, ASCC, CSCS

A thesis submitted to the Faculty of Science and Technology in fulfillment of the requirements for the degree of Doctor of Philosophy

(March 2024)

Director of Studies: Professor Anthony Turner

Supervisors: Dr. Christopher Bishop and Dr. Frank Hills

SUBMISSION FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

This work is being submitted in fulfillment of the degree of Doctor of Philosophy within the field of strength and conditioning.

I certify that this work has not been previously submitted or accepted for the fulfillment of any degree and is not currently being submitted in candidature for any other program. I further certify that the whole of this work is the result of my individual efforts unless otherwise stated. All quotations from books and journals have been acknowledged, and a reference list is appended.

I hereby consent for my thesis, if accepted, to be available for photocopying and inter-library loan and for the title and summary to be made to outside organizations.

I hereby give consent to the University to electronically store and copy the thesis in any approved medium or format for the purpose of future preservation and accessibility.

I hereby consent that upon deposition in the digital repository, the thesis is to be made available to a wide variety of people and institutions, including automated agents and search engines via the Internet.

I hereby consent for the thesis to be incorporated into public access catalogs or services, such as national databases of electronic theses.

Signed: Student: James M. Collins

Date: 26/03/2024

Signed: Director of Studies: Anthony N. Turner

Date: 26/03/2024

ABSTRACT

Testosterone and cortisol have contrasting anabolic and catabolic effects on the musculoskeletal system and altering effects on metabolism and psychological behavior. A literature review was undertaken as part of this thesis to synthesize current research on these hormones' production, regulation, and effects. Testosterone is a potent, naturally secreted androgenic anabolic hormone essential for muscle growth through protein synthesis, inhibiting muscular breakdown, altering muscular strength, metabolic regulation, and behavioral modulation through altered motivation and risk-taking. Cortisol is essential for producing energy due to a stress response from hypoglycemia, exercise, or a fight-or-flight response, and is also essential in the process of muscular hypertrophy. It is also a modulator of status-relevant behavior due to the dual-hormone hypothesis with testosterone. This hypothesis states that the relationship between these two hormones is cyclical, with either hormone inhibiting the others' effects when their concentration levels are high; for strength and conditioning coaches, understanding these hormones is critical for effective training programming.

The potentiation of testosterone through methods such as listening to music or performing physical movements prior to undertaking an athletic endeavor is known as priming. Potentially, when an individual is primed, their performance level could improve due to higher levels of motivation and risk-taking. However, a protocol to achieve this potentiation similar to a physical warm-up protocol is lacking. Therefore, a systematic review and meta-analysis were completed as part of this thesis to examine the current body of literature pertaining to the priming of testosterone before undertaking a physical performance test. Findings showed that testosterone could be primed, which subsequently improved physical performance markers.

Five peer-reviewed articles with 147 subjects met the inclusion criteria relating to testosterone priming in the defined sporting context. The findings of this systematic review and meta-analysis indicate that the viewing of a positive video clip in the presence of a smaller stranger significantly ($p < 0.05$) raises testosterone by 50% (g = 2.90, 95% confidence intervals (CI) 2.56, 3.23), a bigger stranger by 21% (g = 1.00, 95% CI 0.75, 1.25), a bigger friend by 20% (g = 1.10 95% CI 0.85, 1.35), and a smaller friend by 8% (g = 0.49, 95% CI 0.26, 0.73). Similar was found when viewing alone a positive video clip by 11% (g = 0.88, 95% CI 0.64, 1.12) or a successful short video clip by 12% (g = 0.87, 95% CI 0.62,

1.11) and being in the presence an attractive female observer by 39% (g = 0.67, 95% CI 0.61, 0.72). Finally, increased testosterone improved performance makers in skateboard tricks, rugby performance, a three-repetition maximum back squat (3RM), and bench press. On the contrary, aggressive video clips gave mixed results: testosterone rose by 10% (g = 0.67, 95% CI 0.43, 0.90) prior to performing a 3RM squat, with only a trivial finding of 1% (g = 0.03, 95% CI -0.20, 0.26) in men and -10% (g = -0.36, 95% CI -0.56, -0.16) in women before measuring hand grip strength and countermovement jump (CMJ) height. Additionally, the results highlighted a need for more literature regarding testosterone priming. Most primers implemented were video clips, with only one other stimulus recorded in this review, which was the presence of a female observer. Therefore, a wide range of priming techniques and subjects are required to add to the limited data already collected.

Due to the small number of studies found, the aim of Study 1 was to examine the frequency and modes of psychological priming techniques and strategies currently being implemented by athletes of various performance levels. A 15-question, anonymous survey was developed and shared via social media. Ninety subjects met the inclusion criteria, which were made up of 11 professional, 17 semi-professional, and 54 amateur-level athletes, with seven not competing. Priming strategies were implemented by 79% of subjects without using a coach, 10% used strategies with their coach, and 11% did not prime. For athletes, music was the preferred choice (27%), followed by instructional self-talk (24%), motivational self-talk (23%), applied physical actions (20%), and watching video clips (6.3%). For athletes that implemented a priming strategy via a coach, their preferred technique was motivational statements, with 55% implementing this technique, followed by 27% utilizing inspiring team talks, and only 18% playing music. Of those implementing a priming strategy, 66% found them to be either “very” or “extremely effective.” 38% of subjects felt priming accomplished this through increased motivation, 22% felt it reduced their fear and anxiety, 21% thought it improved their intensity, 15% felt it increased strength and power, and 2% thought it improved endurance. The chi-square test also found a significant (φc = 0.27; p = 0.011) relationship with using priming to increase motivation. These results demonstrate that priming strategies are being used irrespective of coach intervention; therefore, educating coaches and athletes on implementing priming techniques has its place when aiming to improve athlete performance.

Study 2 built on the results of the systematic review and meta-analysis, and Study 1, by investigating the priming effect of listening to self-selected music (SSM) or implementing motivational self-talk with imagery (MSTI) prior to performing a maximal strength 3RM back squat. Endocrine markers of salivary testosterone and cortisol concentrations were investigated to identify whether either strategy invoked a change in their concentration levels to explain the mechanisms at work should differences in 3RM across interventions be noted. Due to the COVID-19 pandemic, participation numbers for the following studies were affected. As a result, fifteen healthy collegiate adult subjects with a mean age of 22.5 ± 5.8 years, 173.5 ± 8.2 centimeters (cm) tall, and a mass of 71.7 ± 9.2 kilograms (kg) undertook the test. A repeated measures ANOVA revealed no statistically significant differences in 3RM, testosterone, or cortisol markers in SSM or MSTI groups. However, using Hedges *g* effect size analysis, there were small increases in 3RM back squat performance in MSTI and SSM conditions (*g* = 0.22, 95% CI -0.10, 0.54, and *g* = 0.26, 95% CI -0.23, 0.75 respectively) compared to a control (CON). SSM and MSTI increased testosterone levels compared to CON (*g* = 0.66, 5% CI -0.06, 1.37 and *g* = 0.39, 95% CI -0.27, 1.06, respectively), while trivial changes were observed in cortisol levels. Therefore, a small practical difference occurred in the testosterone: cortisol (TC) ratio in MSTI and SSM (*g* = 0.23, 95% CI -0.41, 0.87 and *g* = 0.31, 95% CI -0.34, 0.96 respectively). In summary, strategies such as SSM and MSTI may prime a healthy adult's performance during training sessions, such that they can increase training intensity; this may be due to increases in testosterone and its potential effect on motivation and risk-taking.

As a result of motivational self-talk (MST) and SSM recording a small effect size increase in the 3RM back squat, the third study investigated the effect of these priming techniques on an upper body performance marker. A bench press exercise was implemented for four sets of four repetitions (reps) at a four-repetition maximum (4RM) intensity. Endocrine markers of salivary testosterone and cortisol concentrations were investigated to identify whether either strategy invoked a change in their concentration levels to explain the mechanisms at work should differences in the four sets of four repetitions across the interventions be noted. Twenty-one healthy collegiate adults with a mean age of 23.0 ± 3.5 years, 176.2 ± 3.9 cm tall, and a mass of 75.3 ± 9.0 kg participated in this study. No statistically significant differences across interventions were found in the 4RM, cortisol, and testosterone markers. Using Hedges *g* effect size, trivial differences in volume load lifted against CON in SSM and MST were found (*g* = 0.09, 95% CI -0.42, 0.59, and *g* = 0.06, 95% CI -0.45, 0.57, respectively). Average barbell velocity demonstrated a trivial increase when comparing MST to CON (*g* = 0.15, 95% CI -0.36, 0.65), but a trivial decrease when SSM (*g* = -0.14, 95% CI -0.65, 0.37) was implemented. Salivary testosterone concentration levels incurred a large increase after MST (*g* = 1.04, 95% CI 0.50, 1.58) and SSM (*g* = 0.85, 95% CI 0.32, 1.38) interventions. Salivary cortisol concentrations produced moderate changes after SSM and MST conditions (*g* = 0.81, 95% CI 0.28, 1.34, and *g* = 0.78, 95% CI 0.25, 1.30, respectively). In summary, no statistically significant results were found. However, meaningful, practical differences were found with the volume of load lifted increasing over the four sets by 31.26 kg and 21.56 kg in SSM and MST, respectively. Therefore, these changes could potentially equate to notable differences over time, with increased testosterone concentration levels potentially driving small load increases.

Research has noted that physical performance markers can improve when being observed. As athletes are observed during performances, Study 4 investigated the observer effect of being viewed in person (OE). Additionally, in recent years, social media has grown in popularity; therefore, being observed virtually via social media (SMO) was also investigated. While warming up, subjects were observed, salivary testosterone and cortisol concentration levels and a subsequent 65% 1RM back squat exercise to repetition failure were tested to assess whether these primers affect a muscular endurance marker as no statistically significant results had been reported in the maximal strength performance markers. Additionally, being primed may assist in pushing through the “muscular burn” felt when performing muscular endurance repetitions rather than maximal strength repetitions. Back squat reps and bar velocity (m/s) were measured, along with the endocrine salivary concentration levels and their ratios. No statistically significant results were found across twelve healthy collegiate adult subjects with a mean age of 22.4 ± 2.9 years,175.0 ± 5.2 cm tall, and a mass of 76.6 ± 7.0 kg. However, using Hedges *g* effect size, practical differences were noted. A moderate increase in testosterone in SMO (*g* = 0.79, 95% CI -0.12, 1.46) was recorded, but only a trivial difference in OE (*g* = 0.06, 95% CI -0.58, 0.71) compared to CON. The SMO condition produced a lower cortisol rise (*g* = 0.09, 95% CI -0.56, 0.73) than OE (*g* = 0.22, 95% CI -0.43, 0.87) and CON. As a result, the TC ratio noted a moderate change in SMO (*g* = 0.58, 95% CI -0.08, 1.24) and OE (*g* = 0.10, 95% CI -0.55, 0.74) compared to CON. The SMO condition produced the most reps performed at 17.50 ± 6.14 reps (*g* = 0.43, 95% CI -0.22, 1.08), OE 17.33 ± 6.72 reps (*g* = 0.38, 95% CI -0.27, 1.03) compared to CON 14.83 ± 5.19 reps. With a small increase in mean bar velocity in both interventions, SMO = 0.49 m/s (*g* = 0.27, 95% CI -0.37, 0.92) and OE = 0.49 m/s (*g* = 0.28, 95% CI -0.37, 0.92) compared to CON = 0.47 m/s. In summary, no statistically significant differences were noted. However, practical differences were. Filming subjects for social media appears to have a greater effect on back squat bar velocity and completed repetitions, along with a higher testosterone and TC ratio than the control and the observer effect. Therefore, performance levels may improve if implemented throughout a training program.

The final study sought to investigate the priming effect of listening to SSM, implementing MSTI, and being observed through SMO before performing a muscle endurance sixteen-repetition maximum back squat (16RM). The barbell average velocity was recorded throughout the back squat, and prior to this, isometric mid-thigh pull (IMTP) and a CMJ were measured. Endocrine markers of salivary testosterone and cortisol concentrations were also taken to investigate the possible underpinning psychophysiological mechanisms at work. Twenty-eight healthy collegiate subjects with a mean age of 28.9 ± 8.0 years, 167.7 ± 34.8 cm tall, and a mass of 78.3 ± 12.5 kg partook in the study. Due to subject availability, not all subjects performed all interventions. Therefore, individual intervention results were measured alongside subjects who completed all three interventions (Trio). Results revealed a significant increase in load lifted in SSM 65.07 ± 5.09 kg (g = 0.55, 95% CI -0.12, 0.99, p < 0.001) vs. CON 50.00 ± 4.42 kg, MSTI 61.14 ± 6.45 kg (g = 0.56, 95% CI -0.12, 1.00, p = 0.007) vs. CON 48.57 ± 4.76 kg and SMO 59.14 ± 5.86 kg (g = 0.55, 95% CI -0.08, 1.01, p = 0.01) vs. CON 47.86 ± 4.80 kg. The Trio group also recorded statistically significant results in SSM 68.10 ± 6.64 kg (g = 0.85, 95% CI -0.05, 1.74, p = 0.001), and MSTI 64.50 ± 8.21 kg (g = 0.60, 95% CI -0.52, 1.72, p = 0.02) vs. CON 50.00 ± 5.73 kg, but not SMO 59.50 ± 7.87 kg (g = 0.40, 95% CI -0.82, 1.63). All other markers and tests did not produce significant changes except for a reduction in peak power during the CMJ in the MSTI intervention (p = 0.04, g = -0.23, 95% CI -0.73, -0.23 (3661.86 ± 277.07 W) compared to control (4307.21 ± 284.66 W)). Moderate to large effect size reductions occurred in cortisol levels in the Trio group (ST g = -0.98, 95% CI -1.98, 0.01 (82%)), with SSM and SMO noting moderate changes (g = -0.68, 95% CI -1.68, 0.32 (93%) and g = -0.67, 95% CI -1.42, 0.09, (88%), respectively) vs. CON (131%). Testosterone levels did not produce any notable changes. In summary, SSM, MSTI, and SMO may prime a healthy adult's performance for muscular endurance exercises but not for maximal strength and power during training sessions. Improvements may result from cortisol concentration levels reducing, as cortisol moderates the effect of testosterone and its subsequent impact on motivation and risk-taking behavior changes.

In conclusion, the findings from this thesis suggest that i) healthy adults are already innately implementing priming techniques to improve performance through listening to music and motivational self-talk and physical actions; ii) priming can improve muscular strength and endurance performances but not maximal muscular strength and power in healthy adults; iii) the underpinning mechanisms for this effect may potentially be the rise in testosterone to increase motivation and subsequent risk-taking to increase the load placed on the barbell to lift more than they initially thought was possible. Simultaneously, the modulation of cortisol to increase the TC ratio appears equally important due to the hormones working in tandem. Further research is required to understand the efficacy of priming more fully.

ACKNOWLEDGMENTS

I would like to dedicate this Ph.D. to my family. Firstly, to my fiancée Rowan, who has been incredibly supportive throughout my academic endeavors. Putting up with my time away from our son Kitt, who was born during this undertaking. And to Kitt for allowing Daddy to sit at his laptop rather than playing with him and his blocks. Secondly, to my parents, who have believed and supported me no matter my area of interest. From moving to New York to work in fashion to my undertaking four degrees back in England. Their love and support had never wavered. Sadly, my father will not see me accomplish this goal as he passed away during the second year of this Ph.D.

I want to express my sincere gratitude to my supervisory team, they have pulled me up to the required standard, and without them, I would not be where I am today. Firstly, my director of studies, Professor Anthony Turner, I will never be able to repay him for his patience and guidance with me. When I was at my lowest point, COVID-19 was affecting my progress, my father had very recently passed, my son was due to be born, and I was questioning whether I could continue; he was always there with the correct words of encouragement, and I will forever be grateful. Secondly, Dr. Christopher Bishop's unrivaled honesty and critiquing elevated my writing to a standard I did not envisage I had, even if it did take some time before I could handle the feedback. Thirdly, Dr. Frank Hills's knowledge and true scientific knowledge are awe-inspiring. I cannot thank him enough for putting up with my endless endocrine testing questions. I am sure he wondered what he had signed up for at times. I would also like to thank Abbie Spiegelhalter for assisting me in collecting data. Without her help, I would not be at this stage in this time frame. Her assistance was invaluable. Lastly, I would like to thank all the subjects who willingly signed up to partake. Without them, none of this would have been possible. So, I am eternally grateful for the time they gave me.

PUBLICATIONS FROM THIS THESIS

Peer-Reviewed Manuscripts

Collins J. Bishop C, Hills F, Speigelhalter A, Cohen R, Turner A. A survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance. Journal of strength and conditioning research. 37: 107-113, 2022.

Peer-Reviewed Conference Presentations

Collins J (2021). A Survey into the use of Priming Techniques Implemented by Athletes and Coaches to Improve Athletic Performance. Postgraduate researchers' summer conference. Middlesex University, London, UK. July

TABLE OF CONTENTS

Chapter 9, Study 5 – A series of acute psychological priming interventions assessing changes in hormonal and physical performance measures

Chapter 10, – Conclusions, Practical Applications, and Directions for Future Research

LIST OF TABLES

LIST OF FIGURES

Chapter 1 PREFACE

1.1 Introduction

Within sports science, the steroid hormone testosterone has predominantly been researched for its effects on the neuromuscular system, primarily focusing on its anabolic effects on muscle mass, strength, and subsequent improvements in sporting performance (Fink et al., 2017). However, testosterone has also been linked to its influence on social and psychological traits, notably increased motivation (Cook et al., 2013). For example, Apicella et al. (2014) showed elevated bioactive testosterone (mean 27.82 picograms per millimeter (pg/ml)) raises financial future risk-taking during monetary gambling, regardless of whether they had previously won (raised by 33.00 pg/ml) or not (raised by 22.43 pg/ml) in 49 men. Therefore, controversy about the exact role testosterone plays in improving physical attributes is widely noted, with various studies reporting conflicting results, with some claiming its role through protein synthesis and others through its psychological adaptions (Kraemer et al., 2017; Mangine et al., 2017; Mobley et al., 2018; Morton et al., 2018).

Before competition or training, performing a warm-up is a widely accepted practice to physically prepare for an upcoming event (Jeffreys, 2007). To achieve this, Jeffreys (2007) suggested the “RAMP” warm-up protocol to “raise” the heart rate, “activate” and “mobilize” muscles and joints, and “potentiate” the effectiveness of the subsequent performance task. However, the mental aspect of warming up appears to lack a similar emphasis and protocol. Strength-based athletes, such as weightlifters, have been known to “psych” themselves before performing (Tod et al., 2005). “Psyching-up” can be described as a self-directed strategy used immediately prior to or during a skill execution to enhance physical performance (Tod et al., 2003). These methods are often referred to as “priming.” There appears to be a paucity of literature examining and explaining the underpinning mechanisms of priming. Changes in testosterone are associated with changes in motivation, power, risk-taking, competition, violence, dominance, seeking status, social and sexual interaction, increased risk-taking, and reduced fear (Mazur & Booth, 1998; McCall & Singer, 2012; Stanton et al., 2011; van Honk et al., 2005). Therefore, if testosterone is primed before performing a physical task, greater risk-taking and motivation could occur, which could subsequently improve performance, as Cook and Crewther (2012b) reported when 12 professional rugby players significantly ($p < 0.001$) increased load lifted in a 3RM back squat after watching various video clips.

The mental preparation will typically involve the implementation of cognitive and behavioral techniques. Behavioral techniques are not based on a conscious mental strategy, such as listening to music (Karageorghis & Priest, 2012). Ishak et al. (2020) report that endocrine changes occur when music is listened to, with alterations in testosterone, cortisol, and oxytocin concentration levels, which may induce the positive effects noted. Karageorghis et al. (2013) reported a significant 2% improvement in a 200 m freestyle time trial while listening to asynchronous music (the music does not match the pace of the activity) in 20 collegiate swimmers. Cognitive techniques involve various structured psychological frameworks; these include imagery, self-talk, goal setting, arousal, and attentional control (Perkins et al., 2001; Slimani et al., 2016; Tod et al., 2015). For example, Lebon et al. (2010) reported significant strength gains in nine sports students after implementing mental imagery strategies during rest periods between sets in 12 training sessions over six weeks. The subjects visualized their muscles contracting for the sled leg press. The number of repetitions completed at 80% of 1RM increased by 17.75 reps, representing eight more than the control group (d = 0.7) (Lebon et al., 2010). Interestingly, Cook and Crewther (2012b) investigated testosterone's response to a priming technique of viewing a training video clip to 12 professional rugby players prior to undertaking a 3RM back squat. Testosterone increased by 8.4%, with back squat load lifted increasing by 4.6%, and cortisol increased by 5.5%

Testosterone is produced via the hypothalamus-pituitary axis, which consists of a dual hormone relationship; cortisol acts as an antagonist to testosterone, inhibiting its production (Cook & Crewther, 2014; Brownlee et al., 2005; Cumming et al., 1983). Increases in cortisol occur in response to physical or psychological stress (Brownlee et al., 2005). Therefore, the modulation of cortisol may be just as significant as priming testosterone. For example, Cook and Crewther (2012) reported that 12 professional rugby players produced their worst match performance (as rated by the head coach) when cortisol was significantly high (17.6%, p <0.01) and testosterone low (-0.7%) compared to baseline. In contrast, the best performance ratings occurred when testosterone was significantly high (12.5%, p <0.001) and cortisol low (1.0%). Therefore, priming may be as much about raising testosterone as it is suppressing cortisol. Providing strength and conditioning coaches (S&C) with an understanding of priming strategies, their underpinning mechanisms, and their potential benefits may prompt them to consider using them for performance enhancement.

1.2 Overview of Thesis and Chapter/Study Outlines

This thesis is structured as a series of investigations researching the effect of acute psychological priming interventions on salivary endocrine measures of testosterone and cortisol and their subsequent impact on physical performance markers.

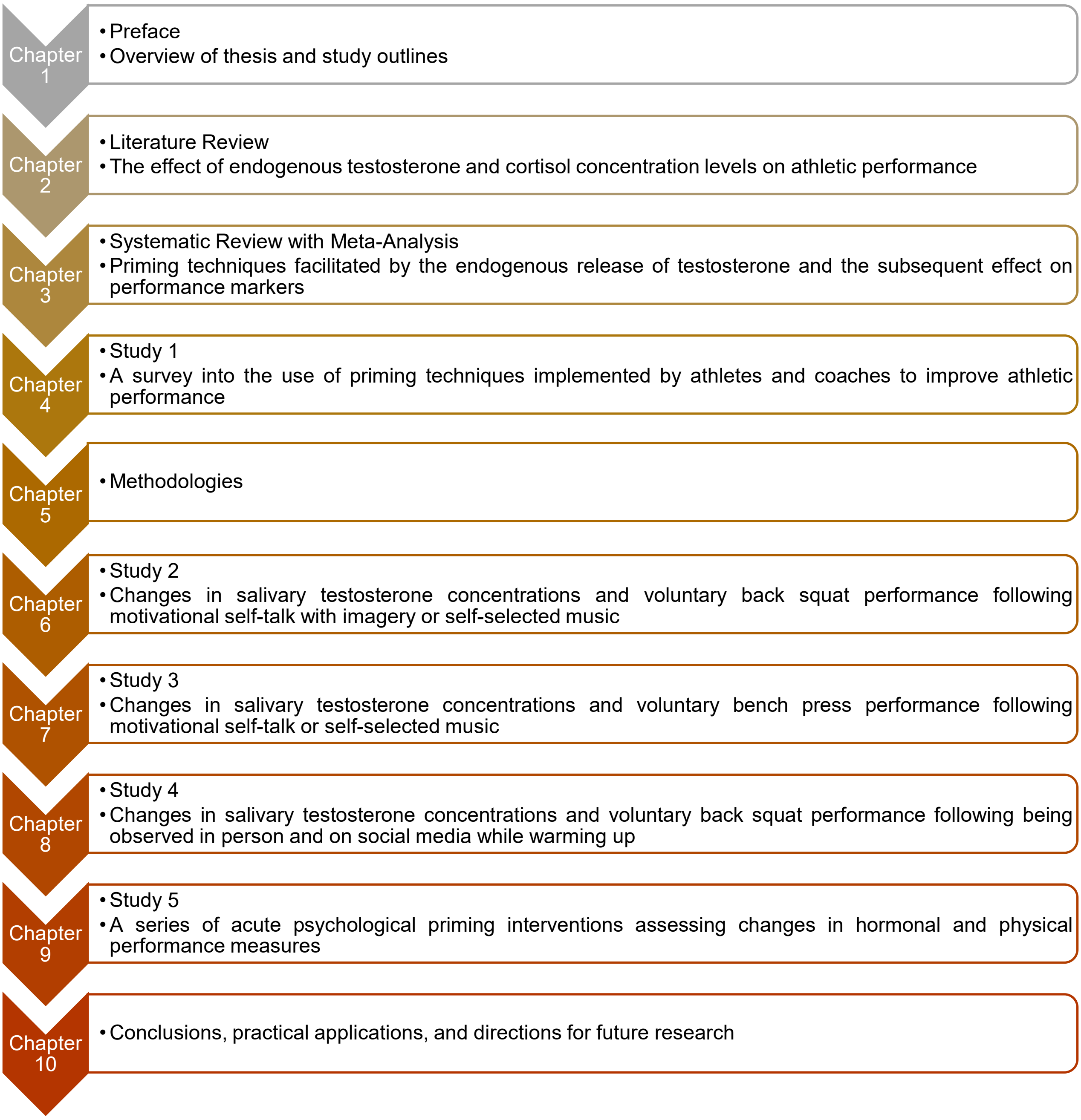

Figure 1.1 Schematic overview of chapters in the thesis.

Chapter 2: Literature Review

The effect of endogenous testosterone and cortisol concentration levels on athletic performance

This literature review explores the roles of testosterone and cortisol in athletic performance, focusing on their musculoskeletal, metabolic, and psychological effects. Testosterone, an anabolic hormone, enhances muscle growth, protein synthesis, and neuromuscular performance while influencing behavior related to motivation and risk-taking. Conversely, cortisol, a catabolic hormone, is crucial for stress response, immune regulation, and metabolism, promoting gluconeogenesis and lipolysis. The balance between these hormones, known as the testosterone-cortisol ratio, is essential for optimizing anabolic and catabolic states, affecting muscle mass, energy availability, and psychological responses.

Chapter 3: Systematic Review with Meta-Analysis

Priming techniques facilitated by the endogenous release of testosterone and the subsequent effect on performance markers: A Systematic Review with Meta-Analysis.

Testosterone has long been linked with its anabolic effects; however, few have analyzed its ability to be primed and its subsequent impact on physical performance. A systematic review and meta-analysis of the literature were undertaken using CINAHL, MEDLINE, and SPORT Discuss databases, along with Google Scholar and ResearchGate. Five studies met the inclusion criteria of a medium-grade PEDro scale result. The findings showed that implementing the priming techniques of video clips and being observed in person can significantly raise testosterone levels and subsequent performance markers. With such a limited number of studies, further investigations using a more extensive array of subjects and techniques are warranted.

Chapter 4: Study 1

A survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance.

The role of an S&C coach is to enhance athletic performance and mitigate the risk of injury through periodized exercise prescription. What has been given less consideration is how coaches can directly affect athlete training effort, behavior, and motivation. As the systematic review and meta-analysis revealed, research into priming strategies is limited.

Therefore, this study distributed a survey to athletes of varying abilities to better understand whether any form of priming was being implemented. If so, what were these strategies, and was there any coach involvement? Harnessing strategies already implemented by athletes could lead to greater performance improvements than prescriptive priming strategies. Understanding the evidence may assist in optimizing training interventions that aim to enhance athletic performance.

Chapter 5: Methodologies

Collating the gleaned information from the systematic review and meta-analysis and Study 1, Study 2,3,4, and 5 were designed to implement the same methodology, with priming techniques and physical performance tests being the variable factor. As a result, a better understanding of the efficacy of the priming techniques and their effects on various tests could be obtained. This chapter outlines the overall methodology and the various interventions implemented.

Chapter 6: Study 2

Changes in salivary testosterone concentrations and voluntary back squat performance following motivational self-talk with imagery or self-selected music.

During the research for this thesis, the Covid-19 pandemic broke out, which affected subject numbers. Therefore, participation in the following studies was lower than anticipated.

Before competition or training, performing a warm-up is a widely accepted practice to physically prepare for an upcoming event. To achieve this, a “RAMP” protocol has been established. The mental aspect of warming up lacks an equivalent protocol. Pre-competition speeches by coaches are routine to try to motivate and instill confidence, as is the use of sports psychology techniques, such as MSTI, to boost self-esteem, manage stress, and provide focus. When athletes are without a coach or sports psychologist, the implementation of priming is lacking. To bridge the gap in the literature, this study aimed to investigate the psychological interventions and priming capability of listening to SSM or engaging in MSTI on testosterone concentration levels and its subsequent 3RM back squat performance against a control condition. The release of cortisol was investigated to explain the mechanisms at work given these hormones' antagonistic relationship on account of a dual-hormone hypothesis. Cortisol has been reported to have an inhibitory effect on testosterone production. It is hypothesized that these psychological methods will decrease cortisol and increase testosterone, producing surges in risk-taking and consequently enhancing performance in the back squat.

Chapter 7: Study 3

Changes in salivary testosterone concentrations and voluntary bench press performance following motivational self-talk or self-selected music.

Leading on from Study 2, this study investigated the priming effects of SSM or MST without imagery on salivary testosterone and cortisol concentration levels and its impact on a subsequent bench press exercise for four sets of four reps at a load of 4RM. Barbell velocity was additionally tested, as this could be more sensitive to small but meaningful changes in performance, as potentially adding more load may not be possible, but repetition velocity may be. We posit that with a music soundtrack that resonates with the athlete and is of a high tempo (126+ bpm) or with MST, the athlete will become “psyched-up,” which will positively affect the strength-based training session.

Chapter 8: Study 4

Changes in salivary testosterone concentrations and subsequent voluntary back squat performance following being observed in person and on social media while warming up.

Predominantly, athletes perform their sporting endeavors in front of audiences. Research suggests that being observed can positively affect performance levels depending on the task. Additionally, in recent years, social media has enabled a virtual observer to be present during performances. Thus, in this study, the priming capabilities of performing a warm-up in the presence of observers, both in-person and virtually via SMO, were investigated. This time, a subsequent 65% 1RM back squat to repetition failure was used to test the efficacy of the primers. Having to perform more reps may induce more motivation to complete. Motivation may not be powerful enough to induce an extra rep at > 90% 1RM. Testosterone and cortisol concentration levels were also tested to note any changes.

Chapter 9: Study 5

A series of acute psychological priming interventions assessing changes in hormonal and physical performance measures.

Due to the subject participation numbers being below the minimum of 24 subjects established from a priori power analysis, a fifth and final study was implemented to add to the data already collected. Following on from the previous study, a 16RM back squat was tested again, with the addition of IMTP and a CMJ to test the efficacy of the priming tools of SSM, MSTI, and being observed via SMO on maximal strength, neuromuscular power, testosterone, and cortisol concentration levels. It is hypothesized that these psychological methods will decrease cortisol and increase testosterone, producing altered psychological and cognitive processing and enhancing performance in the back squat, IMTP, and CMJ.

Chapter 10: Conclusion, Practical Applications, and Directions for Future Research

This chapter summarizes the key findings from each of the studies in the upcoming chapters. It additionally outlines areas for future research to add to the current literature on testosterone priming for improved athletic performance.

Chapter 2 LITERATURE REVIEW

2.0 The effect of endogenous testosterone and cortisol concentration levels on athletic performance

2.1 Introduction

Hormones are essential biochemical messengers transported to target cells to facilitate communication within the body (Turner et al., 2010). Among the hormones that influence physical capabilities, testosterone, and cortisol are particularly significant due to their contrasting anabolic and catabolic effects (Vingren et al., 2012). An understanding of these hormones will assist strength and conditioning coaches on the consequences of manipulating them, allowing them to design and implement training programs to optimize the effects. This literature review will explore the musculoskeletal, metabolic, and psychological effects of testosterone and cortisol and their intricate interactions, providing an overview for enhancing athletic performance.

2.2 Overview of Testosterone

Testosterone is an anabolic, androgenic steroid hormone produced by the Leydig cells in the testes and Theca cells in the ovaries from substrates cholesterol and acetate (Tyagi et al., 2017). In men, the innermost layer of the adrenal cortex, the zona reticularis, secretes prohormone substrates dehydroepiandrosterone (DHEA) and DHEA-sulfate to contribute minimally to the testosterone pool (Tyagi et al., 2017). In women, additions to the testosterone pool come from the zona fasciculata of the adrenal cortex via conversion from progesterone and from peripheral tissues such as breast muscle, bone, and fat (Burger, 2002). The release of testosterone follows the circadian rhythm, which peaks in sleep and is lowest in the late afternoon, with a superimposed ultradian rhythm every ninety minutes (Wittert, 2014). The synthesis of testosterone in the testicular and ovarian tissues is regulated by the Luteinizing hormone and follicle-stimulating hormone from the pituitary, which is stimulated by the gonadotropin-releasing hormone from the hypothalamus via stimulation from the central nervous system (Tyagi et al., 2017; Vingren et al., 2012). In healthy adults, 60% of the testosterone distribution pool is bound to sex hormone-binding globulin, 38% to albumin, and 2% is in its free biological state (Brooks, 1975; Turner, 2010). The former two are unable to enter the intracellular environment. Free testosterone, however, can diffuse through cell membrane walls into the cytoplasm, bind with the intracellular androgen receptors, enter the nucleus, and, in turn, bind with the nucleotide of chromosomal DNA and exert androgenic effects, altering the expression of thousands of genes (Gharahdaghi et al., 2021; Turner, 2010; Vanni & Moon, 2015). Testosterone is responsible for developing secondary male sex characteristics and spermatogenesis and preserving reproductive organs through adulthood (Tyagi et al., 2017). Pertinent to this literature review, it also affects the musculoskeletal and metabolic systems and modulates behavior.

2.3 Musculoskeletal system

Romagnoli et al. (2020) report that 40 – 45% of body mass is skeletal muscle. It is fundamental to athletic performance, physical function, and metabolic health, and low muscle mass has been found to be associated with greater mortality in adults (Lim et al., 2022). Testosterone has been associated with increased muscle cross-sectional area through the accrual of cellular proteins within pre-existing muscle fibers, increased muscle protein synthesis, and intramuscular amino acid uptake to exceed muscle protein breakdown to improve net protein balance (Gharahdaghi et al., 2021; Vingren et al., 2012; Lim et al., 2022). Furthermore, testosterone increases mynuclei content in the muscle cells, which enhances the capacity to synthesize protein, including contractile proteins (Hayes et al., 2010). For example, Gharahdaghi et al. (2019) report that muscle protein accretion significantly (p = 0.007) increased when exogenous testosterone was administered in eighteen 65 – 75-year-old men for six weeks while undertaking resistance exercise, compared to the control group who received a placebo injection (8.3 g vs. 1.9 g). Also, when acute testosterone was administered, protein synthesis significantly (p = 0.009) increased by 34.4% in six healthy prepubertal boys (Mauras et al., 1994). Kvorning et al. (2007) reported that in twenty-two young men when endogenous testosterone is inhibited through inhibiting gonadotropin-releasing hormone for eight weeks, attenuation in muscle mass occurs even while undertaking resistance exercise. Inoue et al. (1994) reported that impaired muscle growth occurs when androgen receptor antagonists inhibit endogenous testosterone from binding to androgen receptors. Finally, it has been reported that testosterone has stimulating effects on releasing other anabolic hormones, such as growth hormone and insulin-like growth factor (IGF)-1 (Vingren et al., 2012); both are potent anabolic hormones, with IGF-1 directly increasing gene transcription via the mammalian target rapamycin (mTOR) pathway. Together, these results suggest that the androgen pathway affects muscle protein synthesis. Interestingly, mixed results have been reported when correlating testosterone, resistance training, and increased skeletal muscle hypertrophy. For example, West and Phillips (2012) found no correlation ($r = 0.14$) between testosterone and skeletal muscle hypertrophy in 56 young men after 12 weeks of resistance exercise training. However, 30 cross-trained female subjects significantly ($p < 0.01$) increased testosterone concentration levels acutely after performing three sets of ten repetitions for eight exercises (Copeland et al., 2002). Furthermore, Ahtiainen et al. (2003) significantly correlated acute testosterone responses and changes in muscle cross-sectional area ($r = 0.76$, $p < 0.05$) after 21 weeks in eight physically active men. Lim et al. (2022) report that potentially the limiting factor in the efficacy of testosterone effects is the androgen receptor content in skeletal muscle. For example, Morton et al. (2018) found no correlation between testosterone and skeletal muscle hypertrophy in 49 resistance-trained men after 12 weeks of resistance exercise training. However, they did find a significant correlation between androgen receptor content and muscle cross-sectional area ($r = 0.51$, $p < 0.01$). Additionally, resistance training has been shown to increase androgen receptor binding with DNA, which in turn improves anabolic signaling. These could be the reason for the variations in reported results regarding testosterone, resistance training, and skeletal muscle hypertrophy.

The nervous system is also affected by testosterone as it can bind with receptors on neurons, thereby offering neuroprotection via the regeneration of structures, cells, and function, along with adaptions to the neuromuscular junction (Bialek et al., 2004; Turner, 2010). Furthermore, it is linked with increasing neuron somal size, plasticity, dendrite length, and diameter (Nagaya & Herrera, 1995). Testosterone can also increase the release of catecholamines which consist of neurotransmitters adrenaline, noradrenaline, and dopamine, which stimulate the central motor system, secretion of growth hormone and IGF-1, muscular enzyme activity, promote energy availability, and augment vascular dilation by modulating blood pressure and modulating the redistribution of blood, all of which alter contractile qualities of skeletal muscle leading to an increase in instantaneous recruitment of muscle mass and subsequently muscular strength (Turner, 2010; Kraemer et al., 1991; Tod et al., 2003). Additionally, a rise in catecholamine levels prior to exercise is called the “anticipatory” response, and the magnitude of the rise equates to the anticipated intensity (Turner, 2010). This rise alters intracellular calcium levels in muscle fibres and neurons (Turner, 2010). Chin et al. (2012) reported that 335 Malaysian Chinese and Malay men aged 40 years and above found a significant ($p < 0.05$) relationship between handgrip strength and testosterone (β = 0.142). Almeido-Neto et al. (2020) reported that testosterone could be related to neuromuscular performance when they investigated 37 young male Brazilian athletes; they reported that those with a higher testosterone level showed significantly (p = 0.08) higher neuromuscular strength levels when performing squat jumps (r = 0.28). Raastad et al. (2000) reported a significant ($p < 0.001$) rise in testosterone (17.4%) compared to baseline when performing front and back squats for three sets of three repetitions at an intensity of three repetition maximum.

2.4 Metabolic

Changes in testosterone concentration levels have been associated with several metabolic effects. When testosterone is low, impaired insulin sensitivity, increased body fat percentage, truncal obesity, hypertension, dyslipidemia, and cardiovascular disease can occur (Kelly & Jones, 2013; Kapoor et al., 2007; Ding et al., 2006). Additionally, testosterone has been shown to inhibit catecholamine-induced lipolysis in abdominal subcutaneous adipose tissue due to a reduction in the expression of β_2-adrenoceptors and hormone-sensitive lipase, which can affect fat metabolism and storage (Dicker et al., 2004; Arner, 2005; Rebuffe-Scrive et al., 1991). However, when testosterone is not low, its effect is pertinent to strength and conditioning. It has been shown to stimulate glycogenesis and inhibit glycolysis in muscle tissue by influencing the expression of glucose transporters and enzymes (Ramamani et al., 1999; Grossman, 2014). Furthermore, testosterone has been shown to inhibit the reduction in muscle glycogen stores during exercise (Breda et al., 2003), suggesting that testosterone may play a role in preventing the breakdown of muscle glycogen stores. Interestingly, Devries (2015) reported that testosterone concentration levels did not affect the amount of muscle glycogen released during exercise. Instead, they reported that estrogen levels were the mediating factor during endurance exercise. However, research into testosterone's effects on metabolic pathways during human exercise is limited. Therefore, conclusions cannot be made on the efficacy of testosterone during exercise on metabolic actions.

2.5 Behavior

Testosterone concentration levels also affect the brain. The effects are crucial for brain development, sexual development, altered mood, and decision-making and are responsible for differences between sexes (Estumano et al., 2019; van Wingen et al., 2010). Barth et al.

(2015) suggest that areas of the brain rich in sex hormone receptors, such as the hippocampus, cerebellum, amygdala, and frontal cortex, can be reshaped by testosterone. Interestingly, these areas can become larger in men than women (Pletzer, 2019). These effects can lead to altered behavior through an upregulation in testosterone secretion, which affects the amygdala functioning (Derntl et al., 2009). The amygdala, responsible for vigilance and arousal, is part of the orbitofrontal cortex within the prefrontal cortex, which regulates its functioning (Derntl et al., 2009; van Wingen et al., 2010; Hermans & van Honk, 2008). Testosterone reduces this regulatory control over the amygdala, enhancing coupling with the thalamus instead, which is responsible for relaying sensory cues, which has been shown to increase risk-taking and reduce vigilance (Derntl et al., 2009). This can activate the mesolimbic-dopaminergic pathways in the nucleus accumbens (Hermans et al., 2010). Therefore, increases in testosterone may increase motivation, risk-taking, aggression, status-seeking behavior, sexual promiscuity, and reduced fear (Hermans & van Honk. 2008; Ronay & Von Hippel, 2010; von Honk et al., 2005; Maestripieri et al., 2014; Eisenegger et al., 2011). Furthermore, the psychologically induced "anticipatory" rise in catecholamines, which drives increased force expression (Turner, 2010), is potentially enhanced by testosterone's stimulation of catecholamines. This highlights the implementation of psyching up pre-exercise to develop optimal force (Turner, 2010). Suay et al. (1999) reported a positive correlation (r = 0.42) between testosterone levels before and after a judo competition and motivation to win in 28 male fighters. Mazur & Booth (1998) suggest a feedback loop between testosterone levels and future behavior, with high testosterone stimulating competition, and a reduction would reduce engagement in any potentially damaging encounters. This was corroborated by Cook and Crewther (2012) when 12 professional rugby players viewed either a video clip of themselves with positive feedback or an opposition player performing successful skills with cautionary feedback. A significant ($p < 0.05$) testosterone increase of 12.2% occurred when the former was undertaken and correlated with better player performance scores, as rated by the head coach, during the subsequent match ($r = 0.81$, $p = 0.001$). The latter intervention experienced only a 0.7% rise in testosterone. It resulted in a player performance that was deemed so poor that the coaches refused to undertake a planned second intervention. Therefore, testosterone levels may influence competitive behavior through motivation to perform, risk-taking, and aggression.

2.6 Overview of cortisol

The hypothalamus-pituitary-adrenal axis controls the release of the steroid hormone cortisol. The sympathetic nervous system stimulates the hypothalamus, which synthesizes and releases corticotropin-releasing factor from the paraventricular nucleus to the anterior pituitary gland (Turner, 2010; Thau et al., 2023). This, in turn, releases the adrenocorticotrophic hormone, which acts on the adrenal cortex to release cortisol bound to either corticosteroid-binding globulin or albumin into the bloodstream (Turner, 2010; Thau et al., 2023). The release of cortisol functions on a negative feedback loop, whereby sufficient cortisol levels inhibit the release of adrenocorticotrophic and corticotropin-releasing hormones (Turner, 2010; Thau et al., 2023). Additionally, the hypothalamus-pituitary-adrenal axis follows the circadian rhythm; as a result, cortisol concentration levels are highest in the morning and lowest at night (Thau et al., 2023).

Most tissues in the body have glucocorticoid receptors; therefore, cortisol affects nearly every organ and system (Kadmiel & Cidlowski, 2013). These include the immune, nervous, respiratory, cardiovascular, musculoskeletal, reproductive, and integumentary systems (Thau et al., 2023). Cortisol secretion occurs due to a stress response from hypoglycemia, exercise, or a fight-or-flight response (Turner, 2010). Its role is to mediate the stress response and regulate immune, metabolism, and inflammatory function (Oakley & Cidlowski, 2013).

2.7 Musculoskeletal system

In strength and conditioning, acute catabolic mechanisms from cortisol release due to the incidence of stress from exercise can be regarded positively if the goal is increased muscular hypertrophy. As exercise is initiated, the sympathetic nervous system activates the adrenal glands to release a surge of catecholamines, resulting in increased heart and respiratory rates (Thau et al., 2023). This perceived threat releases cortisol to enable the body to stay on high alert by providing the required energy availability (Thau et al., 2023). To do this, cortisol initiates gluconeogenesis in the liver, a metabolic pathway to produce glucose from glucogenic amino acids, lactate, or glycerol 3-phosphate from triglycerides (Kuo et al., 2015; Thau et al., 2023). Additionally, cortisol can produce energy through glycogenolysis through epinephrine-induced activation of glycogen phosphorylase (Kamgang et al., 2023). Therefore, when cortisol is present, muscle cells decrease glucose uptake and utilization, and protein degradation increases instead. Turner (2010) states that this skeletal muscle catabolism may be essential for muscular remodeling because the muscle requires disruption for adaptions to occur. However, training goals should be varied to allow the adrenal gland to recover and avoid overtraining, whereby cortisol release becomes chronic and immune system depression remains (Turner, 2010). Cortisol suppresses B cell antibody production and reduces neutrophil migration during inflammation due to these functions being perceived as less important than energy production in times of a perceived threat (Kadmiel & Cidlowski, 2013). Lastly, regarding muscular hypertrophy, anaerobic metabolism acts as a potent stimulus for cortisol release (Turner, 2010); altering training variables to achieve this may achieve greater muscle hypertrophy results.

Hayes et al. (2010) document that even though cortisol is reportedly crucial in adaptations to resistance training, there needs to be more literature to provide evidence of the effect. West and Phillips (2011), however, did report a significant association between cortisol elevations and an increase in Type II muscle fibre area ($r = 0.35$, $p < 0.01$) in 56 young men during a 12-week resistance training study. In another study by Kraemer (1993), nine eumenorrheic female subjects performed either five sets at a 5RM with three minutes of rest or three sets at a 10RM with one minute of rest between sets. Both protocols included the bench press, double leg extension, military press, bent leg incline sit-ups, seated rows, lateral pull-down, arm curls, and leg press. Regardless of the exercise protocol, the participants experienced significant ($p < 0.05$) increases in cortisol post-exercise (Kraemer et al., 1993). Interestingly, Bailey et al. (2021) report that several studies suggest that cortisol's response to resistance training is merely a response to training and has no direct effect on skeletal muscle adaptions. Additionally, Bailey et al. (2021) reported that in 41 elite junior sprint athletes and non-athletes across a season, CSA was reduced by 2.8% and that training-induced cortisol levels had a significant ($p < 0.05$) influence on muscular adaptions. As this was a longitudinal study across a season, potentially the subjects were experiencing chronic high cortisol levels, which created a prolonged catabolic environment, as opposed to an acute secretion, to create minor muscle breakdown for muscular adaptions. These results indicate the need for further investigation.

