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Technical Note

The Effects of Mental Fatigue Induced by the Stroop Test on Muscular Endurance Performance and Neuromuscular Activation in Division III Female Athletes

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ABSTRACT

International Journal of Exercise Science 17(4): 1540-1552, 2024. The purpose of this study was to investigate the effect that mental fatigue, as induced by a Stroop test, has on resistance training performance outcomes such as muscular endurance, power output, and neuromuscular activation. Seven female college-aged NCAA Division III student-athletes with at least one year of resistance training experience and were within the 50th percentile for maximal aerobic capacity provided informed consent for participation. During two separate visits, using a within-subject crossover experimental design, subjects completed either the experimental or control condition. Subjects then completed a to-failure leg press test at 50% of their 1-repetition maximum (1RM) followed by an isometric midthigh pull (IMTP) attempt with electromyography (EMG) analysis. The experimental condition consisted of a 30-minute Stroop test, while the control condition consisted of watching 30 minutes of a sitcom. Both activities were completed while cycling at 40% of their aerobic capacity. A NASA Task Load Index (TLX) inventory was administered following the completion of each cycling session to determine the perceived workload and mental fatigue of each activity. While the mentally fatiguing condition was significantly more mentally fatiguing (p = 0.02) than the control condition, mental fatigue did not statistically affect any of the evaluated performance outcomes (p>0.05). These findings suggest that mental fatigue, a common symptom of psychological stress, does not affect resistance-training-related performance outcomes among female athletic populations.

KEYWORDS: Stress, mental fatigue, resistance training, exercise

INTRODUCTION

Mental fatigue is a state that is characterized by psychological and physical symptoms brought about by high-cognitive-demand tasks (7) and can develop in response to chronic psychological stress (35). It is generally understood that such psychological conditions and phenomena can have physiological effects on the body, and the study of such relationships is known as psychophysiology (2), and the investigation of the subsequent underlying physiological changes is psychobiology (2). The relationship, between mental fatigue and physiology, has been widely studied. It is reported that mental fatigue negatively impacts perceived rates of exertion (RPE), isometric contraction duration, time to exhaustion during endurance testing, and aerobic capacity; however, mental fatigue was also found to not affect maximal aerobic performance (1, 4, 17, 19). Despite the repeated findings indicating that mental fatigue does affect aerobic performance outcomes, research is still inconclusive concerning the underlying physiological mechanisms, such as heart rate response and volume of oxygen consumed (VO_2), causing such performance declines (4, 17). From the psychological perspective, RPE increases when mentally fatigued, and this mental barrier may be inhibiting motivation and subsequent performance (3, 17, 29). From a physiological standpoint, some research has shown that in a mentally fatigued state muscles require greater neuromuscular activation, as shown by increased electromyography (EMG) amplitude, to do the same amount of work, but this is not a phenomenon that has been consistently reported (3).

When considering isometric contractions, Ankand and Herur (1) report a significant average reduction of about 8% in time to failure during low resistance isometric contraction, between a mentally fatigued condition and a control condition. When mentally fatigued, males maintained an isometric contraction at 20% of their max for 97.42 ± 35.58s compared to the 118.33 ± 41.59s they completed during the control, and females maintained their isometric contraction for 56.00 ± 22.18s compared to the 69.11 ± 27.54s average during their control test (1). Marcora et al. (19) report that, during maximal tests of anaerobic capacity, time to exhaustion was significantly reduced by about 8% when participants were mentally fatigued. Mentally fatigued participants lasted, on average, for 640 ± 316s compared to the average of 754 ± 339s when unfatigued (19). Additionally, RPE reportings on a 6-20 scale, were significantly higher, by about 1 point at each time point, when individuals were mentally fatigued compared to the control (19).

Despite the extensive research on the effect of mental fatigue on isometric and aerobic performance (4), minimal research has been conducted looking at the effect of mental fatigue on resistance training, muscular endurance outcomes, and subsequent muscle activation. Brown et al. (3) examined the effect of induced mental fatigue using a Stroop test on muscular endurance during bicep curls using a to-exhaustion test at 50% of 1-repetition maximum (1RM). The results showed no significant changes in the number of repetitions, RPE, or EMG amplitude based on the degree of mental fatigue (3). Brown et al. (4) found similar results as they found no reduction in the number of repetitions performed during body weight muscular endurance testing when participants were mentally fatigued versus when they were not. However, Queiros et al. (27) found that, during three sets of to-failure half-back squats at 70% of 1RM, total training volume was significantly higher following the control condition compared to the cognitively fatiguing condition. Potential limitations and design flaws regarding the use of EMG analysis and the degree of fatigability of the Stroop test in Brown et al. (3), were highlighted as possible factors contributing to the null effect of the findings. However, little is known about how these results may differ under muscular endurance (<65% 1RM) tests (12).