2.8 Metabolism

Maintaining blood glucose is a primary function of glucocorticoids (Wang et al., 2016). Therefore, in addition to its role in gluconeogenesis and glycogenolysis, cortisol generates energy through lipolysis. This catabolic process involves the release of glycerol as a precursor for gluconeogenesis and free fatty acids in adipose tissue for beta-oxidation and for other cells to use for energy (Christiansen et al., 2007; Thau et al., 2023). Divertie et al. (1991) reported that cortisol or saline was administered to subjects over six hours. Subjects that received cortisol increased lipolysis by 60%. Djurhuus et al. (2002) corroborate this as they state that unmistakably cortisol is a potent stimulus of lipolysis as they report a significant (p = 0.01) rise in lipolysis when cortisol was administered to subjects compared to a control (165 vs. 92 micromol/min). Furthermore, cortisol acts on decreasing insulin secretion by pancreatic beta cells and increasing the production of the peptide glucagon from alpha cells of the pancreatic islets of Langerhans in the pancreas (Kamgan et al., 2023; Rix et al., 2019). Glucagon affects liver glycogenolysis, gluconeogenesis, ketogenesis, and lipolysis and decreases lipogenesis (Thau et al., 2023). Cortisol is a counter-regulatory hormone to insulin; therefore, insulin resistance can occur if cortisol remains chronically high (Kamgan et al., 2023).

Endogenous triacylglycerols are the largest energy reserve in the human body, with 60 times the amount of glycogen stored (Muscella et al., 2020). With 17,500 mmol stored in adipose tissue, 300 mmol in skeletal muscle, and 0.5 mmol in plasma in a lean adult male (Muscella et al., 2020; Horowitz & Klein, 2000). The amount of free fatty acids stored within triglycerides is unknown; however, a significant quantity can be used during exercise (Muscella et al., 2020; Ranallo & Rhodes, 1998). Fat and carbohydrate contribution to energy production depends on exercise intensity, duration, training condition, diet, and body composition (Muscell et al., 2020). Purdom et al. (2018) report that the majority of energy supplied from free fatty acids comes between intensities of 45% to 70% of maximal aerobic capacity (VO_2max), with endurance-trained experiencing greater lipolysis compared to untrained subjects (Klein et al., 1994). Neiman et al. (2017) reported that in 24 male runners, fat oxidation increased when running at 70% VO_2max until exhaustion (average 24.9 km), as did cortisol by 95%. Interestingly, Aslankeser and Balc (2017) reported fat oxidation was significantly ($p < 0.05$) 17 times higher in ten athlete subjects compared to eight untrained subjects during a high-intensity intermittent test on a cycle ergometer at an intensity of 80% VO_2max. Therefore, releasing cortisol during aerobic exercise may benefit performance by lipolysis occurring.

2.9 Behavior

Due to the involvement of the hypothalamus-pituitary-adrenal axis in psychological stress, cortisol levels rise when a stressful event occurs (Kluen et al., 2017). Glucocorticoids modulate cognitive functions, including decision-making and risk-taking behavior (Kluen et al., 2017). Cortisol binds with mineralocorticoid and glucocorticoid receptors in the prefrontal-limbic circuits of emotion regulation (Putman et al., 2010), where many receptors are located (Lupien & Lepage, 2001). Studies have also shown that cortisol affects the hippocampus (Stark et al., 2006; Roozendaal, 2002), impairing memory retrieval while enhancing memory consolidation (Stark et al., 2006; Wolf, 2003). These adverse effects have also been associated with reduced cerebral blood flow in the medial temporal lobe (de Quervain et al., 2003). Additionally, Roozendaal (2002) reports that the amygdala mediates both effects. Cortisol enhances the consolidation of fearful and emotional memory, suggesting a specific effect on the amygdala (Drevets et al., 2002; Zorawski & Killcross, 2002), indicating enhanced amygdala and reduced hippocampal functioning when cortisol is high (Stark et al., 2006). Furthermore, an inverse correlation between the prefrontal cortex and amygdala functioning when reacting to fear-related stimuli was noted (Stark et al., 2006). Van Ast et al. (2012) reported that after administering 20 mg of hydrocortisone to 42 healthy subjects prior to undertaking a contextual fear-conditioning paradigm, they reported that fear significantly (p = 0.019) increased in women who received the hydrocortisone. Additionally, Kandasamy et al. (2014) observed subjects becoming more risk-averse when receiving hydrocortisone to raise cortisol levels to 68% of their daily mean, which is the level reported that financial traders experience prior to undertaking a financial risk-taking exercise. Interestingly, they also reported that men began overweighting small probabilities compared to women. Lastly, in a review researching the effects of stress on decision-making, the authors report that stress can impair decision-making, creating competition between emotional and cognitive functioning (Yu, 2016). Rossi et al. (2022) report that the mood state of an athlete prior to competition potentially affects results, with anxiety being a key marker identified. This has been corroborated by higher cortisol levels associated with athletes who have lost compared to winners, such as Rossi et al. (2024), who reported that winners of a volleyball match had a significantly (p = 0.01) lower cortisol level compared to the losers whose cortisol levels had only marginally dropped immediately post-match (166.01 vs 291.59 U/ml).

2.10 TC Ratio

It is proposed that testosterone secretions occur when cortisol secretions are low and vice versa. This relationship has been named the dual-hormone hypothesis. When testosterone levels are high, and cortisol levels are low, testosterone has been positively related to status-seeking behaviors such as competitive, dominant, aggressive, risk-taking, and sexual behaviors (Dekkers et al., 2019). The model predicts that testosterones status-seeking behaviors are inhibited when cortisol is high. Mehta and Josephs (2010) reported that 94 undergraduate students were videotaped in a leadership position. Those who demonstrated dominant behavior had statistically significant ($p < 0.05$) high testosterone concentrations and low cortisol, and those with high cortisol had a non-significant relationship with testosterone levels. Furthermore, Hermans et al. (2008) reported that testosterone admission increased amygdala reactivity to angry faces. Van Honk et al. (1998) noted the opposite effect, whereby high cortisol levels lead subjects' attention away when confronted with angry stimuli. This reciprocal inhibition has been termed functional crosstalk between the hypothalamus-pituitary-adrenal axis (HPA-axis) and the hypothalamus-pituitary-gonadal axis (HPG-axis) (Dekkers et al., 2019). The HPA-axis can suppress the secretion of gonadotropin-releasing hormone, and the HPG-axis inhibits arginine vasopressin synthesis (Salvador, 2012; Dekkers et al., 2019). Additionally, cross-talk has a second mechanism whereby inhibition can be achieved. At the nuclear-receptor level, one axis can block the other axis's receptor; for example, glucocorticoids can decrease androgen receptor synthesis (Dekkers et al., 2019). Therefore, when the stress system is activated, this may overrule gonadal functions. Hamilton et al. (2015) suggest this may be an evolutionary mechanism, suppressing reproductive activity in times of stress. For example, Norman et al. (2015) reported that when testosterone was high, aggressive behavior was raised. However, when trait anxiety was increased, it was shown to moderate this relationship. Therefore, depending on context, increasing one axis and suppressing the other may be beneficial.

2.11 Conclusion

In conclusion, the intricate balance of testosterone and cortisol and their ratio is crucial to underpinning the body's anabolic, catabolic, metabolic, and psychological processes. Testosterone on the HPG-axis is central to the development and maintenance of male reproductive tissues and secondary sex characteristics, and it plays an essential role in muscle mass accrual, muscular strength, metabolic regulation, and motivational risk-taking behavior. Cortisol, on the other hand, is a vital hormone of the HPA-axis and is instrumental in regulating metabolism, immune response, and stress adaption. High cortisol levels can lead to muscle protein breakdown, impaired immune function, energy availability, and psychological anxiety and stress. Therefore, the TC ratio is a valuable marker for assessing the balance between anabolic and catabolic states. This ratio may also alter behavior by promoting or inhibiting motivational and anxiety traits, which could influence performance in a sporting context. Therefore, monitoring or manipulating this ratio may be necessary for athletic training and optimizing performance and recovery. Future research should explore the implications of these hormones' effects on the body in various sporting contexts to understand the optimal ratio for improved performance.

Chapter 3 SYSTEMATIC REVIEW with META-ANALYSIS

3.0 Priming techniques facilitated by the endogenous release of testosterone and the subsequent effect on performance markers: A Systematic Review with Meta-Analysis.

3.1 Introduction

Within sports science, the steroid hormone testosterone has predominantly been researched for its effects on the neuromuscular system, primarily focusing on its anabolic effects on muscle mass, strength, and subsequent improvements in sporting performance (Fink et al., 2017). However, testosterone has also been linked to its influence on social and psychological traits, notably increased motivation (Cook et al., 2013). Therefore, controversy about the exact role testosterone plays in improving physical attributes is widely noted. Specifically, some studies claim testosterone to have a critical role during protein synthesis, while others have focused on the interaction between changes in testosterone and psychological effects (Kraemer et al., 2017; Mangine et al., 2017; Mobley et al., 2018; Morton et al., 2018).

Testosterone originates from the Leydig cells of the testes, the ovaries in women, and partially in the adrenal gland in both sexes. The hypothalamus and the pituitary glands mediate secretion via the hypothalamic-pituitary-gonadal axis (Slimami et al., 2017). Notably, upregulation of this secretion can affect the amygdala (Derntl et al., 2009). The amygdala is part of the orbitofrontal cortex within the prefrontal cortex, which regulates amygdala functioning (Derntl et al., 2009; van Wingen et al., 2009; Hermans & van Honk, 200,8). Testosterone reduces this regulation and enhances coupling with the thalamus, which is responsible for relaying sensory cues, which has been shown to increase risk-taking and reduce vigilance (Derntl et al., 200,9). This can activate the mesolimbic-dopaminergic pathways (the reward pathway) in the nucleus accumbens (Hermans et al., 2010). Therefore, increases in testosterone may increase motivation and aggression (Hermans & van Honk. 2008). This has been extensively examined, along with other psychological factors such as risk-taking (Ronay & Von Hippel, 2010), reduced fear (von Honk et al. 2,005), sexual promiscuity (Maestripieri et al., 2014), and being in a position of perceived power (Klinesmith et al., 2006). Results indicate that these behaviors increase with an acute rise in testosterone, showing a change in motivational balance to a heightened sensitivity to reward and a lower sensitivity toward danger (van Honk et al., 2005). Van Honk et al. (2005) reported a reduction in unconscious emotional responses to fearful faces without influencing levels of conscious anxiety when testosterone was elevated. This suggests increased risk-taking behavior to achieve rewarding aspects of completing the task, indicating that testosterone could have aggression-increasing, fear-reducing, dual-sided motivational properties (van Honk et al., 2005). To support this theory, Apicella et al. (2014) showed elevated bioactive testosterone (mean 27.82 pg/ml) significantly (p = 0.009) raises financial future risk-taking during monetary gambling, regardless of whether they had previously won (raised by 33.00 pg/ml) or not (raised by 22.43 pg/ml) in 49 men, however winning did significantly increase (p = 0.02) testosterone higher than losing (difference 10.57 pg/ml). Subjects in the study of Klinesmith et al. (2006) held a handgun and experienced a rise in testosterone (mean change = 62.05 pg/ml) due to the feeling of power and heightened risk. Finally, Stanton et al. (2011) found that when 154 participants completed a gambling task in both sexes, the higher the testosterone (mean difference = men 31 pg/ml, women 8 pg/ml), the greater the willingness to incur risk. Therefore, if an athlete could replicate this feeling of power and arousal to compete, this could potentially improve their performance levels.

The rise in post-resistance exercise circulatory anabolic hormones such as testosterone is believed to be associated with muscle hypertrophy and protein synthesis through hormone-receptor binding and the up-regulation of intracellular anabolic pathways (Slimami et al., 2017). A previous meta-analysis examined testosterone and cortisol ratios in men and found that acute resistance exercise consistently increased saliva testosterone concentration, with an average effect size of d = 1.06 (Hayes et al., 2015). Similarly, Ahtiainen et al. (2003) reported a correlation between muscle hypertrophy and acute testosterone levels after 21 weeks of heavy resistance training (r = 0.76, p <0.01). Ali et al. (2019) also reported increases in testosterone levels after six weeks of soccer-specific contrast (an increase of 3.7 pg/ml, 17%, p = 0.01) and complex (an increase of 3.89 pg/ml, 28% p = 0.01) training compared to a control group (0.42 pg/m, 3.3%). Conversely, Mangine et al. (2017) and Fink et al. (2016) reported that exercise-induced hormone elevations in muscle growth were independent of specific training programs. Simply put, it was not the repetition, set, or rest configuration that mattered as much as the amount of testosterone released. However, Morton et al. (2016) reported no significant correlation between post-exercise anabolic hormone elevations and muscular strength or hypertrophy improvements; therefore, a consensus on testosterone's effects on athletic performance has yet to be fully agreed upon.

Gleason et al. (2009) reported that in sporting competition, androgens affect personality similarly to in sexual contexts, with increases in motivation and aggression due to rises in testosterone. Levels can rise during the moments before competition through anticipation of the upcoming event (Edwards & Kurlander, 2010). Arruda et al. (2014) also reported that home teams express higher levels of testosterone (pre-game 701 picomoles per liter (pmol-L), post-game 944 pmol-L; 34% increase) compared to when the team plays away from their home venue (pre-game 531 pmol-L, post-game 770 pmol-L; 45% increase). Furthermore, the outcome of the event, such as prize money, prestige, and fame, have also all been shown to cause increases in testosterone levels through these extrinsic motivators. To provide a specific example, testosterone levels in female volleyball players were 20% higher pre-competition (16.07 pg/ml) than pre-practice (13.43 pg/ml; Edwards & Kurlander, 2010). Consequently, victories have shown elevations in concentrations (mean increase of 32.1%), and defeats have been shown to decrease testosterone (mean decrease of 23.8%) in 28 male college students during a memorization test (McCaul et al., 1992). Post-competition testosterone increases have also been linked with increased aggression and willingness to compete again in another dominance contest and re-engage in dominating behavior, whether after victory or not (Wood & Stanton, 2012). Therefore, testosterone may improve volitional motivation and provide one proxy marker for readiness to train and compete (Cook & Beaven, 2013).

Other pre-competition techniques to increase an athlete's physical and mental activation that may have primed testosterone inadvertently are imagery, goal setting, and self-talk (Tod et al., 2015). A systematic review of 53 studies reported increased muscular strength, power, and endurance using imagery of 69, 67, and 55%, respectively. Goal setting also improved these markers by 65, 100, and 63%, respectively. Furthermore, self-talk improved the markers by 61, 67, and 50% (Tod et al., 2015). This indicates that priming techniques that affect mindset before resistance training could be beneficial.

This systematic review aims to critically evaluate psychological priming and its subsequent effect on testosterone prior to completing a performance task, given the potential positive effects of elevated testosterone concentration levels reported in the currently limited body of evidence. Increasing motivation and reducing fear to improve athletic performance and competition levels could benefit coaches and individuals of varying abilities. Therefore, the objective of this systematic review is to undertake a review of various priming techniques to determine their effects on testosterone prior to subsequent sporting and physical endeavors.

3.2 Methods

3.2.1 Literature search methodology

This review was undertaken in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Page, 2021). Peer-reviewed original journal articles were obtained via electronic searches of CINAHL, MEDLINE, and SPORTDiscus databases, along with Google Scholar and ResearchGate. "Testosterone" was combined with specific terms to avoid unrelated articles being returned. These included: "testosterone and music," "testosterone and self-talk," "testosterone and imagery," "testosterone and social media," "testosterone and physical performance," "testosterone and athletic performance," "testosterone and cognitive performance," "testosterone and strength," "testosterone and power," "testosterone and team talk," "testosterone and priming," "testosterone and motivation" and "testosterone and warm up." The inclusion criteria of this review included: 1) limited to the English language, 2) publications up to and including December 2023, 3) only include research in human subjects, 4) implement psychological priming techniques, and 5) include pre and post-intervention testosterone data. Additional searches were undertaken using Google Scholar when full-text articles were inaccessible. Articles collected were then screened on the title and abstract review, with a full-text review conducted using the PEDro scale (Verhagen et al., 1998). Figure 2.1 displays the search methodology implemented.

3.2.2 Grading article quality

A quality appraisal was performed using the PEDro scale in line with the suggestions of Verhagen et al. (1998). Each study was appraised using eleven criteria with a scale of yes and no. An overall score out of eleven was then given to each article and divided into three categories: Low 0 – 4, medium 5 – 8, and high 9 – 11, with the greater the score, the better the article. Two authors independently graded the studies against the criteria (JC, AT), with any disparity arbitrated by (CB).

3.2.3 Statistical analysis

In this meta-analysis, statistical analysis was carried out by calculating the change in testosterone from pre to post-test and dividing them by their standard deviations (Equation 2.1). Ninety-five percent confidence intervals were also computed using the formula of Nakagawa and Cuthill (2007). The magnitude of the effect was interpreted as < 0.2 trivial, 0.2 – 0.49 small, 0.5 – 0.79 moderate, and > 0.8 large.

Equation 2.1. Hedges' *g* equation (Lakens, 2103), where n = 5 $g *= \text{Cohen's } d \times \left(1 - \frac{3}{4(n_1 + n_2 - 9)}\right)$

3.3 Results

A total of 5,574 studies were initially identified, with search results streamlined through journal relevance. Studies from Google Scholar and ResearchGate were included in the initial filtering process, of which 558 were excluded by removing duplicates and studies that did not meet the inclusion criteria. This resulted in 5,016 studies being screened. Studies initially returned represented the following combined database results: "testosterone and music" = 24; "testosterone and self-talk" = 0; "testosterone and imagery" = 13; "testosterone and social media" = 26, "testosterone and physical performance" = 452, "testosterone and athletic performance" = 498, "testosterone and cognitive performance" = 283, "testosterone and strength" = 2,243, "testosterone and power" = 1008, "testosterone and team talk" = 0, "testosterone and priming" = 94, "testosterone and motivation" = 420, "testosterone and warm up" = 40 and "psychological and warm up" = 118. A further 4,989 papers were excluded based on title and abstract review. Finally, 22 full-text articles were assessed for eligibility and disregarded due to studies not meeting the pre-stated inclusion criteria requirements (Figure 3.1).

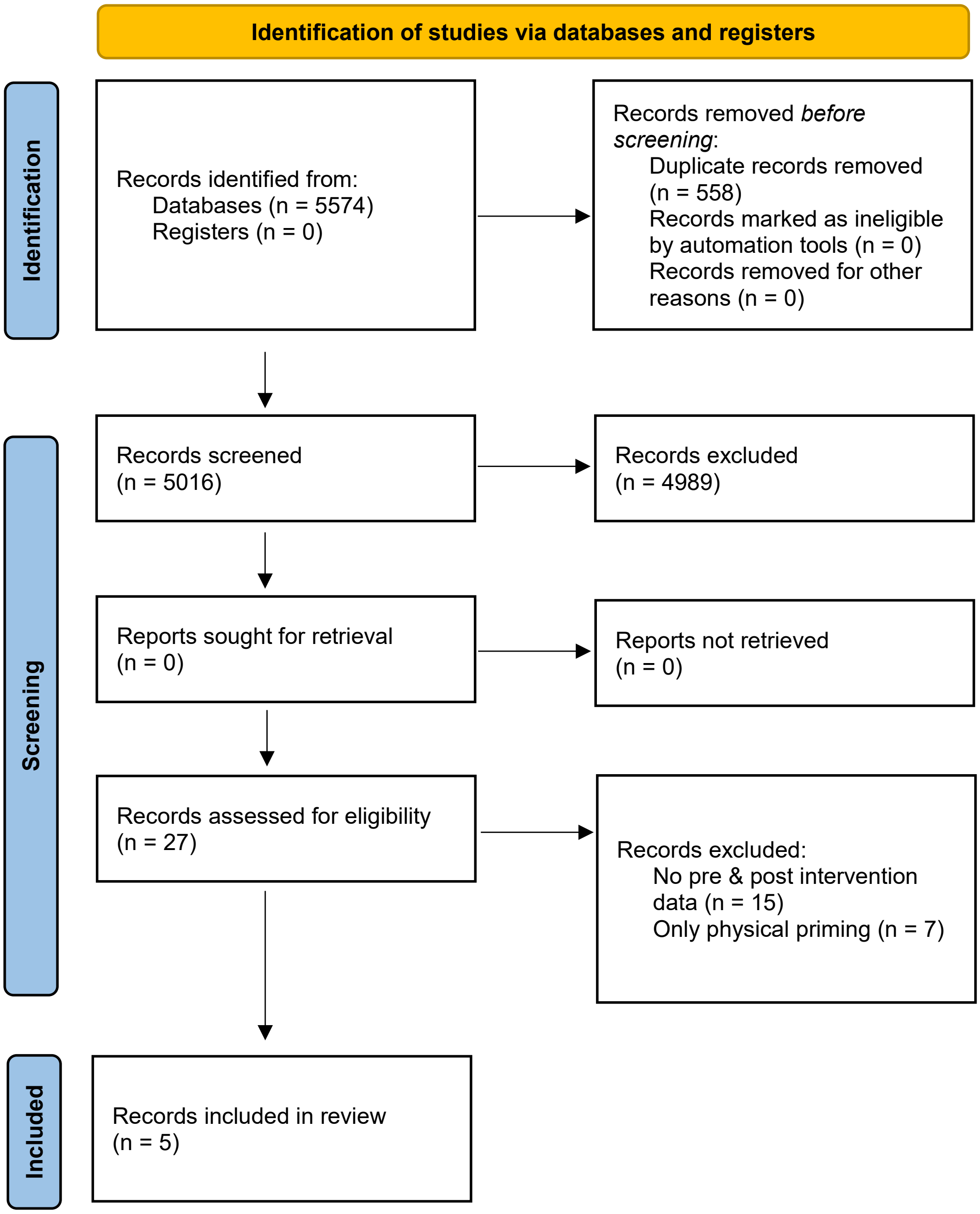

Figure 3.1 Flow diagram showing the identification and selection of studies in the literature for the current review.

Of the remaining five studies, one focused on the presence of an attractive woman priming testosterone, and four investigated the effect of watching video clips on testosterone levels (see Tables 3.1 and 3.2). The PEDro scale (Verhagen et al., 1998) (see Table 3.3) grading identified four articles with a medium grade, and two studies met a high criteria grade of nine or more.

A wide range of performance outcome measures were implemented to demonstrate the effectiveness of the chosen interventions on priming testosterone levels. Multiple measures per study were undertaken, therefore, some studies were counted more than once. The number of studies related to the category of tests includes skateboard tricks (1), 3RM squat (1), rugby performance (2), hand grip strength (1), and countermovement jump peak power (1).

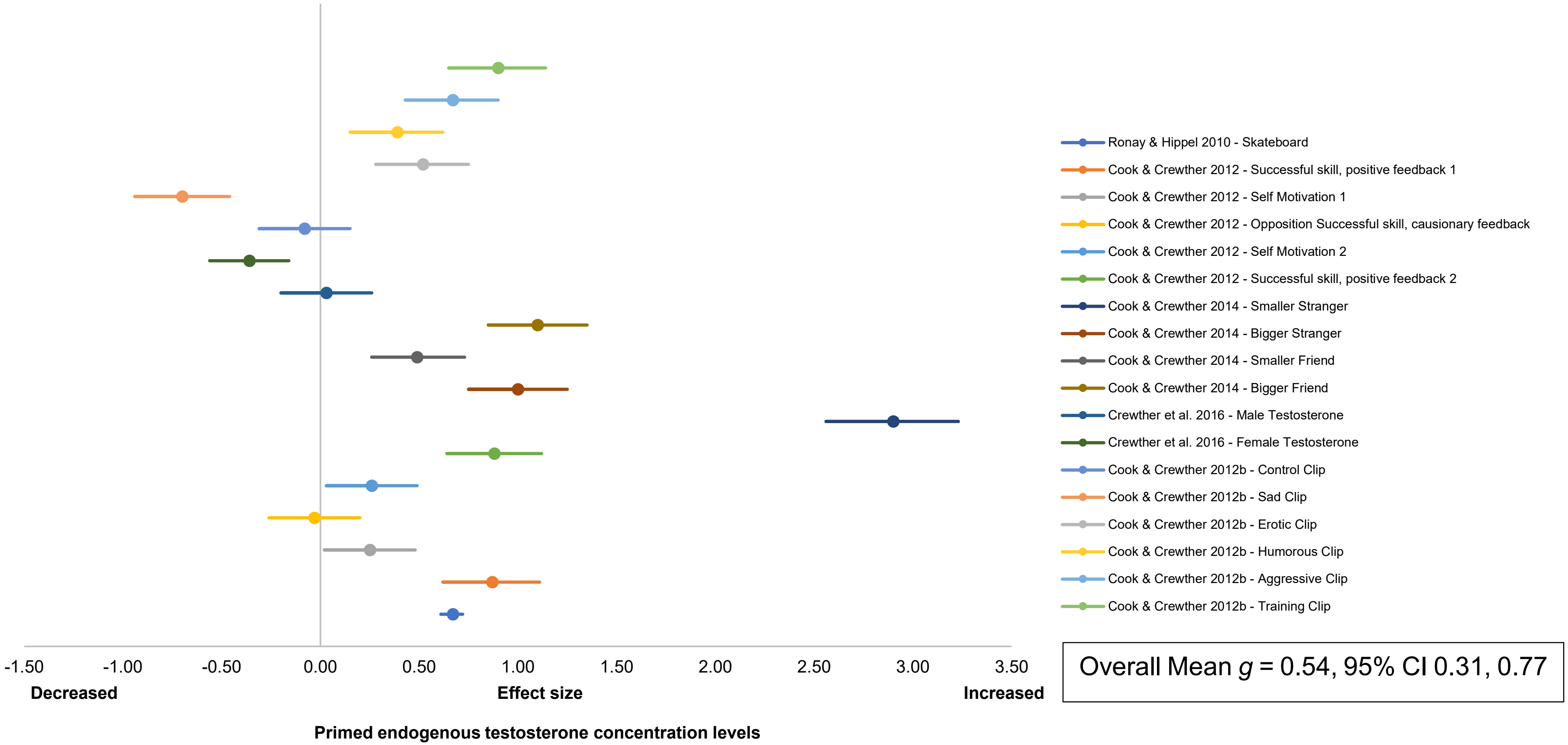

Figure 3.2 Results of primed endogenous testosterone concentration levels using effect size with 95% confidence intervals. The magnitude of the effect was < 0.2 trivial, 0.2 – 0.49 small, 0.5 – 0.79 moderate, and > 0.8 large (Hedges *g*, 2014).

Table 3.1 6 article results on testosterone priming techniques.

Authors	Subjects	Intervention	Metrics Measured	Salivary Testosterone	Cortisol	Significant Difference	PEDro Scale %
Cook and Crewther (2014)	Adult male n = 12 - Mean age: 20 years - Mean height: 1.85 m - Mean weight: 95.7 kg	*Control* - There was not a control session *Intervention* - Post-match video in front of: - Bigger friend - Smaller friend - Bigger stranger - Smaller stranger - Pre match video of same	Rugby match ranked performance - SS = 3.8/5 - SB = 2/5 - FS = 2.8/5 - FB = 1.1/5 - Social or neutral environment = same performance rank	Testosterone % change - NV = 22.6 ± 8.2% - V = 23.9 = 9.9% - SS = 51.8 ± 14.2% - SB = 22.3 ± 13.7% - FS = 8.6 ± 5.0% - FB = 21.4 ± 7.5%	Cortisol % change - NV = 6.7 ± 4.0% - V = 3.5 ± 2.8% - SS = 16.0 ± 7.1% - SB = 26.5 ± 7.1% - FS = -5.8 ± 2.8% - FB = -9.3 ± 4.1%	Post-match intervention T - All sig diff (p <0.001) Post-match intervention C - SS & SB = sig diff (p < 0.001) Match performance - All sig diff (p <0.001) - FB = Best Pre-match T following intervention - FB = sig diff (p < 0.004) Pre-match C - Sig diff (p < 0.05) Match performance V & NV - No sig diff (p > 0.05)	Medium - 63.63%
Crewther et al. (2016)	Adults n = 26 - Men: 12 - Women: 14 Mean age: - Men 24.5 years - Women 23.5 years Mean height: - Men 181.1 cm - Women 164.4 cm Mean weight: - Men 83.5 kg - Women 59.3 kg	*Control* - Control session *Intervention* - 5 X 10s Cycle sprint - View video clip	Hand grip strength - +1.7 ± 0.3 Countermovement jump peak power - -59 ± 35	Testosterone % change Video - Men -1.2 ± 19% - Women -10.4 ± 18%		Sprint T - Sig diff (p <0.05) Video - No Sig diff (p > 0.05)	Medium - 63.63%

Cook and Crewther (2012a)	Adult n = 12 - mean age: 21.8 years - mean weight: 98.5 kg - mean height: 1.85 m	*Control* - Self-motivation *Intervention* - Video clip of successful skill execution with positive feedback - Watching a video clip of opposing player with positive feedback	Rugby performance Key player rating - VPCF2 1.5 - VPCF1 1.8 - SM2 3.3 - SM1 3.7 - VCCF 4.8 Overall performance rating - VPCF1 1.7 - VPCF2 1.8 - VCCF 5.0 - SM1 3.0 - SM2 3.5	Testosterone % change - VPCF1 = 12.5 $\pm$ 5.9% - SM1 = 5.4 $\pm$ 3.7% - VCCF = -0.7 $\pm$ 4.7% - SM2 = 5.0 $\pm$ 2.4% - VPCF2 = 11.8 $\pm$ 4.8%	Cortisol % change - VPCF1 = 1.0 $\pm$ 3.3% - SM1 = 3.6 $\pm$ 4.0% - VCCF = 17.6 $\pm$ 9.7% - SM2 = 4.5 $\pm$ 2.4% - VPCF2 = 0.0 $\pm$ 4.2%	Testosterone Sig diff ($p < 0.05$) - VPCF1 - SM1 - SM2 - VPCF2 Cortisol Sig diff ($p < 0.05$) - VCCF - SM1 - SM2	Medium - 63.63%

Table 3.2 6 article results on testosterone priming techniques continued.

Authors	Subjects	Intervention	Metrics Measured	Salivary Testosterone	Cortisol	Significant Difference	PEDro Scale %
Ronay & von Hippel (2010)	Young Adult Males: n = 96 - Age: 18-35 - Mean age: 21.58 years	*Control:* - Male experimenter *Intervention:* - Female experimenter	Skateboard tricks between sexes - Aborted *d* = 0.75 - Successful *d* = 0.42 - Crash landing *d* = 0.50	Post Intervention ST - FE T = 295.95 ± 143.69 pmol/L - ME T = 212.88 ± 101.62pmol/L		Female experimenter Skateboard fewer aborted tricks Sig diff ($p < 0.001$) Skateboard more successful tricks Sig diff ($p < 0.001$) Skateboard more crash landings Sig diff ($p < 0.001$) Male experimenter No sig diff ($p > 0.20$)	High - 81.81%
Cook and Crewther (2012b)	Adult n = 12 - Mean age: 21.2 years - Mean height: 1.90 - Mean weight: 99.0 kg	*Control* - Neutral *Intervention* - Video clips - Sad - Erotic - Aggressive - Training motivational - Humorous	Squat 3RM improved by: - Aggressive clip = 5.4% - Training clip = 4.6% - Erotic clip = 2.1% - Humorous clip = no sig diff - Sad clip = no sig diff	Testosterone % change - Control = -1.3 ± 4.1% - Sad = -5.7 ± 2.7% - Erotic = 4.8 ± 2.0% - Humorous = 3.7 ± 2.7% - Aggressive = 10.0 ± 5.2% - Training = 8.4 ± 5.0%	Cortisol % change - Control = -2.8 ± 10.8% - Sad = 5.2 ± 10.0% - Erotic = 6.9 ± 3.7% - Humorous = -0.5 ± 6.4% - Aggressive = 13.0 ± 6.9% - Training = 5.5 ± 8.0%	Sig diff ($p < 0.05$) - Erotic, humorous, aggressive & training clips Erotic, aggressive & training clips Sig diff ($p < 0.05$) 3RM - Erotic, aggressive, training clips Sig diff ($p < 0.05$)	Medium - 45.45%

Sig dif = significant difference, n = number, *g* = effect size, CI = 95% confidence interval, ST = skateboard tricks, RL = reversed learning, FE = female experimenter, ME = male experimenter, FB = friend bigger, FS = friend smaller, SB = stringer bigger, SS = stranger smaller, T = testosterone, HGS = hand grip strength, CMJPP = countermovement jump peak power, VPCF1 = video clip of successful skill with positive feedback, VPCF2 = video clip of successful skill with positive feedback, VCCF = video clip successful skill completion by opposition player with cautionary feedback, SM1 = self-motivation, SM2 = self-motivation, NV = no video, V = video.

Table 3.3 PEDro Scale Results.

	Ronnay & Von Hippel (2010)	Cook & Crewther (2012a)	Cook & Crewther (2014)	Crewther et al. (2016)	Cook & Crewther (2012b)
Eligibility criteria specified	Y	Y	Y	Y	N
Subject randomly allocated to groups	N	Y	Y	Y	N
Allocation was concealed	Y	N	N	N	N
Groups had similar baselines	Y	Y	Y	Y	Y
Blinding of all subjects	Y	N	N	N	N
Blinding all therapists	Y	N	N	N	N
Blinding of all assessors	N	N	N	N	N
1 key outcome obtained from 85% of subjects	N	Y	Y	Y	Y
All subjects received treatment or control condition	Y	Y	Y	Y	Y
Between group stats reported	Y	Y	Y	Y	Y
Reporting of point measures & measures of variability	Y	Y	Y	Y	Y
Total	8/11	7/11	7/11	7/11	5/11

Y = yes, N = no.

3.4 Discussion

This systematic review aimed to critically evaluate the available literature pertaining to the implementation of testosterone priming techniques prior to completing a physical performance task. Data analyzed from five studies indicated that priming testosterone may exhibit a moderate improvement (g = 0.54, 95% CI 0.31, 0.77) in subsequent performance tasks. Particularly with motivational video clips, when other people are present, or when an attractive woman is used. Evidence pertaining to the use of sad or cautionary video clips failed to raise testosterone levels significantly, and mixed findings occurred when implementing aggressive video clips.

3.4.1 The effects of watching video clips

The highest increase in saliva testosterone concentration levels was reported by Cook and Crewther (2014), with a 51.8% increase (g = 2.90, 95% CI 2.56 - 3.23). Twelve professional rugby players watched video clips individually of themselves performing both successful and unsuccessful skills from a match played one day earlier. This was in front of a stranger or friend who was either bigger or smaller in physical stature. All scenarios increased testosterone significantly ($p < 0.05$), with the presence of a smaller stranger (SS) producing the greatest increase (51.8%, g = 2.90, 95% CI 2.56 - 3.23). Cortisol levels rose when viewing the video clip in front of strangers, with a bigger stranger (SB) increasing cortisol significantly by 26.5% and SS by 16.0%. In front of friends, a bigger friend (FB) decreased cortisol significantly by -9.3% and -5.8% in front of a smaller friend (FS). Cortisol concentration levels have been reported to rise in the presence of a psychological or physical threat (Hannibal & Bishop, 2014). Thus, having strangers observing subjects view a video clip of themselves may potentially be stressful for the subject, whereas having friends observing could be stress relieving. Interestingly, when players undertook their first resistance training session three days later, which consisted of three sets of power cleans, back squats, and bench presses, testosterone and cortisol levels altered favorably during the resistance training session. Those who watched the videos had 9.2% higher pre-session testosterone levels and incurred a greater testosterone rise post-session, with a 23.9% increase compared to 22.6% in those who did not watch the videos. Indicating resistance training increases testosterone levels similarly whether subjects are primed or not. However, those who watched the videos still observed a 9.3% increase post-session. Cortisol levels in players who viewed video clips were also lowest pre-session by 3.2% and rose the least post-session, 3.5%, compared to 6.7% for those who did not watch videos. During the second performance test, a rugby match played seven days later, those players who watched the videos had pre-match testosterone levels that were significantly ($p < 0.01$) higher (9.2%) compared to those who did not watch, with players who viewed the video in front of SB, FS, and FB all producing significantly ($p < 0.05$) better match-ranked performances than those who viewed in front of SS. However, no match-ranked differences existed between players who watched the videos and those who did not. This indicated that implementing a testosterone priming strategy six to seven days before a rugby match is potentially not efficacious. However, it demonstrates that male athletes' hormonal stress responses are malleable and can be influenced by different psychological and social stressors before a physical endeavor three days later (Crewther & Cook, 2012), especially when strangers are present (Phillips et al., 2009).

A reduced period between intervention and commencement of a physical endeavor occurred in Cook and Crewther's (2012a) investigation. Instead of days, it was 15 minutes before a professional competitive rugby match. Twelve players watched either: i) a video clip of themselves producing a successful skill execution, along with positive feedback from their coach (VPCF), ii) a video clip of a successful skill executed by an opposing player along with cautionary feedback (VCCF), or iii) the player was left to self-motivate. A significant ($p < 0.05$) testosterone increase of 12.2% occurred when VPCF was undertaken ($g = 0.87$, 95% CI 0.62, 1.11), compared to only 0.7% in VCCF and 5.2% when self-motivating. This also correlated with better player performance scores, as rated by the head coach, during the subsequent match ($r = 0.81$, $p = 0.001$). These findings may be related to the proposed effects of testosterone on player behavior, as Cook and Crewther (2012) suggest testosterone levels may have influenced competitive behavior through motivation to perform, risk-taking, and aggression. Coates and Herbert (2008) support this, suggesting that higher testosterone levels increase risk-taking behavior in adult males. This is consistent with the findings of Trumble et al. (2012), who produced a soccer profile report whereby greater testosterone levels prior to a match were associated with improved self-rated performances ($p = 0.004$). Interestingly, not only were the match performances affected by testosterone levels, but VCCF produced a significant ($p < 0.01$) cortisol rise of 17.6% compared to 0.5% with VPCF or self-motivate 5.8%. This potentially may have also contributed to the negative performance outcome in VCCF, as high levels of cortisol are detrimental and negatively impact performance (Siart et al., 2017). This study may indicate that timings, social contact, and intervention content may affect testosterone priming, cortisol levels, and subsequent rugby performances.

In another study by Cook and Crewther (2012b), they repeated their methodology from the previous 2012a study, whereby a short 15-minute period was implemented between testosterone priming and undertaking a 3RM back squat. Video clips were used again, this time, they varied in content. Either an aggressive, control, erotic, humorous, sad, or training clip was viewed by twelve professional rugby players prior to performing the lift. A significant ($p < 0.001$) large 10% rise in testosterone occurred after watching an aggressive clip displaying large rugby hits ($g = 0.67$, 95% CI 0.43, 0.90), which is consistent with Carré and McCormick's (2008) findings whereby when more aggressive behavior is displayed (to a Point Subtraction Aggression Paradigm task), the higher the testosterone response. The training clip featuring a UFC fighter produced an 8.4% increase ($g = 0.90$, 95% CI 0.65, 1.14), with erotic and humorous clips displaying significantly improved levels also (4.8%, $g = 0.52$, 95% CI 0.28, 0.75, 3.7%, $g = 0.39$, 95% CI 0.15, 0.62), respectively. In comparison, the sad and control clips reduced levels by -5.7% ($g = -0.70$, 95% CI -0.94, -0.46) and -1.3% ($g = -0.08$, 95% CI -0.31, 0.15), respectively. These findings indicate that simply watching video clips does not alter testosterone levels, instead, it is the psychological content of the clips creating change (Cook & Crewther, 2012b). Interestingly, correlations between increases in testosterone and 3RM performances occurred ($r = 0.85$, $p = 0.001$), with overall strength and body mass also increasing by 2.0% (3.1 kg) and 0.5% (0.5 kg). Furthermore, this occurred despite cortisol levels increasing significantly ($p < 0.05$) by 13% after viewing the aggressive and erotic clips by 6.9%. The training and sad clip raised cortisol by 5.5% and 5.2%, respectively, with the humorous and control clips lowering (-0.5% and -2.8%, respectively), indicating cortisol levels did not adversely affect the potentially positive effects of testosterone when performing a 3RM back squat 15 min post priming intervention.

Testosterone responses to aggressive video clips have shown mixed results. Crewther et al. (2016) reported decreased testosterone levels by 10.4% in women (g

= -0.36, 95% CI -0.56, -0.16) and 1.3% in men (*g* = 0.03, 95% CI -0.20, 0.26). A significant rise in concentrations occurred after implementing a priming strategy of 10 x 5 s cycle sprinting strategy, which increased concentration levels by 15% in women and 20% in men. Interestingly, this is despite women having less than half the amount of testosterone as males, indicating that women can achieve similar relative changes with the appropriate stimulus (Crewther et al., 2016). The countermovement jump or handgrip strength tests did not improve after watching the video or undertaking the cycle sprints. Cortisol levels were not reported; therefore, it is unknown whether concentration levels affected these additional performance tasks. Crewther et al. (2016) suggest that affective stress or pre-test cortisol levels may affect hormonal testing results. Therefore, it is of interest to coaches to understand that the social environment before priming may affect the efficacy of video clip priming and the timings and content of videos shown.

3.4.2 The effect of being watched

Testosterone was raised significantly (83.07pmol/L, *g* = 0.67, 95% CI 0.61, 0.72) when the presence of a female examiner observed male subjects performing a difficult skateboarding trick compared to a male examiner (Ronay & Hippel, 2010). More aborted tricks (*d* = 0.75) and crash landings (*d* = 0.50) also occurred in front of the female examiner, which increased the potential to get hurt. This aligns with previous findings of increased risk being taken when testosterone is raised (Rupp & Wallen, 2007). The increased testosterone levels may have been influenced by the skateboarders' attraction to the female examiner. Sexual displays in humans may be adaptive and successful for reproduction; however, they may be costly in terms of survival, which has been found with other species (Hunt et al., 2004). Wilson and Daly (2004) support this notion, suggesting that the presence of an attractive woman can increase males discounting future consequences, which can drive risk-taking further.

This study did not investigate the male subject's sexuality to fully understand their behavior, which could have had a profound effect on the data collected. They did not test with any other women, so they cannot discount that the presence of any woman will cause a rise in testosterone. Cortisol levels or pre-testing testosterone concentrations were also not taken; therefore, they cannot state for certain whether testosterone rose or dropped with either sex observing. Lastly, testing female subjects for their reaction to an attractive male examiner would have given more clarity to the data.

3.5 Directions for Future Research

Due to the limited literature available, further research is required on testosterone priming to determine the most efficacious strategy more clearly. Most analyses implemented video clips as the priming strategy, with only two other stimuli recorded in this review. Also, a limited number of performance markers were implemented to determine the efficacy of the altered hormonal homeostasis. Half of the studies used subjective measures such as rating player match performances. Consequently, more robust, measurable physiological markers could provide more gravitas to understanding this topic better.

Interestingly, no studies implemented psychological techniques such as self-talk, imagery, or music, even though many studies report improved performance when these modalities are undertaken. For instance, Karageorghis et al. (2013) played asynchronous music to 20 collegiate swimmers and reported a significant improvement in a 200 m freestyle time trial of 2%. Parker et al. (2011) also showed significant improvements in both a 50 m swimming time trial performance (0.82 s difference; $p < 0.01$) and hand grip strength (2.2 kg difference; $p < 0.05$) after listening to music prior to the race. Radcliffe et al. (2013) also reported an increase in electromyographic activity, program adherence, strength, technique development, and stress regulation via the use of imagery. Finally, Lebon et al. (2010) reported an increase of 17.75 reps ($r = 0.70$) when performing the leg press exercise to failure at 80% 1RM in nine sports students after visualizing their muscles contracting before performing the exercise. Additionally, Fukui (2001) reported that music can significantly ($p < 0.0001$) increase testosterone in 35 female subjects. Thus, some evidence exists that such priming techniques may be worth further investigating.

A limitation of the included studies is often a small sample size and lack of diversity among the subjects. Studies would have also benefited from consistently reporting cortisol levels alongside testosterone as these hormones work together, potentially impacting athlete performance. Longitudinal studies would also clarify whether the chosen stimuli primed the testosterone or whether other factors affected results. S&C coaches and sports professionals could use this information to provide discrete performance improvements in training and competition. In summary, future research is required in many populations with multiple stimuli and performance measures to clarify the most efficacious protocol for priming testosterone for physical performance.

3.6 Conclusion

The body of literature indicates that implementing testosterone priming can successfully improve performance measures when implemented close to the time of performing. Particularly the use of positive video clips and an attractive female observer with male subjects. However, with only five articles found and mixed results from aggressive videos, this highlights the need for future research to fully understand what elevates testosterone concentration levels during priming and what performance markers the priming can affect.

Chapter 4 STUDY 1

4.0 A survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance *(published ahead of print in the Journal of Strength and Conditioning Research)*

4.1 Introduction

The primary role of S&C coaching is to enhance athletic performance and mitigate any potential risk of injury (Sousa, 2019). Therefore, professional practice emphasizes exercise prescription with the intention of creating progressive overload and sport-specific neuromuscular adaptations. However, research suggests that the role is much more complex, with a wide variety of skill sets (for example, creating game day itineraries, keeping teams to a schedule, being sideline managers, and handling team discipline) needed to maximize athletic performance (Massey et al., 2004; Radcliffe et al., 2018). What is possibly given less consideration is how S&C coaches can directly affect athlete training effort, behavior, and motivation, and thus further adaptions by this means. Psychological priming (also known as "psyching-up") of an athlete for a given physical task has been defined as "*the use of cognitive techniques designed to improve performance before or during competition*" (Tod et al., 2005). Early research from Owen and Lee (1987) suggested that successful athletes use cognitive strategies differently to less successful athletes and produce greater athletic performances as a result of increased self-confidence and self-efficacy, which, in turn, helps regulate arousal for the physical task in question. For example, Gould et al. (1992) interviewed the U.S. 1988 Olympic weightlifting team and reported that their best performance occurred after undertaking mental preparation techniques of visualization, positive self-talk, and focusing on tactical strategies.

In preparation for physical activity, athletes will typically undertake a "warm-up" to physically and mentally prepare themselves to perform (Jefferys, 2007). The mental preparation will typically involve the implementation of cognitive and behavioral techniques. Behavioral techniques are a nonconscious mental strategy, such as listening to music, which potentially can alter emotions and moods, heighten arousal, reduce inhibition, and induce higher states of functioning (Karageorghis & Priest, 2012). Cognitive techniques involve various structured psychological frameworks. These include imagery, self-talk, goal setting, arousal, and attentional control (Perkins et al., 2001; Slimani et al., 2016; Tod et al., 2015). It has been postulated that these techniques can increase focus of attention, self-efficacy, motivation, confidence, mental activation, and physiological arousal (Brewer et al., 2019; Tod et al., 2015). For example, goal-setting facilitates self-regulation, with the goal of defining what constitutes an acceptable level of performance (Laukka & Quick, 2011). Therefore, effort and specificity are central to this framework being successful (Chen & Latham, 2014).

Williams and Krane (1993) commented that athletic performance levels can be improved when cognitive-behavioral strategies are implemented. Lebon et al. (2010) confirmed this when reporting significant strength gains in nine sports students after implementing mental imagery strategies during rest periods between sets in 12 training sessions over six weeks. The subjects visualized their muscles contracting for the sled leg press. The number of repetitions completed at 80% of 1RM increased by 17.75 repetitions, representing eight more than the control group ($d = 0.7$) (Lebon et al., 2010). Sprinting performance over a test distance of 30 m has also been reported to improve when implementing a 30-second imagery technique immediately before ($d = 0.61$) and at 1 min ($d = 0.40$) and 2 min ($d = 0.30$) intervals before the test, in 16 male regional sprinters (Hammoudi-Nassib et al., 2014). Therefore, the implementation of cognitive priming techniques before undertaking an athletic performance can potentially achieve increases in performance levels.

Gould et al. (1992) reported how athletes may use music to prime their performances. Similar to cognitive strategies, this behavioral technique can alter emotions and moods, heighten arousal, reduce inhibition, and induce higher states of functioning (Karageorghis et al., 2013). For example, Karageorghis et al. (2013) reported a significant 2% improvement in a 200 m freestyle time trial while listening to asynchronous music (the music does not match the pace of the activity) in 20 collegiate swimmers. Research into priming for strength and power using music is in its infancy (Karageorghis et al., 2013; Laukka & Quick, 2011; Lim et al., 2014); however, the emerging research using music to prime strength performance has typically reported positive results (Karageorghis et al., 2018). Improvements in handgrip strength by 0.63 N·kg were noted after listening to pre-task fast-tempo music (at 126 beats per minute (BPM), played at a high audio volume of 80 decibels), compared with matched controls (Karageorghis et al., 2018).

It has been reported that S&C coaches are in an ideal position to implement psychological interventions in training because they are independent of the sports coach but have regular contact with the athlete (Arvinen-Barrow et al., 2010). Therefore, recent research has focused on understanding the knowledge, use, and perceptions of these strategies with S&C coaches (Radcliffe et al., 2018; Radcliffe et al., 2015; Radcliffe et al., 2013). Interviews conducted with 18 coaches identified that they predominately use priming strategies to enhance confidence and arousal regulation, largely through goal setting (Radcliffe et al., 2013). To gain a wider understanding of priming strategies being used, Radcliffe et al. (2013) investigated the employment of psychological strategies from 112 S&C coaches. Strategies ranged from simple techniques that are easy to measure (e.g., goal-setting) to more complex techniques that require an increased understanding of psychology (e.g., imagery); however, the former were used far more frequently than the latter. Radcliffe et al. (2018) reported that the reason for this was that coaches felt that they had insufficient knowledge and an inability to inform their athletes about complex strategies. Coaches also identified that if athletes believe the strategy is customized to them, then they are more likely to respond positively rather than using a strategy with no personal link to themselves.

Thus, athlete priming represents an additional strategy to maximize training intensity, overload, and, ultimately, adaptations. However, there is a distinct lack of research investigating the implementation of such techniques (Radcliffe et al., 2015). Furthermore, previous research has not considered the athlete's perspective of priming, something that seems especially pertinent given the aim is for their performance to improve. Linking this to the current research could demonstrate how prevalent priming is and whether athletes are consciously believing and implementing such strategies for the reported physiological or psychological benefits or whether they are inadvertently undertaking these measures.

Harnessing strategies already implemented by athletes could lead to greater performance improvements rather than using prescriptive priming strategies. Strength and conditioning coaches and sport scientists in general should be aware of the various stimuli being used, and note that they can be deliberately planned. In this study, we aim to (a) identify whether any form of priming was being implemented, (b) what these strategies were, and (c) whether there was any coach involvement. Understanding the evidence may assist in optimizing training interventions which aim to enhance athletic performance.

4.2 Methods

4.2.1 Experimental Approach to the Problem

As this research area is relatively new, a pragmatic approach was taken. An expert panel consisting of sports psychologists and S&C coaches formulated the questions (survey) and initially piloted it on a small group of sports science students. This process and the ensuing feedback, reflection, and subsequent edits resulted in the design of the short anonymous survey used within this study. The survey contains exploratory quantitative questions addressing whether athletes of varying abilities engaged in the use of priming techniques before performance or practice. If they did, which techniques did they use, what were their feelings toward the priming strategy, and where did they learn or adopt it from.

4.2.2 Subjects

A convenience sample method was implemented with a total of 90 subjects from 93 fully completing the questionnaire, with three being removed because of partial completion and subsequently not reporting enough information. Inclusion criteria required all subjects to be a minimum age of 18 years and have a minimum training experience of 5 years with a coach in their respective sport. Seventy-one were male, 18 were female, and one subject did not identify their sex. The median age of subjects is 28 $\pm$ 7.47 years (range, 24 – 33 years), and the median training age in their sport of 11 $\pm$ 7.57 years (range, 8 – 18 years) (Table 4.1). Subject's ability levels ranged from those who did not compete in sport (*n* = 7, 7.9%), to amateur (*n* = 54, 60.7%), semi-professional (*n* = 17, 19.1%), and professional (*n* = 11, 12.4%). Sporting backgrounds were from CrossFit, weightlifting, bodybuilding, powerlifting, rugby, athletics, running, golf, hurling, Jiu-jitsu, volleyball, trampolining, gymnastics, cycling, climbing, hockey, judo, rowing, Gaelic football, and swimming. Subjects were informed that data would be collected anonymously and that by proceeding, they were providing their written informed consent for their participation in the research. Ethical approval was granted by the London Sport Institute Research and Ethics Committee at Middlesex University.

4.2.3 Procedures

This survey was administered via the online survey platform Qualtrics. This online method was chosen because of the platform's ease of access, user-friendly interface, and offered a wider reach to athletes, which could potentially increase response rates. Subjects were requested to complete the questionnaire regarding selected priming techniques, along with open-ended questions allowing space to expand on any strategies that were implemented. Multiple answers could be given for select questions should the subject have chosen to do so. The survey was standardized with all questions presented in the same order. The utilization of a quantitative approach was suggested for improving the efficacy of future priming intervention programs. Data were analyzed using Microsoft Excel and IBM SPSS Statistics software (version 25.0; SPSS, Inc).

4.2.4 Questionnaire

The online survey contained 9 – 15 questions for subjects to respond to, consisting of multiple-choice and open-ended formats for greater depth of answers (http://links.lww.com/JSCR/A300). Specific protocols were undertaken to ensure questions did not consist of any bias. This involved pilot testing on a comparable athletic sample (n = 30) after a panel of experts agreed on the questioning. Part one collected the subject's demographic information, reported in Table 3.1 (questions 1 through 5). Part 2 investigated athlete's use of priming strategies (questions 6 through 9), their perceptions of its effectiveness (questions 10 and 11, which are reported in Table 3.2), their development and support of using priming strategies (questions 12 through 14), and the timing of priming use (question 15). Multiple answers could be given for the type of priming strategies implemented. The majority of questions implemented binary answer questions, with select questions using a Likert scale

(McHugh, 2013), where answers were based on existing research investigating priming strategies (Lebon et al., 2010; Rejeski, 1985; Tod et al., 2005).

4.2.5 Statistical Analyses

Quantitative statistical analyses were conducted on survey responses. Subjects who partially completed the demographic questions but did not complete the priming questions were removed from the data sample. All data were initially analyzed in Microsoft Excel. The research was summarized by calculating the percentage of support for each answer given. Further statistical analysis was later undertaken using IBM SPSS Statistics software (version 25.0; SPSS, Inc), with chi-square tests being performed to determine levels of significance athletes felt toward the use of priming interventions, with significance being determined at $p < 0.05$ (Lim et al., 2014).

4.3 Results

Because of the nature of specific questions asked, multiple answers may have been given for some questions. Of the 90 subjects, 71 (78.7%) used psychological priming, whereas 10 (11.2%) did not, with 9 (10.1%) using them with their coach. The most popular priming strategy used (Table 4.2) was music (n = 34, 26.6%), followed by instructional self-talk (n = 31, 24.2%), motivational self-talk (n = 29, 22.7%), physical actions, such as stamping feet or hitting their chest (n = 25, 19.5%), watching video clips (n = 8, 6.3%), and other (n = 1, 0.8%). From the nine subjects who used strategies through their coach, motivational statements were the most frequently used (n = 6, 54.5%), followed by motivating team talks (n = 3, 27.3%) and listened to the coach's choice of music (n = 2, 18.2%). Of the subjects who used music themselves, the genres listened to were rap (n = 9, 18.8%), hip hop (n = 8, 16.7%), rock (n = 4, 10.4%), metal (n = 4, 10.4%), rhyme and blues (n = 4, 8.3%), dance (n = 3, 6.3%), general high-tempo (n = 3, 6.3%), instrumental (n = 3, 6.3%), house (n = 2, 4.2%), music related to motivational films (n = 2, 4.2%), pop (n = 2, 4.2%), electronic (n = 1, 2.1%), and techno (n = 1, 2.1%). The video clips that were viewed were of "other people successfully lifting" (n = 5, 71.4%), "themselves successfully lifting" (n = 1, 14.3%), and other or non-specified motivational videos (n = 1, 14.2%; Table 4.3).

The subjects' perception of the effectiveness of the implemented priming technique was very positive, with "very effective" (*n* = 33, 50.8%) making up the majority of the answers given. "Moderately effective" (*n* = 16, 24.6%), followed by "extremely effective" (*n* = 10, 15.4%), "slightly effective" (*n* = 5, 7.7%), and "not effective at all" (*n* = 1, 1.5%). Subjects felt priming was worthwhile because it increased their motivation (*n* = 48, 38.1%), reduced fear and anxiety (*n* = 28, 22.2%), increased competition/session intensity (*n* = 26, 20.6%), increased strength and power (*n* = 19, 15.1%), increased endurance (*n* = 3, 2.4%), and other category (*n* = 2, 1.6%), consisting of, increased focus, help with strategy, prepare them for high rating of perceived efforts, part of a routine or superstition, and increased confidence. Levels of significance through a chi-square test found that increasing motivation was the only statistically significant result ($\varphi c = 0.27$; $p = 0.011$).

The origin of why priming techniques were being implemented predominately occurred through experience and education (*n* = 39, 50.0%), followed by a somewhat intuitive implementation by the athlete (*n* = 20, 25.6%), the coach telling them to (*n* = 13, 16.7%), and learned behavior from a peer (*n* = 6, 7.7%). These techniques were mainly employed when training had begun (*n* = 44, 37.0%), before the competition (*n* = 35, 29.4%), during the competition (*n* = 24, 20.2%), and only on maximal effort days (*n* = 14, 11.8%).

Across all performance levels, the use of priming techniques was high, with all semi-professional athletes implementing a technique (*n* = 22, 100%), followed by amateur athletes (*n* = 54, 85.1%), and professionals (*n* = 12, 83.3%) (Table 4.4). The motivation to train was to improve performance (*n* = 45, 53.6%), to stay fit and healthy (*n* = 33, 39.3%), or another reason (*n* = 6, 7.1%). The most popular sports undertaken by the subjects were CrossFit, weightlifting, bodybuilding, and powerlifting (*n* = 24, 30.4%), followed by football (*n* = 16, 20.3%), rugby (*n* = 6, 7.6%), athletics (*n* = 5, 6.3%), running and golf (*n* = 4, 5.1%), hurling (*n* = 3, 3.8%), Jiu-jitsu, and no sport (*n* = 2, 2.5%). The following sports listed have just one subject (1.3%) participating in them: volleyball, trampolining, cycling, climbing, hockey, judo, rowing, Gaelic football, swimming, skiing, cricket, tennis, and a retired Gaelic football player.

Table 4.1 Demographic, competitive, and motivation information of the survey.

Age (Median)	28 (Range: 19 - 63)
Training Age (Median)	11 (Range: 1 - 35)
Resistance Training Frequency (Median)	4 (Range: 0 - 11)
Sports Training Frequency (Median)	2 (Range 0 - 10)
Training Level *n* (%)	
Amateur	54 (60.7%)
Semi-Professional	17 (19.1%)
Professional	11 (12.4%)
Does Not Compete	7 (7.9%)
Motivation to Train *n* (%)	
Improve Competition Performance	45 (53.6%)
Stay Fit & Healthy	33 (39.3%)
Other	6 (7.1%)

n = Number of subjects

Table 4.2 Summary of athlete's perceptions of priming.

	Count (*n*)	Percentage (%)	Significance (p <0.05)
How effective are priming and psyching-up strategies in improving your performance? (n = 74)			
Not effective at all	1	1.5%	p = 0.188
Slightly effective	5	7.7%	p = 0.414
Moderately effective	16	24.6%	p = 0.515
Very effective	33	50.8%	p = 0.987
Extremely effective	10	15.4%	p = 0.614
In what way do you think priming helps your performance? (n = 74)			
Increases motivation	48	38.1%	p = 0.011
Reduces fear and anxiety	28	22.2%	p = 0.214
Increases competition or session intensity	26	20.6%	p = 0.68
Increases strength and power	19	15.1%	p = 0.367
Increase Endurance	3	2.4%	p = 0.68
Other	2	1.6%	

Table 4.3 Summary of athlete's use and perceptions of priming.

	Count (*n*)	Percentage (%)	Significance ($p = <0.05$)
Do you use psychological priming strategies?			
Yes	71	78.7%	
No	10	11.2%	
Yes, directed by the coach	9	10.1%	
Which priming strategy do you personally use?			
Music	34	26.6%	$p = 0.791$
Instructional self-talk	31	24.2%	$p = 0.344$
Motivational self-talk	29	22.7%	$p = 0.968$
Physical	25	19.5%	$p = 0.620$
Video	8	6.3%	p = 0.088
Other	1	0.8%	
Which priming strategy does your coach use to psych you up? *12 Athletes identified their coaches to use priming strategies. 10 answered*			
Motivational statements	6	54.5%	
Team talks: inspiring and motivating	3	27.3%	
Music	2	18.2%	
When do you use the priming technique?			
When you train	44	37.0%	$p = 0.265$
Before your competition	35	29.4%	$p = 0.163$
While you compete	24	20.2%	$p = 0.493$
Only on maximum effort days	14	11.8%	$p = 0.971$
Other	2	1.7%	

Only on maximal effort days = training sessions involving resistance exercise of 5RM to 1RM or when maximal intensity is required in an athlete's training.

Table 4.4 Analysis of priming use and perceived effectiveness.

	Priming count (*n*)	Perceived positive effectiveness of priming (%)
Performance level		
Amateur	54	85.1%
Semi-professional	22	100%
Professional	12	83.3%

4.4 Discussion

This study sought to further understand whether athletes have been implementing cognitive or behavioral priming strategies to improve physical performance. It was identified that there was a need to obtain an assessment directly from athletes because the majority of research to date investigated S&C coaches (Ronay & von Hoppel, 2010; Slimani et al., 2016; Sousa, 2019). A large proportion of athletes (78.7%) across all ability levels in this study reported using psychological priming strategies to enhance their performance. Strategies using various stimuli were implemented before and during training or competition. A significant relationship (φc 5 0.72; p = 0.011) was observed when priming was implemented to improve motivation.

Radcliffe et al. (2013) reported that the top 2 attributes that athletes felt were needed for successful performances were increased motivation and confidence. This study identified a large proportion of subjects felt their priming method improved performance significantly ($\varphi c = 0.72$; $p = 0.011$) via increased motivation (38.1%), followed by reduced fear and anxiety (22.2%), competition/session intensity (20.6%), and perceived increase in strength and power (15.1%), which are also in line with previous research (Radcliffe et al., 2013). Interestingly, these traits have all been shown to be associated with anabolic hormonal changes (Klinesmith et al., 2006; Ronay & von Hoppel, 2010; von Honk et al., 2005). Cook et al. (2013) examined associations between salivary-free testosterone and training motivation in elite male rugby union players, and they found that changes in pre-workout free endogenous testosterone concentrations correlated strongly ($r = 0.81$) with voluntary workloads. Cook and Beavan (2013) also reported salivary testosterone concentration levels strongly correlated with bench press ($r = 0.83$) and squat ($r = 0.67$) performances at a self-selected workload, as well as maximal medicine ball throws for distance ($r = 0.70$). Therefore, a potential association may occur between elevated testosterone concentration levels and an athlete's psychological and behavioral state, which subsequently may lead to improved physical performance. The results from this survey were in line with Cook et al. (2013), who suggested that improved motivation and confidence levels may potentially lead to improved physical performance.

In the present study, music was the most popular mode for priming (26.6%), followed by instructional self-talk (24.2%), motivational self-talk (22.7%), physical actions (19.5%, such as stamping feet, clenching fists, or jaw, slapping head or back), and watching video clips (10.8%). Karageorghis and Priest (2012) reported that the effect of music magnifies an athlete's psychological state and physical performance levels. Listening to music before undertaking a 50 m freestyle race showed significant improvements in both swimming race performance (0.82 s difference; $p < 0.01$) and handgrip strength (2.2 kg difference; $p < 0.05$) (2011). Eliakim et al. (2007) also reported similar results after 12 male and 12 female volleyball players undertook a 30-second Wingate test and significantly ($p < 0.05$) increased peak anaerobic power from 10.7 to 11.1 W·kg after arousing music was played during a 10 min warm-up. In addition, the use of music has been shown to significantly improve anaerobic endurance when holding a 1.1 kg dumbbell extended in front of the body until muscular failure in 58 physically active subjects (11% improvement; $d = 5\ 0.4$) (Crust & Clough, 2006). Miller et al. (2010) also reported that music can significantly increase low- to moderate-intensity endurance oxygen uptake (1.18 ml·kg·min difference), minute ventilation (3.91 l·min difference), enjoyment (3.35 points higher out of a score of 10), and reduced subjects' rating of perceived effort (0.65 difference) in 20 university students when running at 78% heart rate maximum, for 20 mins on a treadmill. More recently, Moss et al. (2018) reported small to large effect size (0.2 – 1.2) improvements in muscular strength in 16 university students when listening to self-selected music while undertaking the back squat and bench press at 60 and 70% 1RM to repetition failure. The increases in muscular endurance may be the result of an ergogenic effect of delaying fatigue or increasing work capacity through the impedance of physiological feedback signals associated with physical exertion (Karageorghis & Priest, 2012). However, this effect seems to have little impact on high-intensity running (MacDaugall

& Moore, 2005). It has been reported that this is the result of lower information processing abilities to external stimuli at high intensities (Ronay & von Hoppel, 2010; Tod et al., 2015); thus, it seems that music may have a more prominent effect on high-intensity efforts compared with low-intensity exercise bouts. Interestingly, the ideal music tempo seems to be 120 bpm because this is the cutoff point from varying music aesthetics, neurophysiology, and human locomotion (Hirasaki et al., 1999; MacDougall & Moore, 2005; Slimani et al., 2016). It is a tempo that reflects natural rhythmicity (MacDougall & Moore, 2005) and could potentially be the point whereby the intensity switches to a higher level.

Interestingly, imagery was not reported to be used by any subjects in the present study. Research has shown that increased electromyographic activity, strength, technique development, program adherence, and stress regulation are all achieved via the use of imagery (Radcliffe et al., 2013). Imagery is a complex strategy to implement because of greater emphasis on psychological elements (Radcliffe et al., 2013); therefore, the lack of implementation could be the result of athletes not being exposed to such a technique or given specific guidance or coaching on how to undertake the strategy. The self-talk technique was also employed by only half of the present sample, despite existing research supporting its use because of increased arousal, confidence, belief, muscular strength, and power (Tod et al., 2003). These findings potentially indicate that it could be an underused priming strategy. However, self-talk has been shown not to elicit as favorable results for improving muscle endurance markers compared with preparatory arousal, goal setting, and free-choice psych-up (Tod et al., 2015). Also, when compared with motivational self-talk, instructional and cognitive restructuring self-talk (to modify or replace negative thoughts) did not produce positive results (Tod et al., 2015).

The timing of implementing a priming strategy was preferred to be undertaken during training (37.0%), followed by before competition (29.4%), during competition (20.2%), and on maximal effort days (11.8%). Research into the efficacy of implementing priming strategies at varying times seems to be sparse. However, Crust (2006) reported that listening to music for the entirety of holding a 2.2 kg dumbbell horizontally in front of the body was more efficacious by 7.5 s than only listening before the task in 27 male undergraduate students. Elliott et al. (2005) also implemented motivational music during a 20 min cycle at 60 – 80% of maximum heart rate in 18 students and found that distance covered increased by 0.99 km compared with no music played. Priming strategies implemented pre-task appear to be more common. For example, a self-selected psychological “psych-up” significantly improved peak torque by 61 N (11.8%) during a five-rep chest press in 20 adults when performed 1 min before the test (von Honk et al., 2005). Hammoudi-Nassib et al. (2017) also reported improvements of 5.7% in 30 m sprint performance when a “psych-up” with imagery 30 s before undertaking the task in 16 student male sprinters. Positive results associated with using imagery pre-task for high-intensity exercise could be the result of the anxiety-reducing benefits that run alongside the increase in self-confidence and motivation (McHugh, 2013), which may not occur with music. Interestingly, Peynirocioglu et al. (2000) found basketball free-throw shots significantly improved ($p < 0.01$) by 14 completed baskets after 120 students performed a self-selected imagery strategy before performing the task. This may indicate that psychological priming could also improve skill-based performance markers when implemented before a given task. However, with research on the implementation of non-music strategies during competition being sparse, based on the current literature, the efficacy of the timing of priming strategies and whether the techniques elicit positive results with high-intensity tasks is mixed and requires further research.

An additional aim of this study was to understand whether athletes recognize that their coaches are incorporating priming strategies because this may be the most viable way to support the implementation of such techniques. The results indicate that only 10.1% of coaches used priming strategies to support their athletes’ performance. Of these athletes, 9.0% were professional, 27.3% were semi-professional, and 63.7% were amateur, with amateur athletes better supported by their coaches. However, coaches of professional athletes may not have been using conscious priming techniques but rather passive subtle techniques such as images on walls whereby the athletes were only subconsciously aware of them. Nonetheless, Radcliffe et al. (2018) reported that coaches felt that they did not have the requisite skill levels to integrate appropriate psychological strategies but were aware of their importance and significance. This would align with the results from this study whereby only 44.4% ($n = 4$) of the semi-professional and professional athletes implemented the use of a coaching priming strategy. Radcliffe et al. (2013) reported a much higher use of psychological strategies from coaches. The disparity in findings could be interpreted in a couple of ways: coaches use them with a select few athletes, or athletes may not acknowledge or realize the use of certain strategies.

It has been previously identified by coaches that one of the barriers to implementing priming strategies is the perceived negative attitude athletes have toward learning and using these techniques (Radcliffe et al., 2018). This study reported that priming strategies were used by 88.8% of subjects. However, this result could be the result of differing perceptions of priming. For example, coaches may not consider physical actions or watching videos as priming, whereas athletes may. Aligning definitions between coaches and athletes would eliminate any confusion and potentially increase strategies being implemented and should be a source for future research, particularly as these findings would suggest that athletes' perceptions toward priming strategies are potentially not as skeptical as coaches may believe. Results here also support the lack of coach involvement toward priming, with few coaches encouraging their athletes with these methods; however, athletes were intuitively undertaking priming strategies regardless that they had a positive perception toward them. If coaches had greater knowledge and confidence in priming strategies, they may be able to consider using them for the purpose of performance enhancement. The findings from this study would indicate that at an organizational level, perhaps psychological, strategies could be given greater consideration with the education of coaches.

A limitation of this study is the small sample size of professional athletes (n = 11) surveyed, along with the relatively small subject number from the various sports, with many sports represented only having one subject. Additionally, greater description should have been given to the questions asked, along with a greater number of questions to gain more depth; for example, this investigation failed to ask how long before training priming occurred and how priming knowledge was obtained. Therefore, further research is required to determine the efficacy of the physiological effects of the preferred priming strategies and their subsequent effect on athletic performance through a wide range of sports and athletic abilities.

4.5 Conclusion

This study shows that a significant proportion of athletes from all performance levels questioned felt that their priming technique improved performance, particularly the use of the behavioral stimulus of listening to music and physical actions, along with cognitive motivational self-talk. This provides potential direction in targeting techniques for specific strategies to be developed. As cognitive and behavioral psychological priming strategies were similarly undertaken, S&C coaches should, therefore, be equipped to develop both for their athletes. To facilitate this, sporting organizations should allow such opportunities for S&C coaches to access educational workshops or mentorships with sports psychologists to develop their knowledge and confidence to implement psychological strategies to improve preparation for training and competition.

Chapter 5 METHODOLOGIES

5.1 Introduction

Applying the results from Chapter 3, the systematic review with meta-analysis, and Study 1 (Chapter 4), a survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance, these identified the direction the following investigations should take. These studies investigate the effect of priming techniques that were either already used by participants from Study 1, previously explored in the systematic review, or had yet to be examined upon various physical performance markers. Each study's methodologies maintained a similar protocol to compare the primers' efficacy. Each study altered either the primer and/or physical performance marker. The overall methods for all four of the following studies are below.

5.2 Experimental approach to the problem

Each study conducted a randomized cross-over design using a convenience sampling method, whereby subjects undertook either a CMJ or IMTP or a self-selected load in 16RM back squat, 3RM back squat, four sets of a 4RM bench press, or a 65% 1RM back squat to failure. These tests measured power, maximal strength, muscular strength, and strength endurance. Force plates (Hawkin Dynamics Inc, USA) were used to measure jump height, peak power, reactive strength index modified (from the CMJ), and peak force. A "push band" (Push Inc, Toronto) was implemented to measure average barbell velocity. Given participation availability and COVID restrictions, subjects partook in one, two, or three interventions. Therefore, results are split into individual interventions. The same protocols were administered in each intervention. During the 15-minute warm-up prior to the testing, subjects either partook in (a) listening to SSM, (b) implementing MSTI, (c) undertaking MST, (d) being filmed for SMO on an iPhone 12 smartphone (Apple Inc, California, USA), (e) being observed in person, or (f) passively (CON group) warming up. Before the interventions and post-warm-up, subjects provided saliva samples to analyze salivary testosterone and cortisol concentration levels.

5.3 Procedures

On arrival at the testing facility and in a randomized order, subjects gave a saliva sample, followed by undertaking an intervention for five minutes of either MST with/ without imagery, listening to self-selected music, being observed, or a control condition. A physical warm-up then proceeded consisting of a 15-minute standardized "RAMP" (raise heart rate, activate and mobilize joints, followed by potentiating the body) protocol (including ten inch worms, ten front lunges per side, ten "world's greatest stretch" per side, ten single-leg glute bridge per side), followed by three sets of five reps at a self-selected load of either a bench press or back squat exercise. Load increased each set by a self-selected amount, with a two-minute rest (Sheppard & Triplett, 2016) before preparing to undertake a physical test. A second saliva sample was then taken. The allotted time of twenty minutes between silva samples was given as changes in salivary testosterone concentration levels can be seen after fifteen minutes, and cortisol concentration levels can peak ten to fifteen minutes after a stressful situation (Molina et al., 2013; Hannibal & Bishop, 2014; Cook & Crewther, 2012). The time of day of the testing session was standardized to account for the daily circadian rhythm with the natural fluctuations in cortisol and testosterone (Kraemer et al., 2001). At least 72 hours separated each condition tested. Before testing, all subjects had a familiarization session, which enabled the determination of either the IMTP bar height, the 4RM bench press load, the 16RM, 3RM, or 65% 1RM back squat load, and aiding in determining the music playlist (for the self-selected music condition) and engagement in self-talk with/without imagery (see Figure 5.1).

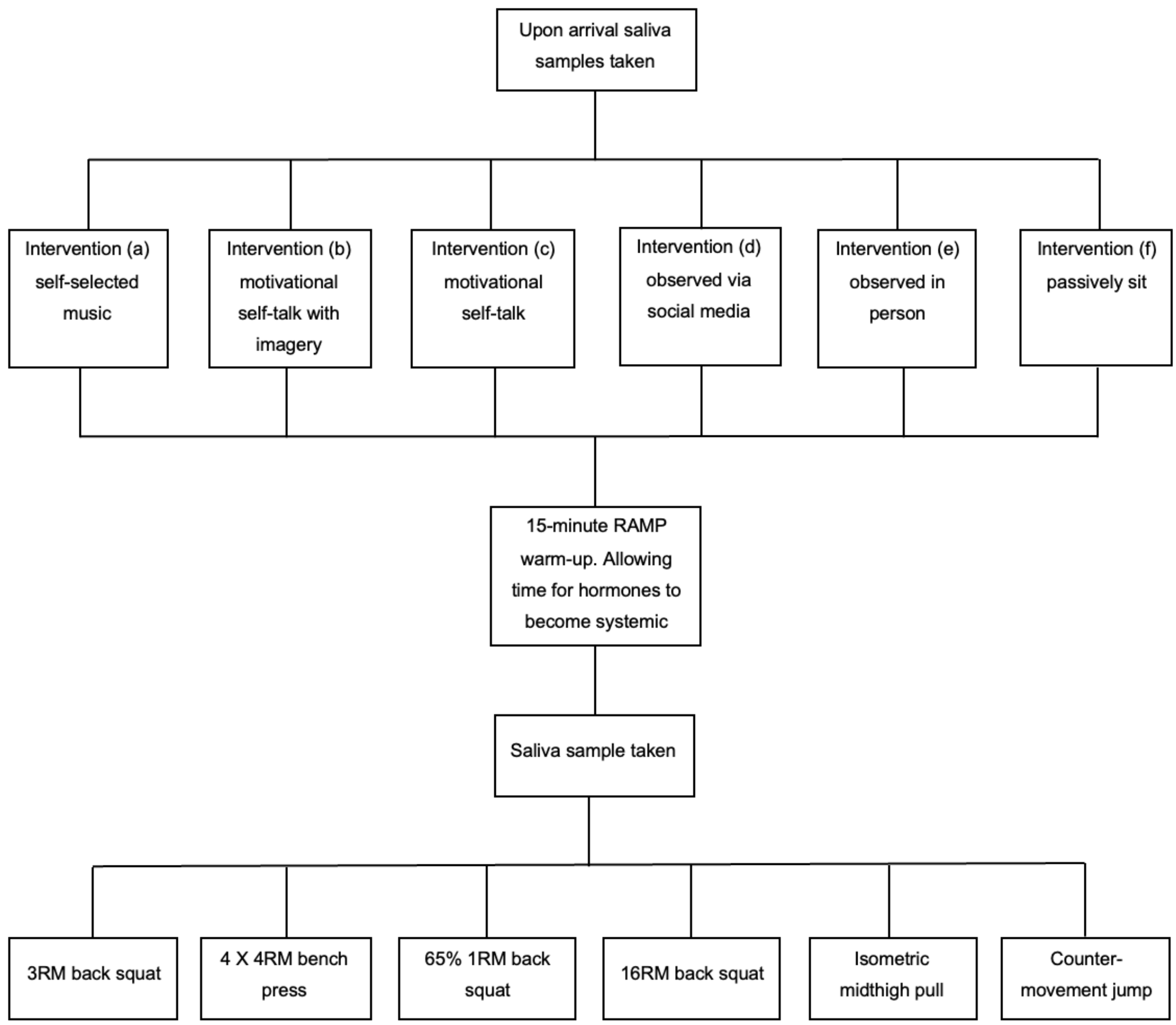

Figure 5.1 Experimental design.

5.4 Motivational self-talk

Subjects were given a script containing positive motivational statements (Hardy, 2006), which was followed by external coaching cues (Winkelman, 2018) consisting of phrases: "I WILL push the floor away," "I CAN push this barbell up," and "I WILL explode up." If subjects had a phrase they preferred to use that was not listed, this was allowed and refined during the familiarization session. For the added imagery component, subjects were given an imagery script containing elements of the "PETTLEP" (physical, environmental, task, timing, learning, emotion, and perspective) imagery framework (Holmes & Collins, 2001) and guided to imagine a positive emotion while visualizing themselves performing the subsequent tests successfully, either as though they were watching themselves on television or looking through their own eyes.

When combining motivation with imagery, this procedure is classified as motivational-general and cognitive-specific imagery, with subjects reciting to themselves their motivational statements while positively feeling and seeing themselves performing a successful task (Hall et al., 2009; Noordin & Cumming, 2008).

5.5 Self-selected music

The psychological effect of music can be very individualized, with influences on emotions, mood, behavior, attitudes, and cognition affecting everyone differently (Terry & Karageorghis, 2006; Karageorghis & Terry, 1997). Therefore, subjects self-selected the music of their choice rather than implementing pre-selected music as long as the songs were of the required bpm, as rhythm and tempo have been shown to prompt physical reactions to enhance performance (Terry & Karageorghis, 2011). Therefore, in line with Karageorghis (2018), who reported increases in handgrip strength when 52 male athletes listened to songs at 125 bpm and at the loudest decibel of 90. Therefore, subjects were asked to listen to songs in a Spotify playlist called “125 bpm songs,” which contained songs with a BPM of 125. Subjects used their headphones with their smartphones and were asked to play the music at the highest audio level.

5.6 Social media

In recent years, social media platforms have enabled a virtual observer effect. Therefore, a novel approach was implemented. As the subjects warmed up, they were continuously observed with a mounted iPhone 12 camera. The mounted camera was known to the subjects, and they were told that the film was to be uploaded to the university's social media platforms.

5.7 In-person observation

As the subjects warmed up, they were continuously observed in person. Ten in-person strangers whom the subjects did not know and were masters-level college students would stand on the edge of the room, observing the subjects through the whole intervention. To blind the subjects, they were told the students happened to be in the facility by chance. This is a novel experiment that has yet to be researched.

5.8 4RM Bench press

The bench press test was undertaken four minutes after the final warm-up set. The protocol was standardized, with all subjects told to lay supine on a bench with eyes below a racked bar. Both hands were pronated and positioned slightly wider than shoulder-width apart so that the elbows were at a 90-degree angle at the bottom of the movement, whereby the bar touches the chest (Baechle & Earle, 2008). A 4RM load was investigated as strength is a critical athletic characteristic. Therefore, could subjects be primed to a level whereby they could overcome their previous best effort. The load lifted was recorded in kilograms (kg) using an International Weightlifting Federation (IWF) Olympic competition barbell and plates (Eleiko; Halmstad, Sweden). An accelerometer training device was attached to the barbell to test velocity (m/s) for all four reps ("Push Band"; Push Inc, Toronto) to determine whether the barbell was being pushed quicker after the intervention. Callaghan et al. (2022) report that the test-retest reliability of this accelerometer is reliable at all loads (ICC = 0.79 – 0.92; CV 2.63 – 6.89%) except at 20% 1RM in the bench press and back squat (ICC 0.49 – 0.64; CV = 3.13 – 3.62%). Additionally, Lake et al. (2019) report that the “Push Band” peak velocity measure at 60% (ICC = 0.836 – 0.983; CV 1.2 – 7.2%) and 90% (ICC = 0.866 – 0.986; CV 2.3 – 7.1%) 1RM in the bench press is reliable and that compared to motion capture the “Push Band” is valid (mean difference at 60% 1RM -5%; at 90% -14%). Therefore, it is acceptable to implement this device for these studies. A four-minute rest period whereby the subject sat on the bench was taken between the four sets to allow for adequate recovery. The researchers provided no verbal encouragement. Reps not completed were classified as failed and recorded as 0 kg.

5.9 Countermovement jump

Lower-body power is a critical component in many sports. Therefore, a CMJ test was implemented with the metrics of jump height, modified reactive strength index, and peak power assessed. Post-warm-up and once the examiner is ready, the subjects stand on the portable force plate (Kistler 9286 Force Plates, Winterthur, Switzerland;

measurement range Fx and Fy = -2.5 – 2.5 kN and Fz 0 – 10 kN; sample frequency set at 1000 Hz; calibrated using subject body weight to detect force plate accuracy) with hands on hips, upright trunk, and feet shoulder-width apart. On the mark from the examiner of "go," they then dropped down for a short self-selected countermovement before using maximal effort to jump as high as possible, keeping their legs straight, with no knee tuck, and their feet in a dorsiflexion position. Subjects performed three trials, with three minutes of rest between each trial. The highest CMJ was used for statistical analysis. The researcher gave no verbal encouragement. Kistler BioWare 5.3 software was used to collect the data from the force plates, converting the trials into useful information. Chavda et al. (2017) Microsoft Excel spreadsheet was implemented to interpret the information gathered. Lastly, Kistler force plates were used as they have been reported to have high test-retest reliability (ICC 1.00) and very good validity score with a high correlation with the My Jump 2 app (r = 0.999, p = 0.001) when performing a CMJ (Plakoutsis et al., 2023).

5.10 Isometric midthigh pull

Using Kistler force plates and an Absolute Performance isometric rig (Cardiff, UK), the IMTP test assessed peak force (N) output and force at 100, 200, and 300 m/s as in various sports, applying force rapidly is deemed important in actions such as change of direction, jumping, and throwing (Newton & Kraemer, 1994). 30 m sprint performance was significantly correlated ($p < 0.05$; r = 0.433) to force output at 100 m/s in 25 collegiate soccer players (Kuki et al., 2017). Mason et al. (2021) also reported very large correlations between IMTP and maximal sprint speed and 100, 150, and 200 m/s (r = 0.51, r = 0.66, r = 0.76, respectively) in eleven professional soccer players. Keogh et al. (2020) that maximal force, absolute peak force, and force at 150, 200, and 250 m/s are reliable (ICC 0.91, CV 9.8%), and James et al. (2017) report that peak force measured on portable force plates is highly reliable (ICC 0.96, CV 9.2%) and an acceptable validity score of ICC = 0.88 and CV of 9.2% against a fixed force plate. This test has also been strongly related to 1RM in lower body exercises; for example, Witt et al. (2016) reported a significant ($p < 0.05$) correlation between IMTP and a 1RM deadlift exercise (r = 0.88) in nine subjects. This is a multijoint, fixed-position isometric test, which replicates the "second pull" position of the clean or snatch weightlifting movement, which is the moment the highest forces and bar velocities are generated during these weightlifting exercises (Beckham et al., 2018). Four minutes after performing the CMJ, subjects stand next to the force plate, once the examiner is ready, they stand on the force plate with their knees flexed to an angle between 125-135° and hips 140-150° (Beckham et al., 2018). On the examiner's mark of "go," subjects pull against a fixed bar set anteriorly to the thighs for five seconds using maximal force. The researcher gave no verbal encouragement.

5.11 Back squat

Back squat tests were undertaken four minutes after the final warm-up set. If the attempt failed, a three-minute rest was given before their next attempt with a 3 kg reduced load. This process was replicated until an attempt had been completed. Before performing the test, squat depth was calculated whereby the thigh descended to a parallel position with the head of the femur in the same horizontal plane as the superior border of the patella (Coutts et al., 2007). A box was then positioned posteriorly to the subject at the abovementioned height as they performed the exercise, controlling the individualized depth across all trials. Barbell load was recorded in kg using an IWF weightlifting competition Olympic barbell and plates (Eleiko; Halmstad, Sweden). An accelerometer ("Push Band"; Push Inc, Toronto) training device was attached to the barbell to determine the average velocity (m/s) for all reps. No verbal encouragement from the researcher was used.

5.12 Saliva sampling

Subjects were asked to refrain from eating or drinking for two hours before testing and to arrive at the laboratory at the same time for each session. This is due to the effects of the circadian clock, which is an endogenous biological "clock" driven by environmental cues which sets physiological rhythms, including hormonal secretions over a 24 hour period. As a result, testosterone and cortisol incur the largest secretion in the morning and slowly decrease throughout the day (Dickmeis, 2009). Subjects had saliva samples taken on arrival at the laboratory, and after the warm-up, they were asked to place a sterile swab in their mouth and allow saliva to soak in for two minutes. The swab was removed, placed into salivate collection tubes (Sarstedt, Leicester, UK), and stored at -80°C. Before biochemical analysis, samples were thawed and centrifuged at 3000 revolutions per minute for three minutes to obtain clear saliva with low viscosity. Salivary testosterone and cortisol levels were determined by employing a commercially available enzyme-linked immunosorbent assay (ELISA, IBL-Hamburg, Germany. See Appendix C) with detection limits of 20 and 0.4 nanomoles per liter (nmol/L). ELISA salivary hormone testing is significantly correlated to blood serum testing in both testosterone and cortisol ($r = 0.96$, $p < 0.001$ and $r = 0.91$, $p < 0.001$, respectively). Male testosterone testing results have a higher correlation than females (male $r = 0.91$ and female $r = 0.62$) (Salimetrics, 2022; Salimetrics, 2021). Evans (1996) states that the magnitude of a correlation above 0.60 is strong; therefore, a mixed sample method was implemented. Additionally, the subjects' results will be compared to themselves. Therefore, the results of pooling are unaffected. The precision of the testing for the studies was estimated by the coefficient of variation. In Johnson's (2009) article researching the assessment of salivary hormones, he reports that intra- and inter-assay CV of less than 10% is considered good; therefore, for this study, the intra- and inter-assay coefficients of variation (COV) were set to below 9%.

5.13 Statistical analysis

Statistical analysis, including intraclass correlation coefficient and standard error of measurement (SEM) to measure reliability were completed using Microsoft Excel and IBM SPSS Statistics 27. Endocrine markers, bench press and back squat loads, barbell velocity, IMTP, and CMJ were analyzed using repeated measures ANOVA with Bonferroni Post hoc analysis. Repeated measures ANOVA testing are robust to violations of normality (Field, 2013), which are likely when measuring salivary testosterone and cortisol outside of highly trained athletes (Crewther et al., 2011; Turner et al., 2017). It has been reported that elite athletes' hormone responses can differ considerably from lesser-trained as these individuals are more sensitive to stress due to their bodies not being efficient at regulating stress responses. Physical exercise stabilizes hormonal responses through repeated exposure and adaption, becoming more resilient to fluctuations (Montoya et al., 2011). Statistical significance was set at an alpha level of $p < 0.05$. Practical differences were examined using effect size analysis (Hedges g) with magnitudes of difference interpreted according to Cohen (1992), whereby < 0.20 = trivial; 0.20 – 0.49 = small; 0.5 – 0.79 = moderate; > 0.8 = large. Ninety-five percent confidence intervals (CI) were also calculated per Hedge and Olkin (2014). Effect sizes and 95% CI were calculated using Microsoft Excel. Data for testosterone and cortisol were analyzed as a percentage change (± SEM) from each testing day's baseline, and barbell loads, velocity, IMTP, and CMJ were assessed as a percentage change (± SEM) from the control condition. Individual case study analysis was undertaken to identify high and low-endocrine individual responses to the interventions. Lastly, subject participation numbers were calculated at a minimum of 24 from a priori power analysis (using G*Power (Version 3.1, University of Dusseldorf, Germany), implementing a statistical power of 0.8 and type 1 alpha level of 0.05).

Chapter 6 STUDY 2

6.0 Changes in salivary testosterone concentrations and voluntary back squat performance following motivational self-talk with imagery or self-selected music

6.1 Introduction

Before competition or training, performing a warm-up is a widely accepted practice to physically and mentally prepare for an upcoming event (Jeffreys, 2007). It is well established that increasing blood flow, muscle, and core temperature through physical preparation improves the rate of force development, muscle strength and power, oxygen delivery, and metabolic reactions (Bergh & Ekblom, 2001; Enoka, 2002; Hoffman, 2002; Jeffreys, 2007; McArdie et al., 2001). To achieve this, Jeffreys (2007) suggested the 'RAMP' warm-up protocol to “raise” the heart rate, “activate” and “mobilize” muscles and joints, and “potentiate” the effectiveness of the subsequent performance task. However, the mental aspect of warming up appears to lack a similar emphasis and protocol. Pre-competition speeches by coaches are routine to try and motivate and instill confidence, as is the use of sports psychology techniques, such as motivational self-talk and imagery, to boost self-esteem, manage stress, and provide focus (Cook & Crewther, 2012). These methods are often referred to as 'priming.' When athletes are without a coach or sports psychologist, the implementation of priming is possibly absent altogether due to the lack of knowledge, value, and protocols (Pain & Harwood, 2004). Unlike physical warm-ups, there appears to be a dearth of supporting research assessing the efficacy of mental priming interventions and how they relate to improving physical performance.

Strength and power-based athletes have naturally used cognitive strategies during or prior to training or competition to "psych" themselves up (Tod et al., 2005). A systematic review of 18 studies determined that an increase in muscular strength was evident (61 – 75%) after implementing cognitive psyching-up strategies involving imagery, self-talk, goal setting, preparatory arousal (a self-directed activity to increase emotional arousal), and free choice (Tod et al., 2015). Self-talk is defined as “*self-addressed verbalizations that can serve both instructional and motivational functions*”

(Blanchfield et al., 2013, p. 999). It has been proposed to enhance sporting performance (Tod et al., 2011), regulate effort, and enhance motivation (Hardy et al., 2015). Blanchfield et al. (2013) reported the effects of motivational self-talk on 24 recreationally trained subjects, cycling at 80% peak power output to exhaustion. Both time to exhaustion ($d = 0.69$, $p < 0.05$) and rating of perceived effort ($d = 0.80$, $p < 0.05$) showed significant improvement. Hypothesized mechanisms for the positive effects include increasing concentration, focus, and confidence, decreasing anxiety, and increasing neuromuscular drive, with the latter attributable to the release of catecholamines (Tod et al., 2015). However, there is a paucity in the literature regarding the extent to which performance can be enhanced and the mechanisms involved when using self-talk (Tod et al., 2011).

Another cognitive technique often used is imagery, which is proposed to be the link between physical and imagined movements and has become a widely used stimulation and performance-enhancing tool (Holmes & Collins, 2001; Slimani et al., 2017). It has been defined as "*an experience that mimics real experience and involves using a combination of different sensory modalities in the absence of actual perception*" (Cumming and Ramsey, 2009, p. 5). Ranganathan et al. (2004) showed that elbow flexion strength increased by 13.5% in 24 healthy subjects compared to a control group when motor imagery was incorporated for five times 15-minute training sessions each week for 12 weeks. However, it has been postulated that the effects of self-talk and imagery may be enhanced when combining the two methods, as self-talk may improve the quality of the imagery (Hardy et al., 2001). Cumming et al. (2006) investigated the effect of psychological priming by comparing positive facilitative imagery and self-talk ("I will hit the bull's eye") against negative debilitative imagery and self-talk ("I will miss the bull's eye") on dart-throwing accuracy. Imagery and self-talk scripts were given to subjects; they were told to vividly visualize the simple self-talk statement immediately before throwing the dart. Results revealed that 95 undergraduate students threw more darts closer to the bullseye when implementing the facilitative priming before performing the test than when they used the negative debilitative priming ($p < 0.006$). This result may indicate the potential effects of implementing both motivational priming strategies together. However, further investigations with similar study designs are warranted to corroborate this theory.