The use of EMG analysis via amplitude has been previously used, but in Brown, et al. (3) much of the data was removed from analysis due to excessive noise in the readings. The repetitive movement in an environment with minimal control over extraneous movements, such as seen in open kinetic chain resistance training, may account for some of the unclear and unusable EMG results yielded in that study. To make EMG reading cleaner and analysis more easily digestible, it is hypothesized that a single EMG reading could be collected during maximal testing at the end of each session using a closed kinetic chain movement or a single maximal effort task, such as an isometric mid-thigh pull (IMTP) (26).

A Stroop test is a tool designed to assess attention capacity and processing speed by asking participants to name the color of the ink used to print words while the words themselves spell different colors (31). Queiros et al. found that Stroop tests that lasted for about 30 minutes induced greater mental fatigue as compared to Stroop tests that failed to meet the 30-minute threshold (33). There have been questions among scientists regarding the validity of tests intended to induce mental fatigue. Inventories, such as the NASA Task Load Index (TLX), intended to measure workload, can be administered after Stroop testing to determine whether mental fatigue was induced as a result of the completion of the Stroop test, by evaluating the task's workload (7). The NASA TLX is one of the few inventories determined to be reliable (Cronbach's alpha > 0.80) (34), and a convergently valid (Perceived Workload Scale and Rating Scale Mental Effort, $r = 0.81$ and $r = 0.77$ respectively) (13) assessment of workload. The NASA TLX is a subjective assessment tool consisting of six Visual Analogue Scales (VAS), referred to as adjusted ratings (AR): mental demand, physical demand, temporal demand, performance, effort, and frustration. The response is assigned numerical values and a formula is used to produce a workload score that can be compared between conditions. The mental demand AR VAS rating can be used independently to measure mental fatigue, as Díaz-García et al. (7) indicate that Visual Analogue Scales are concurrently valid (Stanford Sleepiness Scale, $r > 0.30$) (15) and reliable (Cronbach's alpha > 0.90) (15) means of assessing mental fatigue.

The present study seeks to further investigate the effects of mental fatigue on resistance training performance outcomes. Therefore, the purpose of the study is to determine the potential effect of mental fatigue using a Stroop test on muscular endurance during to-failure resistance training testing, as well as subsequent neuromuscular activation rate of force development, reaction time, and maximum isometric force.

METHODS

Participants

Participants were 10 NCAA Division III collegiate female athletes at the University of Lynchburg with a minimum of 1 year of formal resistance training experience under the guidance of the university strength and conditioning coach. However, only 7 subjects were included in the final analysis due to the subject mortality of 3 participants. Participants also had to demonstrate they maintained an aerobic capacity above the 50th percentile, according to the guidelines for ACSM Cycle Ergometer-Based Cardiorespiratory Fitness Classification (Page 91, Table 3.9) (16). Additional participant demographic information can be found in Table 1. All participants were injury-free and cleared for physical activity, and provided informed consent before participation. The Institutional Review Board approved protocols at the University of Lynchburg (LHS2324020) and was carried out fully in accordance with the ethical standards of the *International Journal of Exercise Science* (22).

Table 1. Participant demographics.

Variable	Mean ± SD
Age	21.43 ± 0.79
Height (cm)	165.17 ± 3.63
Weight (kg)	68.13 ± 9.34
RHR (bpm)	68.71 ± 8.40
Body Fat Percentage (%BF)	26.26 ± 5.41
Percent Muscle Mass (%MM)	31.71 ± 2.31
Aerobic capacity (ml · kg^{-1} · min^{-1})	35.16 ± 3.14

Protocol

This study was a single-blind, within-subject, randomized, cross-over design consisting of three total visits in the late afternoon with a minimum of 72 hours between visits to allow for adequate recovery to minimize the risk of delayed onset muscle soreness (DOMS) impacting the perception of fatigue during subsequent assessments (18, 21).