A survey of 90 athletes reported that 89% implemented at least one priming strategy before or during training or competition, with the most popular method being music (46 %) (Collins et al., 2021). Music appears to be an essential component of pre-competition routines for athletes, which has generally produced positive results (Bishop et al., 2007; Biagini et al., 2012). Evidence suggests this is accomplished by music altering or regulating mood, evoking memories, and raising spirits. Consequently, this increases work output, heightens arousal, induces a higher state of functioning, and reduces inhibitions (Karageorghis & Priest, 2012). For example, when music was played continuously during a 200 m freestyle trial in 20 collegiate swimmers, performances improved significantly by 2% ($p < 0.05$) (Karageorghis et al., 2013). Similarly, in 12 healthy male student cyclists, when music tempo was increased by 10%, their distance covered improved significantly by 2.1%, power by 3.5%, and pedal cadence by 0.7% ($p < 0.05$) (Waterhouse et al., 2009). Handgrip strength has also been shown to increase in 153 senior (65+ years of age) subjects when listening to their favorite music compared to their least favorite ($d = 0.42$) (Elzen et al., 2020). Ishak et al. (2020) report that endocrine changes in testosterone, cortisol, and oxytocin concentration levels may induce these positive effects, along with alterations in salivary immunoglobulin A, heart rate, and blood pressure levels. Additionally, it is postulated that increases in testosterone may induce risk-taking behaviors, which drive motivation. However, there appears to be a dearth of research examining music's effect on hormones and physical performance. A systematic review of music's effect on the endocrine system revealed that only three studies had investigated this phenomenon (Ishak et al., 2020). Mixed results were reported as the aims of the other studies were to relax the subjects rather than arouse them.

To bridge the gap in the literature, the overall aim of this study was to investigate the psychological interventions and priming capability of listening to SSM or engaging in MSTI on testosterone concentration levels and its subsequent 3RM back squat performance against a control condition. The release of cortisol will also be investigated to explain the mechanisms at work given these hormones' antagonistic relationship on account of a dual-hormone hypothesis, whereby testosterone’s effects are inhibited when cortisol is high and vice versa (Dekkers et al., 2019). Cortisol has been reported to have an inhibitory effect on Leydig cell function, which subsequently results in a decreased production of testosterone (Brownlee et al., 2005; Cook &

Crewther, 2014; Mehta & Josephs, 2010; Mehta & Prasad, 2015). This reciprocal inhibition has been termed functional crosstalk (Dekkers et al., 2019). It is hypothesized that these psychological methods will decrease cortisol and increase testosterone, producing surges in risk-taking and consequently enhancing performance in the 3RM back squat.

6.2 Methods

Please see Chapter 5 for the relevant methodology and statistical procedures.

6.2.1 Subjects

Nine healthy collegiate adult males (22.4 ± 2.1 years, 178.1 ± 8.2 cm tall, and a mass of 75.6 ± 9.2 kg) and six healthy collegiate adult females (22.5 ± 3.7 years, 168.9 ± 4.7 cm tall, and a mass of 67.8 ± 11.2 kg), all in good health and free from injury, with at least three years resistance training experience, volunteered to participate in this study. Subjects were classed as recreational, attending the gym at least twice weekly. All subjects provided informed consent, with study procedures meeting Middlesex University's ethical approval.

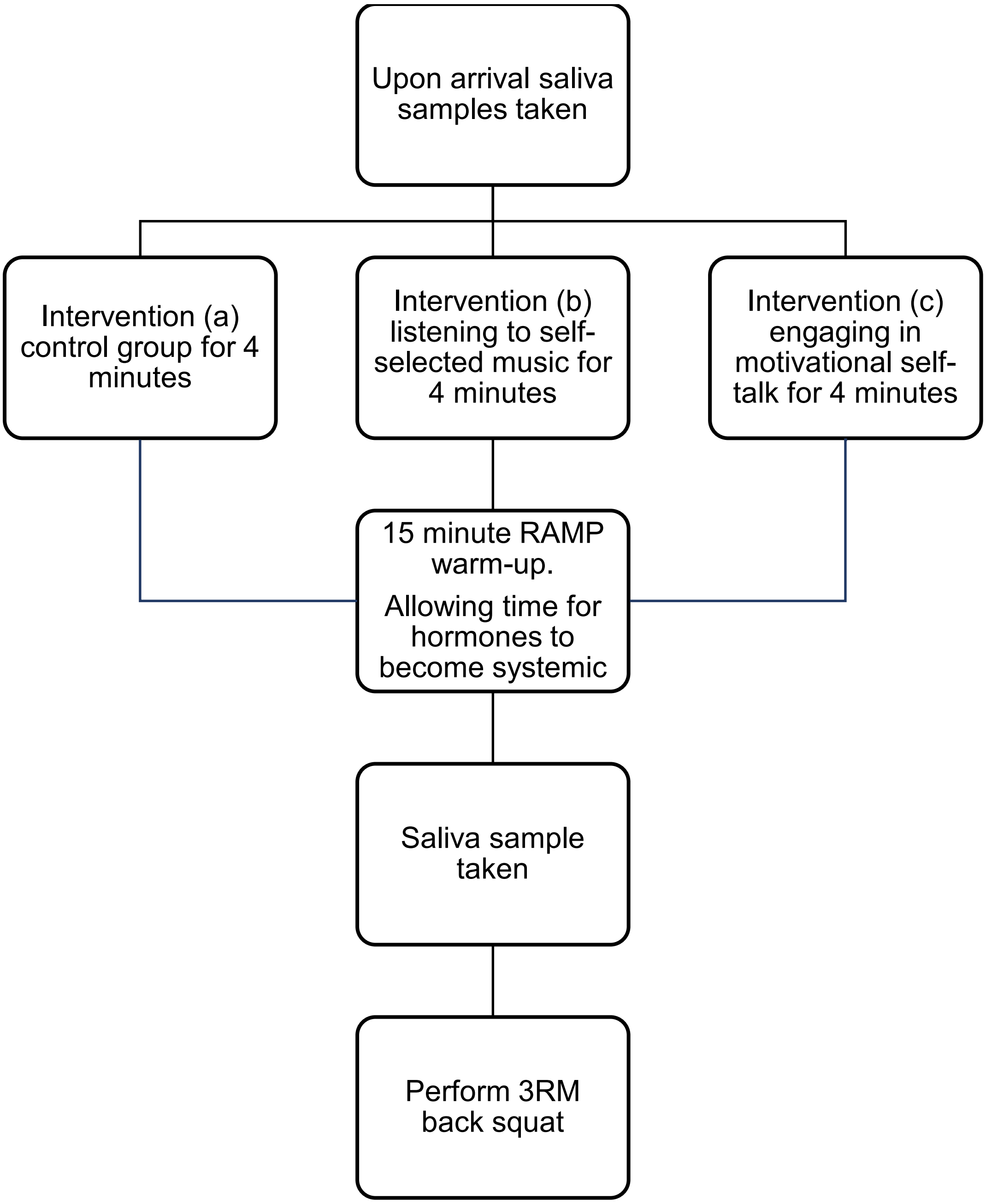

Figure 6.1 Experimental design.

6.3 Results

No statistically significant differences were noted in 3RM (*p* = 0.61), testosterone (*p* = 0.28), or cortisol (*p* = 0.89) markers. Compared to the CON (91 ± 22 kg) condition, there was a practically small increase in 3RM back squat load lifted in the MSTI (96 ± 23 kg, *g* = 0.22, 95% CI, -0.10, 0.54) and SSM (97 ± 25 kg, *g* = 0.26 95% CI, -0.23, 0.75) conditions, corresponding to a change of 5.2% and 6.4% respectively (Figure 6.2 and 6.3). Intraassay COV was 8.1%. Salivary testosterone concentrations were increased by MSTI 113 ± 38% (g = 0.39, 95% CI -0.27, 1.06), SSM 120 ± 35% (g = 0.66, 95% CI -0.06, 1.37), and CON 100 ± 22% (Figure 6.4 and 6.5). Salivary cortisol concentrations were CON 101 ± 33%, MSTI 99 ± 24 %, and SSM 103 ± 31%, which led to trivial effects sizes for both conditions of MSTI g = 0.08 (95% CI -0.56, 0.71) and SSM g = 0.07 (95% CI -0.55, 0.70) (Figure 6.6 and 6.7). As a consequence, the TC ratio (p = 0.68) resulted in the CON 9 ± 45%, MSTI 20 ± 48%, and SSM 22 ± 35%, equating to small effect sizes of MSTI g = 0.23 (95% CI -0.41, 0.87) and SSM g = 0.31 (95% CI -0.34, 0.96) (Figure 6.8 and 6.9). However, there was no statistically significant correlation in any of the interventions between 3RM, testosterone, or cortisol (CON 3RM – testosterone r = 0.11, CON 3RM – cortisol r = 0.25, MSTI 3RM – testosterone r = 0.25, MSTI 3RM – cortisol r = 0.06, SSM 3RM – testosterone r = 0.41, SSM 3RM – cortisol r = 0.27).

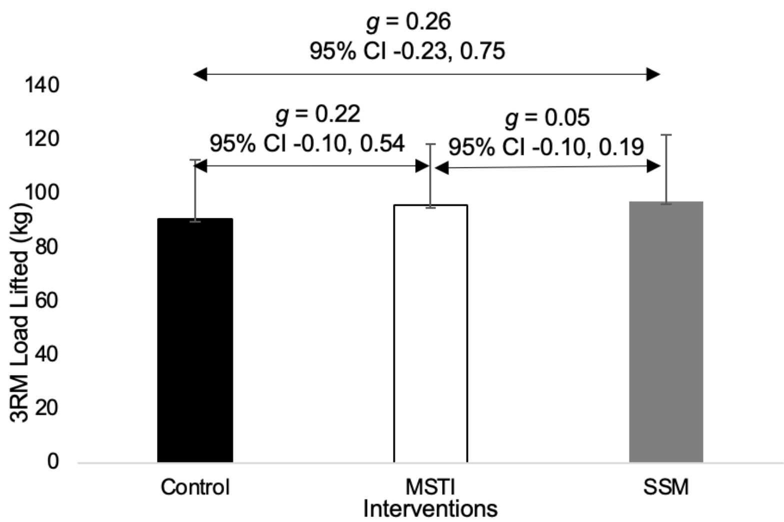

Figure 6.2 The mean 3RM back squat load lifted in kilograms for the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions with standard deviation. g = effect size, and CI = 95% confidence intervals.

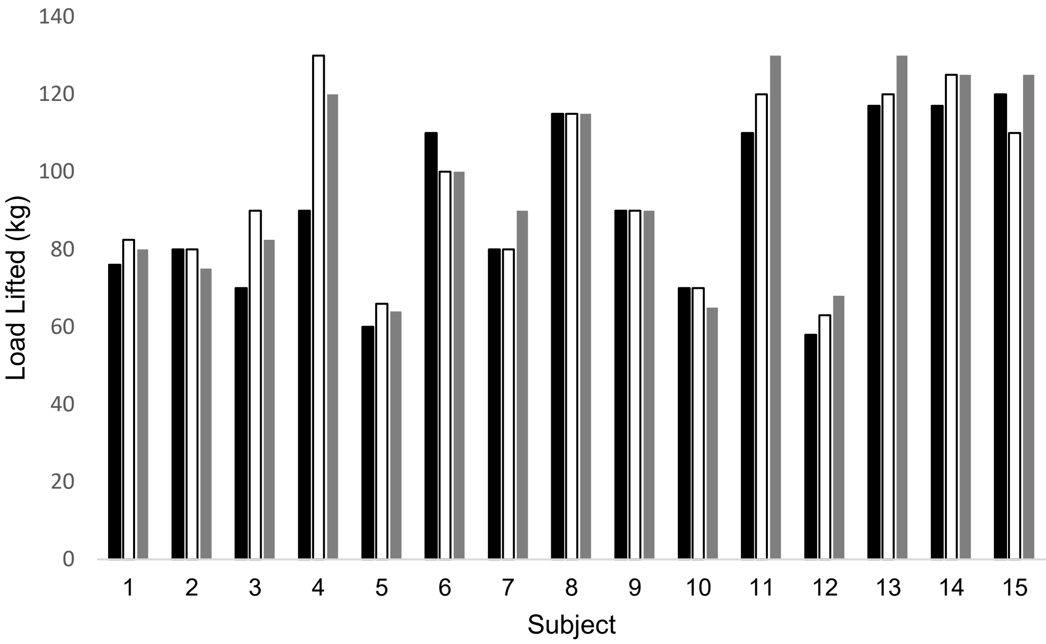

Figure 6.3 The individual 3RM back squat load lifted in kilograms for the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions.

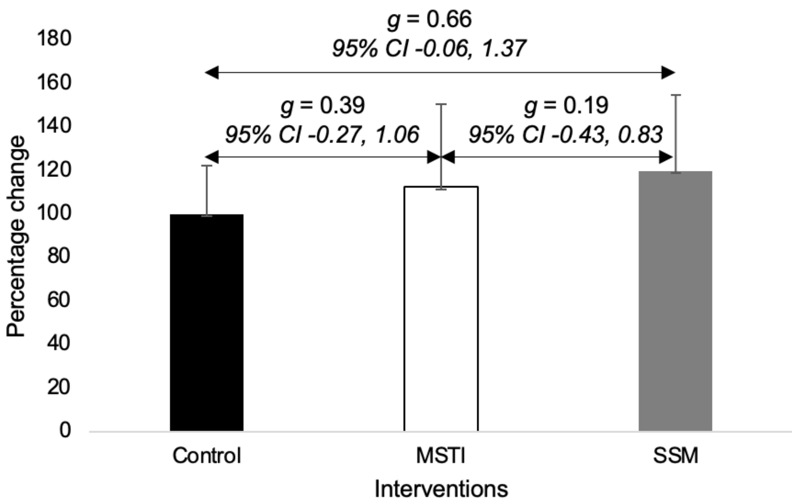

Figure 6.4 The mean percentage change in testosterone concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions with standard deviation. *g* = effect size, and CI = 95% confidence intervals.

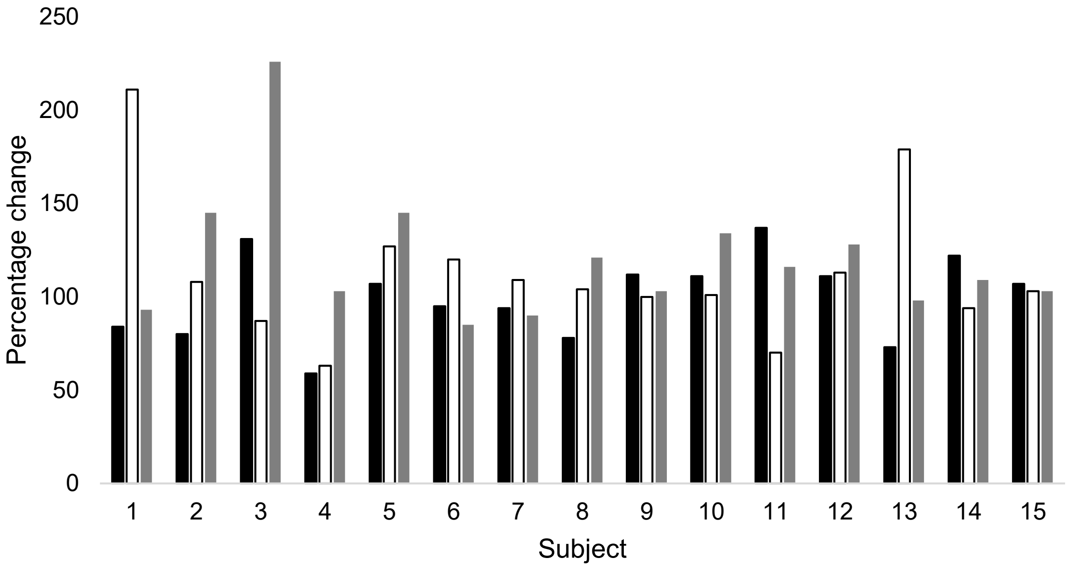

Figure 6.5 The individual percentage change in testosterone concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions.

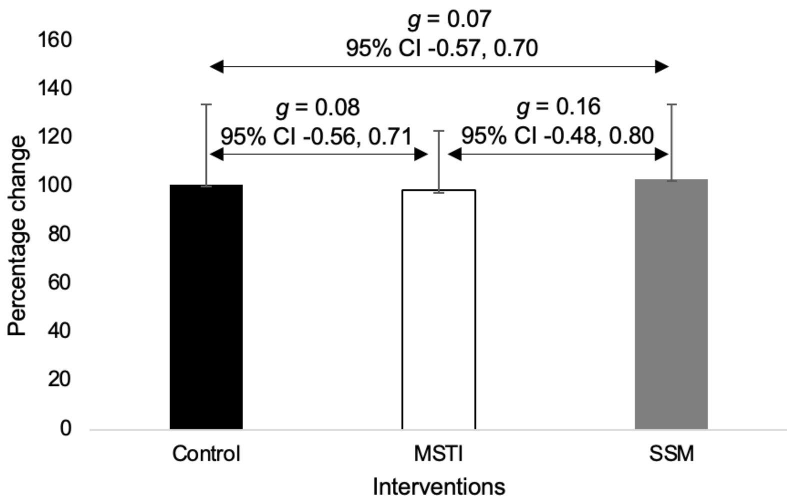

Figure 6.6 The mean percentage change in cortisol concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions with standard deviation. *g* = effect size, and CI = 95% confidence intervals.

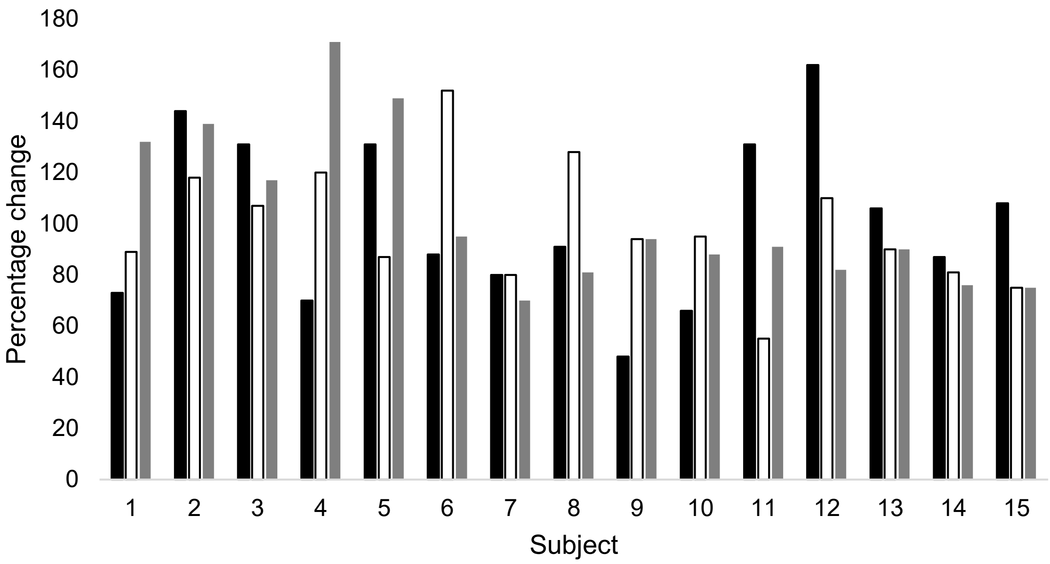

Figure 6.7 The individual percentage change in cortisol concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions.

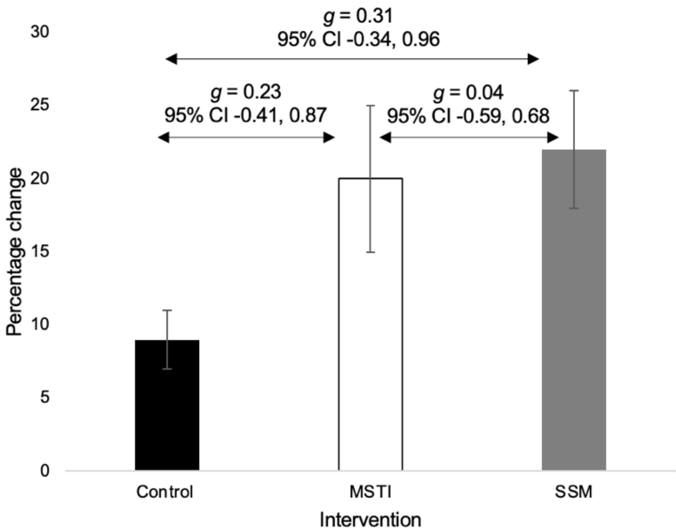

Figure 6.8 The mean percentage change in testosterone to cortisol ratio concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions with standard deviation. *g* = effect size, and CI = 95% confidence intervals.

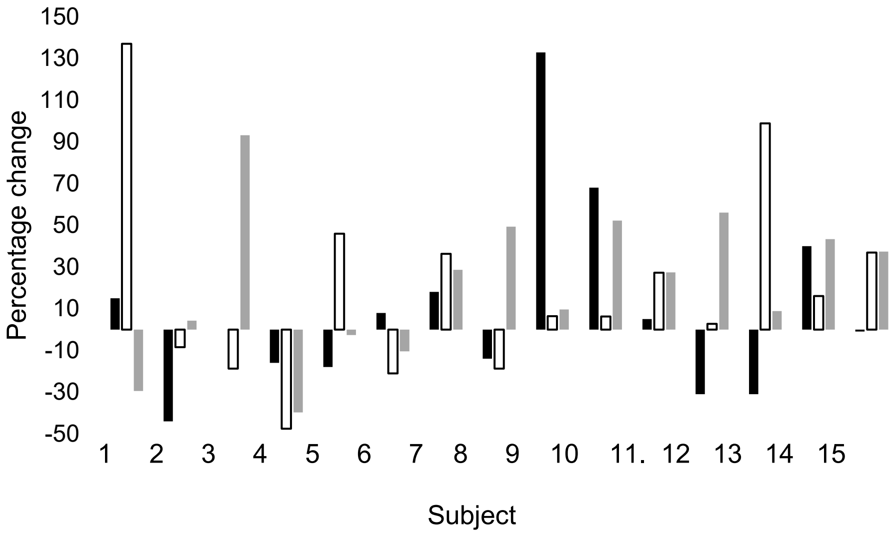

Figure 6.9 The individual percentage change in testosterone to cortisol ratio concentrations in the motivational self-talk with imagery (open bars), self-selected music (grey bars), and control (black bars) conditions.

6.3 Discussion

The present study investigated psychological interventions of listening to SSM and MSTI on testosterone and cortisol concentration levels and their priming capability on a subsequent 3RM back squat against a CON of passively sitting in a silent room. Post hoc analysis found no statistically significant changes compared to control subjects and no correlation between endocrine markers and 3RM back squat performance; however, small and moderate positive effect size changes were noted in 3RM back squat load lifted, testosterone, and TC ratio.

Both MSTI and SSM strategies produced an improved 3RM back squat by 5 $\pm$ 2 kg (5.8%, g = 0.22, 95% CI -0.10, 0.54) and 6 $\pm$ 4 kg (7.1%, g = 0.26, 95% CI -0.23, 0.75) respectively, with testosterone increasing by 12.5%, g = 0.39 (95% CI -0.27, 1.06) and 19.9%, g = 0.66 (95% CI -0.06, 1.37) respectively. These findings are similar to those of Cook and Crewther (2012), who reported that psychological strategies could prime a 3RM back squat. When testosterone concentration levels have increased, they can increase the release of catecholamines neurotransmitters adrenaline, noradrenaline, and dopamine, which can lead to instantaneous recruitment of muscle mass, increase in intracellular calcium levels, and subsequent muscular strength (Turner, 2010;

Kraemer et al., 1991; Tod et al., 2003). However, the absence of a correlation reported is contrary to Crewther et al. (2012), who reported a correlation of $r = 0.92$ between testosterone and a 1RM back squat, but is in line with West and Phillips (2011), who reported no association between acute testosterone secretion and leg press strength. Although the practical differences in our findings are small to moderate, collectively, these changes throughout a training program could potentially lead to meaningful improvements in performance over time. Additionally, CI analysis suggests that some individuals may experience large positive changes while others may have small detrimental changes. Therefore, this form of psychological priming should be developed individually and may require training to implement it. Equally, these priming strategies are quick, easy, and free. Although a statistical correlation did not occur through this study, had the sample size been larger and more homogenous, as per Crewther et al. (2012), these results could be added to the literature associating testosterone with motivation. Currently, there is too much variability in the results due to the sample size; for example, the large differences in CI could result from the varied androgen receptor availability because of the diversity of subjects.

This study is the first to show that SSM can improve performance in the back squat. Previously, Karageorghis et al. (2018) showed an increase in handgrip strength of 0.63 N/kg in 52 male athletes, and Biagini et al. (2012) showed no difference in repetitions to failure across three sets of bench press at 75% 1RM in 20 male subjects when SSM was played during the entire testing session. In contrast, in this present study, music was only listened to before lifting, which may have enabled the athlete to focus on the motor skill. Equally, the subject may have already benefited from enhanced motivation and neuromuscular drive due to the release of testosterone by the SSM. Given the absence of literature, more research is required to validate this statement and to eliminate this association as causal, as indicated by correlational analysis. However, it should be noted that no study has shown any detrimental effects of listening to music before or during strength training. Only from this study, where 95% CI is reported, can it be noted that while some may experience a large magnitude of change, such as Subjects Two and Three with 65% and 95% increases in testosterone, respectively, some athletes may experience small and negative effects from SSM as Subject Eleven did with a decrease of -19% (Figure 6.5). Therefore, it is prudent to advise that individuals trial this ergogenic aid with various timings and music genres, as there will inevitably be between-subject differences in its effectiveness.

The review by Tod et al. (2003) estimated that psyching-up could lead to a 12% increase in strength compared with control conditions. In a separate study, Tod et al. (2005) supported this by reporting an 8.1% increase in three sets of five repetitions of isokinetic bench press in 20 male and female subjects. Herein, we report a 7.1% improvement in one set of 3RM back squats in the SSM intervention; however, McGuigan et al. (2007) failed to show such an effect. In their study, 1RM back squat performance was unaffected following a free-choice psyching-up technique in 20 men and women with 4.5 years of weight training experience. Results may differ because of the psyching-up method used. The current study used MSTI consisting of positive external cues to increase confidence and focus on the task (Hardy, 2006). Following the intervention, McGuigan et al. (2007) also noted significant increases in cortisol (pre 13.8 nmol, post 21.8 nmol), which may suggest subjects incurred increased stress levels. For example, low cortisol concentrations may be related to positive psychological constructs, such as high self-efficacy (McAuley & Rudolph, 1995). In contrast, higher concentrations may be associated with negative affective states, such as anxiety (Smyth et al., 1998), and are potentially a consequence of subjects being unfamiliar with the test or attaching importance to it (Davis et al., 1981; Scavo et al., 1991). Here, subjects were familiar with the test, and the MSTI was designed to increase self-efficacy. Therefore, cortisol during the SSM and MSTI conditions did not significantly change; however, it did drop to the extent that the TC ratio increased by 12.1% and 10.4%, respectively, against the control condition. However, it should be noted again that according to the calculated 95% CI, some individuals may experience a small decrease in performance following these strategies, as Subject Six did in both SSM and MSTI conditions, lifting 9.1% less with increased cortisol of 7% and 64% respectively compared to control. Thus, individuals are again advised to trial and develop the ergogenic aids.

It has been reported that cortisol may jointly work with testosterone to moderate status-seeking behaviors (Cook & Crewther, 2014), with cortisol largely moderating the effect of testosterone (Mehta & Josephs, 2010; Mehta & Prasad, 2015). Relationships between testosterone and behavior are generally found when cortisol levels are low

(Mehta & Prasad, 2015). Untrained individuals also typically exhibit a larger neuroendocrine stress response than trained individuals when undertaking the same workloads (Hackney, 2006). Therefore, psychological priming may be as much about controlling the release of cortisol as it is about raising testosterone. In light of this, SSM and MSTI may have controlled any increased stress through better focus, confidence, and less anxiety, as, on average, only trivial changes occurred (g = -0.07 and g = 0.08, respectively).

Finally, we note that no subject's testosterone concentration levels were reduced during SSM. Given the high likelihood that athletes experience increased testosterone levels when performing, their ability to use and translate it may be a potentially limiting factor. For example, Crewther et al. (2012) showed that in ten weight-trained male athletes, only those who could back squat double their body weight demonstrated a relationship between the back squat and sprint performance when testosterone levels were high (r = 0.92 and r = -0.87 respectively). This is potentially based on physiological adaptations centering on Type II fiber content and androgen receptor availability, thus the means to actualize the steroid effects (Folland & Williams, 2007). Therefore, it may be that these ergogenic aids are best represented in strong, healthy adults who themselves would require new and innovative means of increasing training intensity, such as those identified here.

6.4 Limitations

This study's small sample size of subjects was below the priori power calculation of a minimum of 24, limiting deeper analysis, such as comparing males and females, varying age ranges, and professional athletes versus amateurs. This study only chose a 3RM back squat test and, therefore, cannot correlate the changes noted here to other measures of athletic performance, such as during jumping and sprinting. Lastly, a coefficient of variation of 9% in hormonal changes may be too large to signal subtle changes in the hormonal status.

6.5 Conclusion

Due to the small subject sample size, no statistically significant results occurred; however, due to the small and moderate effect size changes, this investigation suggests the potential use of SSM and MSTI for priming healthy adults to complement their athletic endeavors. These results potentially support the current evidence for priming, with the addition of a novel finding that these strategies may also associated with increases in testosterone while potentially limiting the release of cortisol. In summary, it is recommended that the use of simple, freely available strategies, such as SSM and MSTI, should be implemented to prime an individual's performance during training sessions so that they work harder and take more risks (or rather, attempt to lift more weight and perform extra repetitions). While these changes may be slight, they are meaningful and could generate significant improvements in athletic performance over a long-term training program. Individuals are also advised to trial these ergogenic aids and develop a strategy that best responds to their preferences.

Chapter 7 STUDY 3

7.0 Changes in salivary testosterone concentrations and voluntary bench press performance following motivational self-talk or self-selected music

7.1 Introduction

Testosterone is an androgen steroid produced by the Leydig cells and ovaries through the hypothalamus-pituitary axis (Mazur & Booth, 1998). Acute secretions have been reported after performing resistance training exercises, which have subsequently been linked to improvements in muscular strength and hypertrophy through an upregulation in neuron binding, enhanced protein synthesis, increased myonuclei, satellite cell proliferation, and the displacement of glucocorticoids such as cortisol (Kadi, 2008; Kraemer et al., 1998; Kraemer et al., 2008; Loebel & Kraemer, 1998). This cascade can lead to enlarged cross-sectional areas of type I and II muscle fibers (Turner et al., 2010). For example, Ahtiainen et al. (2003) reported strong correlations between testosterone and isometric strength ($r = 0.84$, $p < 0.01$), in addition to muscle cross-sectional area ($r = 0.76$, $p < 0.05$) in 16 subjects when undertaking bilateral leg extension resistance exercise for five sets of ten reps over 21 weeks. Turner et al. (2010) state that S&C coaches can enhance testosterone secretions to optimize adaptions through skillful manipulation of periodized resistance training programs.

However, less consideration and research within S&C have been given to how coaches can affect training and competition motivation, task engagement, effort, intensity, and behavior across a training program (Collins et al., 2022; Radcliffe et al., 2015). Many strength-based athletes, such as weightlifters, “psych” themselves prior to performing (Tod et al., 2005). Study 1 showed the prevalence of psychological priming in 90 athletes, with 89% implementing some form of priming strategy and 65% reporting improvements in motivation (Collins et al., 2022). Typical cognitive techniques include imagery, self-efficacy statements, self-talk, relaxation, visualization, preparatory arousal, and focused attention to increase physical and mental activation (Tod et al., 2005). “Psyching-up” can be described as a self-directed strategy used immediately prior to or during a skill execution to enhance physical performance (Tod et al., 2003). Tod et al. (2015) meta-analysis reported that a free-choice psyching-up protocol was associated with positive increases in muscular strength from 12 studies, whereby subjects selected their preferred cognitive method to arouse themselves to increase activation levels for the upcoming task. Furthermore, Tod et al. (2005) also reported an 11.8% increase in volume load when 20 male and female subjects performed a bench press exercise for five reps after implementing a self-selected "psych-up" for 30 s. This form of motivational self-talk strategy is popular amongst coaches and athletes. It can be described as sentences said to oneself for a specific purpose to increase self-confidence, positive mood, and effort (Hardy et al., 2001). Shukri et al. (2019) reported that 45 trained men significantly ($p < 0.001$) increased the number of bench press repetitions performed to failure after implementing motivational self-talk compared to control and instructional self-talk (24.4 reps, 17.9 reps, and 20.1 reps, respectively). Hypothesized mechanisms for the positive effects include reduced anxiety and increased focus, concentration, confidence, and neuromuscular drive, which are attributable to the release of catecholamines (Tod et al., 2015).

Based on Study 1's findings, the most popular psychological priming method implemented amongst athletes was a non-cognitive strategy of listening to music (26.6%). Non-cognitive or behavioral strategies do not have a conscious mental component, which can invoke heightened arousal, alter emotions, and reduce inhibition (Karageorghis & Priest, 2012). The effects of music on athletic performance have predominantly focused on its implementation during fitness classes or aerobic-based training, where it mediates its benefits via rhythm (Kornysheva et al., 2010) and dissociation from effort (Karageorghis & Priest, 2012). Karageorghis (2018), however, did report a significantly ($p = 0.001$) improved handgrip strength of 0.63 N/kg ($d = 0.50$) after listening to fast-tempo music prior to the task (at 126 beats per minute [bpm], played at 80 decibels) compared to 52 matched controls. Additionally, Bartolomei et al. (2015) reported a significant ($p = 0.03$) 5.8% increase in bench press reps when performed to failure at 60% 1RM while self-selected music was listened to in 31 resistance-trained men. However, only a few studies have investigated the influence of music on resistance training (Silva et al., 2020). Therefore, more studies are required to substantiate the limited findings.

Research has shown that these psychological strategies may assist in achieving performance goals by modulating testosterone release (Cook & Crewther, 2012; Gilson et al., 2008). Testosterone has been linked with psychological traits such as status-seeking, motivation, power, competition, violence, dominance, social and sexual interaction, increased risk-taking, and reduced fear (Mazur & Booth, 1998; McCall & Singer, 2012; Stanton et al., 2011; van Honk et al., 2005). For example, Klinesmith et al. (2006) reported increased testosterone levels in 30 male college students when they held a gun for 15 minutes (d = 1.53), correlating with a subsequent increase in aggressive behavior and risk-taking (r = 0.64). In sport, Cook and Crewther (2012) investigated the priming capabilities of playing a motivational video with a concurrent team talk on 12 elite rugby players. Testosterone increased by 12.2%, positively correlating with coach-assessed in-game player performance (r = 0.81). Therefore, testosterone may modulate behavior, subsequently improving performance and positive adaptions experienced by athletes. However, the hypothalamus-pituitary axis consists of a dual hormone relationship whereby cortisol acts as an antagonist to testosterone, inhibiting its production (Cook & Crewther, 2014; Brownlee et al., 2005; Cumming et al., 1983). Increases in cortisol occur in response to physical or psychological stress (Brownlee et al., 2005). For example, a public speaking stress test for 20 minutes incurred significant salivary cortisol concentration elevations (r = 0.85) (Kirschbaum et al., 1992). Additionally, Cook & Crewther (2012) incurred greater cortisol increases compared to testosterone when implementing aggressive (cortisol 13%; testosterone 10%) and erotic (cortisol 7%; testosterone 5%) video clips on 12 professional rugby players prior to performing a back squat exercise. Therefore, the modulation of cortisol may be just as important as priming testosterone. However, this relationship with athletic performance has been sparsely researched and requires more attention to add to the literature to understand the mechanisms at work.

This study investigated the priming effects of SSM or MST on salivary testosterone and cortisol concentration levels and its impact on a subsequent bench press exercise for four sets of four reps. Subjects self-selected loads in line with Cook et al. (2013). We hypothesize that by providing a music soundtrack that resonates with the individual and is of a high tempo (126+ bpm) (Karageorghis, 2018) or with motivational self-talk (Tod et al., 2015), the individual will become “psyched up” which consequently will have a positive effect on the strength-based training session.

7.2 Methods

Please see Chapter 5 for the relevant methodology and statistical analysis.

7.2.1 Subjects

Fourteen healthy collegiate adult males (23.9 ± 3.8 years of age, 177.6 ± 3.3 cm tall and a mass of 78.7± 8.6 kg) and seven collegiate adult females (21.1 ± 2.0 years of age, 173.3 ± 3.5 cm tall and a mass of 67.9 ± 4.3 kg), free from injury and all in good health, with a minimum training experience of three years, participated. Subjects attended the gym at least twice weekly and were classed as recreational. All subjects gave informed consent, and the study procedures met Middlesex University's ethical requirements.

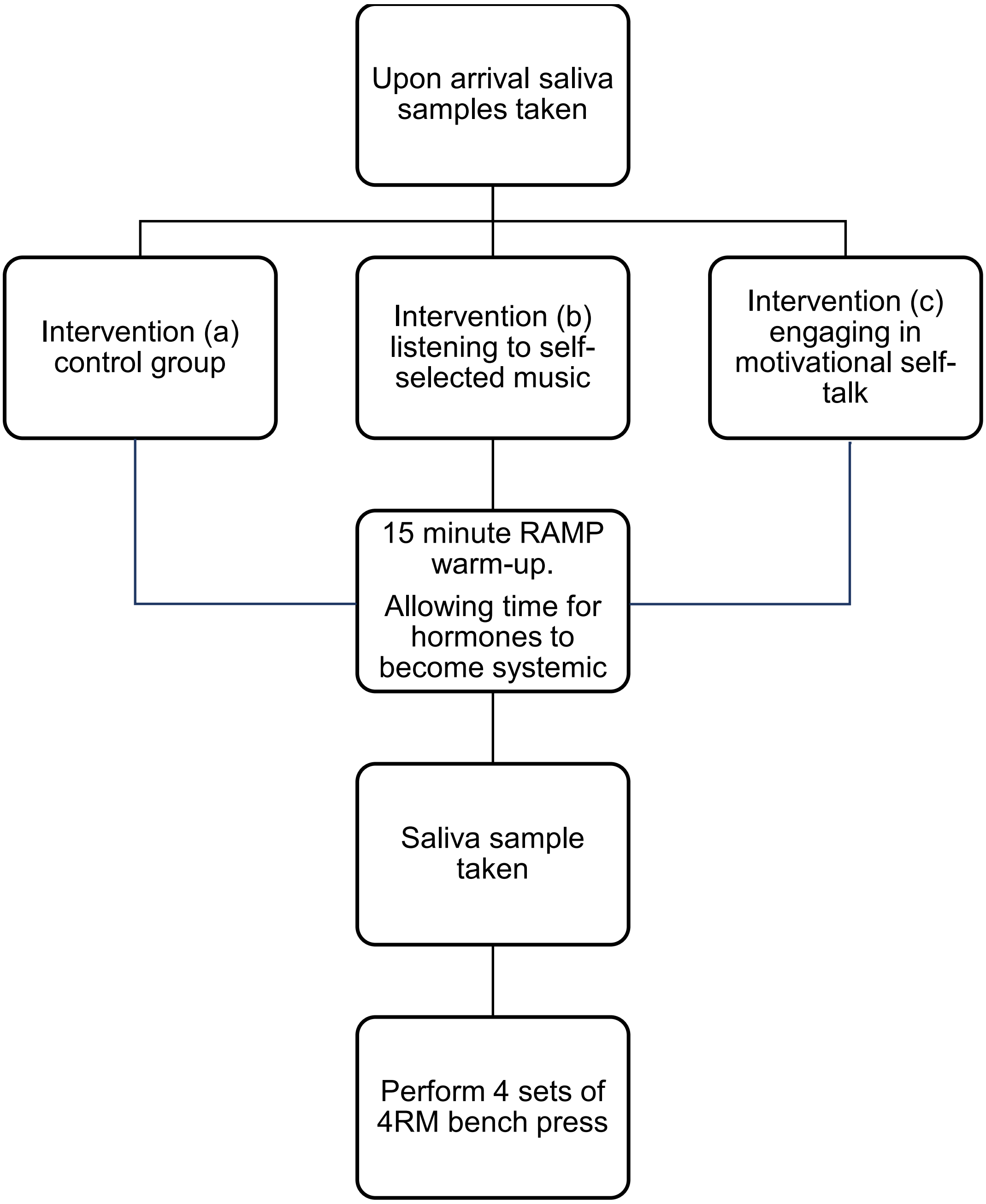

Figure 7.1 Experimental design.

7.3 Results

No statistically significant differences were noted across any intervention (4RM p = 0.06, cortisol p = 0.89, testosterone p = 0.28, TC ratio p = 0.68), only practical differences. In the total volume of load lifted (VL), a trivial difference occurred with SSM 1092.81 ± 360.67 kg, g = 0.09 (95% CI -0.42, 0.59), as did MST 1083.11 ± 341.46 kg, g = 0.06 (95% CI -0.45, 0.57) compared to CON 1061.55 ± 360.56 kg (Figures 7.2 and 6.3). Cortisol levels incurred a moderate difference between SSM 108.22 ±

31.82%, g = 0.81 (95% CI 0.28, 1.34), MST 111.41 ± 42.66%, g = 0.78 (95% CI 0.25, 1.30), and CON 81.36 ± 32.78%, with only a trivial difference between SSM and MST g = 0.09 (95% CI -0.42, 0.60) (Figures 7.8 and 7.9). Average barbell velocity across the strength training session demonstrated a trivial increase when comparing MST 0.32 ± 0.10 m/s, g = 0.15 (95% CI -0.36, 0.65) to CON 0.30 ± 0.08 m/s, and a trivial decrease comparing SSM 0.29 ± 0.08 m/s g = -0.14 (95% CI -0.65, 0.37) to CON. Between SSM and MST g = 0.28 (95% CI -0.23, 0.79) (Figures 7.4 and 7.5). Intraassay COV was 7.8%. Testosterone demonstrated a large increase after MST 135.07 ± 35.91%, g = 1.04 (95% CI 0.50, 1.58) and SSM 122.14 ± 21.10%, g = 0.85 (95% CI 0.32, 1.38) to control 103.65 ± 21.58 %, with a small difference between MST and SSM g = 0.43 (95% CI -0.08, 0.94) (figure 7.6, figure 7.7). TC ratio resulted in a small difference between CON and SSM 22%, g = -0.48 (95% CI -1.00, 0.03), a trivial difference between CON and MST 10%, g = -0.19 (95% CI -0.70, 0.32), and a small difference between SSM and MST 15%, g = 0.32 (95% CI -0.19, 0.83) (Figures 7.10 and 7.11). However, there was no statistically significant correlation in any of the interventions between 4RM, testosterone, or cortisol (CON 4RM – testosterone r = 0.06, CON 4RM – cortisol r = -0.49, SSM 4RM – testosterone r = -0.09, SSM 4RM – cortisol r = 0.30, MST 4RM – testosterone r = -0.16, MST 4RM – cortisol r = 0.16).

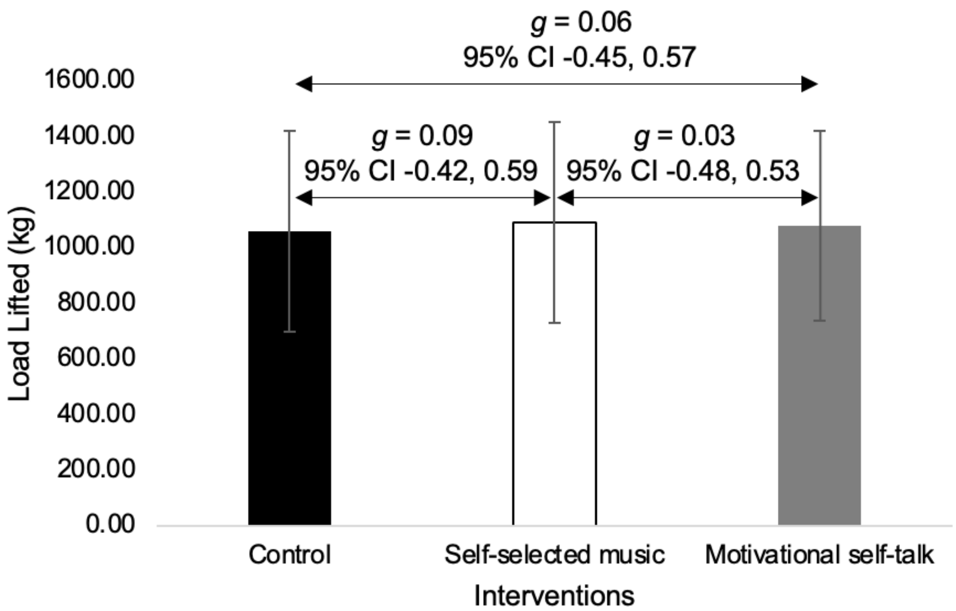

Figure 7.2 The mean total load lifted for four sets of four repetitions in the bench press exercise in the self-selected music (open bars), motivational self-talk (grey bars), and

control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals.

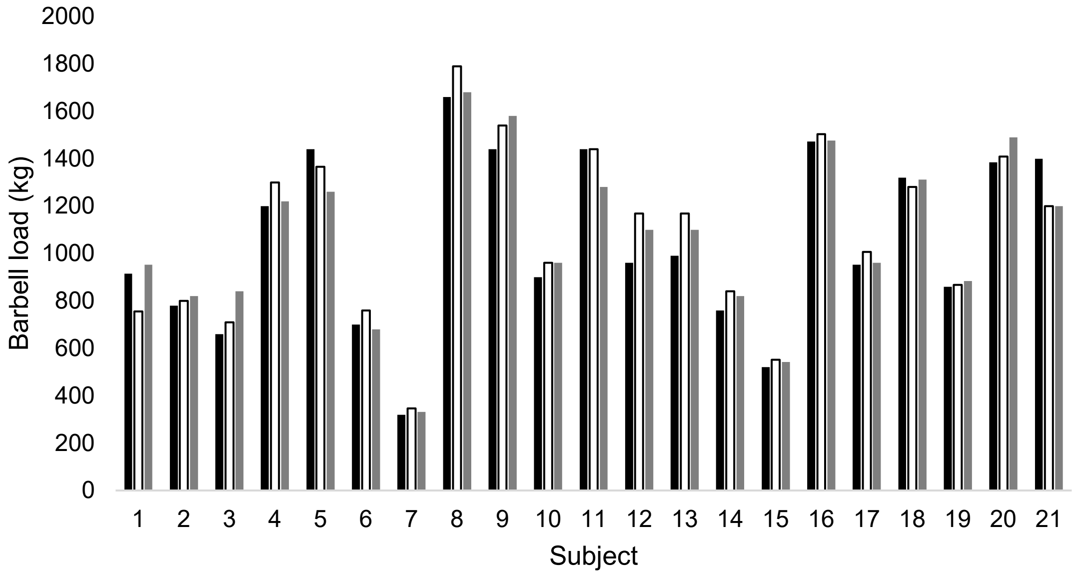

Figure 7.3 The individual total load volume lifted for four sets of four repetitions in the bench press exercise (kg) in the motivational self-talk (grey bars), self-selected music (open bars), and control (black bars) conditions.

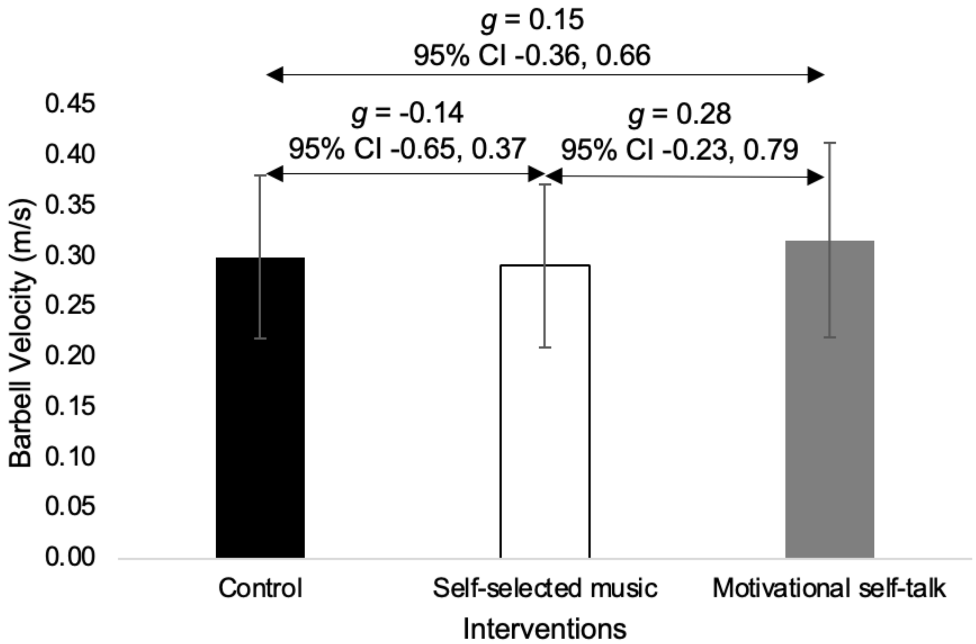

Figure 7.4 The mean barbell velocity in the self-selected music (open bars), motivational self-talk (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

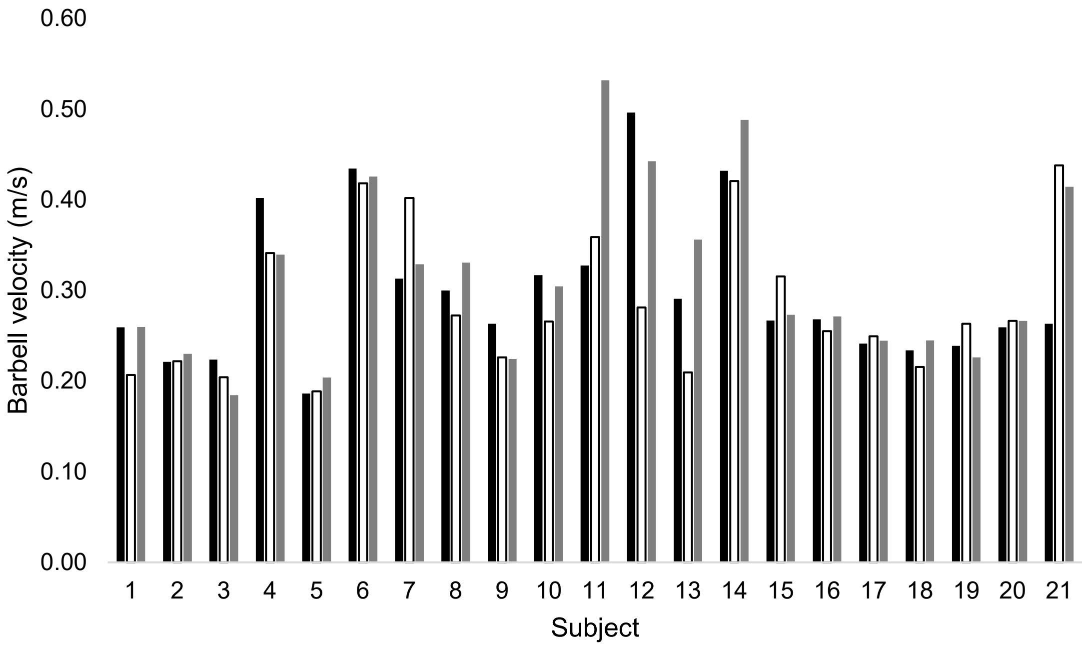

Figure 7.5 The individual bench press average velocity (m/s) repetitions in the motivational self-talk (grey bars), self-selected music (open bars), and control (black bars) conditions.

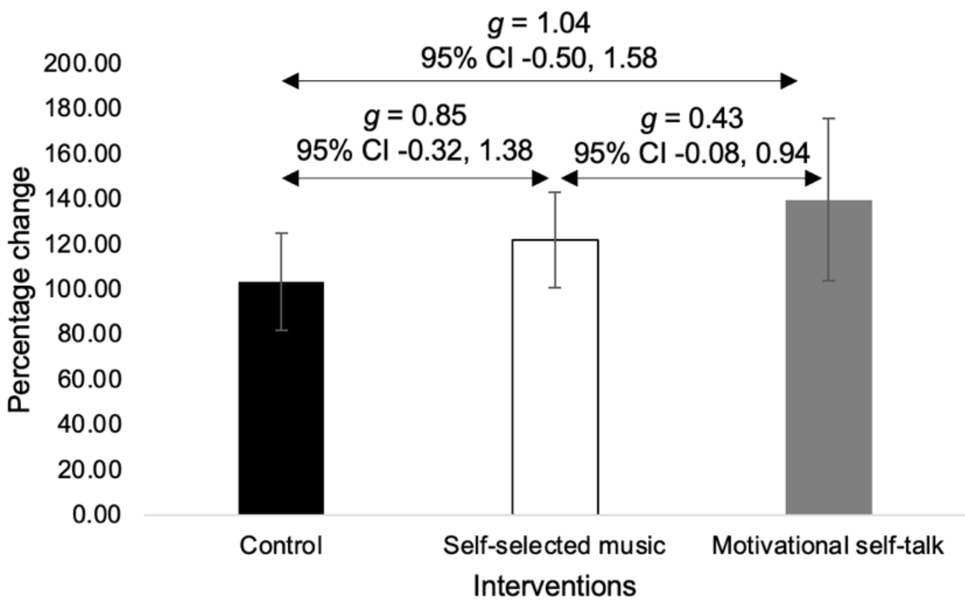

Figure 7.6 The mean percentage change in testosterone in the self-selected music (open bars), motivational self-talk (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

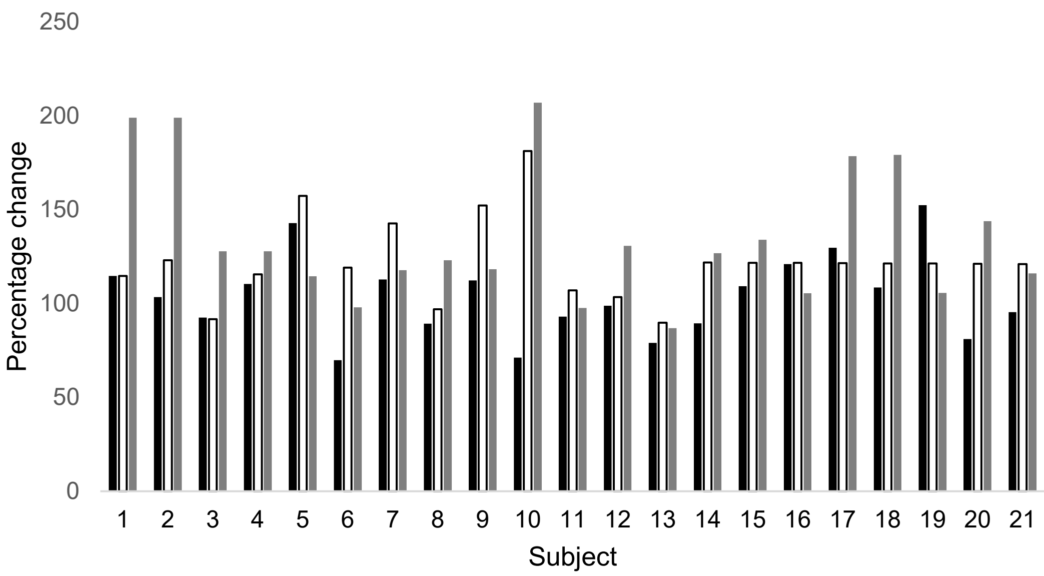

Figure 7.7 The individual percentage change in testosterone concentrations in the motivational self-talk (grey bars), self-selected music (open bars), and control (black bars) conditions.

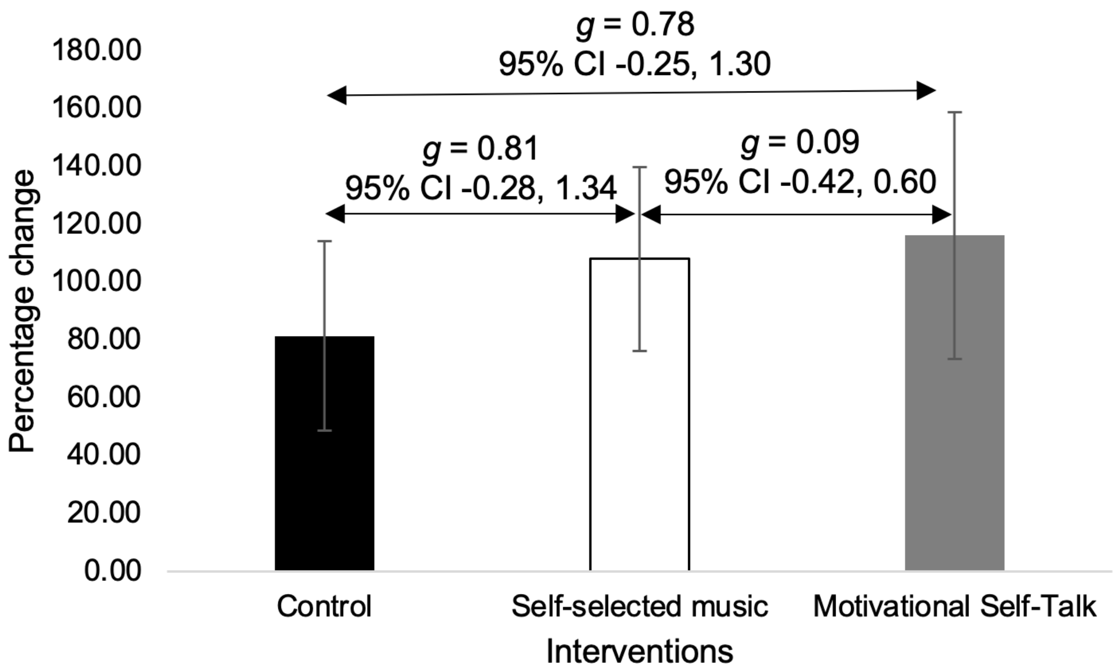

Figure 7.8 The mean percentage change in cortisol in the self-selected music (open bars), motivational self-talk (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

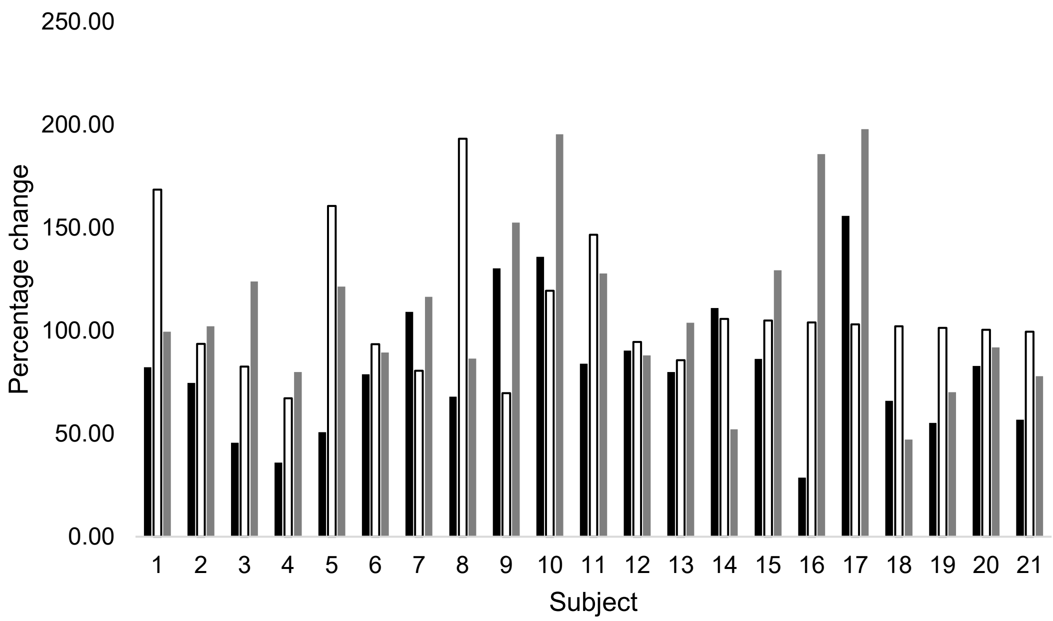

Figure 7.9 The individual percentage change in cortisol concentrations in the motivational self-talk (grey bars), self-selected music (open bars), and control (black bars) conditions.

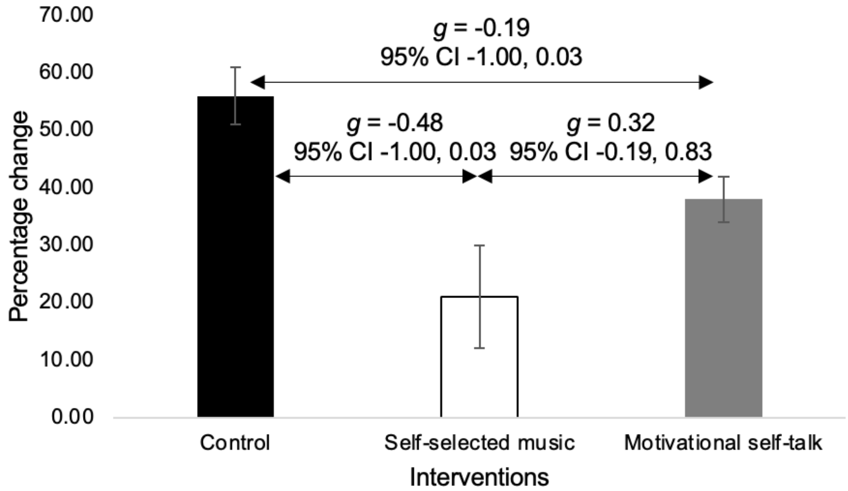

Figure 7.10 The mean percentage change in the testosterone: cortisol ratio in the self-selected music (open bars), motivational self-talk (grey bars), and control (black bars).conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

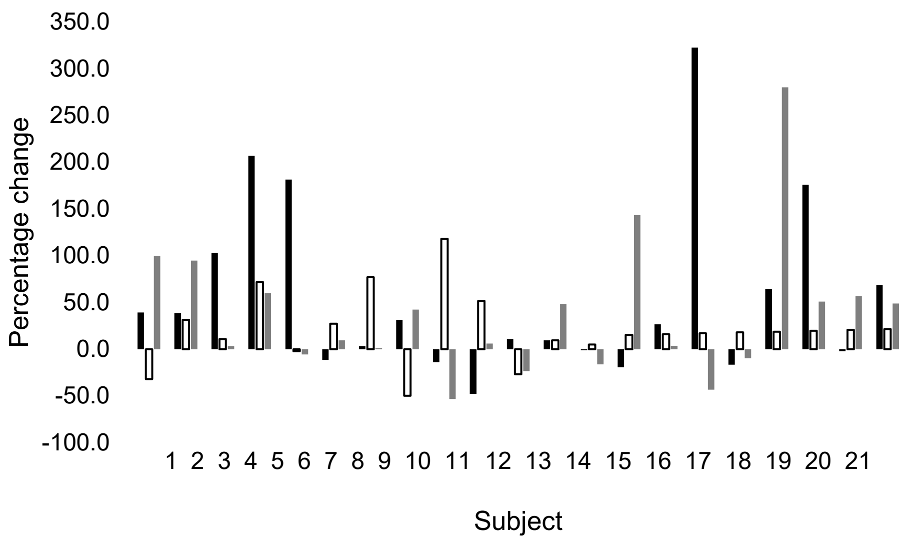

Figure 7.11 The individual percentage change in the testosterone: cortisol ratio in the motivational self-talk (grey bars), self-selected music (open bars), and control (black bars) conditions.

7.4 Discussion

This investigation sought to build on previous literature by identifying priming strategies that can be used to "psych-up" athletes before a resistance training session and the effect it has on salivary testosterone and cortisol concentration. Statistically, no significant results or correlations were found; however, meaningful, small, moderate, and large effect size differences were found in testosterone, cortisol, and their ratio.

Analysis of the CI indicates that some individuals may experience large positive changes while others experience small negative changes. A large increase of 35% in testosterone levels occurred in MST and SSM by 18% compared to CON. While changes in total VL from four sets of four reps bench press were not statistically or practically significant (CON 1061.55 ± 360.56 kg, SSM 1092.81 ± 360.67 kg, MST 1083.11 ± 341.46 kg), examination of the raw data revealed that the MST and SSM groups had small individual increases in barbell load of 1.25 – 10 kg or performed an extra rep within one or two of the sets. Therefore, potentially these changes, over time, may equate to notable differences. Future research should utilize lighter loads (> 6RM) to enable the detection of small changes. For example, subjects reported attempting extra repetitions but failed. Thus, these attempts were not recorded, albeit recognized within average velocity; presumably, using lighter loads would be more sensitive to any extra work performed as performing extra repetitions at a lighter load is potentially easier.

Weakley et al. (2020) reported that barbell velocity for a four-repetition effort should be approximately 0.42 m/s. The average barbell velocity in this study was mixed in the intervention groups compared to the control. MST velocity was 0.32 m/s, and SSM was 0.29 m/s compared to CON at 0.30 m/s. This potentially suggests that subjects either chose loads that were too heavy due to their primed state, where they were willing to be more effortful, or they may have felt tired and therefore applied less force to each rep. Interestingly, barbell velocity was slower when comparing SSM to MST, suggesting that music may have provided a greater intrinsic drive to work toward failure. Additionally, this could be because the MST group used cues focusing on "exploding" with the barbell. Therefore, implementing cues around performing greater work and the bar feeling "light-weight" may prime subjects to work closer to failure and increase their VL further. According to the 95% CI, both interventions could experience moderate increases in barbell speed, as demonstrated by Subject Twenty-One, with velocities of 0.44 and 0.41 m/s in SSM and MST, respectively, compared to 0.26 m/s in the control condition. However, Subject Four recorded the opposite result with an increased velocity during the control condition of 0.40 m/s, compared to 0.34 m/s in both intervention conditions. Future research should investigate the direction or context of cues, how they modulate performance, and whether acute changes are greater than the measurement of error.

Compared to control conditions, testosterone demonstrated a large increase following SSM of 18% (d = 0.84, 95% CI 0.24, 1.43) and MST with 35% (d = 1.05, 95% CI 0.41, 1.70), which may, in part explain the lower velocities under these conditions due to more load being lifted. Furthermore, MST demonstrated a small increase in testosterone compared to the SSM condition (d = 0.44, 95% CI -0.09, 0.97). Assuming testosterone's link with motivation and effort and its role within neuromuscular force (French et al., 2007; Hamdi & Mutungi, 2010), it may be that with a different cueing strategy, this intervention had the potential to show greater performance improvements; for example, Schoenfeld et al. (2018) reported greater strength improvements using an internal cue (16.2%) of "squeeze the muscle," compared to an external cue (2.6%) of "get the weight up," in 30 college-aged men performing an isometric elbow flexion test. This statement is untested and requires further research. Interestingly, salivary cortisol concentration levels were highest in the intervention groups of SSM 108% (d = 0.80, 95% CI 0.21, 1.38) and MST 116% (d = 0.77, 95% CI 0.18, 1.35) compared to 81% for the CON condition. This may have occurred due to the subjects becoming too aroused and "psyched-up," leading to decreased performance in what is known as the inverted U hypothesis, and some anxiety may have occurred (Aren & Landers, 2003).

Consequently, the TC ratio was the highest in the CON condition, 1.56%, compared to 1.43% and 1.21% in MST and SSM, respectively. Given the dual-hormone relationship, whereby cortisol has been reported to blunt the production of testosterone by the HPA-axis surpassing secretion of gonadotropin-releasing hormone and glucocorticoids decreasing androgen receptor synthesis in cells (Brownlee et al., 2005; Salvador, 2012; Dekkers et al., 2019), these results may indicate that cortisol had not been modulated during the interventions and that had it, then potentially testosterone may have been secreted to a larger amount, which in turn may have improved performance further. However, as noted in the 95% CI, testosterone and cortisol could have reported larger secretions with only the possibility of a small decrease. Therefore, individuals are advised to trial and develop the use of the different ergogenic aids through changes in music and cues to learn which aids limit the release of cortisol and increase testosterone; for example, Subject Ten increased testosterone in both conditions SSM and MST by 110% and 136% respectively. However, cortisol rose by 59% more in MST. It decreased in SSM by 17%, indicating the potential large improvement in the TC ratio in the MST condition was blunted due to increased stress experienced. Variations in cues could reduce this, making the priming technique more effective.

This study demonstrates the within-session priming effects of SSM and MST, their effect on testosterone, and subsequent performance. Furthermore, while the impact of music has been examined extensively, it tends to be in the context of fitness classes or aerobic-based training, where it mediates its benefits via rhythm (Kornysheva et al., 2010) and dissociation from effort (Karageorghis & Priest, 2012). Here, we posit that providing a music playlist that is of a high tempo (> 126 bpm) and resonates with the individual can get an individual “psyched-up” to help improve strength-based training. Self-talk, considered a form of “psyching-up,” has been more widely examined and is beneficial to strength and power training, generally on account of the release of catecholamines (Tod et al., 2011). Here, we can add to the literature supporting its use and demonstrate a novel finding that MST strategies are potentially facilitated by increases in testosterone. In summary, simple, freely available strategies, such as SSM and MST, can prime a healthy collegiate adult’s performance during training sessions such that they are willing to work harder and take more risks.

7.5 Limitations

The limitations of this study are the small sample size of subjects which was below the calculated priori power analysis, and professional athletes. Therefore, comparing males and females, varying age ranges, and professional athletes versus amateurs could not be undertaken. This study only chose to test four sets of 4RM bench presses. Therefore, it was unable to determine any associated meaningful changes on an individual level, for example, during a sprint and jump test. Additionally, a potential limitation of analysis could be that a coefficient of variation of 9% in hormonal changes may be too large to signal subtle changes in status.

7.6 Conclusion

Based on this study's results, the modulation of cortisol may be as important as increasing testosterone concentration levels. To positively modulate behavior, implementing motivational self-talk may have a larger impact on testosterone concentration levels than self-selected music or passively sitting in a room. However, implementing MST and SSM that resonates with the individual so as not to increase their cortisol and stress levels which may potentially blunt priming that could assist in improving performance. Due to the dearth of literature, a vast array of priming strategies and performance markers are to be researched and potentially implemented. Therefore, future investigations are needed to build on this research.

Chapter 8 STUDY 4

8.0 Changes in salivary testosterone concentrations and voluntary back squat performance following being observed in person and on social media while warming up

8.1 Introduction

Triplett (1898) first established an observer effect when examining how an individual's behavior was affected by the presence of others. He noted that cyclists' speed increased when racing in the presence of another rider compared to racing alone against the clock. This discovery demonstrated a co-action effect, whereby behavior change occurs when two or more individuals work on the same task (Hamilton & Lind, 2016). Furthermore, Zajonc (1965) reported a behavior change in multiple animals, specifically in the presence of an audience, thereby classifying this as the audience effect theory. He suggested that increased arousal may affect performance; however, this depends on the context of the task in question. Easily performed or well-rehearsed tasks produced better outcomes than challenging or new tasks, where performance dropped; for example, an accomplished golf player would perform better with an audience, whereas a poor or beginner golf player would perform worse. More recently, Tennie et al. (2010) suggested that the audience effect theory is a form of reputation management in the eyes of others, which requires a behavior response dependent on the given task and who is observing. This is supported by Chen et al. (2011), who suggested that the presence of peers heightens feelings for reward, which motivates changes in behavioral decision-making. This was noted when 51 19 – 24-year-old college students significantly increased loads lifted in 1RM bench press (women 1.5 kg and men 1.8 kg, $p < 0.05$) and leg press (women 4.1 and men 8.5 kg, $p < 0.05$) when being observed by two individuals of the opposite gender (Baker et al., 2011).

In recent years, social media platforms have enabled a virtual observer effect. Sherman et al. (2016) reported increased neural responses in the medial prefrontal cortex and hippocampus (both in the brain) in adolescent subjects when observing their photographs versus neutral photographs submitted by peers, which had more "likes." These brain regions are associated with social cognition and memories (Mars et al., 2012; Zaki et al., 2009), indicating that these photographs may have been scanned more carefully. Also, when viewing positive feedback on their pictures, increased activity in the nucleus accumbens, which is responsible for feelings of reward, occurred. Harackiewicz and Larson (1986) suggest that recognition of one's contributions can enhance feelings of competence. Brady and O'Regan (2009) also note that the number of "likes" and feedback comments on an individual's pictures provides self-validation, suggesting that social media for self-presentation can be rewarding and potentially motivating. Interestingly, when subjects viewed photographs of risky behaviors (for example, a picture of a marijuana cigarette or a rude gesture) by peers, decreased activation in the cognitive control network occurred. This indicates that observing peer behavior promotes down-regulation in cognitive control in high-risk scenarios, increasing the potential to undertake risk-taking behavior, such as smoking a cigarette or taking provocative pictures (Mars et al., 2012). Therefore, there could be potential for this to be reversed, that posting a photograph or video of risk-taking behavior could promote the undertaking of risk-taking behavior to obtain positive feedback and "likes." For example, an individual posting a video of themselves undertaking a heavy load deadlift exercise, which can be classed as risky, viewers of this video may feel compelled to compete, leading them to try a deadlift load far beyond their capability, which would increase the chance of incurring an injury. Research is sparse in this area, and further investigation is warranted.

Our desire to seek status serves our primitive drive and can, in part, be explained by the "Biosocial Model of Status" (Janak et al., 2015; Mazur & Booth, 1998). This model suggests that testosterone motivates competitive behaviors that serve to increase status. Testosterone is a product of the hypothalamus-pituitary axis. It has been associated with assertive, dominant, aggressive, and leader-like behavior and increased risk-taking traits, especially when competition or a goal is present (Mazur & Booth, 1998). For example, a self-selected bench press ($r = 0.83$, $p < 0.01$) and back squat ($r = 0.67$, $p = 0.01$) performed for three repetitions were strongly correlated to individual variation in pre-exercise salivary testosterone concentration levels in 12 female elite netball players (Cook & Beaven, 2013). Cortisol, a steroid hormone also a product of the hypothalamus-pituitary axis, has been associated with psychological stress (Kirschbaum et al., 1993). For example, Kirschbaum et al. (1992) reported significant cortisol elevations (189%, $p = 0.001$) 30 minutes after undertaking a public speaking stress test, indicating that the subjects found the test stressful. Cook and Crewther (2014) suggest that cortisol works jointly with testosterone; thus, increased cortisol levels may affect the TC ratio due to the dual-hormone hypothesis. Relationships between increased testosterone and behavior are generally found at low cortisol levels (Mehta & Prasad, 2015). Therefore, for optimal performance, anxiety should be seen at moderate levels; otherwise, panic will overcome the individual, leading to decreased performance in what is known as the inverted U hypothesis (Arent & Landers, 2003). The hypothesis reports an optimal level of arousal; too much or too little will negatively affect the individual (Arent & Landers, 2003).

Cook and Crewther (2014) identified improved strength and in-competition performance after 12 elite rugby union players viewed a one-hour video of mixed content from the previous match in a social environment. Testosterone increased by 51.8% ($p < 0.01$) in those who experienced the best head coach-ranked match performances, which consisted of the players completing several key skills, suggesting the priming of testosterone prior may have contributed. A strong correlation was also seen ($r = 0.85$, $p < 0.003$) between 3RM back squat performance and testosterone levels after various video clips were viewed by 12 professional rugby players (Cook & Crewther, 2012). Indicating that increasing testosterone levels before undertaking athletic endeavors may improve performance levels and understanding which testosterone primers and for which individuals are the most efficacious could enhance performance further.

Thus, in this study, we aim to investigate the priming capabilities of performing a warm-up and a subsequent 65% 1RM back squat to repetition failure in the presence of observers, both in person and virtually via social media. Changes in testosterone to the intervention are also examined to at least explain the mechanisms at work and to add to existing research demonstrating the priming effects of this endocrine marker on sports performance. Finally, we will investigate the release of cortisol on account of the TC ratio and the dual-hormone relationship.

8.2 Methods

Please see Chapter 5 for the relevant methodology and stats.

8.2.1 Subjects

A total of 12 subjects were recruited for this study using a convenience sample method. The cohort consisted of nine healthy collegiate adult males (22.3 ± 2.9 years of age, 176.1 ± 5.7 cm tall and a mass of 80.0 ± 5.8 kg) and five healthy collegiate adult females (22.4 ± 3.2 years of age, 173.0 ± 3.9 cm tall and a mass of 70. ± 4.8 kg), all considered physically fit and injury-free, with at least three years resistance training experience participated. Subjects attended the gym at least twice weekly and were classed as recreational. Before signing their informed consent form, each subject was provided a complete explanation, with study procedures meeting Middlesex University's ethical approval.

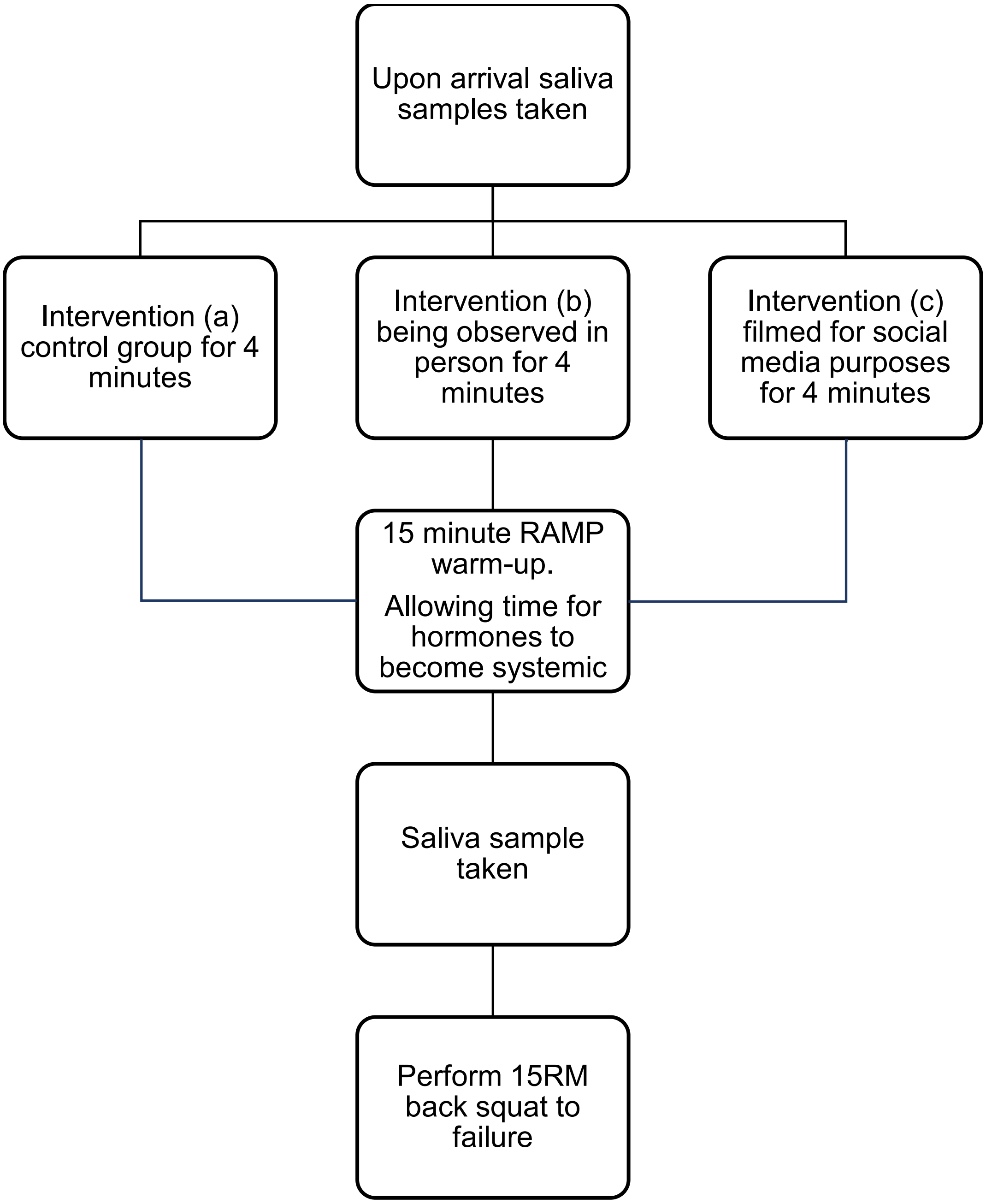

Figure 8.1 Experimental design.

8.3 Results

No statistically significant differences were noted (total reps p = 0.13, testosterone p = 0.07, cortisol p = 0.70), however, practical differences were. Average barbell velocity incurred a small difference in both interventions, social media (SMO) 0.49 ± 0.09 m/s, g = 0.27 (95% CI -0.37, 0.92), and the observer effect (OE) 0.49 ± 0.09 m/s, g = 0.28 (95% CI -0.37, 0.92), compared to CON 0.47 ± 0.08 m/s (Figures 8.4 and 8.5). The

SMO condition produced the most reps performed at 17.33 ± 6.14 reps, *g* = 0.38 (95% CI -0.27, 1.03) with OE at 17.50 ± 6.72 reps, *g* = 0.43 95% (CI -0.22, 1.08), compared to CON 14.83 ± 5.91 reps (Figures 8.2 and 8.3). Intraassay COV was 8.5%. A moderate increase in testosterone occurred in SMO 113.29 ± 40.76%, *g* = 0.79 (95% CI -0.12, 1.46), but only a trivial difference in OE 85.76 ± 30.20%, *g* = 0.06 (95% CI -0.58, 0.71) compared to CON 83.74 ± 31.45% (Figures 8.6 and 8.7). SMO condition produced a lower cortisol rise of 118.19 ± 28.79%, *g* = 0.09 (95% CI -0.56, 0.73), compared to OE 131.71 ± 54.88 %, *g* = 0.22 (95% CI -0.43, 0.87), and CON 121.20 ± 35.98% (figure 8.8, figure 8.9). As a result, the TC ratio noted a moderate decrease in OE -19 ± 0.44%, *g* = 0.10 (95% CI -0.55, 0.74), and CON -23 ± 0.42%, with SMO increasing by 2% ± 0.43 *g* = 0.58 (95% CI -0.08, 1.24) (Figures 8.10 and 8.11). However, there was no statistically significant correlation in any of the interventions between total reps completed, testosterone, or cortisol (CON reps – testosterone *r* = 0.09, CON reps – cortisol *r* = -0.41, OE reps – testosterone *r* = 0.37, OE reps – cortisol *r* = -0.22, SMO reps – testosterone *r* = -0.17, SMO reps – cortisol *r* = -0.36).

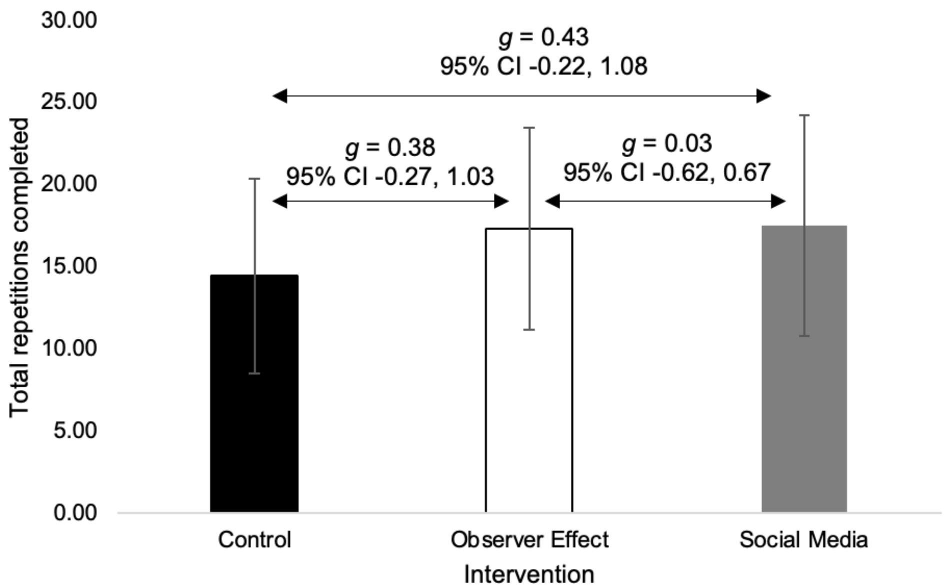

Figure 8.2 The mean change in total repetitions of the back squat in the observer effect (open bars), social media (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

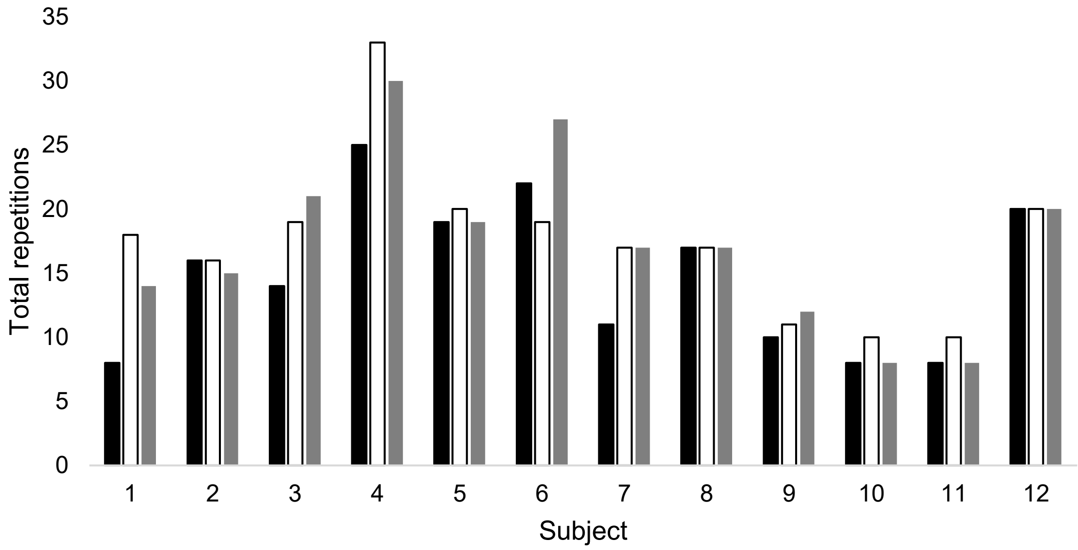

Figure 8.3 The individual total repetitions performed for the back squat exercise (kg) in the observer effect (open bars), social media (grey bars), and control (black bars) conditions.

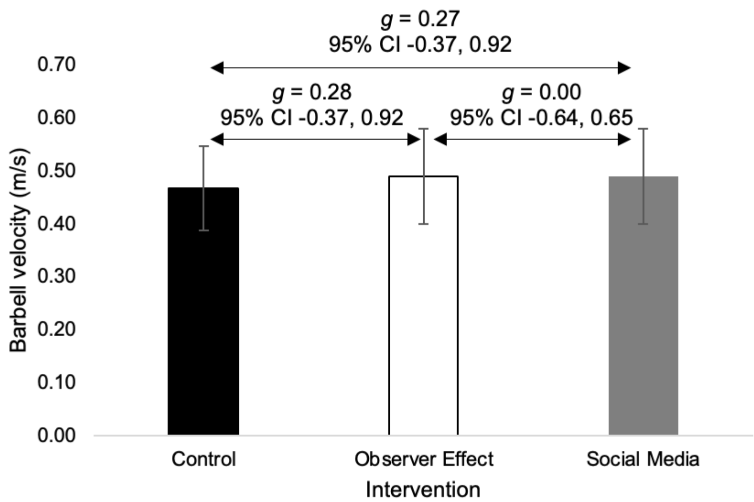

Figure 8.4 The mean percentage change in barbell velocity in the observer effect (open bars), social media (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

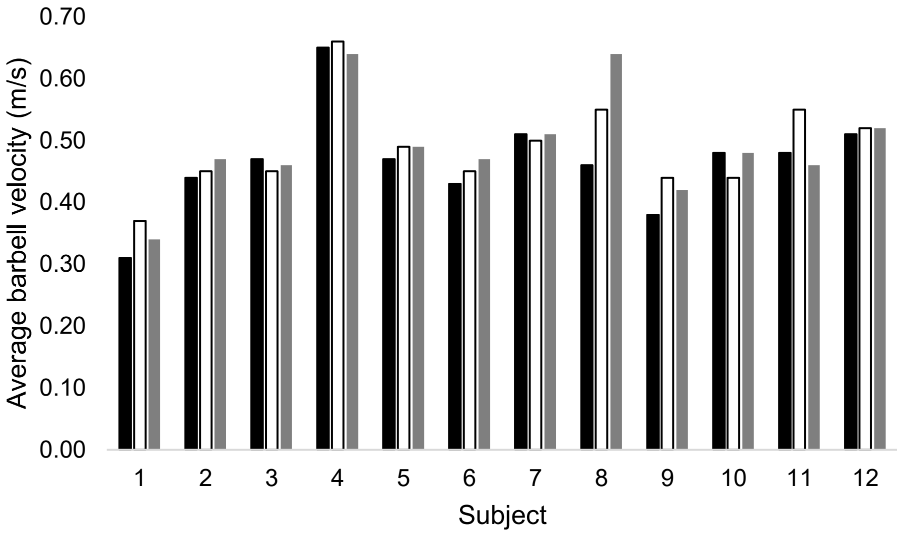

Figure 8.5 The individual back squat average velocity (m/s) repetitions in the observer effect (open bars), social media (grey bars), and control (black bars) conditions.

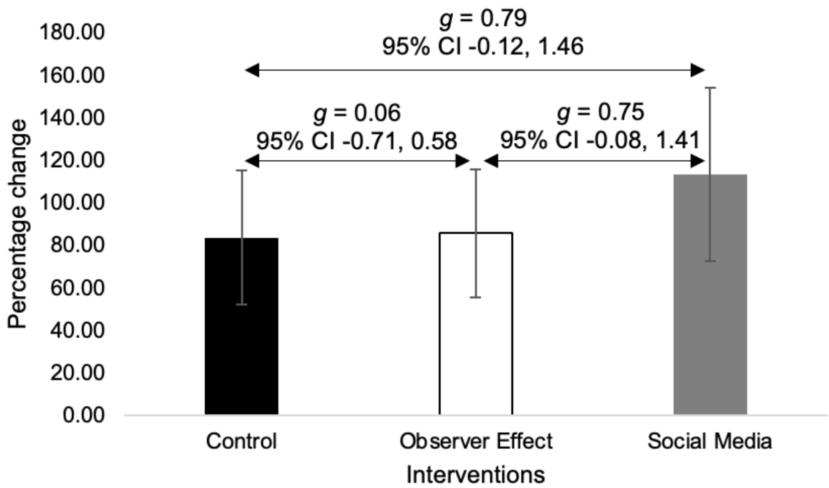

Figure 8.6 The mean percentage change in testosterone concentrations in the observer effect (open bars), social media (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

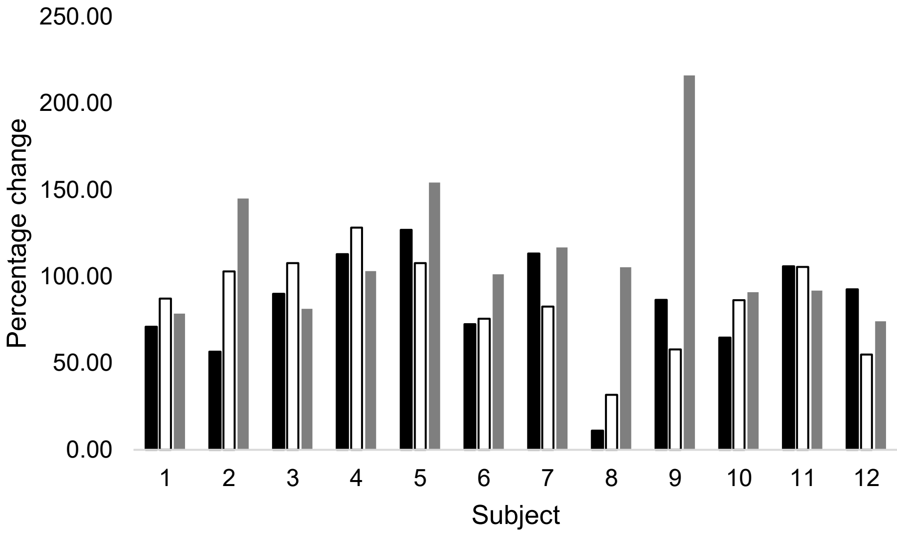

Figure 8.7 The individual percentage change in testosterone concentrations in the observer effect (open bars), social media (grey bars), and control (black bars) conditions.

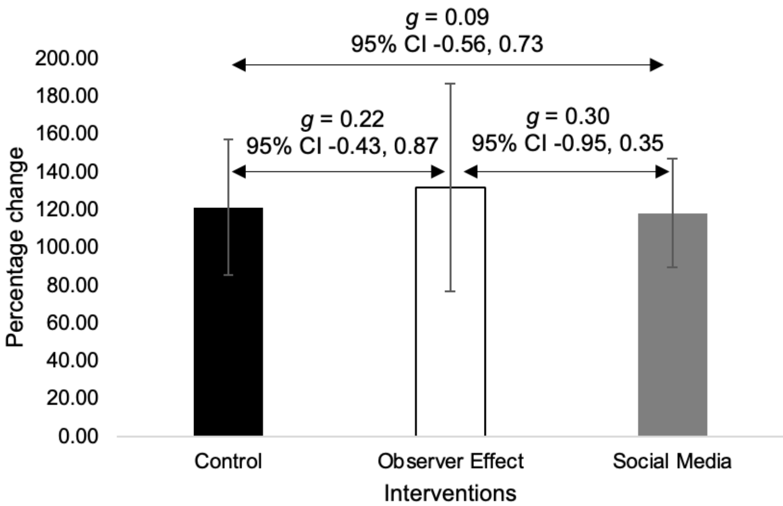

Figure 8.8 The mean percentage change in cortisol concentrations in the observer effect (open bars), social media (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

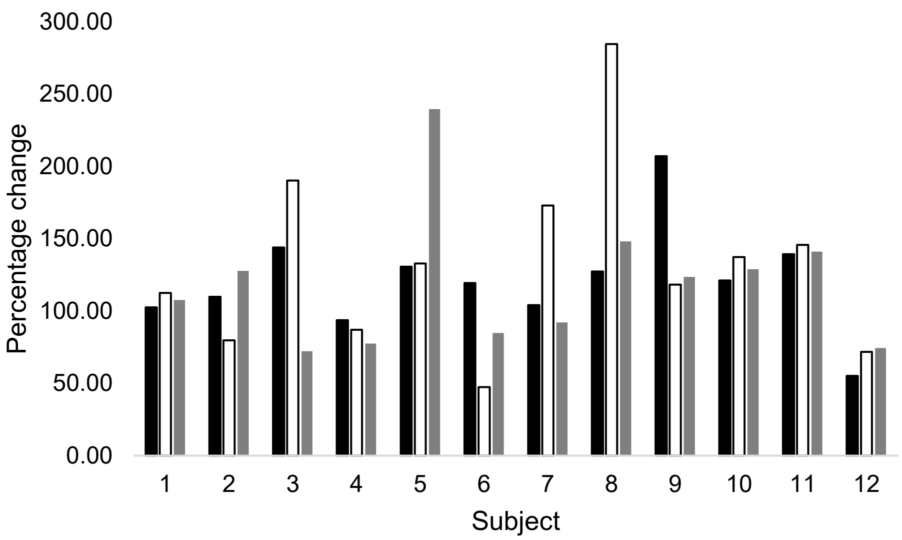

Figure 8.9 The individual percentage change in cortisol concentrations in the observer effect (open bars), social media (grey bars), and control (black bars) conditions.

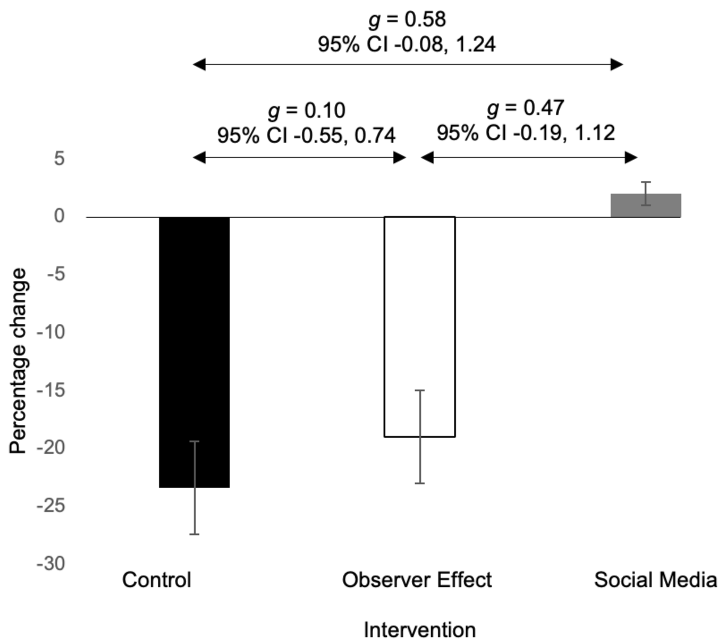

Figure 8.10 The mean percentage change in the testosterone: cortisol ratio in the observer effect (open bars), social media (grey bars), and control (black bars) conditions, with standard deviation, effect size (*g*), and 95% confidence intervals (CI).

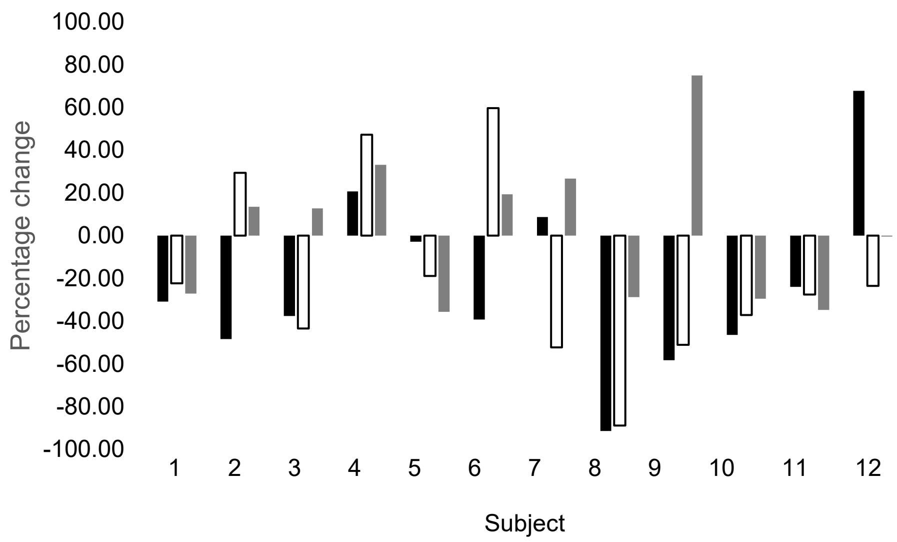

Figure 8.11 The individual percentage change in the testosterone: cortisol ratio in the observer effect (open bars), social media (grey bars), and control (black bars) conditions.

8.4 Discussion

This investigation sought to add to the limited literature on priming healthy collegiate adults during their warm-up via the use of the observer effect both in-person and virtually via social media. Statistically, no significant results were reported, and there was no correlation between endocrine markers and repetitions completed in the back squat exercise. However, small and moderate effect size differences were noted in repetitions completed, barbell velocity, testosterone, cortisol, and TC ratio. Although small, these changes, over time, may equate to notable differences, as noted by the 95% confidence intervals reported, potentially leading to improvements in performance markers.

A moderate effect size increase in salivary testosterone concentration levels was noted in the SMO condition 113.2% (g = 0.79, 95% CI = -0.12, 1.46) compared to the trivial in-person OE 85.7% (g = 0.06, 95% CI -0.58, 0.71) and control 83.7%. An increase in total reps completed and barbell velocity in the back squat exercise may have occurred due to the increase in the endocrine marker, particularly in the SMO 17.50 reps (g = 0.43, 95% CI -0.22, 1.08) condition, compared to OE 17.33 reps (g = 0.38, 95% CI -0.27, 1.03), and control 14.83 reps. Bar velocity also improved in SMO 0.49 m/s (g = 0.27, 95% CI -0.37, 0.92) and OE 0.49 m/s (g = 0.28, 95% CI -0.37, 0.92), compared to control 0.47 m/s. These results are in line with Cook et al. (2013), who reported a correlation of free testosterone levels before training in 15 men to self-selected back squat and bench press workloads (r = 0.81, p <0.001). Cook and Crewther (2012), Cook and Beaven (2013), and Crewther et al. (2012) support these findings by correlating back squat performance with testosterone levels (r = 0.85, r = 0.67, and r = 0.92, respectively). Interestingly, Alexander et al. (2021) did not make any associations between total testosterone and hand grip strength in 716 women. This result may have occurred due to the exercise testing maximal strength rather than repetitions. Therefore, because these back squat performance improvements are mirrored by moderate increases in testosterone and moderate increases in the TC ratio (SMO 102%, g = 0.58, 95% CI -0.08, 1.24; OE 81%, g = 0.10, 95% CI -0.55, 0.74; CON 77%), we speculate that a priming strategy whereby testosterone is modulated through behavior and motivation through what subjects perceive to be a status-seeking opportunity can be used to maximize performance. However, due to the sample size being below the calculated minimum 24 from priori power analysis (using G*Power (Version 3.1, University of Dusseldorf, Germany), implementing a statistical power of 0.8 and type 1 alpha level of 0.05), there is likely too much variability in the results, and subject variations in testosterone may occur due to the diversity in androgen receptor availability. For example, Subject Two incurred an 81% and 154% increase in testosterone in OE and SMO, respectively, compared to the control condition, and Subject Fourteen testosterone level decreased in SMO compared to CON by 20%.

The OE condition consisted of being watched by strangers instead of cheering teammates, where improvements are likely to occur due to their presence (Baker et al., 2011). The subject's inexperienced status likely perceived the situation as stressful in front of strangers, as evidenced by the small increase in cortisol 131.7% (g = 0.22, 95% CI -0.43, 0.87) compared to SMO 118.2% g = 0.09 (95% CI = -0.56, 0.73). However, back squat performance did not get worse, possibly due to subjects having a minimum training age of three years to participate. Therefore, the exercise may have been at a low skill level for them. In highly skilled tasks, such as performing a golf swing, performance would likely have declined in line with Zajonc's (1965) research. Alternatively, although speculative, the rating of perceived exertion (RPE) to perform the back squat may have diminished due to the observers present. Winchester et al. (2012) reported significant reductions in RPE during three 20-minute moderate 60% intensity running trials in ten active men when observed by both males and females (d = 0.53, p = 0.013). While the subjects of this study acknowledged that observers would be higher in number when filmed for SMO, it is posited that this is potentially offset as first-hand judgment is eliminated, as the video can be edited or even deleted. Unlike the direct observer effect, this situation potentially allows the subject to concentrate on their innate drive to seek status.

In conclusion, the back squat exercise performance can potentially be primed using the observer effect via in-person means and, to a greater extent, through virtual protocols. The idea that the performance would be shared on SMO platforms appeared to act as a primer of effort, demonstrated by a small improvement in performance through increases in bar velocity and total reps completed. With SMO providing a status-seeking opportunity and eliminating any jeopardy of failure, this mode appears to be the most beneficial and straightforward of the two conditions to implement in the field. The performance results mirror the endocrine results with testosterone, producing a large increase when both observer effects are implemented. This result could explain the mechanisms at work. More research is required to build upon this hypothesis.

8.5 Limitations

The limitations of this study are the small sample size of subjects and the lack of professional athletes. Therefore, comparing males and females, varying age ranges, and professional athletes versus amateurs could not be undertaken. This study only chose to test one set of 65% 1RM back squat to repetition failure, therefore unable to determine any associated meaningful changes on an individual level, for example, during a sprint and jump test. Finally, a limitation of the analysis could be that a coefficient of variation of 9% in hormonal changes may be too large to note subtle changes in hormone levels.

8.6 Conclusion

Healthy collegiate adults can potentially use social media platforms to prime their performances; however, they must perceive them as a positive addition to their current status and hierarchy within their team and community. Therefore, it is suggested that these video-based opportunities be saved for days when they turn up unmotivated or where maximum effort and intensity are essential to guard against the possibility that repeated use of social media is subject to some dilution of benefits. Furthermore, while observers can be off-putting, it may not be detrimental to low-skill tasks such as those used within resistance training. That said, it can cause small increases in cortisol, which, over time, may prove detrimental. Therefore, caution is advised.

Chapter 9 Study 5

9.0 Assessing the efficacy of various psychological priming interventions on hormonal and physical performance measures

9.1 Introduction

As previously noted, testosterone priming can potentially improve performance via non-cognitive psychological techniques that can heighten arousal, alter emotions, and reduce inhibition (Karageorghis & Priest, 2012), which can lead to increased motivation to take greater risks while performing an athletic endeavor. Studies 2, 3, and 4 report that techniques used to accomplish this can be music, motivational self-talk, imagery, and observation. However, analysis of individual subjects revealed that the results were mixed. For example, in Study 2, Subject Three, when undertaking MSTI, lifted 20 kg more in the 3RM back squat, but testosterone (107%) was reduced compared to CON (131%). In Study Three, Subject Two experienced a 96% increase in testosterone and load lifted of 820 kg in the MST condition compared to CON 780 kg, and Subject Nineteen's testosterone rose 47% less than CON but lifted 24 kg more in the four times 4RM bench press. Therefore, further investigation is warranted.

This study aims to add and expand on the data collected in the previous studies due to the limited number of subjects partaking in them, which was below the minimum 24 subjects calculated from a priori power analysis using G*Power (Version 3.1, University of Dusseldorf, Germany), implementing a statistical power of 0.8 and type 1 alpha level of 0.05. This study will investigate the psychological interventions and priming capability of listening to SSM, being observed through SMO, or engaging in MSTI on testosterone concentration levels and its subsequent effect on performance markers. Previously, muscular power and maximal strength were not investigated. Therefore, these will be examined in a CMJ and IMTP. A muscle endurance test of a 16RM back squat will also be performed. All markers will be analyzed against a CON condition. The release of testosterone and cortisol will also be investigated to explain the mechanisms at work given the previously discussed dual-hormone hypothesis. It is hypothesized that these psychological methods will decrease cortisol and increase testosterone, producing altered psychological and cognitive processing and enhancing performance in the 16RM, IMTP, and CMJ.

9.2 Methods

Please see Chapter 4 for the relevant methodology and statistics.

9.2.1 Experimental approach to the problem

This study conducted a randomized cross-over design using a convenience sampling method, whereby 28 subjects undertook a CMJ, IMTP, and then a 16RM back squat, where power, maximal strength, muscular endurance, and barbell average velocity were measured (Figure 9.1). Force plates (Kistler 9286 Force Plates, Winterthur, Switzerland) and a “push band” (Push Inc, Toronto) were used to measure jump height, muscular strength, and barbell velocity. Given availability to participate, subjects partook in either one, two, or three interventions. Therefore, results are split into individual interventions of SSM, MSTI, and SMO, and those that completed all three (Trio). The same protocols were administered in each intervention. During the 15-minute warm-up prior to the testing, subjects either (a) listened to SSM, (b) engaged in MSTI, (c) were filmed for social media on an iPhone 12 (Apple Inc, California, USA), or (d) passively (CON group) warming up. Before the interventions and post-warm-up, subjects provided saliva samples to analyze salivary testosterone and cortisol concentration levels.

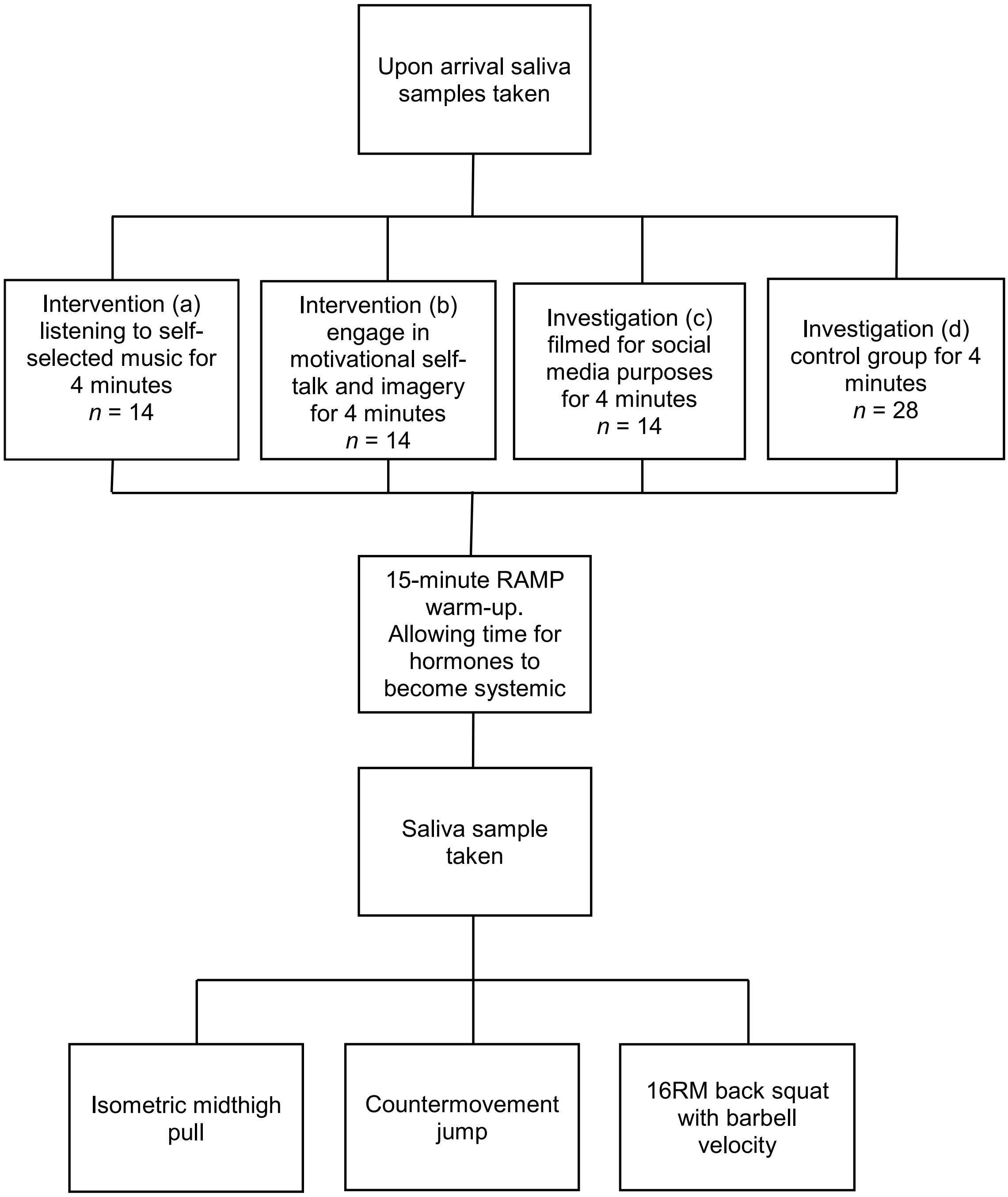

Figure 9.1 Experimental design.

9.2.2 Subjects

Seventeen healthy collegiate adult males (25.94 ± 6.81 years, 170.80 ± 43.84 cm tall, and a mass of 82.94 ± 8.11 kg) and eleven healthy collegiate adult females (28.36 ± 9.75 years, 163.97 ± 12.41 cm tall, and a mass of 68.47 ± 11.88 kg), all in good health and free from injury, with at least three years resistance training experience, volunteered to participate in this study. Of these, ten subjects completed three interventions, with eighteen completing one or two conditions. Subjects were classed as recreational, attending the gym at least twice weekly. All subjects provided informed consent, with study procedures meeting Middlesex University's ethical approval.

9.3 Results

9.3.1 16RM back squat

Repeated measures ANOVA showed a statistically significant difference between interventions (p = 0.032). Post hoc analysis using showed statistically significant differences in 16RM back squat loads lifted (p < 0.05) SSM 65.07 ± 5.09 kg, g = 0.55, 95% CI -0.12, 0.99 (p < 0.001) vs. CON 50.00 ± 4.42 kg, MSTI 61.14 ± 6.45 kg g = 0.56, 95% CI -0.12, 1.00 (p = 0.007) vs. CON 48.57 ± 4.76 kg, SMO 59.14 ± 5.86 kg g = 0.55, 95% CI -0.08, 1.01 (p = 0.01) vs. CON 47.86 ± 4.80 kg. Subjects that completed all of the interventions (Trio) recorded statistically significant results in SSM 68.10 ± 6.64 kg g = 0.85, 95% CI -0.05, 1.74 (p = 0.001), MSTI 64.50 ± 8.21 kg g = 0.60, 95% CI -0.52, 1.72 (p = 0.02) vs. CON 50.00 ± 5.73 kg. SMO did not 59.50 ± 7.87 kg g = 0.40, 95% CI -0.82, 1.63.

No statistically significant differences were noted in the average barbell velocity (p = 0.33) across all interventions. Effect size differences show trivial changes in all interventions except for the MSTI condition, whereby a small effect size reduction occurred.

9.3.2 Isometric mid-thigh pull

No statistically significant differences or notable effect size differences were noted across all interventions. Force recorded at 100, 200, and 300 m/s was unreliable and, therefore, unable to be analyzed.

9.3.3 Countermovement jump

No statistically significant jump height differences were recorded across all interventions. A moderate effect size reduction was noted in the MSTI intervention g = -0.57, 95% CI -1.37, 0.23 (0.32 ± 0.02 m vs. CON 0.39 ± 0.04 m), along with a small effect size reduction in SMO and a trivial reduction in SSM. The Trio subjects recorded a small effect size increase in the SSM condition, with MSTI and SMO recording trivial changes.

MSTI recorded the only statistically significant peak power result (p = 0.04) compared to control, with peak power decreasing by a small effect size of g = -0.23, 95% CI -0.73, -0.23 (3661.86 ± 277.07 Watts (W)) compared to CON (4307.21 ± 284.66 W). The other results were statistically not significant, with either trivial or small effect size changes. In the Trio group, SMO recorded a moderate effect size increase of g = 0.79, 95% CI -0.04, 1.53 (4322.60 ± 256.68 W), with MSTI producing a large reduction of g = -1.39, 95% CI -2.25, -0.53 (3723.00 ±300.16 W) compared to control 4023.40 ± 316.36 W. SSM produced a small effect size decrease compared to control.

RSI modified did not produce any statistically significant results. A large g = -1.45 (95% CI -2.35, -0.55) effect size reduction occurred in the MSTI intervention of 0.44 ± 0.04, compared to 0.54 ± 0.04 in CON. SSM (0.51 ± 0.05) and SMO (0.46 ± 0.05) produced moderate and large effect size reductions of g = -0.40 (95% CI -0.89, 0.10) and g = -0.88, (95% CI -1.73, 0.03) against the CON (0.55 ± 0.04 and 0.54 ± 0.04, respectively). In the Trio group, MSTI recorded a large effect size reduction of g = -1.33 (95% CI -2.24, 0.40) (0.47 ± 0.05), with SSM producing a moderate reduction g = -0.46 (95% CI -1.11, 0.20) (0.51 ± 0.06) compared to the CON (0.55 ± 0.05), with SMO recording a small decrease.

9.3.4 Testosterone

No statistically significant differences were recorded across all interventions. However, MSTI recorded a moderate effect size reduction of g = -0.52 (95% CI -1.40, 0.37) (95 ± 4.90% vs. CON 107 ± 6.30%), with SMO and SSM noting small and trivial reductions, respectively. The Trio group noted large reductions in MSTI and SMO g = -0.92 (95% CI -2.26, 0.42 and g = -0.92, (95% CI -2.05, -0.22) respectively (97 ± 6.53% and 90 ± 10.57% vs. CON 116 ± 5.93% respectively). A moderate reduction was recorded in SSM g = -0.75 (95% CI -1.73, 0.23) (99 ± 7.20%).

9.3.5 Cortisol

No statistically significant differences were recorded across all interventions. A moderate effect size reduction was noted in MSTI *g* = -0.59 (95% CI -1.59, 0.41) (84 ± 6.39% vs. CON 113 ± 17.42%), and a small effect reduction was recorded in SMO, with SSM recording a trivial increase. The Trio group recorded a large reduction in MSTI *g* = -0.98 (95% CI -1.98, 0.01) (82 ± 6.83%), and SSM and SMO noted moderate reductions of *g* = -0.68 (95% CI –1.86, -0.32) (93 ± 9.83%) and *g* =-0.67 (95% CI -1.42, -0.09) (88 ± 14.85 % vs. CON 131 ± 21.97%).

9.3.6 Testosterone: cortisol ratio

No statistically significant differences were recorded across all interventions. All trials recorded trivial changes except for the MSTI intervention, whereby they recorded a small change. The Trio subjects recorded a moderate effect size reduction in the MSTI condition *g* = -0.61 (95% CI -1.46, 0.25) (85 ± 5.03%). A small reduction occurred in SSM, with SMO recording a trivial change. Intraassay COV was 6.8%,and in Trio 8.7%.

Table 9.1 Results of the self-selected music intervention compared to the control (*n* = 14).

Subject ID	16RM (kg)		Velocity (m/s)		IMTP (N)		CMJ (m)	
	CON ± SD	SSM ± SD	CON ± SD	SSM ± SD	CON ± SD	SSM ± SD	CON ± SD	SSM ± SD
4	50 ± 3.54	55 ± 2.12	0.69 ± 0.02	0.53 ± 0.01	1809.17 ± 148.70	2084.21 ± 148.64	0.29 ± 0.03	0.33 ± 0.03
6	85 ± 1.41	92 ± 3.54	0.62 ± 0.02	0.75 ± 0.03	2640.1 ± 137.75	2724.96 ± 86.17	0.44 ± 0.03	0.41 ± 0.01
9	30 ± 2.83	70 ± 3.54	0.55 ± 0.02	0.48 ± 0.03	758.57 ± 71.83	722.35 ± 47.14	0.27 ± 0.02	0.28 ± 0.01
10	60 ± 4.24	85 ± 4.95	0.74 ± 0.04	0.70 ± 0.01	1580.09 ± 80.72	1566.84 ± 73.16	0.36 ± 0.05	0.38 ± 0.03
13	70 ± 0.71	75 ± 2.83	0.58 ± 0.05	0.60 ± 0.02	1683.07 ± 69.47	1864.87 ± 106.13	0.39 ± 0.01	0.36 ± 0.01
14	50 ± 2.83	75 ± 5.66	0.52 ± 0.06	0.60 ± 0.01	861.08 ± 94.92	837.98 ± 2.61	0.36 ± 0.03	0.40 ± 0.01
15	60 ± 1.41	90 ± 1.41	0.60 ± 0.04	0.72 ± 0.01	2349.49 ± 189.65	2481.81 ± 236.94	0.41 ± 0.06	0.38 ± 0.03
17	50 ± 6.36	75 ± 9.19	0.72 ± 0.03	0.57 ± 0.06	1848.67 ± 205.50	1668.36 ± 224.04	0.38 ± 0.07	0.37 ± 0.02
18	40 ± 4.95	45 ± 1.41	0.60 ± 0.06	0.50 ± 0.06	1659.86 ± 76.81	1052.23 ± 125.40	0.39 ± 0.01	0.24 ± 0.03
19	30 ± 0.71	40 ± 6.36	0.43 ± 0.05	0.45 ± 0.03	652.70 ± 59.04	660.68 ± 17.45	0.33 ± 0.02	0.51 ± 0.16
22	30 ± 2.12	34 ± 4.95	0.55 ± 0.04	0.63 ± 0.04	907.85 ± 42.54	990.52 ± 95.30	0.22 ± 0.01	0.22 ± 0.01
24	40 ± 3.54	50 ± 3.54	0.53 ± 0.02	0.58 ± 0.01	1556.44 ± 93.67	1305.27 ± 121.63	0.47 ± 0.02	0.29 ± 0.03
25	40 ± 5.66	50 ± 1.41	0.60 ± 0.03	0.48 ± 0.01	1813.23 ± 189.76	1478.42 ± 263.59	0.36 ± 0.02	0.27 ± 0.04
28	65 ± 4.95	75 ± 2.12	0.64 ± 0.03	0.63 ± 0.04	1562.74 ± 229.66	1873.87 ± 139.63	0.37 ± 0.03	0.48 ± 0.03
Mean	**50.00 ± 3.23**	**65.07 ± 3.79**	**0.60 ± 0.04**	**0.59 ± 0.03**	**1548.79 ± 120.72**	**1522.31 ± 120.56**	**0.36 ± 0.03**	**0.35 ± 0.03**
ES & 95% CI		***g* = 0.55 (-0.12, 0.99)**		***g* = -0.11 (-0.53, 0.75)**		***g* = -0.04 (-0.19, 0.27)**		***g* = -0.12 (-0.58, 0.82)**
Significance		***p* < 0.001**		***p* = 0.68**		***p* = 0.69**		***p* = 0.73**
ICC	**0.956**	**0.982**	**0.916**	**0.969**	**0.962**	**0.912**	**0.519**	**0.678**

SSM = self-selected music, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, TC ratio = testosterone: cortisol ratio, kg = kilograms, m/s = meters per second, N = Newtons, m = meters, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.2 Results of the self-selected music intervention compared to the control (*n*=14).

Subject ID	CMJ RSI Modified		CMJ Peak Power (W)		Testosterone (%)		Cortisol (%)		TC Ratio (%)	
	CON ± SD	**SSM ± SD**	**CON ± SD**	**SSM ± SD**	**CON**	**SSM**	**CON**	**SSM**	**CON**	**SSM**
4	0.36 ± 0.05	0.43 ± 0.04	4179 ± 151.59	4392 ± 226.38	79.68	295.74	33.33	600.00	41.83	202.88
6	0.84 ± 0.08	0.71 ± 0.02	5011 ± 147.67	4616 ± 1.73	116.78	100.49	75.00	130.00	64.22	129.36
9	0.41 ± 0.02	0.42 ± 0.08	2435 ± 19.60	2432 ± 20.95	129.55	79.12	100.00	54.17	77.19	68.46
10	0.52 ± 0.07	0.50 ± 0.02	4742 ± 1249.35	5116 ± 229.40	114.04	116.29	185.71	109.09	162.85	93.81
13	0.55 ± 0.16	0.48 ± 0.10	5224 ± 159.72	5275 ± 208.18	89.81	55.88	39.29	53.85	43.74	96.37
14	0.46 ± 0.06	0.42 ± 0.04	3773 ± 386.98	3859 ± 205.82	100.53	57.63	100.00	45.45	99.47	78.88
15	0.73 ± 0.16	0.64 ± 0.09	4970 ± 476.35	4265 ± 277.32	111.35	91.61	83.33	125.00	74.84	136.45
17	0.64 ± 0.09	0.58 ± 0.03	4265 ± 277.32	4497 ± 253.37	90.82	85.07	300.00	100.00	330.33	117.55
18	0.56 ± 0.03	0.25 ± 0.04	5207 ± 39.72	2355 ± 178.23	102.15	123.71	90.00	87.50	88.10	70.73
19	0.58 ± 0.02	0.91 ± 0.38	3993 ± 89.31	5277 ± 2878.60	115.96	113.70	83.33	72.73	71.86	63.96
22	0.32 ± 0.10	0.27 ± 0.06	2660 ± 190.84	2989 ± 109.14	130.31	133.38	153.85	133.33	118.06	99.96
24	0.78 ± 0.26	0.71 ± 0.17	6019 ± 1735.84	5863 ± 1662.09	113.70	113.64	50.00	80.00	43.98	70.39
25	0.50 ± 0.06	0.46 ± 0.17	4742 ± 192.50	4745 ± 173.55	120.80	84.27	82.61	85.37	68.38	101.30
28	0.40 ± 0.05	0.41 ± 0.14	3178 ± 119.56	3305 ± 78.82	157.16	97.33	140.00	80.00	89.08	82.20
Mean	**0.55 ± 0.09**	**0.51 ± 0.10**	**4314.14 ± 373.98**	**4213.29 ± 464.54**	**112.33**	**110.56**	**108.32**	**125.46**	**98.14**	**100.88**
ES & 95% CI	***g* = -0.40 (-0.89, 0.10)**		***g* = -0.23 (-0.73, 0.27)**		***g* = -0.04 (-0.98, 0.90)**		***g* = 0.15 (-0.76, 1.07)**		***g* = 0.05 (-0.77, 0.86)**	
Significance	***p* = 0.38**		***p* = 0.68**		***p* = 0.92**		***p* = 0.71**		***p* = 0.90**	
ICC	**0.521**	**0.434**	**0.713**	**0.777**						

SSM = self-selected music, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, RSI = reactive strength index, TC ratio = testosterone: cortisol ratio, W = Watts, % = percentage, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.3 Results of the motivational self-talk and imagery intervention compared to the control (n = 14).

Subject ID	16RM (kg)		Velocity (m/s)		IMTP (N)		CMJ (m)	
	CON ± SD	**MSTI ± SD**	**CON ± SD**	**MSTI ± SD**	**CON ± SD**	**MSTI ± SD**	**CON ± SD**	**MSTI ± SD**
4	50 ± 3.54	52 ± 4.24	0.69 ± 0.02	0.53 ± 0.04	1809.17 ± 148.70	1696.25 ± 420.37	0.29 ± 0.03	0.28 ± 0.01
6	85 ± 1.41	85 ± 3.54	0.62 ± 0.02	0.62 ± 0.01	2640.10 ± 137.75	2386.32 ± 103.90	0.44 ± 0.03	0.43 ± 0.01
8	70 ± 2.83	80 ± 2.12	0.62 ± 0.05	0.66 ± 0.03	2448.56 ± 82.55	2202.00 ± 46.25	0.82 ± 0.29	0.35 ± 0.02
9	30 ± 2.83	40 ± 5.66	0.55 ± 0.02	0.48 ± 0.04	758.57 ± 71.83	898.96 ± 81.67	0.27 ± 0.02	0.29 ± 0.03
10	60 ± 4.24	70 ± 5.66	0.74 ± 0.04	0.70 ± 0.01	1580.09 ± 80.72	1738.14 ± 164.38	0.36 ± 0.05	0.41 ± 0.01
14	50 ± 2.83	70 ± 7.07	0.52 ± 0.06	0.45 ± 0.03	861.08 ± 94.92	977.26 ± 70.37	0.36 ± 0.03	0.39 ± 0.02
15	60 ± 1.41	100 ± 7.07	0.60 ± 0.04	0.65 ± 0.04	2349.49 ± 189.65	2265.18 ± 126.61	0.41 ± 0.06	0.42 ± 0.02
17	50 ± 6.36	100 ± 3.54	0.72 ± 0.03	0.51 ± 0.01	1848.67 ± 205.50	1556.31 ± 408.98	0.38 ± 0.07	0.35 ± 0.04
18	40 ± 4.95	45 ± 0.71	0.60 ± 0.06	0.68 ± 0.01	1659.86 ± 76.81	1162.44 ± 67.26	0.39 ± 0.01	0.31 ± 0.04
19	30 ± 0.71	35 ± 2.83	0.43 ± 0.05	0.53 ± 0.04	652.70 ± 59.04	794.35 ± 44.04	0.33 ± 0.02	0.26 ± 0.02
20	30 ± 4.24	37 ± 2.12	0.60 ± 0.01	0.55 ± 0.03	612.48 ± 88.95	844.99 ± 68.45	0.28 ± 0.02	0.26 ± 0.04
21	30 ± 1.41	42 ± 2.12	0.60 ± 0.03	0.34 ± 0.01	1220.40 ± 107.71	1143.18 ± 109.49	0.58 ± 0.02	0.17 ± 0.05
22	30 ± 2.12	30 ± 3.54	0.55 ± 0.04	0.62 ± 0.05	907.85 ± 42.54	1007.49 ± 67.88	0.22 ± 0.01	0.23 ± 0.01
28	65 ± 4.95	70 ± 1.41	0.64 ± 0.03	0.59 ± 0.04	1562.74 ± 229.66	1681.66 ± 54.16	0.37 ± 0.03	0.34 ± 0.03
Mean	**48.57 ± 3.13**	**61.14 ± 3.69**	**0.61 ± 0.03**	**0.57 ± 0.03**	**1493.70 ± 115.45**	**1453.90 ± 131.11**	**0.39 ± 0.05**	**0.32 ± 0.03**
ES & 95% CI	***g* = 0.56 (-0.12, 1.00)**		***g* = -0.42 (-1.13, 0.30)**		***g* = -0.06 (-0.23, 0.10)**		***g* = -0.57 (-1.37, 0.23)**	
Significance	***p* = 0.007**		***p* = 0.18**		***p* = 0.50**		***p* = 0.11**	
ICC	**0.956**	**0.916**	**0.916**	**0.946**	**0.962**	**0.900**	**0.519**	**0.945**

MSTI = motivational self-talk and imagery, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, TC ratio = testosterone: cortisol ratio, kg = kilograms, m/s = meters per second, N = Newtons, m = meters, ES = hedges g effect size, p = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.4 Results of the motivational self-talk and imagery intervention compared to the control (*n* = 14).

Subject ID	CMJ RSI_Modified		CMJ Peak power		Testosterone (%)		Cortisol (%)		TC Ratio (%)	
	CON ± SD	**MSTI ± SD**	**CON ± SD**	**MSTI ± SD**	**CON**	**MSTI**	**CON**	**MSTI**	**CON**	**MSTI**
4	0.36 ± 0.05	0.35 ± 0.04	4179 ± 151.59	4163 ± 53.01	79.68	90.54	33.33	85.71	41.83	94.67
6	0.84 ± 0.61	0.61 ± 0.03	5011 ± 147.67	4368 ± 39.88	116.78	110.96	75.00	92.31	64.22	83.19
8	0.70 ± 0.23	0.48 ± 0.05	5669 ± 595.39	5135 ± 64.07	84.98	82.07	105.88	62.50	124.59	76.16
9	0.41 ± 0.02	0.43 ± 0.05	2435 ± 19.60	2470 ± 112.06	129.55	90.59	100.00	90.00	77.19	99.35
10	0.52 ± 0.07	0.55 ± 0.05	4742 ± 1249.35	4912 ± 124.19	114.04	54.27	185.71	54.55	162.85	100.51
14	0.46 ± 0.06	0.46 ± 0.03	3773 ± 386.98	3946 ± 21.36	100.53	76.27	100.00	64.00	99.47	83.91
15	0.73 ± 0.16	0.61 ± 0.02	4970 ± 476.35	4449 ± 17.01	111.35	93.65	83.33	70.00	74.84	74.74
17	0.64 ± 0.09	0.64 ± 0.07	4265 ± 277.32	4365 ± 253.37	90.82	119.48	300.00	63.33	330.33	53.01
18	0.56 ± 0.03	0.51 ± 0.03	5207 ± 39.72	4469 ± 112.01	102.15	106.21	90.00	100.00	88.10	94.15
19	0.58 ± 0.02	0.20 ± 0.05	3993 ± 89.31	2327 ± 54.62	115.96	117.63	83.33	100.00	71.86	85.01
20	0.34 ± 0.02	0.49 ± 0.27	4167 ± 55.23	2194 ± 41.51	106.21	87.65	76.92	81.82	72.42	93.35
21	0.74 ± 0.07	0.23 ± 0.02	6052 ± 318.56	2544 ± 114.12	63.82	111.12	60.47	136.36	94.74	122.72
22	0.32 ± 0.10	0.28 ± 0.04	2660 ± 190.26	2794 ± 150.14	130.31	112.77	153.85	121.74	118.06	107.95
28	0.40 ± 0.05	0.36 ± 0.01	3178 ± 119.56	3130 ± 67.18	157.16	88.53	140.00	66.67	89.08	75.31
Mean	**0.54 ± 0.08**	**0.44 ± 0.05**	**4307.21 ± 294.06**	**3661.86 ± 87.46**	**107.38**	**95.84**	**113.42**	**84.93**	**107.83**	**88.86**
ES & 95% CI	***g* = -1.45 (-2.35, 0.55)**		***g* = -0.23 (-0.73, 0.27)**		***g* = -0.52 (-1.40, 0.37)**		***g* = 0.59 (-0.41, 1.59)**		***g* = -0.41 (-1.42, 0.60)**	
Significance	***p* = 0.055**		***p* = 0.041**		***p* = 0.19**		***p* = 0.20**		***p* = 0.39**	
ICC	**0.521**	**0.928**	**0.713**	**0.989**						

MSTI = motivational self-talk and imagery, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, RSI = reactive strength index, TC ratio = testosterone: cortisol ratio, W = Watts, % = percentage, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.5 Results of the social media observation intervention compared to the control (n = 14).

Subject ID	16RM (kg)		Velocity (m/s)		IMTP (N)		CMJ (m)	
	CON ± SD	**SMO ± SD**	**CON ± SD**	**SMO ± SD**	**CON ± SD**	**SMO ± SD**	**CON ± SD**	**SMO ± SD**
6	85 ± 3.54	80 ± 3.54	0.62 ± 0.02	0.62 ± 0.01	2640.10 ± 137.75	2559.61 ± 62.25	0.44 ± 0.03	0.32 ± 0.01
9	30 ± 1.41	50 ± 2.83	0.55 ± 0.02	0.57 ± 0.05	758.57 ± 71.83	806.23 ± 109.49	0.27 ± 0.02	0.29 ± 0.01
10	60 ± 2.83	80 ± 2.12	0.74 ± 0.04	0.71 ± 0.02	1580.09 ± 80.72	1670.23 ± 77.96	0.36 ± 0.05	0.39 ± 0.02
13	70 ± 0.71	70 ± 1.41	0.58 ± 0.05	0.52 ± 0.02	1683.07 ± 69.47	1622.72 ± 176.50	0.39 ± 0.01	0.37 ± 0.04
14	50 ± 2.83	40 ± 2.12	0.52 ± 0.06	0.57 ± 0.04	861.08 ± 94.92	831.94 ± 55.71	0.36 ± 0.03	0.40 ± 0.01
15	60 ± 1.41	90 ± 2.12	0.60 ± 0.04	0.72 ± 0.03	2349.49 ± 189.65	2769.60 ± 115.88	0.41 ± 0.06	0.49 ± 0.03
17	50 ± 6.36	85 ± 3.54	0.72 ± 0.03	0.53 ± 0.03	1848.67 ± 205.50	697.55 ± 57.29	0.38 ± 0.07	0.38 ± 0.02
19	30 ± 0.71	40 ± 0.71	0.43 ± 0.05	0.45 ± 0.01	652.7 ± 59.04	697.55 ± 117.60	0.33 ± 0.02	0.33 ± 0.05
20	30 ± 4.24	30 ± 2.12	0.60 ± 0.01	0.51 ± 0.01	612.48 ± 88.95	773.48 ± 25.98	0.28 ± 0.02	0.22 ± 0.02
21	30 ± 1.41	39 ± 2.83	0.60 ± 0.03	0.37 ± 0.02	1220.40 ± 107.71	1116.52 ± 119.36	0.58 ± 0.02	0.19 ± 0.02
22	30 ± 2.12	25 ± 3.54	0.55 ± 0.04	0.64 ± 0.04	907.85 ± 42.54	1487.02 ± 335.57	0.22 ± 0.01	0.23 ± 0.01
24	40 ± 3.54	70 ± 2.12	0.53 ± 0.02	0.65 ± 0.05	1556.44 ± 93. 67	1633.83 ± 153.20	0.47 ± 0.02	0.40 ± 0.01
25	40 ± 5.66	54 ± 2.12	0.60 ± 0.03	0.40 ± 0.01	1813.23 ± 189.76	1753.39 ± 227.95	0.36 ± 0.02	0.24 ± 0.02
28	65 ± 4.95	75 ± 1.41	0.64 ± 0.03	0.65 ± 0.11	1562.74 ± 229.66	1852.83 ± 54.08	0.37 ± 0.03	0.40 ± 0.02
Mean	**47.86 ± 2.98**	**59.14 ± 2.32**	**0.59 ± 0.03**	**0.57 ± 0.03**	**1431.92 ± 118.66**	**1448.04 ± 120.63**	**0.37 ± 0.03**	**0.33 ± 0.02**
ES & 95% CI	***g* = 0.55 (-0.08, 1.01)**		***g* = -0.20 (-0.90, 0.50)**		***g* = 0.01 (-0.34, 0.35)**		***g* = -0.88 (-1.73, 0.03)**	
Significance	***p* = 0.01**		***p* = 0.40**		***p* = 0.88**		***p* = 0.21**	
ICC	**0.956**	**0.985**	**0.916**	**0.977**	**0.962**	**0.946**	**0.519**	**0.933**

SMO = social media observation, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, TC ratio = testosterone: cortisol ratio, kg = kilograms, m/s = meters per second, N = Newtons, m = meters, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.6 Results of the social media observation intervention compared to the control (*n* = 14).

Subject ID	CMJ RSI_Modified		CMJ Peak Power (W)		Testosterone (%)		Cortisol (%)		TC Ratio (%)	
	CON ± SD	**SMO ± SD**	**CON ± SD**	**SMO ± SD**	**CON ± SD**	**SMO ± SD**	**CON ± SD**	**SMO ± SD**	**CON ± SD**	**SMO ± SD**
6	0.36 ± 0.05	0.35 ± 0.10	4179 ± 151.59	4231 ± 118.16	116.78	122.93	75.00	166.67	64.22	135.58
9	0.84 ± 0.08	0.40 ± 0.05	5011 ± 147.67	2820 ± 150.72	129.55	123.68	100.00	100.00	77.19	80.86
10	0.7 ± 0.23	0.52 ± 0.04	5669 ± 595.39	4926 ± 148.92	114.04	12.79	185.71	17.86	162.85	139.57
13	0.41 ± 0.02	0.56 ± 0.17	2435 ± 19.60	5065 ± 343.57	89.81	119.92	39.29	76.47	43.74	63.77
14	0.52 ± 0.07	0.60 ± 0.04	4742 ± 1249.35	5266 ± 170.12	100.53	111.86	100.00	95.65	99.47	85.51
15	0.46 ± 0.06	0.71 ± 0.06	3773 ± 386.98	4784 ± 164.08	111.35	67.39	83.33	63.64	74.84	94.42
17	0.73 ± 0.16	0.80 ± 0.13	4970 ± 476.35	4757 ± 444.60	90.82	111.40	300.00	114.29	330.33	102.59
19	0.64 ± 0.09	0.62 ± 0.17	4265 ± 277.32	4392 ± 400.05	115.96	82.39	83.33	40.00	71.86	48.55
20	0.56 ± 0.03	0.24 ± 0.02	5207 ± 39.72	2514 ± 140.16	106.21	91.36	76.92	55.00	72.42	60.20
21	0.58 ± 0.02	0.21 ± 0.07	3993 ± 89.31	2493 ± 89.14	63.82	130.69	60.47	60.00	94.74	45.91
22	0.34 ± 0.02	0.30 ± 0.02	4167 ± 55.23	2918 ± 79.08	130.31	105.27	153.85	150.00	118.06	142.49
24	0.74 ± 0.07	0.56 ± 0.02	6052 ± 318.56	4928 ± 130.86	113.70	99.97	50.00	150.00	43.98	150.05
25	0.32 ± 0.10	0.24 ± 0.04	2660 ± 190.26	4580 ± 215.88	120.80	126.00	82.61	27.27	68.38	21.64
28	0.40 ± 0.05	0.36 ± 0.06	3178 ± 119.56	4239 ± 101.52	157.16	78.30	140.00	83.33	89.08	106.42
Mean	**0.54 ± 0.08**	**0.46 ± 0.07**	**4307.21 ± 294.06**	**4136.64 ± 192.63**	**111.49**	**98.85**	**109.32**	**85.73**	**100.80**	**91.25**
ES & 95% CI	***g* = -0.40 (-0.89, 0.10)**		***g* = -0.23 (-0.73, 0.27)**		***g* = -0.43 (-1.06, 0.20)**		***g* = -0.37 (-0.50, 0.24)**		***g* = -0.15 (-0.88, 0.59)**	
Significance	***p* = 0.15**		***p* = 0.68**		***p* = 0.29**		***p* = 0.29**		***p* = 0.64**	
ICC	**0.773**	**0.434**	**0.713**	**0.947**						

SMO = social media observation, CON = control condition, SD = standard deviation, 16RM = 16 rep maximum back squat, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, RSI = reactive strength index, TC ratio = testosterone: cortisol ratio, W = Watts, % = percentage, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, 95% CI = 95% confidence intervals, and ICC = intraclass correlation coefficient.

Table 9.7 16RM back squat and average barbell velocity results for those that completed all the interventions (*n* = 10).

Subject ID	**16RM (kg)**				**Velocity (m/s)**			
	CON ± SD	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**	**CON ± SD**	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**
6	85 ± 1.41	92 ± 3.54	85 ± 3.54	80 ± 3.54	0.62 ± 0.02	0.75 ± 0.03	0.62 ± 0.01	0.62 ± 0.01
9	30 ± 2.83	70 ± 3.54	40 ± 5.66	50 ± 2.83	0.55 ± 0.02	0.48 ± 0.03	0.48 ± 0.04	0.57 ± 0.05
10	60 ± 4.24	85 ± 4.95	70 ± 5.66	80 ± 2.12	0.74 ± 0.04	0.70 ± 0.01	0.70 ± 0.01	0.71 ± 0.02
14	50 ± 2.83	75 ± 5.66	70 ± 7.07	40 ± 2.12	0.52 ± 0.06	0.60 ± 0.01	0.45 ± 0.03	0.57 ± 0.04
15	60 ± 1.41	90 ± 1.41	100 ± 7.07	90 ± 2.12	0.60 ± 0.04	0.72 ± 0.01	0.65 ± 0.04	0.72 ± 0.03
17	50 ± 6.36	75 ± 9.19	100 ± 3.54	85 ± 3.54	0.72 ± 0.03	0.57 ± 0.06	0.51 ± 0.01	0.53 ± 0.03
18	40 ± 4.95	45 ± 1.41	45 ± 0.71	40 ± 1.41	0.60 ± 0.06	0.50 ± 0.06	0.68 ± 0.01	0.45 ± 0.04
19	30 ± 0.71	40 ± 6.36	35 ± 2.83	40 ± 0.71	0.43 ± 0.05	0.45 ± 0.03	0.53 ± 0.04	0.45 ± 0.01
22	30 ± 2.12	34 ± 4.95	30 ± 3.54	25 ± 3.54	0.55 ± 0.04	0.63 ± 0.04	0.62 ± 0.05	0.64 ± 0.04
28	65 ± 4.95	75 ± 2.12	70 ± 1.41	75 ± 1.41	0.64 ± 0.03	0.63 ± 0.04	0.59 ± 0.04	0.65 ± 0.11
Mean	**50.00 ± 3.18**	**68.10 ± 4.31**	**64.50 ± 4.10**	**59.50 ± 2.33**	**0.60 ± 0.04**	**0.60 ± 0.03**	**0.58 ± 0.03**	**0.59 ± 0.04**
ES & 95% CI		***g* = 0.85 (-0.05, 1.74)**	***g* = 0.60 (-0.52, 1.72)**	***g* = 0.40 (-0.82, 1.63)**		***g* = 0.00 (-0.67, 0.67)**	***g* = -0.20 (-1.17, 1.58)**	***g* = 0.00 (-0.34, 0.34)**
Significance		***p* = 0.001**	***p* = 0.02**	***p* = 0.09**		***p* = 0.84**	***p* = 0.65**	***p* = 1.00**

CON = control condition, SD = standard deviation, SSM = self-selected music, MSTI = motivational self-talk and imagery, SMO = social media observation, 16RM = 16 rep maximum back squat, kg = kilograms, m/s = meters per second, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, and 95% CI = 95% confidence intervals.

Table 9.8 Isometric mid-thigh pull and countermovement jump results for those that completed all the interventions (*n* = 10).

Subject ID	**IMTP (N)**				**CMJ (m)**			
	CON ± SD	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**	**CON ± SD**	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**
6	2640.10 ± 137.75	2724.96 ± 86.17	2386.32 ± 103.90	2559.61 ± 62.25	0.44 ± 0.03	0.41 ± 0.01	0.43 ± 0.01	0.32 ± 0.01
9	758.57 ± 71.83	722.35 ± 47.14	898.96 ± 81.67	806.23 ± 109.49	0.27 ± 0.02	0.28 ± 0.01	0.29 ± 0.03	0.29 ± 0.01
10	1580.09 ± 80.72	1566.84 ± 73.16	1738.14 ± 164.38	1670.23 ± 77.96	0.36 ± 0.05	0.38 ± 0.03	0.41 ± 0.01	0.39 ± 0.02
14	861.08 ± 94.92	837.98 ± 2.61	977.26 ± 70.37	831.94 ± 55.71	0.36 ± 0.03	0.40 ± 0.01	0.39 ± 0.02	0.40 ± 0.01
15	2349.49 ± 189.65	2481.81 ± 236.94	2265.18 ± 128.61	2769.60 ± 115.88	0.41 ± 0.06	0.38 ± 0.03	0.42 ± 0.02	0.49 ± 0.03
17	1848.67 ± 205.50	1668.36 ± 224.04	1556.31 ± 408.98	697.55 ± 57.29	0.38 ± 0.07	0.37 ± 0.02	0.35 ± 0.04	0.38 ± 0.02
18	1659.86 ± 76.81	1052.23 ± 125.40	1162.44 ± 67.26	1376.63 ± 63.85	0.39 ± 0.01	0.24 ± 0.03	0.31 ± 0.04	0.33 ± 0.03
19	652.70 ± 59.04	660.68 ± 17.45	794.35 ± 44.04	696.76 ± 117.60	0.33 ± 0.02	0.51 ± 0.16	0.26 ± 0.02	0.22 ± 0.05
22	907.85 ± 42.54	990.52 ± 95.30	1007.49 ± 67.68	1487.02 ± 335.57	0.22 ± 0.01	0.22 ± 0.01	0.23 ± 0.01	0.23 ± 0.01
28	1562.74 ± 229.66	1873.87 ± 139.63	1681.66 ± 54.16	1852.83 ± 54.08	0.37 ± 0.03	0.48 ± 0.03	0.34 ± 0.03	0.40 ± 0.02
Mean	**14582.12 ± 118.84**	**1457.96 ± 104.78**	**1446.81 ± 119.10**	**1474.84 ± 104.97**	**0.35 ± 0.03**	**0.37 ± 0.03**	**0.34 ± 0.02**	**0.35 ± 0.02**
ES & 95% CI		***g*** **= -0.03 (-0.22, 0.28)**	***g*** **= -0.05** ***(-1.05, 1.15)***	***g*** **= -0.08 (-0.37, 0.21)**		***g*** **= 0.22 (-0.34, 0.77)**	***g*** **= -0.13 (-0.53, 0.27)**	***g*** **= 0.00 (-1.20, 1.20)**
Significance		***p*** **= 0.75**	***p*** **= 0.64**	***p*** **= 0.71**		***p*** **= 0.62**	***p*** **= 0.47**	***p*** **= 0.71**

CON = control condition, SD = standard deviation, SSM = self-selected music, MSTI = motivational self-talk and imagery, SMO = social media observation, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, and 95% CI = 95% confidence intervals.

Table 9.9 Modified reactive strength index and peak power during the countermovement jump results for those that completed all the interventions (*n* = 10).

Subject ID	**CMJ RSI Modified**				**CMJ Peak Power**			
	CON ± SD	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**	**CON ± SD**	**SSM ± SD**	**MSTI ± SD**	**SMO ± SD**
6	0.84 ± 0.08	0.71 ± 0.02	0.61 ± 0.03	0.35 ± 0.10	5011 ± 147.57	4616 ± 1.73	4368 ± 39.88	4231 ± 118.16
9	0.41 ± 0.02	0.42 ± 0.08	0.43 ± 0.05	0.40 ± 0.05	2435 ± 19.60	2432 ± 20.95	2470 ± 112.06	2820 ± 150.72
10	0.52 ± 0.07	0.50 ± 0.02	0.55 ± 0.05	0.52 ± 0.04	4742 ± 1249.35	5116 ± 299.40	4912 ± 124.19	4926 ± 148.92
14	0.46 ± 0.06	0.42 ± 0.04	0.46 ± 0.03	0.60 ± 0.04	3773 ± 386.98	3859 ± 205.82	3946 ± 21.36	5266 ± 170.12
15	0.73 ± 0.16	0.64 ± 0.09	0.61 ± 0.02	0.71 ± 0.06	4970 ± 476.35	4265 ± 277.32	4449 ± 17.01	4784 ± 164.08
17	0.64 ± 0.09	0.58 ± 0.03	0.64 ± 0.07	0.80 ± 0.13	4265 ± 277.32	4497 ± 253.37	4365 ± 253.37	4757 ± 444.60
18	0.56 ± 0.03	0.25 ± 0.04	0.51 ± 0.03	0.58 ± 0.02	5207 ± 39.72	2355 ± 178.23	4469 ± 112.01	3993 ± 89.31
19	0.58 ± 0.02	0.91 ± 0.38	0.20 ± 0.05	0.62 ± 0.17	3993 ± 89.31	5277 ± 2878.60	2327 ± 54.62	4392 ± 400.05
22	0.32 ± 0.10	0.27 ± 0.06	0.28 ± 0.04	0.30 ± 0.02	2660 ± 190.26	2989 ± 109.14	2794 ± 150.14	2918 ± 79.08
28	0.40 ± 0.05	0.41 ± 0.14	0.36 ± 0.01	0.36 ± 0.06	3178 ± 119.56	3305 ± 78.82	3130 ± 67.18	4239 ± 101.52
Mean	**0.55 ± 0.07**	**0.51 ± 0.09**	**0.47 ± 0.04**	**0.52 ± 0.07**	**4023.40 ± 299.61**	**3871.10 ± 423.34**	**3733.00 ± 95.18**	**4232.60 ± 186.66**
ES & 95% CI		***g* = -0.46 (-1.11, 0.20)**	***g* = -1.33 (-2.26, 0.40)**	***g* = -0.39 (-1.20, 0.41)**		***g* = -0.39 (-1.16, 0.30)**	***g* = -1.39 (-2.25, 0.53)**	***g* = 0.79 (-0.04, 1.53)**
Significance		***p* = 0.503**	***p* = 0.081**	***p* = 0.705**		***p* = 0.667**	***p* = 0.145**	***p* = 0.427**

CON = control condition, SD = standard deviation, SSM = self-selected music, MSTI = motivational self-talk and imagery, SMO = social media observation, IMTP = isometric mid-thigh pull, CMJ = countermovement jump, RSI = reactive strength index, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, and 95% CI = 95% confidence intervals.

Table 9.10 Testosterone and cortisol salivary concentration results for those that completed all the interventions (*n* = 10).

Participant	Testosterone (%)				Cortisol (%)			
	Control	SSM	MSTI	SMO	Control	SSM	MSTI	SMO
6	116.78	100.49	110.96	122.93	75.00	130.00	92.31	166.67
9	129.55	79.12	90.59	123.68	100.00	54.17	90.00	100.00
10	114.04	116.29	54.27	12.79	185.71	109.09	54.55	17.86
14	100.53	57.63	76.27	111.86	100.00	45.45	64.00	95.65
15	111.35	91.61	93.65	67.39	83.33	125.00	70.00	63.64
17	90.82	85.07	119.48	111.40	300.00	100.00	63.33	114.29
18	102.15	123.71	106.21	82.39	90.00	87.50	100.00	40.00
19	115.96	113.70	117.63	91.36	83.33	72.73	100.00	55.00
22	130.31	133.38	112.77	105.27	153.85	133.33	121.74	150.00
28	157.16	97.33	88.53	78.30	140.00	80.00	66.67	83.33
Mean	**116.87**	**99.83**	**97.04**	**90.74**	**131.12**	**93.73**	**82.26**	**88.64**
ES & 95% CI		***g* = -0.75 (-1.73, 0.23)**	***g* = -0.92 (-2.26, 0.42)**	***g* = -0.92 (-2.05, 0.22)**		***g* = -0.68 (-1.68, 0.32)**	***g* = -0.98 (-1.98, 0.01)**	***g* = -0.67 (-1.42, 0.09)**
Significance		***p* = 0.71**	***p* = 0.64**	***p* = 0.64**		***p* = 0.13**	***p* = 0.08**	***p* = 0.13**

SSM = self-selected music, MSTI = motivational self-talk and imagery, SMO = social media observation, % = percentage, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, and 95% CI = 95% confidence intervals.

Table 9.11 Testosterone and cortisol salivary concentration ratio results for those that completed all the interventions (n = 10).

Subject ID	TC Ratio (%)			
	Control	**SSM**	**MSTI**	**SMO**
6	64.22	129.36	83.19	135.58
9	77.19	68.46	99.35	80.86
10	162.85	93.81	100.51	139.57
14	99.47	78.88	83.91	85.51
15	74.84	136.45	74.74	94.42
17	330.33	117.55	53.01	102.59
18	88.10	70.73	94.15	48.55
19	71.86	63.96	85.01	60.20
22	118.06	99.96	107.95	142.49
28	89.08	82.20	75.31	106.42
Mean	**117.60**	**94.14**	**85.71**	**99.62**
ES & 95% CI		***g* = -0.40 (-1.34, 0.53)**	***g* = -0.61 (-1.46, 0.25)**	***g* = -0.29 (-1.16, 0.57)**
Significance		***p* = 0.36**	***p* = 0.28**	***p* = 0.49**

SSM = self-selected music, MSTI = motivational self-talk and imagery, SMO = social media observation, TC ratio = testosterone: cortisol ratio, % = percentage, ES = hedges *g* effect size, *p* = statistical significance measured at < 0.05, and 95% CI = 95% confidence intervals.

9.4 Discussion

This study examined the effect of priming through psychological interventions of SSM, MSTI, and SMO on testosterone and cortisol before performing a 16RM back squat, IMTP, and CMJ against a control condition of sitting passively. Analysis of the results found statistically significant (p < 0.05) increases in the 16RM back squat load in all conditions except SMO in the Trio group. No other statistically significant results were noted. MSTI recorded a moderate reduction in cortisol (g = -0.59, 95% CI –1.59, 0.41), as did SSM (g = -0.68, 95% CI -1.68, 0.32) and SMO (g = -0.67, 95% CI -1.42, 0.09) in the Trio group, with MSTI noting a large change (g = -0.98, 95% CI -1.98, 0.01). All other results were either trivial or small improvements or small to moderate decrements against CON. Although there were no statistically significant increases in testosterone, notable reductions in cortisol levels, which positively improved the TC ratio, may indicate part of the underpinning mechanisms at work when priming to undertake a muscle endurance exercise.

9.4.1 16RM back squat and average barbell velocity

This investigation shows that implementing psychological priming prior to performing a 16RM back squat can significantly improve the load lifted (Tables 9.1, 9.3, 9.5, and 9.7). These findings are similar to Cook and Crewther (2012), who reported that implementing the psychological strategy of viewing positively emotive video clips can significantly (p <0.001) prime a 3RM back squat in 12 highly trained male athletes. SSM recorded the largest loads lifted, with mean loads of 65 kg in the individual intervention and 68 kg in the Trio group compared to 50 kg in CON, a 30% and 36% increase, respectively. This aligns with Ballman et al. (2021), who reported that in ten resistance-trained men, repetitions (d = 0.98) and motivation (d = 0.93) significantly (p < 0.05) improved after listening to self-selected music three minutes prior to performing a bench press at 75% 1RM to repetition failure. However, this is contrary to Biagini et al. (2012), who reported no difference in repetitions to failure across three sets of bench press at 75% 1RM in 20 male subjects when SSM was played during the entire testing session. Therefore, listening to music before may enable the subject to focus on the motor skill at hand. Equally, the subject may already have benefited from enhanced motivation and neuromuscular drive, which has been reported to increase due to excitation in the motor cortex as a result of listening to music (Gordon et al., 2018).

Tod et al. (2003) reported that psyching-up could lead to a 12% increase in strength compared to controlled conditions. MSTI noted a 26% increase in load lifted. In the Trio group, load lifted increased by 29%, which aligns with Tod et al. (2005), who reported a significant (p = 0.03, 11.8%) increase in bench press barbell load for five reps in 20 resistance-trained subjects. However, the systematic review of Tod et al. (2015) reported that in 50% of studies, self-talk was not efficacious in improving muscular endurance. In the present study, subjects used motivational self-talk and external cues with motivational-general and cognitive-specific imagery, which may have increased arousal and self-efficacy.

The SMO intervention increased load lifted by 24% and in the Trio group by 19% compared to the CON group, potentially indicating that the “audience effect theory” (Zajonc, 1965) becomes prevalent through social media. However, this did not increase the subject's motivation to a greater degree than the other interventions, as SMO self-selected load lifted was the least. Therefore, being observed virtually may not increase motivation and subsequent risk-taking to a great enough degree to perform significantly better than other priming methods.

Barbell average velocity did not improve in any intervention against CON. However, as mean loads lifted increased in the intervention groups, barbell velocity will decrease according to the force-velocity curve (Zatsiorsky & Kraemer, 2006). Therefore, the resulting barbell velocities appear primed due to only recording trivial and small effect size decrements. Interestingly, mean final rep velocities did not decrease, potentially suggesting that subjects did not go to true repetition failure, indicating that additional repetitions could have been attempted. Therefore, future research is required to investigate primed velocity markers at the same load as the control in a muscle endurance test.

9.4.2 Isometric mid-thigh pull and countermovement jump

No statistically significant or notable effect size differences occurred in any intervention while performing IMTP. This aligns with Evan et al. (2000), who reported that electromyographic and maximal force results did not differ against a control when performing a maximal isometric elbow flexion test following 20 s of psyching-up in 15 strength-trained men. Bartolomei et al. (2015) reported a similar result with no change in load lifted during a maximal strength test of a 1RM bench press while listening to SSM in 31 resistance-trained men.

CMJ jump height and RSI Mod recorded no statistically significant differences across all interventions. However, CMJ peak power did with MSTI significantly ($p = 0.04$), decreasing peak power (3661.86 W) compared to CON (4307.21 W). This is contrary to Tod et al. (2009) findings in 24 men and women, where vertical jump height significantly ($p < 0.05$, $d = 0.64$) improved after performing motivational self-talk prior to the test. Therefore, the subjects of this study may not have been primed adequately to promote the extra effort required to increase maximal force production. This is potentially linked to the lack of elevation in testosterone and the subsequent increase in risk-taking from the priming techniques.

9.4.3 Testosterone and cortisol

Contrary to the hypothesis, testosterone did not significantly increase compared to control. Instead, all interventions reduced concentration levels. This is in contrast to Cook and Crewther (2012), who associated increased testosterone concentrations with improved performance. Even though the variability of salivary analytes in non-elite athletes has been noted previously (Crewther et al., 2011; Turner et al., 2017), these results were surprising. Additionally, endocrine variability markedly affected the results due to the small subject sample size. For example, Subjects Ten and Fourteen in SMO recorded a 104% increase and a 50% decrease, respectively, in testosterone levels during the intervention. This variability demonstrates that a larger subject sample size would indicate whether this accurately represents the sample population or is an outlier response. Therefore, further investigations are needed with larger sample sizes if non-elite athletes are used.

Interestingly, cortisol was reduced in all but one intervention (SSM), which subsequently improved the TC ratio in all but one intervention. Cortisol may work jointly with testosterone, moderating testosterone effects such that relationships between testosterone and behavior are seen when cortisol levels are low (Cook &

Crewther, 2014; Mehta & Josephs, 2010). Additionally, cortisol levels are linked with stress levels, and this is potentially how the subjects' performances were primed to increase in the 16RM back squat test. This may have been because stress levels reduced, allowing mechanisms such as risk-taking, status-seeking behaviors, and motivation to increase. In agreement with the results of Karageorghis et al. (1996, 2018) and the review of Tod et al. (2011), music and MSTI can act as an ergogenic aid during strength training. Therefore, priming may be as much about controlling the release of cortisol as it is about raising testosterone. SSM, MSTI, and SMO may have controlled increased stress through better focus and less anxiety.

This study demonstrates that prior to undertaking a muscle endurance strength exercise such as a 16RM back squat, priming through SSM, MSTI, and SMO can improve the subsequent performance, potentially through a decrease in cortisol concentration levels. We posit that providing a music playlist of a high tempo (> 125 bpm) that resonates with the athlete, implementing MSTI, or being viewed through SMO allows athletes to concentrate on the task at hand and helps to improve muscular endurance strength-based training. However, further research is required as studies have yet to research the underpinning link of endocrine changes with MSTI and SMO priming technique. Additionally, more research is required into using priming with these techniques in maximal strength and power training, as there is a dearth in literature.

In conclusion, simple, freely available strategies, such as SSM, MSTI, and SMO, can prime an athlete's performance during muscular endurance training sessions such that they are willing to work harder. Lastly, we should note that according to the calculated 95% CI, some individuals may experience a small decrease in performance following any of these strategies, as Subject Four in the Trio group lifted 10 kg less in SMO compared to control but not in SSM and MSTI conditions (25 kg and 20 kg respectively). Thus, individuals are again advised to trial and develop the ergogenic aids.

9.5 Limitations

The limitations of this study are the small sample size of subjects and a lack of professional athletes. Therefore, comparing males and females, varying age ranges, and professional athletes versus amateurs could not be undertaken. Additionally, this study only chose to test one set of a 16RM back squat, IMTP, and CMJ, whereas testing during competition or a sprint test would add to the literature. Additionally, analysis of the hormones applied a coefficient of variation of 9% to note any changes, this potentially may be too large to note subtle changes in levels.

9.6 Conclusion

This investigation suggests that strength and conditioning coaches implement SSM, MSTI, and SMO techniques for priming athletes to complement their athletic endeavors, particularly when undertaking muscle endurance exercises. Over a long-term training program, these performance improvements could enhance athletic performance. As the priming methods studied appear to be efficacious through an improved TC ratio, athletes are advised to trial all these free and easy–to–implement ergogenic aids to develop a strategy that best responds to their preferences. Healthy collegiate adults are advised to initiate priming at least 15 minutes before undertaking a muscle endurance exercise to allow enough time for hormone change to become systemic.

Chapter 10

10.0 Conclusions, Practical Applications, and Directions for Future Research

10.1 Overall Summary

This thesis delved into the impact of psychologically priming endogenous testosterone concentrations on physical performance tests among resistance-trained subjects. The insights gained contribute to existing literature, highlighting the potential of endocrine level manipulation through priming to influence performance outcomes. Coaches and academics can potentially implement the techniques explored in this research as a pre-performance guide and a foundation for future investigations.

10.2 Key Findings

The systematic review and meta-analysis revealed a limited exploration of testosterone priming through psychological techniques in physical performance tasks. Notably, video clips emerged as a popular mode, with motivational clips of subjects performing rugby skills successfully proving the most effective, with aggressive rugby clips producing mixed results. Being observed resulted in the only other statistically significant rise in testosterone levels. Despite many studies reporting improved performance when these modalities are undertaken, the absence of research on commonly used sports psychology techniques, such as MST and imagery, underscored an opportunity for further exploration and a need to identify the mechanisms underpinning these changes.

Performance markers used were mainly subjective, with player performances rated by the head coach, which did improve when primed. Quantitative markers, such as 3RM back squat, handgrip strength, and CMJ, reported mixed results, with muscular strength markers improving, but power exercises did not. Again, a paucity of markers resulted from the low number of studies. Another limitation of the studies researched is their lack of subjects and diversity. Additionally, the studies would have benefited from consistently reporting cortisol levels alongside testosterone as these hormones work in tandem, potentially affecting each other and subsequently affecting performances. Therefore, to gain further knowledge of how priming is being implemented, why it is implemented, and the prevalence of it among athletes, it was agreed upon that the first study of this thesis was a survey.

Study 1 uncovered that a substantial number (78.7%) of subjects incorporated psychological priming in their training or performance. Listening to music emerged as the predominant strategy, followed by instructional and motivational self-talk. A noteworthy aspect was the coach's involvement in directing priming for 10.1% of athletes. Interestingly, results from questions that were not part of the original aims gave a greater insight. A large proportion of subjects felt their priming method improved performance significantly ($\varphi c = 0.72$; $p = 0.011$) via increased motivation (38.1%), followed by reduced fear and anxiety (22.2%), competition/session intensity (20.6%), and perceived increase in strength and power (15.1%). These traits have all been shown to be associated with anabolic hormonal changes. Therefore, the findings from this study show that a significant proportion of athletes from all performance levels felt that their priming technique improved performance. This provided direction in targeting techniques for the remainder of these investigations.

In response to these findings, three studies were designed to evaluate different primers, focusing on the most popular from the survey, SSM and MST. These were implemented in two of the three studies. Neither study found significant results with these primers, even though testosterone increased throughout. However, they may have motivated the subjects enough to incur a small effect size change in the load lifted in a 3RM back squat, which is notable considering the difficulty of the exercise. However, the results were only trivial when performing four sets of 4RM bench presses. This could be due to the reduced muscle mass involved in the exercise or the fact that performing more reps is more challenging to increase motivation. However, individual responses suggest that tailoring priming techniques to individual preferences could yield more significant results.

The final two primers were passive, as the subjects were observed via social media or in person. These techniques were chosen from the results of the systematic and meta-analysis review, whereby the largest change occurred when being observed by a stranger. Once again, testosterone rose but not significantly, predominantly with the SMO technique. This, in turn, produced the most reps when performing a 65% 1RM back squat (g = 0.33) compared to the OE condition (g = 0.28). These results were similar, even though SMO had a much larger testosterone increase. Potentially, it is harder to alter motivation when more reps are to be completed. However, the priming strategy did modulate behavior enough to improve the number of reps performed. This is potentially through the increased TC ratio, and motivation stemmed through the perceived opportunity for status enhancement if they maximized their performance.

A limitation of the three studies was the number of subjects in each study, 15, 21, and 12, respectively, due to the Covid-19 pandemic. Therefore, a further study was incorporated. The fifth and final study investigated SSM, SMO, or MSTI on testosterone and cortisol concentration levels. These techniques were chosen because they all had large changes in testosterone in the previous studies. Subjects participated in one, two, or three interventions, depending on availability. A more extensive set of performance tasks was also undertaken with CMJ, and IMTP was added to the 16RM back squat to test testosterone's effects on maximal strength, power, and muscular endurance to provide the ability to note any small but meaningful changes should they occur. Additionally, this allowed for more subjects to undertake more priming techniques and performance markers. Lastly, a limitation of the analysis could be that a coefficient of variation of 9% was implemented to note changes in hormone status. This may have been too large to note subtle changes in concentration levels.

Analysis of the results found statistically significant ($p < 0.05$) increases in the 16RM back squat load in all conditions except SMO in the Trio group. The trio group only had ten subjects out of the 28 that partook. Therefore, there may not have been enough subjects to note significant changes, as a minimum of 24 subjects to partake in the study was calculated using priori power analysis. Testosterone levels decreased across all interventions compared to control. However, interestingly, MSTI recorded a moderate reduction in cortisol (g = -0.59), as did SSM (g = -0.68) and SMO (g = -0.67) in the Trio group, with MSTI noting a large change (g = -0.98). These reductions improved the TC ratio via lowering cortisol as opposed to raising testosterone. This may be as efficacious as raising testosterone to increase motivation. This may indicate part of the underpinning mechanisms at work during priming. It may be as important to lower cortisol as it is to raise testosterone as cortisol receptors, and the HPA-axis can suppress testosterone secretion and its subsequent binding to cells. Therefore, if cortisol remains low, testosterone does not require raising as much as the testosterone-cortisol ratio will be weighted towards testosterone implementing its effects.

10.3 Practical Applications

The findings from this thesis show that a significant proportion of athletes from all performance levels have already implemented priming techniques to improve performance through the behavioral stimulus of listening to SSM and MST. The results from the four studies of this thesis attest to the use of these techniques, with the additional mode of being filmed for social media. Therefore, this provides potential direction in targeting techniques for developing specific strategies. To facilitate this, sporting organizations should allow such opportunities for S&C coaches and athletes of all ability levels to access educational workshops or mentorships with sports psychologists to expand their knowledge and confidence to implement psychological strategies to improve preparation for training and competition.

These results support the current evidence for priming, with the addition of finding that these strategies are also partly associated with changes in the TC ratio through either an increase in testosterone or limiting the release of cortisol. It is recommended that SSM, MSTI, and SMO priming strategies be implemented to “psych” an individual at least 15 minutes before a warm-up for heavy load and muscular endurance resistance exercise to allow enough time for hormone change to become systemic. When results were analyzed per subject, responses appeared individualized, with some subjects responding better or worse than the average. Therefore, individuals are advised to trial all these free and easy-to-implement ergogenic aids to develop a strategy that best responds to their preferences. Techniques ideally will raise testosterone so individuals work harder, take more (calculated) risks (or, rather, attempt to lift more weight and perform extra repetitions), and keep cortisol low to not inhibit testosterone through techniques that the athlete does not find stress-inducing. This particularly applies to the use of social media platforms. Individuals must perceive them as a positive addition to their current status and hierarchy within their team and community. Therefore, it is suggested that these video-based opportunities be saved for days when athletes are unmotivated or where maximum effort and intensity are essential to guard against the possibility that repeated use of social media is subject to some dilution of benefits. Furthermore, being observed can be off-putting; however, it may not be detrimental to low-skill tasks such as those used within resistance training. That said, it can cause small increases in cortisol, which, over time, may prove detrimental. Therefore, caution is advised.

While these changes in load or repetitions completed may be slight, they are meaningful and could significantly improve athletic performance over a long-term training program. Therefore, it is recommended that simple, freely available strategies, such as SSM, MSTI, MST, and SMO, should be implemented to prime an individual's performance.

10.4 Directions for Future Research

Numerous areas could be investigated in priming testosterone for physical performance in the future. This thesis investigated SSM, MST, MSTI, OE, and SMO priming strategies. Many other techniques can be researched, such as physical actions and watching video clips. Furthermore, due to the limited literature available, further research is required on testosterone priming to determine the most efficacious of these strategies. The role of cortisol should be researched to the same degree as testosterone, given their dual hormone hypothesis. As this thesis has shown, priming may have as much to do with raising testosterone levels as it is suppressing the increase in cortisol. Additionally, a limited number of performance markers have been researched to determine the efficacy of the altered hormonal homeostasis. Half the studies reviewed used subjective measures such as rating player match performances. More robust, measurable physiological markers could provide more gravitas to the collected data.

A limitation of the studies researched is their lack of subjects and diversity. Investigating the effects of priming on amateur, semi-professional, and professional men and women would add greater depth to the current literature. Lastly, longitudinal studies would also clarify whether the stimuli were priming the testosterone or whether other factors were affecting results and how long the present stimuli would affect testosterone levels before the effect began to reduce.

In summary, this thesis advances our understanding of testosterone's priming effects on physical performance and offers practical insights for coaches and healthy adults to optimize training and competition intensity. The identified gaps in the literature present exciting opportunities for further research, fostering a more comprehensive understanding of the intricate interplay between psychological priming, hormonal responses, and athletic performance.

References

Ahtianen JP, Pakarinen A, Alen M, Kraemer WJ, Hakkinen K. Muscle hypertrophy, hormonal adaptions, and strength development during strength training in strength-trained and untrained men. European Journal of Applied Physiology 89: 555–63, 2003.

Ali K, Verma S, Ahmand I, Singla D, Saleem M, Hussain ME. Comparison of complex versus contrast training on steroid hormones and sports performance in male soccer players. *Journal of chiropractic medicine*. 18: 131–138, 2019.

Almeida-Neto P, Gama de Matos D, Pinto V, Dantas P, Cesario T, et al. Can the neuromuscular performance of young athletes be influenced by hormone levels and different stages of puberty? *Int J Environ Res Public Health*. 17: 16; 5637, 2020.

Apicilla CL, Dreber A, Mollerstrom J. Salivary testosterone change following monetary wins and losses predict future financial risk-taking. *Psychoneuroendocrinology*. 39: 58–64, 2014.

Aren SM, Lander DM. Arousal, anxiety, and performance: A reexamination of the inverted-u hypothesis. *Research quarterly for exercise and sport*. 74: 436–444, 2003.

Arner P. Effects of testosterone on fat cell lipolysis. Species differences and possible role in polycystic ovarian syndrome. *Biochmie*. 87: 1; 39–43, 2005.

Arruda AFS, Aoki MS, Freitas CG, Drage G, Oliveira R, Crewther BT, Moreira A. Influence of competition playing venue on the hormonal responses, state anxiety and perception of effort in elite basketball athletes. *Physiology and behavior*. 130: 1–5, 2014.

Arvinen-Barrow M, Penny G, Hemmings B, Corr S. UK chartered physiotherapists' personal experiences in using psychological interventions with injured athletes: An Interpretative Phenomenological Analysis. Psychol Sport Exerc 11: 58–66, 2010.

Aslander Z, Balci S. Re-examination of the contribution of substrates to energy expenditure during high-intensity intermittent exercise in endurance athletes. *Peer J*. 5: 3769, 2017.

Baechle TR, Earle RW. Essentials of Strength Training and Conditioning (3rd ed.). Champaign, Ill.: *Human Kinetics*. 2008.

Bailey J, Irving R, Dawson P, Brown D-R, Campbell E. Influence of training-induced testosterone and cortisol changes on skeletal muscle and performance in elite junior athletes. *American journal of sports science and medicine*. 9: 1; 13–23. 2021.

Baker S, Jung A, Petrella J. Presence of Observers Increases One Repetition Maximum in College-age Males and Females. *International journal of exercise science,* 4: 199–203, 2011.

Barth C, Villringer A, Sacher J. Sex hormones affect neurotransmitters and shape the adult female brain during hormonal transition periods. *Front neurosci*. 9: 37, 2015.

Bartolomei S, Michele RD, Merni F. Effects of self-selected music on maximal bench press strength and strength endurance. *Perceptual and motor skills.* 120: 714–721, 2015.

Bashin, S, Cunningham GR, Hayes, FJ, Matsumoto AM, Snyder PJ, Swerdloff RS, Montori VM. Testosterone therapy in men with androgen deficiency syndromes: an Endocrine society clinical practice guideline. *J Clin Endo Metab*. 95: 2536–59, 2010,

Bashin S, Taylor WE, Singh R, Artaza J, Sinha-Hikim I, Jasuja R., Choi H, Gonzalez-Cadavid NF. The mechanisms of androgen effects on body composition: Mesenchymal pluripotent cell as the target of androgen action. *J Gerontol*. 58: 12, 2003.

Beaven MC, Gill ND, Cook J. Salivary testosterone and cortisol responses in professional rugby players after four resistance exercise protocols. *Journal of strength and conditioning research*. 22: 426–432, 2008.

Beckham G, Sato K, Santana H, Mizuguchi S, Haff G, Effect of body position on force production during the isometric midthigh pull. J Strength Cond Res. 32: 48–56, 2018.

Bergh U, Ekblom B. Influence of muscle temperature on maximal strength and power output in human muscle. *Acta Physiol Scand*. 107: 332–337, 1979.

Bernhardt PC, Dabbs JM, Fielden JA, Lutter CD, Testosterone changes during vicarious experiences of winning and losing among fans at sporting events. *Physiology and behavior*. 65: 59-62, 1998.

Biagini M, Brown L, Coburn J, Judelson D, Statler T, Bottaro M, Longo N. Effects of self-selected music on strength, explosiveness, and mood. *J Strength Cond Res*. 26: 1934-1938, 2012.

Bialek M, Zaremba P, Borowicz K, Czuczwar S. Neuroprotective role of testosterone in the nervous system. *Polish Journal of Pharmacology*. 56: 509–518, 2004.

Bishop D. Warm up I: Potential mechanisms and the effects of passive warm up on exercise performance. Sports Med. 33: 439–454, 2016.

Bishop DT, Karageorghis CI, Loizou G. A grounded theory of young tennis players' use of music to manipulate emotional state. *JSEP*. 29: 584–607, 2007.

Blanchfield A, Hardy J, de Morree HM, Staiano W, Marcora SM. Talking yourself out of exhaustion: The effects of self-talk on endurance performance. *Med Sci Sports Exerc*. 46: 998–1007, 2013.

Bland JM, Altman DG. Best (but oft forgotten) practices: testing for treatment effects in randomized trials by separate analyses of changes from baseline in each group is a misleading approach. *Am J Clin Nutr*. 102: 991–994, 2015.

Bonifazi M, Ginanneschi F, Della Volpe R, Rossi A. Effects of gonadal steroids on the input-output relationship of the corticospinal pathway in humans. *Brain Res*. 1011: 187–194, 2004.

Brady B, O'Regan C. Meeting the challenge of doing an RCT evaluation of youth mentoring in Ireland: A journey of mixed methods. *Journal of mixed methods research*. 3: 265–280, 2009.

Breda E. Effect of testosterone and endurance training on glycogen metabolism in skeletal muscle of ionic hyperglycemic female rats*. British Journal of Sports Medicine,* 37; 4; 345–350, 2023.

Brewer BW, Haznadar A, Katz D, Van Raalte JL, Petitpas AJ. A mental warm-up for athletes. Sport Psychol 33: 213–220, 2019.

Brooks R. Androgens. *Clin Endocrinol Metab*. 4: 503–520, 1975.

Brownlee KK, Moore AW, Hackney AC. Relationship between circulating cortisol and testosterone: Influence of physical exercise. *J sports sci med*. 4: 76–83, 2005.

Burger H. Androgen production in women. *Fertility sterility*. 77: 3; 3–5, 2002.

Callaghan DE, Guy JH, Elsworthy N, Kean. Validity of the PUSH band 2.0 and speed4lifts to measure velocity during upper and lower body free-weight resistance exercises. *J sports sci med*. 40: 968–975, 2002.

Carré JM, McCormick CM. Aggressive behavior and change in salivary testosterone concentrations predict willingness to engage in a competitive task. *Hormones and behavior.* 54: 403–409, 2008.

Carré JM, Putman SK. Watching a previous victory produces an increase in testosterone among elite hockey players. *Psychoneuroendocrinology.* 35: 475–479, 2010.

Celec P, Ostatniková D, Hodosy J. On the effects of testosterone on brain behavioral functions. *Frontiers in neuroscience*. 9: 12, 2015.

Chein J, Albert D, O'Brien L, Uckert K, Steinberg L. Peers increase adolescent risk-taking by enhancing activity in the brain's reward circuitry. *Developmental science*. 14: 2, 2011.

Chavda S, Bromley T, Jarvis P, Williams S. Force-time characteristics of the countermovement jump: Analyzing the curve in Excel. Strength and conditioning journal. 40: 2, 2017.

Chen CC, Fernald RD. Visual information alone changes behavior and physiology during social interactions in a cichlid fish. PLoS *One.* 6: 1–12, 2011.

Chen I-C, Hill JK, Ohleüller R, Roy DB, Thomas CD. Rapid range shifts of species associated with high levels of climate warming. *Science*. 333: 1024–1026, 2011.

Chen X, Latham GP. The effect of priming learning vs. performance goals on a complex task. Organ Behav Hum Decis Process 125: 88–97, 2014.

Chin K-Y, Soelaiman I-N, Mohamed I, Shaher S, Islami N, et al. Testosterone is associated with age-related changes in bone health status, muscle strength, and body composition. *The aging male*. 15: 4; 240–245, 2012.

Christiansen J, Djurhuus C, Gravholt C, Iverson P, Christiansen J, et al., Effects of cortisol on carbohydrate, lipid, and protein metabolism: Studies of acute cortisol withdrawal in adrenocortical failure. *The journal of clinical endocrinology and metabolism*. 92: 9; 3553–3559, 2007.

Coates JM, Gurnell M, Sarnyai Z. From molecule to market: steroid hormones and financial risk-taking. *Philosophical Transactions of the Royal Society of Biological Sciences.* 365: 1363–1368, 2010.

Coates JM, Herbert J. Endogenous steroids and financial risk taking on a London trading floor. *Proc Natl Acad Sci.* 105: 6167–6172, 2008.

Cohen J, A power primer. *Psychological Bulletin*. 112,:155–159, 1992.

Cohen J. Statistical power analysis for the behavioral sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers. 1988.

Collins J, Bishop C, Hill F, Spiegelhalter A, Cohen A, Turner A. A survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance. The journal of strength and conditioning research. 37: 107-113, 2022.

Cook CJ, Beaven MC. Individual perception of recovery is related to subsequent sprint performance. *British journal of sports medicine*. 47: 11, 2013.

Cook CJ, Beaven MC. Salivary testosterone is related to self-selected training load in elite female athletes. Physiology and Behavior. 8–12: 116–117, 2013.

Cook CJ, Crewther BT, Kilduff LP. Are free testosterone and cortisol concentrations associated with training motivation in elite male athletes? *Psychology of sport and exercise*. 14: 882–885, 2013.

Cook CJ, Crewther BT. Changes in salivary testosterone concentrations and subsequent voluntary squat performance following the presentation of short video clips. *Physiology and behavior*. 61: 17–22, 2012.

Cook C, Crewther BT. The effects of different pre-game motivational interventions on athlete-free hormonal state and subsequent performance in professional rugby union matches. *Physiology and behavior*. 106: 683–688, 2012.

Cook C, Crewther BT. The social environment during a post-match video presentation affects the hormonal responses and playing performance of professional male athletes. *Physiology and behavior.* 130: 170–175, 2014.

Copeland J, Consitt L, Trembley M. Hormonal responses to endurance and resistance exercise in females aged 19-69 years. *The Journal of Gerontology*: Series A. 57: 4, 2002.

Coutts A, Reaburn P, Piva T, Murphy A. Changes in selected biomechanical, muscular strength, power, and endurance measures during deliberate overreaching and tapering in rugby league players. *International Journal of Sports Medicine*. *28*: 116–124, 2007.

Crewther BT, Cook CJ. A longitudinal analysis of salivary testosterone concentrations and competitiveness in elite and non-elite women athletes. *Physiology and behavior*. 188: 157–161, 2018.

Crewther BT, Cook C, Cardinale M, Weatherby R, Lowe T. Two emerging concepts for elite athletes: The short-term effects of testosterone and cortisol on the neuromuscular system and the dose-response training role of these endogenous hormones. *Sports Medicine*. 41: 103–123, 2011.

Crewther BT, Cook CJ. Effects of different post-match recovery interventions on subsequent athlete hormonal state and game performance. *Physiology and behavior*. 106: 471–475, 2012.

Crewther BT, Cook CJ, Gaviglio CM, Kilduff LP, Drawer S. Baseline strength can influence the ability of salivary free testosterone to predict squat and sprinting performance. *Journal of strength and conditioning research.* 26: 261–268, 2012.

Crewther BT, Kilduff LP, Cook CJ, Middleton MK, Bruce PJ, Yang G-Z. The acute potentiating effects of back squats on athlete performance. *Journal of strength and conditioning Research*. 25: 3319–3325, 2011.

Crewther BT, Kilduff LP, Finn C, Scott P, Cook C. Salivary testosterone response to a physical and psychological stimulus and subsequent effects on physical performance in healthy adults. *Hormones*. 15: 248–255, 2016.

Crewther B, Lowe T, Weatherby R, Gill N, Keogh J. Neuromuscular performance of elite rugby union players and relationships with salivary hormones. *J Strength Cond Res*. 23: 2046–2053, 2009.

Crewther BT, Sanctuary CE, Kilduff LP, Carruthers JS, Gaviglio CM, Cook CJ. The workout responses of salivary-free testosterone and cortisol concentration and their association with the subsequent competition outcomes in professional rugby league. *Journal of strength and conditioning research.* 27: 471–476, 2013.

Crust L. Carry-over effects of music in an isometric muscular endurance task. Percept Mot Skills 98: 985–991, 2004.

Crust L, Clough PJ. The influence of rhythm and personality in the endurance response to motivational asynchronous music. J Sports Sci 24: 187–195, 2006.

Cumming, J. Nordin SM, Horton R, Reynolds S. Examining the direction of imagery and self-talk on dart-throwing performance and self-efficacy. *The Sport Psychologist*. 20: 257–274, 2006.

Cumming DC, Quigley ME, Yen SC. Acute suppression of circulating testosterone levels by cortisol in men. *The journal of clinical endocrinology and metabolism*. 57: 671–673, 1983.

Cumming J, Ramsey R. In book imagery interventions in sport. Advances in applied sport psychology: A review, chapter: sport imagery interventions. Editors: Mellalieu S, Hanton S. Routledge. 5–36, 2009.

Davis HA, Gass GC, Bassett JR. Serum cortisol response to incremental work in experienced and naïve subjects. *Psychosom Med*. 43: 127-32, 1981.

Dekeers T, Agelink van Rentergem J, Meijer B, Popma A, Wagemaker E, et al., A meta-analytical evaluation of the dual-hormone hypothesis: Does cortisol moderate the relationship between testosterone and status, dominance, risk-taking, aggression, and psychopathy? *Neuroscience and biobehavioral reviews*. 96: 250–271, 2019.

DeSoto CM, Hitlan RT, Rory-Sean S, McAdams D. Testosterone fluctuations in young men: The difference between interacting with like and not like others. Evolutionary *Psychology*. 2010.

Devries M. Sex-based differences in endurance exercise muscle metabolism: impact on exercise and nutritional strategies to optimize health and performance in women. *Experimental physiology.* 101: 2; 243–249, 2015.

Dickmeis T. Glucocorticoids and the circadian clock. *Journal of Endocrinology*. 200: 3-32, 2009.

Dicker A, Rydén M, Näslund E, Muehlen I, Wirén M, Lafontan M, Arner P. Effects of testosterone on lipolysis in human pre-adipocytes from different fat depots. *Diabetologia*. 47: 420–428, 2004.

Edwards D, Kurlander LS. Women's intercollegiate volleyball and tennis: Effects of warm-up, competition, and practice on saliva levels of cortisol and testosterone. *Hormones and behavior*. 58: 606-613, 2010.

Eliakim M, Meckel Y, Nemet D, Eliakim A. The effect of music during warm-up on consecutive anaerobic performance in elite adolescent volleyball players. Int J Sports Med 28: 321–325, 2007.

Elliott D, Carr S, Orme D. The effect of motivational music on submaximal exercise. Eur J Sport Sci 5: 97–106, 2005.

Elzen NVD, Daman V, Duijkers M, Otte K, Wijnhoven E, Rikkert MO. The power of music: Enhancing muscle strength in older people. *Healthcare.* 7: 82, 2020.

Enoka RM. Neuromechanics of Human Movement. Champaign Ill: *Human Kinetics* 2002.

Estimano D, Ferreira L, Bezzerra P, Pinheiro de Silva M, Jardim G, et al. Alternation of testosterone levels changes brain wave activity patterns and induces aggressive behavior in rats. *Endocrinology*. 10, 2019.

Evan B, Hatfield B, Spalding T, Frazer M, Caherty F. The effect of a psyching strategy on neuromuscular activation and force production in strength-trained men. *Research quarterly for exercise and sport*. 71: 162–170, 2000.

Evans J. Straightforward statistics for the behavioral sciences. *Brooks/Cole Publishing*. Pacific Grove, California. 1996.

Field A. Discovering Statistics using IBM SPSS Statistics (Vol. 4). London: Sage. 2013.

Fink J, Schoenfeld B, Kikuchi N, Nakazato K. Acute and long-term responses to different rest intervals in low-load resistance training. *Int J Sports Med.* 38: 118–124, 2016.

Fink J, Schoenfeld BJ, Nakazato K. The role of hormones in muscle hypertrophy. *The physician and sports medicine*. 46: 1-6, 2018.

Folland J, Williams A. The adaptations to strength training: Morphological and neurological contributions to increased strength. *Sports Med.* 37: 145–168, 2007.

Fukui H, Music and testosterone – A new hypothesis for the origin and function of music. *Annals of the New York Academy of sciences*. 930: 448 – 451, 2001.

Fukui H, Yamashita M. The effects of music and visual stress on testosterone and cortisol in men and women. *Neuroendocrinal Lett.* 24:173-180, 2003.

Gharahdaghi N, Phillips B, Szewczyk N, Smith K, Wilkinson D, Atherton P. Links between testosterone, estrogen, and the growth hormone/insulin-like growth factor axis and resistance exercise muscle adaptions. *Frontiers physiology*. 11, 2021.

Gharahdaghi N, Rudrappa S, Brook M, Idris I, Crossland H, Hamrock C, et al. Testosterone therapy induces molecular programming augmenting physiological adaptions to resistance exercise in older men. *J cachexia sarcopenia muscle*. 10: 1276–1294, 2019.

Glatthorn J, Gouge S, Nussbaumer S, Stauffacher S, Impellizzeri F, Maffiuletti N. Validity and reliability of optojump photoelectric cells for estimating vertical jump height. J Strength Cond Res. 25: 556–560, 2011.

Gleason ED, Fuxjager MJ, Oyegbile TO, Marler CA. Testosterone release and social context: when it occurs and why. *Neuroendocrinal*. 30: 460-469, 2009.

Gordon C, Cobb P, Balasubramaniam R. Recruitment of the motor system during music listening: An ALE meta-analysis of fMRI data. Plos one. 13: 11, 2018.

Grossman M. Testosterone and glucose metabolism in men: current concepts and controversies. *Journal of Endocrinology*. 220: 3, 2014.

Gould D, Eklund R, Jackson S. U.S. Olympic wrestling excellence: Mental preparation, pre-competitive cognition and affect. Sport Psychol 1988 6: 358–382, 1992.

Grgic J. Effects of music on resistance exercise performance: a narrative review. *Strength and conditioning journal*. 44: 4, 2022.

Hackney A. Stress and the neuroendocrine system: The role of exercise as a stressor and modifier of stress. *Expert Review of Endocrinology and Metabolism*. 1: 783–792, 2006.

Hall C, Mack D, Paivio A, Hausenblas H. Imagery Use by Athletes: Development of the Sport Imagery Questionnaire. *International Journal of Sport Psychology*. 29: 73–89, 1998.

Hall CR, Munroe-Chandler KJ, Cumming J, Law B, Ramsey R, Murphy L. Imagery and observational learning use and their relationship to sport confidence. *Journal of Sport Sciences.* 27: 327–37, 2009.

Hamilton L, Carré J, Mehta P, Olmstead N, Whitaker J. Social neuroendocrinology of status: a review and future directions. *Adapt Human Behav Physiol.* 1: 202–230, 2015.

Hamilton AF, Lind F. Audience effects: what can they tell us about social neuroscience, theory of mind, and autism? *Culture and Brain*. 4: 159–177, 2016.

Hammoudi-Nassib S, Chtara M, Briki W, et al. Effects of psyching-up on sprint performance. J Strength Cond Res 31: 2066–2074, 2017.

Hammoudi-Nassib S, Chtara M, Nassib S, et al. Time intervals moderates the relationship between psyching-up and actual sprint performance. J Strength Cond 28: 3245–3254, 2014.

Hannibal KE, Bishop MD. Chronic stress, cortisol dysfunction, and pain: A psychoneuroendocrine rationale for stress management in pain rehabilitation. *Physical therapy*. 94: 1816–1825, 2014.

Harackiewicz JM, Larson JR. Managing motivation: The impact of supervisor feedback on subordinate task interest. *Journal of personality and social psychology*. 51 547-556, 1986.

Hardy J, Gammage K, Hall C. A descriptive study of athlete self-talk. *The Sport Psychologist*. 15: 306–318, 2001.

Hardy J, Oliver E, Tod D. A framework for the study and application of self-talk within sport. In Mellalieu S, Hanton S (Eds). *Advances in applied sport psychology: A review*. London: Routledge. 37–74, 2009.

Hardy, J. Speaking clearly: A critical review of the self-talk literature. *Psychology of Sport and Exercise*, 7: 81–97, 2006.

Hatzigeorgiadis A, Zourbanos N, Galanis E, Theodorakis Y. Self-talk and sports performance: A meta-analysis. *Perspectives on psychological science*. 6: 348-356, 2011.

Hayes L, Bickerstaff G, Baker J. Interactions of cortisol, testosterone, and resistance training: influence of circadian rhythms. *Chronobio Int*. 27: 4; 675–705, 2010.

Hayes LD, Grace F, Baker J, Sculthorpe N. Exercise-induced responses in salivary testosterone, cortisol, and their ratios in men: A meta-analysis. *Sports medicine.* 45: 5, 2015.

Hedge LV, Olkin I. Statistical methods for meta-analysis. *Orlando, academic press*. 2014, p.86.

Hermans E, Ramsey J, van Honk J. Exogenous testosterone enhances responsiveness to social threat in the neural circuitry of social aggression in humans. *Biol. Psychiatry*. 63: 263–270, 2008.

Hellhammer DH, Hubert W, Schürmeyer T. Changes in saliva testosterone after psychological stimulation in men. *Psychoneuroendocrinology.* 10: 77–81, 1985.

Hirasaki E, Moore ST, Raphan T, Cohen B. Effects of walking velocity on vertical head and body movements during locomotion. Exp Brain Res 127: 117–130, 1999.
Holmes P, Collins D. The PETTLEP approach to imagery: A functional equivalence model for sports psychologists. *Journal of Applied Sport Psychology.* 13: 60–83, 2001.

Hoffman J. Physiological Aspects of Sports Performance and Training. Champaign Ill: Human Kinetics. 2002.

Horowitz J, Klein S. Lipid metabolism during endurance exercise. *Am J. Clin. Nutr.* 72: 558S–563S, 2000.

Hunt J, Brooks R. Jennions MD, Smith MJ, Bentsen CL, Bussiere LF. High-quality male field crickets invest heavily in sexual display but die young. *Nature.* 432: 1024-1027, 2004.

Ishak MW, Herrera N., Halbert A., Tu J, Gao W. Music and biomarkers of stress: A systematic review. *International journal of healthcare and medical sciences*. 6: 82–92, 2020.

James LaP, Roberts L, Haff G, Kelly V, Beckman E. Validioty and reliability of a portable isometric mid-thigh clean pull. *Journal of strength and conditioning research*. 31: 137-1386. 2017.

Janak P, Tye K, Sciences, B., Sciences, C. From circuits to behavior in the amygdala. *Nature.* 517: 284–292, 2015.

Jeffreys, I. RAMP warm-ups: more than simply short-term preparation. *Professional Strength and Conditioning*. 2017.

Jeffreys I. Warm-up revisited: The ramp method of optimizing warm-ups. Prof Strength Cond 6: 12–18, 2007.

Kadi F. Cellular and molecular mechanisms responsible for action of testosterone on human skeletal muscle. A basis for illegal performance enhancement. *British journal of pharmacology*. 154: 522–528, 2008.

Kadmiel M, Cidlowski J. Glucocorticoid receptor signaling in health and disease. *Trends Pharmacol Sci*. 34: 9. 518–530, 2013.

Kamgang V, Murkwe M, Wanke-Nya M. Biological effects of cortisol. Cortisol – between physiology and pathology, eds Paun D. 2023.

Karageorghis CI, Cheek P, Simpson SD, Bigliassi M. Interactive effects of music tempi and intensities on grip strength and participative affect. Scand J Med Sci Sports 28: 1166–1175, 2018.

Karageorghis CI, Hutchinson JC, Jones L, Farmer HL, Ayhan MS, Wilson RC. Psychological, psychophysical, and ergogenic effects of music in swimming. *Psychology of sport and exercise*. 14: 560–568, .2013.

Karageorghis CI, Priest DL. Music in the exercise domain: a review and synthesis (part i). *int rev Sport Exerc Psychol*. 5: 44–66, 2012.

Karageorghis C, Terry P. The psychophysical effects of music in sport and exercise: A review. *Journal of Sport Behavior*. 20: 54–68, 1997.

Kelly M, Jones T. Testosterone: a metabolic hormone in health and Journal of eccrinology disease. 217: 3. 2013.

Keogh C, Collins D, Warrington G, Comyns T. Intra-trial reliability and usefulness of isometric mid-thigh pull testing on portable force plates. *J Hum Kinet*. 71: 33-45, 2020.

Kidd T, Carvalho L, Steptoe A. The relationship between cortisol responses to laboratory stress and cortisol profiles in daily life. *Biological Psychology.* 99: 34-40, 2014.

Kirschbaum, C, Pirke KM, Hellhammer DH. The ‘trier social stress test’ – a tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*. 28: 76-81, 1983.

Kirschbaum C, Wüst S, Faig HG, Hellhammer DH. Heritability of cortisol responses to human corticotropin-releasing hormone, ergometry, and psychological stress in humans. *Journal of Clinical Endocrinology Metabolism*. 75: 1526-1530, 1992.

Klein S, Coyle E, Wolfe R. Fat metabolism during low-intensity exercise in. endurance-trained and untrained men. *Am J Physiol*. 267: 934–940, 1994.

Klinesmith J, Kasser T, McAndrew F. Guns, testosterone, and aggression: An experimental test of a meditational hypothesis. Psychol Sci 17: 568–571, 2006.

Kornysheva K, von Cramon DY, Jacobsen T, Schubotz RI. Tuning-in to the beat: Aesthetic appreciation of musical rhythms correlates with a premotor activity boost. *Human brain mapping*. 31: 48-64, 2010.
Kraemer W, Fleck S, Dziados J, Harmen E, Marchitelli L, et al. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *Journal of Applied Physiology*. 75: 2; 594–604, 1993.

Kraemer W, Loebel C, Volek J, Ratamess N, Newton R, Wickham R, Hakkinen K. The effect of heavy resistance exercise on the circadian rhythm of salivary testosterone in men. *European Journal of Applied Physiology*. 84, 13-18, 2001.

Kraemer W, Noble B, Culver B, Lewis R. Changes in plasma proenkephalin peptide F and catecholamine level during graded exercise in men. Proc Nat Acad Sci. USA 82: 6349–6351, 1985.

Kraemer WJ, Ratamess NA, Hormonal responses and adaptations to resistance exercise and training. Journal of *Sports Medicine.* 35: 339-61, 2005.

Kraemer WJ, Ratamess, NA., Nindl, BC. Recovery responses of testosterone, growth hormone, and IGF-1 after resistance exercise. *Journal of Applied Physiology.* 122: 549–558, 2016.

Kraemer WJ, Vingren JL, Spiering B. Endocrine responses to resistance training. In: Essentials of strength training and conditioning. Beachle TR, Earle RW. eds. Champaign, IL. 41–64, 2008.

Kraemer WJ, Volek JS, Bush JA, Putukian M, Sebastianelli WJ. Hormonal responses to consecutive days of heavy-resistance exercise with or without nutritional supplement. *Journal of Applied Physiology*. 85: 1544–1555, 1998.

Krane V, Williams J. Psychological characteristics of peak performance. *Applied sport psychology: personal growth to peak performance*: William J, McGraw H: New York NY, USA, 2006.

Kuki S, Sato K, Stone M, Okano K, Yoshida T et al., The relationship between isometric mid-thigh pull variables, jump variables and sprint performance in collegiate soccer players*. Journal of trainology*. 6: 2, 2017.

Kuo T, McQueen A, Chen T, Wang J. Regulation of glucose homeostasis by glucocorticoids. *Adv Exp Med Biol*. 872: 99–126, 2015.

Kvorning T, Andersen M, Brixen K, Schjerling P, Suetta C, Madsen K. Suppression of testosterone does not blunt mRNA expression of myoD, myogenin, IGF, myostatin or androgen receptor post strength training in humans. Journal of physiology. 578: 579–593, 2007.

Lake J, Augustus S, Austin K, Comfort P, McMahon J, et al. The reliability and validity of the bar-mounted PUSH Band 2.0 during bench press with moderate and heavy loads. *Sports medicine and biomechanics*. 37: 2685–2690, 2019.

Lakens, D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. *Front Psychol*. 2013; 4: 863.

Laukka P, Quick L. Emotional and motivational uses of music in sports and exercise: A questionnaire study among athletes—Psychol Music 41: 198–215, 2011.

Lautenbach F, Jera D, Loeffler J, Musculus L. Give me five? Examine the psychophysiological effects of high fives in athletes. *Applied psychophysiology and biofeedback*. 44: 211–219, 2019.

Lebon F, Collet C, Guillot A. Benefits of motor imagery training on muscle strength. J Strength Cond Res 24: 1680–1687, 2010.

Lim HBT, Karageorghis CI, Romer LM, Bishop DT. Psychophysiological effects of synchronous versus asynchronous music during cycling. Med Sci Sports Exerc 46: 407–413, 2014.

Lim C, Nunes E, Currier B, McLeod J, Thomas A, Phillips S. An evidence-based narrative review of mechanisms of resistance exercise-induced human skeletal muscle hypertrophy. *Med Sci Sports Exerc*. 54: 9; 1546–1559, 2022.

Loebel CC, Kraemer WJ. A brief review: Testosterone and resistance exercise in men. *Journal of strength and conditioning research*. 12: 57–63, 1998.

Macone D, Baldari C, Zelli A, Guidetti L. Music and physical activity in psychological well-being. Percept Mot Skills 103: 285–295, 2006.

Mangine GT, Hoffman JR, Gonzalez AM, Adam M, Townsend JR, Wells AJ, et al. Exercise-induced hormone elevations are related to muscle growth. *Journal of Strength and Conditioning Research.* 2017; 31 45–53.

Markovic G, Dizdar D, Jukic I, Cardinale M. Reliability and factorial validity of squat and countermovement tests. *J Strength Cond Res*. 18: 551–555, 2004.

Mars RB, Neubert F-X, Noonan MAP, Sallet J, Toni I, Rushworth MFS. On the relationship between the “default mode network” and the “social brain.” *Frontiers in human neuroscience*. 6: 189, 2012.

Mason L, Kirkland A, Steele J. the relationship between isometric mid-thigh pull variables and athletic performance measures: Empirical study of English professional soccer players and meta-analysis of extant literature. *Journal of sports medicine and physical fitness*. 61: 645-655, 2021.

Massey CD, Vincent J, Maneval M. Job analysis of college Division I-A football strength and conditioning coaches. J Strength Cond Res 18: 19–25, 2004.

McCaul KD, Gladue A, Joppa M. Winning, losing, mood, and testosterone. *Hormones and behavior*. 26: 486–504, 1992.

Mauras N, Haymond M, Darmaun D. Calcium and protein kinetics in prepubertal boys: positive effects of testosterone. *Journal of clinical investigation*. 93: 3; 1014–9; 1994.

Mazur A, Booth A. Testosterone and dominance in men. Behavioral *and brain sciences.* 21: 353–363, 1998.

McArdle W, Katch F, Katch V. Exercise Physiology: Energy, Nutrition and Human Performance (Fifth Ed) Baltimore: *Lippincott Williams and Wilkins*, 2001.

McCall C, Singer T. The animal and human neuroendocrinology of social cognition, motivation, and behavior. *Nature Neuroscience*, 15, 681–688, 2012.

McCrary J, Ackermann B, Halaki M. A systematic review of the effects of upper body warm-up on performance and injury. *Br J Sports Med*. 49: 935–942, 2016.

McGowen C, Pyne D, Thompson K, Rattray B. Warm-up strategies for sport and exercise: mechanisms and applications. *Sports Med*. 45: 1523–1546, 2015.

McGuigan M, Ghiagiarelli J, Tod D. Maximal strength and cortisol responses to psyching-up during the squat exercise. *Journal of sports sciences*. 23: 687–692, 2005.

McHugh M. The chi-square test of independence. Biochem Med 23: 143–149, 2013.

Mehta PH, Josephs RA. Testosterone and cortisol jointly regulate dominance: Evidence for a dual-hormone hypothesis. *Hormones and Behavior*. 58: 898-906, 2010.

Mehta PH, Prasad S. The dual-hormone hypothesis: a brief review and future research agenda. *Current opinion in behavioral sciences*. 3: 163–168, 2015.

Miller T, Swank AM, Robert JR, Wheeler B. Effect of music and dialogue on perception of exertion enjoyment, and metabolic responses during exercise. J Fitness 6: 45–52, 2010.

Mobley CB, Haun CT, Roberson A, Mumford PW, Kephart WC, Romero MA, et al. Biomarkers associated with low, moderate, and high vastus lateralis muscle hypertrophy following 12 weeks of resistance training. *PloS One*. 13: 4, 2018.

Molina A, Hernandez-Lopez L, de la O C, Chavira-Ramirez R, Mondragon-Ceballos R. Changes in men's salivary testosterone and cortisol levels, and in sexual desire after smelling female axillary and vulvar scents. Frontiers of Endocrinology. 4: 159, 2013.

Montoya E, Terburg D, van Honk J, Bos P. Testosterone, cortisol, and serotonin as key regulators of social aggression: A review and theoretical perspective. *Motivation and Emotion*. 36: 75-73, 2011.

Morton RW, Oikawa SY, Wavell CG, Mazara N, McGlory C, Quadrilatero J, et al. Neither load nor systemic hormones determine resistance training-mediated hypertrophy or strength gains in resistance-trained young men. *J Appl Physiol*. 121: 129–138, 2016.

Morton RW, Sato K, Gallagher MPB, Oikawa SY, McNicholas PD, Fujita S, Phillips SM. Muscle androgen receptor content but not systemic hormones are associated with resistance training-induced skeletal muscle hypertrophy in healthy, young men. *Front Physiol*. 9: 1373, 2018.

Moss S, Enright K, Cushman S. The influence of music genre on explosive power, repetitions to failure and mood responses during resistance training. Psychol Sport Exerc 37: 128–138, 2018.

Muscella A, Stefàno E, Lunetti P, Capobianco L, Marsigliante S. The regulation of fat metabolism during aerobic exercise. *Biomolecules*. 10: 12; 1699, 2020.

Nagaya N, Herrera A. Effects of testosterone on synaptic efficacy at neuromuscular junctions in asexual, dimorphic muscle of male frogs. *Journal of physiology*. 483: 141–53, 1995.

Neiman D, Sha W, Pappan K. Il-6 linkage to exercise-induced shifts in lipid-related metabolites: A metabolomics-based analysis. *J Proteome Res*. 3: 16; 970-977, 2017.

Nakagawa S, Cuthill IC. Effect size, confidence interval, and statistical significance: a practical guide for biologies. *Biological Reviews*. 82: 591-605, 2007.

Newton R, Kraemer W. Developing explosive muscular power: Implications for a mixed methods training strategy. *Strength and conditioning journal*. 16: 20-31, 1994.

Noordi S, Cumming J. Types and functions of athletes' imagery: Testing predictions from the applied model of imagery use by examining effectiveness. *International Journal of Sport and Exercise Psychology*. 6: 189–206, 2008.

Norman R, Moreau B, Welker K, Carré J. Trait anxiety moderates the relationship between testosterone responses to competition and aggressive behavior. Adapt. *Human Behav. Physiol*. 1: 312–324, 2015.

Oakley R, Cidlowski J. The biology of the glucocorticoid receptor: new signaling mechanisms in health and disease. *J Allergy Clin Immunol*. 132: 5; 1033–1044, 2013.

O'Connor DB, Archer J, Frederick CW Wu. Effects of testosterone on mood, aggression, and sexual behavior in young men: A double-blind, placebo-controlled, cross-over study. *The journal of clinical endocrinology and metabolism*. 89: 2837–2845, 2004.

Owen L, Lee C. Current status of sport psychology. Aust Psychol 22: 62–67, 1987.

Page M. The PRISMA statement: an updated guideline for reporting systematic reviews. *The BMJ*. 372: 71, 2021.

Pain M, Harwood C. Knowledge, and perceptions of sport psychology within English soccer. *Journal of sports sciences*. 22: 9, 2004.

Parker, L., Sealey, RM, Swimbourne, A. The effect of preparatory arousal on hand grip strength and 50 meter freestyle swim performance. *International journal of exercise science*. 5: 2, 2011.

Pavio A. Cognitive and motivational functions of imagery in human performance. Can J Appl Sport Sci 10: 22–28, 1985.

Perkins D, Wilson GV, Ker JH. The effects of elevated arousal and mood on maximal strength performance in athletes. J Appl Sport Psychol 13: 239–259, 2001.

Petit J, Karageorghis C. Effects of video, priming, and music on motivation and self-efficacy in American football players. *International journal of sports science & coaching*. 15: 685–695, 2020.

Peynircioglu ZF, Thompson JLW, Tanielian TB. Improvement strategies in free-throw shooting and grip-strength tasks. J Gen Psychol 127: 145–156, 2000.

Phillips AC, Gallagher S, Carroll D. Social support, social intimacy, and cardiovascular reactions to acute psychological stress. *Ann Behavior Medicine.* 37: 38–45, 2009.

Plakoutsis G, Zapantis D, Panagiotopoulou E-M, Paraskevopoulos E, Moutzouri M. Reliability and validity of the portable KForce plates for measuring countermovement jump (CMJ). Applied biosciences and bioengineering. 13: 20, 2023.

Pletzer, B. Sex hormones and gender role relate to gray matter volumes in sexually dimorphic brain areas. *Front Neurosci*. 13: 592, 2019.

Purdom T, Kravitz L, Dokladny K, Mermier C. Understanding the factors that effect maximal fat oxidation. *J Int. Soc Sports. Nutr*. 13: 3, 2018.

Putman P, Antypa N, Crysovergi P, van der Does W. Exogenous cortisol acutely influences motivated decision-making in healthy young men. *Psychopharmacology*. 208: 257–263, 2010.

Radcliffe JN, Comfort P, Fawcett T. Barriers to the prescription of psychological strategies by strength and conditioning specialists. J Strength Cond Res 32: 1948–1959, 2018.

Radcliffe JN, Comfort P, Fawcett T. Psychological strategies included by strength and conditioning coaches in applied strength and conditioning. J Strength Cond Res 29: 2641–2954, 2015.

Radcliffe JN, Comfort P, Fawcett T. The perception of psychology and the frequency of psychological strategies used by strength and conditioning practitioners. J Strength Cond Res 27: 1136–1146, 2013.

Ranallo R, Rhodes E. Lipid metabolism during exercise. *Sports Med*. 26: 29–42, 1998.

Ranganathan VK, Siemionow V, Liu JZ, Sahgal V, Yue GH. From mental power to muscle power and gaining strength by using the mind. *Neuropsychological*. 42: 944–956, 2004.

Rebuffe-Scrive M, Marin P, Bjorntorp P. Effect of testosterone on abdominal adipose tissue in men. *Int J Obes*. 15: 791–795, 1991.

Rejeski W. Perceived exertion. An active or passive process? Int J Sport Psychol 7: 371–378, 1985.

Rix I, Nexøe-Larsen, Bergmann N, Lund A, Knop F. Glucagon physiology. *Endocrinology book* Feingold K., Anawalt B., Blackman M., et al., eds. South Dartmouth, USA. 2019.

Robin N, Dominique L, Guillet-Descas E, Hue O. Beneficial effects of motor imagery and self-talk on service performance in skilled tennis players. *Frontiers in psychology*. 2022.

Romagnoli C, Zonefrati R, Sharma P, Innocenti M, Cianferotti L, Brandi L. Characterization of skeletal muscle endocrine control in an in vitro model of myogenesis. *Calcified tissue int.* 107: 18–30, 2020.

Ronay R, von Hoppel W. The presence of an attractive woman elevates testosterone and physical risk-taking in young men. *Social psychological personality science*. 1: 57-64, 2010.

Rupp HA, Wallen K. Relationship between testosterone and interest in sexual stimuli: the effect of experience. *Hormones and behavior*. 52; 581–589, 2007.

Salvador A. Steroid hormones and some evolutionary-relevant social interactions. *Motiv. Emot*. 36: 74–83, 2012.

Scavo D, Barletta C, Vagiri D, Letizia C. Adrenocorticotropic hormone, beta-endorphin, cortisol, growth hormone, and prolactin circulating levels in nineteen athletes before and after half-marathon and marathon. *J Sports Med Phys Fitness*. 31: 401–6, 1991.

Schultheiss O, Campbell K, McClelland D. Implicit power motivation moderates men's testosterone responses to imagined and real dominance. *Hormones and behavior*. 36: 234–241. 1999.

Schoenfeld B, Vigotsky A, Contreras B, Golden S, Alto A, Larson R, et al., Differential effects of attentional focus strategies during long-term resistance training. *European journal of sports science.* 18: 705–712, 218.

Serpell BG, Strahorn J, Colomer C, McKune A, Cook C, Puma K. The effect of speed, power and strength training and a group motivational presentation on physiological markers of athlete readiness: A case study in professional rugby. *Int J Sports Physiol Perform*. 14: 125–129, 2018.

Shelton T, Mahoney M. The content and effect of "psyching-up" strategies in weight lifters. *Cognitive therapy and research*. 2: 275–284, 1978.

Sheppard JM, Triplett NT. Program design for resistance training In Haff GG, Triplett NT. Editors. Essentials of strength training and conditioning. 4th ed. Champaign: Human Kinetics; 2016.

Sherman LE, Payton AA, Hernandez LM, Greenfield PM Dapretto M. The power of the like in adolescence: Effects of peer influence on neural and behavioral responses to social media. *Psychological science.* 27: 1027–1035, 2016.

Shukri N, Abdullak M, Japilus S, Azmi S, Mustafa M, Nadzalan A. Electromyographical analysis and performance during bench press exercise: The influence of self-talk. *International journal of recent technology and engineering*. 8: 2277–3878, 2019.

Silva N, Rizardi F, Fujita R, Villalba MM Gomes MM. Preferred music genre benefits during strength tests: increased maximal strength and strength endurance and reduced perceived exertion. *Perceptual and motor skills*. 128: 324–337, 2020.

Siart B, Nimmerichter A, Vidotto I, Wallner B. Status, stress and performance in track and field athletes during the European games in Baku (Azerbaijan). *Sci Rep*. 7: 6076, 2017.

Silva NRDS, Rizardi FG, Fujita RA, Villalba MM, Gomes MM. Preferred music genre benefits during strength tests: increased maximal strength and strength-endurance and reduced perceived exertion. *Perceptual and motor skills*. 128: 324-337, 2020.

Simonsmeier B, Andronie M, Buecker S, Frank C. The effects of imagery interventions in sports: a meta-analysis. *International review of sport and exercise psychology*. 14: 186-207, 2021.

Slimani M, Cheour F, Moalla W, Baker J. Hormonal responses to a rugby match: A brief review. *The journal of sports medicine and physical fitness.* 58: 5, 2017.

Slimani M, Tod D, Chaabene H, Miarka B. Effects of mental imagery on muscular strength in healthy and patient subjects: A systematic review. J Sports Sci Med 15: 434–450, 2016.

Smith J, Ockenfels MC, Porter L, Kirschbaum C, Hellhammer DH, Stone AA. Stressors and mood measured on a momentary basis are associated with salivary cortisol secretion. *Psychoneuroendocrinolgy.* 23: 353-370, 1998.

Sousa T The role of a strength and conditioning coach. In: Rocha Piedade S, Imhoff A, Clatworthy M, Cohen M, Espregueira-Mendes J. editors. The Sports Medicine Physician. New York, NY: Springer Cham, 2019, pp. 107–199.

Stanton SJ, Mullette-Gillman O'DA, McLaurin RE, Kuhn CM, LaBar KS, Platt, ML., and Huettel SA. Low and high-testosterone individuals exhibit decreased aversion to economic risk. *Psychological science.* 22: 447-453, 2011.

Staron S, Karapondo D, Kraemer W, Fry A, Gordon S, Falkel J, Hagerman J, Hikida R. Skeletal muscle adaptions during early phase of heavy resistance training in men and women. *Journal of Applied Physiology*. 76: 1247–1255, 1994.

St Clair Gibson A, Swart J, Tucker R. The interaction of psychological and physiological homeostatic drives and role of general control principles in the regulation of physiological systems, exercise, and the fatigue process-The Integrative Governor theory. *European journal of sports science. 18*: 25–36, 2018.

Stork M, Kwan M, Gibala M, Martin K. Music enhances performance and perceived enjoyment of sprint interval exercise. *Medicine and science in sports and exercise*. 47: 1052–1060, 2015.

Suay F, Salvador A, Gonzalez-Bono E, Sanchis C, Martinez M., et al. Effects of competition and its outcome on serum testosterone, cortisol, and prolactin. *Psychoneuroendocrinology*. 24: 551-666, 1999.

Tennie C, Frith U, Frit CD. Reputation management in the age of the World Wide Web. *Trends in cognitive science*. 14: 482–488, 2010.

Terry P, Karageorghis C. Music in the exercise domain: a review and synthesis (part 1) *International review of sport and exercise psychology*. 5: 44–66, 2011.

Terry P, Karageorghis C. Psychophysical effects of music in sport and exercise: An update on theory, research, and application. Joint Conference of the Australian *Psychological Society and the New Zealand Psychological Society*. Melbourne, Australia. 414–419, 2006.

Thau L, Gandhi J, Sharma S. Physiology, cortisol. *Statpearls*. 2023

Theodorakis Y, Weinberg R, Natsis P, Douma I, Kazakas P. The effects of motivational versus instructional self-talk on improving motor performance. *The sport psychologist*. 14: 253–272, 2000.

Trumble BC, Cummings D, von Rueden C, O'Connor KA, Smith EA, Gurven M, et al. Physical competition increases testosterone among Amazonian forager-horticulturalists: a test of the 'challenge hypothesis.' *Proc R Soc B*. 279: 1739, 2012.

Tod D, Edwards C, McGuigan M, Lovell G. A systematic review of the effect of cognitive strategies on strength performance. *Sports medicine*. 45: 1589–1602, 2015.

Tod D, Hardy J, Oliver EJ. Effects of self-talk: A systematic review. *Journal of sports and exercise psychology.* 33: 666–687, 2011.

Tod D, Iredale F, Gill N. "Psyching-up" and muscular force production. Sports Med 33: 47–58, 2003.

Tod D, Iredale F, McGuigan M, Gill N. "Psyching-up" enhances force production during the bench press exercise. J Strength Cond Res 19: 599–603, 2005.

Tod D, Thatcher R, McGuigan M, Thatcher J. Effects of instructional and motivational self-talk on the vertical jump. *Journal of strength and conditioning research.* 23: 196–202, 2009.

Turner A, Comfort P, Moody J, Jeffreys I. Neuroendocrinology and resistance training in adult males. *UK strength and conditioning association*. 17: 15–24, 2010.

Turner A, Kilduff L, Marshall G, Phillips J, Noto A, et al., Competition intensity and fatigue in elite fencing. *Journal of strength and conditioning research*. 31: 3128-3136, 2017.

Triplett N. The dynamogenic factors in pacemaking and competition. *American journal of psychology*. 9: 507–533, 1988.

Turne A, Kilduff L, Marshall G, Phillips J, Noto A, Buttigieg C, Gondek M, Hills FA, Dimitriou L. Competition intensity and fatigue in elite fencing. *Journal of strength and conditioning research.* 31: 3128–3136, 2017.

Turner A. Neuroendocrinology and resistance training in adult males. *United Kingdom Strength and Conditioning association*.17, 2010.

Tyagi V, Scordo M, Yoon R, Liporace F, Greene L. Revisiting the role of testosterone: Are we missing something? *Reviews in urology*. 19: 1; 16–24, 2017.

Van Cutsem J, Marcora S, De Pauw K, Bailey S, Meeusen R, Roelands B. The effects of mental fatigue on physical performance: a systematic review. *Sports Medicine. 47*: 1569-1588, 2017.

Van Honk J, Peper J, Schutter DJ. Testosterone reduces unconscious fear but not consciously anxiety: implications of the disorders of fear and anxiety. B*iol Psychiatry*. 58: 218-25, 2005.

Van Honk J, Tuiten A, van den Hout H, Koppeschaar H, Thijssen E, et al., Baseline salivary cortisol levels and preconscious selective attention for threat. A pilot study. *Psychoneuroendocrinology*. 23: 741–747, 1998.

Vanni P, Moon J. Physiological and psychological effects of testosterone on sport performance: A critical review of literature. *The sport journal*. 24, 2015.

Van Wingen G, Mattern C, Jan Verkes R, Buitelaar J, Fernandez G. Testosterone reduces amygdala-orbitofrontal cortex coupling. *Psychoneuroendocrinology*. 35: 1; 105–113, 2010.

Vermeer AB, Krol I, Gauster C, Wagner B, Eisenegger C, Lamm C. Exogenous testosterone increases status-seeking motivation in men with unstable low social status. *Psychoneuroendocrinology*. 113: 104–152, 2020.

Viau V. Functional cross-talk between the hypothalamic-pituitary-gonadal and adrenal axes. *Journal of Neuroendocrinology*. 14: 6, 506–513, 2002.

Vingren J, Kraemer W, Ratamess N, Anderson J, Volek J, Maresh C. Testosterone physiology in resistance exercise and training. *Sports medicine*. 40: 1037–1053, 2010.

Wackerage H, Schoenfeld B, Hamilton L, Lehti M, Hulmi J. Stimuli and sensors that initiate skeletal muscle hypertrophy following resistance exercise. *Journal of Applied Physiology*. 126: 30–43, 2019.

Wagels L, Votinov M, Kellermann T, Konzok J, Jung S et al., Exogenous testosterone and monoamine-oxidase. A polymorphism influences anger, aggression, and neural responses to provocation in males. *Neuropharmacology*. 156. 2019.

Wagner J, Flinn MV, England BG. Hormonal response to competition among Mae coalitions. *Evolution and human behavior*. 23: 437-442, 2002.

Walter N, Nikoleizig L, Alfermann D. Effects of self-talk on competitive anxiety, self-efficacy, volitional skills, and performance: An intervention study with junior sub-elite athletes. MDPI. 7: 148, 2019.

Wang Z, Mick G, Wang X, Xie X, Li G, et al. Cortisol promotes endoplasmic glucose production via pyridine nucleotide redox. *The journal of endocrinology*. 229: 1; 25–26, 2016.

Waterhouse P, Hudson P, Edwards B. Effects of music tempo upon submaximal cycling performance. *Scandinavian Journal of Medical Sciences in Sports,* 20, 662–669, 2010.

Weakly J, Bryan M, Banyard B, McLaren S, Scott T, Garcia-Ramos A. Velocity-based training: From theory to application. *Strength and Conditioning Journal*. 43: 31-49, 2021.

West DWD, Philips SM. Associations of exercise-induced hormone profiles and signs of strength and hypertrophy in a large cohort after weight training. *European Journal of Applied Physiology,* 112: 693-702, 2011.

Williams J, Krane V. Psychological characteristics of peak performance. In: Applied Sport Psychology; Personal Growth to Peak Performance. Williams JM, ed. Mountain View, CA: Mayfield, 4th ed., 1993, pp. 137–147.

Wilson M, Daly M. Do pretty women inspire men to discount the future. *Biology letters.* 271: 177–179, 2004.

Winchester R, Turne L, Thomas K, Ansler L, Thompson KG, Micklewright D. Observer effects on the rating of perceived exertion and affect during exercise in recreationally active males. *Perceptual and motor skills*. 115: 213–37, 2012.

Winkelman N. Attentional Focus and Cueing for Speed Development. *Strength and Conditioning Journal*. 40: 13–25, 2018.

Wittert G. The relationship between sleep disorders and testosterone in men. *Asian J Androl*. 16: 2; 262–265, 2014.

Witt J, English K, Crowell J, Ploutz-Snyder. Isometric mid-thigh pull reliability and relationship to deadlift 1RM. *The Journal of Strength and Conditioning Research,* 32: 2, 2016.

Wood RI, Stanton SJ. Testosterone and sport: Current perspectives. *Hormones and behavior*. 61: 147–155, 2012.

Zajonc RB. Social facilitation. *Science*. 149: 269-274, 1965.

Zaki J, Weber J, Bolger N, Ochsner T. The neural bases of empathic accuracy. *Proceedings of the national academy of sciences of the United States of America*. 106: 11382-11387, 2009.

Zatsiorsky V, Kraemer J. Science and Practice of Strength Training. Champaign, Illinois: Human Kinetics. 2006.

APPENDICES:

Appendix A: Ethical Approval Form

London Sport Institute REC

The Burroughs
Hendon
London NW4 4BT

Main Switchboard: 0208 411 5000

18/11/2021

APPLICATION NUMBER: 19107

Dear James Michael Collins and all collaborators/co-investigators

Re your application title: Priming's effect on strength and power performance

Supervisor: Chris Bishop, Anthony Turner

Co-investigators/collaborators:

Thank you for submitting your application. I can confirm that your application has been given APPROVAL from the date of this letter by the London Sport Institute REC.

The following documents have been reviewed and approved as part of this research ethics application:

Document Type	File Name	Date	Version
Methods and data	Ethics - Methods	06/11/2021	1
HTA Consent Training Declaration	Ethics HTA Signed Form	06/11/2021	1
Materials	Ethics - Sample transportation	06/11/2021	1
Materials	Ethics - Questionnaire	06/11/2021	1
Materials	Ethics - Saliva procedure	06/11/2021	1
LabRAT	Ethics - LSI Lab Risk Assessment Form	06/11/2021	1
LabRAT	Ethics - NSREC LabRAT Guidance	06/11/2021	1
Debriefing Sheet	Ethics - Debriefing Guide	06/11/2021	1
Materials	Ethics - HTA Transportation of Human Tissue SOP V7 Oct20	06/11/2021	1
In-Person Face to Face Research Template	Ethics - In Person Face-to-Face Research	06/11/2021	1
Participant Recruitment Information	Ethics - Invitation Sheet	06/11/2021	1
Informed Consent Form	Ethics - Participation Information Sheet	06/11/2021	1
Health Screen Questionnaire	Ethics - (LSI) Health Screen Questionaire	17/11/2021	1
Informed Consent Form	Ethics - Consent Form	17/11/2021	2
Data Protection Declaration	Ethics - Signed Data Protection Checklist & Declaration for Research	17/11/2021	1
Resubmission Response to Feedback Summary	Ethics - Resubmission Feedback Summary	17/11/2021	1
Revised documents as part of resubmission	Ethics - Consent Form	17/11/2021	2

Page 1 of 2

Although your application has been approved, the reviewers of your application may have made some useful comments on your application. Please look at your online application again to check whether the reviewers have added any comments for you to look at.

Also, please note the following:

1. Please ensure that you contact your supervisor/research ethics committee (REC) if any changes are made to the research project which could affect your ethics approval. There is an Amendment sub-form on MORE that can be completed and submitted to your REC for further review.

2. You must notify your supervisor/REC if there is a breach in data protection management or any issues that arise that may lead to a health and safety concern or conflict of interests.

3. If you require more time to complete your research, i.e., beyond the date specified in your application, please complete the Extension sub-form on MORE and submit it your REC for review.

4. Please quote the application number in any correspondence.

5. It is important that you retain this document as evidence of research ethics approval, as it may be required for submission to external bodies (e.g., NHS, grant awarding bodies) or as part of your research report, dissemination (e.g., journal articles) and data management plan.

6. Also, please forward any other information that would be helpful in enhancing our application form and procedures - please contact MOREsupport@mdx.ac.uk to provide feedback.

Good luck with your research.

Yours sincerely,

Chairs Dr Rhonda Cohen/ Dr Anne Elliott

London Sport Institute REC

Appendix B: Published Articles from the Thesis

Original Research

The Journal of Strength and Conditioning Research™

A Survey Into the Use of Priming Techniques Implemented by Athletes and Coaches to Improve Athletic Performance

James Collins, Chris Bishop, Frank Hills, Abbie Spiegelhalter, Rhonda Cohen, and Anthony Turner

London Sport Institute, Middlesex University, The Burroughs, Hendon, London, United Kingdom

Abstract

Collins, J, Bishop, C, Hills, F, Spiegelhalter, A, Cohen, R, and Turner, A. A survey into the use of priming techniques implemented by athletes and coaches to improve athletic performance. *J Strength Cond Res* 37(1): 107–113, 2023—This study aimed to examine the frequency and modes of psychological priming techniques and strategies being implemented by athletes of a variety of performance levels. A 15-question, anonymous questionnaire was developed and shared via social media sites. The survey implemented a quantitative method approach to collect background information (e.g., demographics, competition, and training history), the prevalence of priming, and the methods used. Ninety subjects met the inclusion criteria (71 men, 18 women, and 1 subject did not identify their sex), with a median age of 28 ± 7.47 years (range, 24–33 years) and training experience of 11 ± 7.57 years (range, 8–18 years). Self-selected participation level accounted for 11 professional, 17 semiprofessional, and 54 amateur-level athletes. Priming strategies were implemented by 79% of subjects without the use of a coach, 10% used strategies with their coach, and 11% did not prime. For athletes, music was the preferred choice (27%), followed by instructional self-talk (24%), motivational self-talk (23%), applied physical actions (20%), and watching videos clips (6.3%). Coaches preferred motivational statements with 55% implementing this technique, followed by 27% using inspiring team talks, and only 18% playing music. Of those who implemented a priming strategy, 66% found them to be either "very" or "extremely" effective," With 38% of subjects feeling that priming accomplished this through increased motivation, 22% felt that it reduced their fear and anxiety, 21% thought that it improved their intensity, 15% felt that it increased strength and power, and 2% felt that it improved endurance. The chi-square test also found a significant ($\varphi c = 0.27$; $p = 0.011$) relationship with the use of priming to increase motivation. These results demonstrate that priming strategies are being used irrespective of coach intervention; therefore, educating coaches and athletes on the implementation of priming techniques has its place when aiming to improve athlete performance.

Key Words: strategy, psychological, questionnaire, preparedness, physical enhancement

Introduction

The primary role of strength and conditioning (S&C) coaching is to enhance athletic performance and mitigate any potential risk of injury (39). Therefore, professional practice emphasizes exercise prescription, with the intention of creating progressive overload and sport-specific neuromuscular adaptations. However, research would suggest that the role is much more complex, with a wide variety of skill sets (e.g., creating game day itineraries, keeping teams to a schedule, being sideline managers, and handling team discipline (24)) needing to be used to maximize athletic performance (24,33). What is possibly given less consideration is how S&C coaches can directly affect athlete training effort, behavior, and motivation and thus further adaptions by this means. Psychological priming (also known as "psyching-up") of an athlete for a given physical task has been defined as "the use of cognitive techniques designed to improve performance before or during competition" (42). Early research from Owen and Lee (28) suggested that successful athletes who use cognitive strategies differently than less successful athletes produced greater athletic performances, as a result of increased self-confidence and self-efficacy, which in turn, helps regulate arousal for the physical task in question. For example, Gould et al. (10), interviewed the U.S. 1988 Olympic weightlifting team and reported their best performances occurred after undertaking mental preparation techniques of visualization, positive self-talk, and focusing on tactical strategies.

In preparation for physical activity, athletes will typically undertake a "warm-up" to physically and mentally ready themselves to perform (14). The mental preparation will typically involve the implementation of cognitive and behavioral techniques. Behavioral techniques are those not based on a conscious mental strategy, such as listening to music, which potentially can alter emotions and moods, heighten arousal, reduce inhibition, and induce higher states of functioning (15). Cognitive techniques involve various structured psychological frameworks, these include imagery, self-talk, goal setting, arousal, and attentional control (31,38,40). It has been postulated that these techniques can increase focus of attention, self-efficacy, motivation, confidence, mental activation, and physiological arousal (2,40). For example, goal-setting facilitates self-regulation, with the goal defining what constitutes an acceptable level of performance (19). Therefore, effort and specificity are central to this framework being successful (3).

Williams and Krane (44) commented that athletic performance levels can be improved when cognitive behavioral strategies are implemented. Lebon et al. (20) confirmed this

Address correspondence to Chris Bishop, C.Bishop@mdx.ac.uk.

Journal of Strength and Conditioning Research 37(1)/107–113

Appendix C: Enzyme-linked immunosorbent assay

The protocol for extracting the data from saliva samples is:

- Saliva samples are placed in a 96-well microtite plate
- An enzyme with testosterone/cortisol conjugated to horseradish peroxidase is added to each well
- Samples are then incubated for an hour to allow time for testosterone/cortisol to compete with the conjugated testosterone/cortisol to bind to the wells.
- Unbound components are then washed away
- A substrate called Tetramethylbenzidine (TMB) is now added
- Bound testosterone/cortisol enzyme conjugate reacts to TMB turning the solution a blue color
- The optical density is read on a standard plate reader at 450mm
- The amount of testosterone/cortisol enzyme conjugate present is proportional to the amount of testosterone/cortisol in the sample
- Results are plotted on a standard curve graph

Reliability

All samples are duplicated, with the final result an average of both results. Additionally, control samples that are part of the enzyme-linked immunosorbent assay are tested at the same time. Results of these samples must have a coefficient of variation of less than 10% to be classed as reliable.