The intake visit encompassed the completion of the informed consent and all of the necessary intake testing. The session started with the completion of informed consent and the Physical Activity Readiness Questionnaire (PAR-Q+). Anthropometric data was then collected, such as height (seca 222; Seca, Hamburg, Germany), weight (BWB-800; Tanita Co., Tokyo, Japan), percent body fat (%BF), and percent muscle mass (%MM) using a multi-component bioelectrical impedance analysis (BIA; MC-780U PLUS Multi-Frequency Segmental Body Composition Analyzer; Tanita Co., Tokyo, Japan).

Participants then completed 1RM and rate of force development (RFD) testing for Mid Thigh Isometric Pull (IMTP) (iLoad Pro Digital USB; Loadstar Sensors, Fremont, California). Before completion of the test, participants underwent a standardized dynamic warmup (10 jumping jacks, 10 X-jacks, 10 clap jacks, 10 dynamic squat stretches, 10 world's greatest stretches, and 10 single-leg glute bridges) and education session for the movement and equipment. Participants were then connected to EMG analysis equipment (IX-TA-220 Recorder with Popular Sensors; iWorx Systems, Dover, New Hampshire) using LabScribe software (iWorx Systems, Dover, New Hampshire) using the artifact removal feature to clean the EMG data from artifacts. Electrodes (Telectrode PE ECG Foam Monitoring Electrodes 43mm x 45mm Oval; Bio ProTech, Cerritos, California) were attached to the rectus femoris of the subject's dominant leg, halfway between the superior border of the patella and the anterior superior iliac spine (ASIS). Participants then completed three trials of a single repetition of IMTP using an isometric dynamometer with a minimum of 3 minutes of rest between trials, during which the participant must return to a low-intensity heart rate (5). Data was then recorded during which the participant had the greatest 1RM, including isometric mid-thigh pull 1RM (IMTP 1RM) in Newtons (N), IMTP rate of force development (RFD; msec), IMTP reaction time (RT; msec) and EMG amplitude (mV).

Participants then completed a 1RM testing for leg press on a plate-loaded, incline hip sled (I-LP; Williams Strength, West Columbia, South Carolina). The test was estimated to require anywhere from 4-6 sets with a minimum of 3 to 5 minutes of rest between each attempt (12). First, 10 repetitions at 50% of the participants self-reported, estimated 1RM were completed for warmup and familiarization. Set 2 entailed the completion of 5 repetitions at 70% self-reported estimated 1RM. Set 3 entails the completion of 3 repetitions at 90% self-reported estimated 1RM. Following the third warm-up set, participants completed a series (3 to 5 sets) of 1RM attempts of 10% load increases until failure, with a minimum of 3-5 minutes between each attempt (12). Attempt intensity was assessed via rate of perceived exertion (RPE; 6-20 point scale).

Participants then completed a VO_{2max} graded cycling test on an electro-magnetically braked cycle ergometer (Corival, Lode, Groningen, The Netherlands) with metabolic cart analysis (TrueOne 2400 Metabolic Measurement System, Parvo Medics, Salt Lake City, Utah). The test started with a 5-minute cycling warm-up at a self-selected pace at an intensity no greater than the first testing stage (8, 11). Participants were introduced to the protocol before testing and were instructed to hold their thumbs up at the end of each stage to indicate they were ready to continue and hold up their index finger to indicate they needed to stop in one minute. The test was a graded cycle ergometer test designed to last for approximately 8-15 minutes starting at 50W and increasing the intensity by 25W every 2 minutes until volitional exhaustion or when participants could no longer maintain a cadence of at least 50 rotations per minute (rpm). During the test, gas analysis was detected breath by breath and averaged every 15 seconds, heart rate was collected every 30 seconds using a chest-mounted strap (H10; Polar, Kempele, Finland) and RPE was recorded every two minutes using the 15-point (6-20) Borg Scale. Following test termination participants completed a 5-minute cycling cooldown at a self-selected pace. A true VO_{2max} was determined when subjects' VO_2 shows little to no change with an increase in intensity or if a respiratory exchange ratio (RER) > 1.10, RPE ≥ 18 on Borg's Scale, and HR > 90% age-predicted maximal HR was achieved (6).

Experimental and Control Visits: The experimental and control visits each started with either a high or low mentally fatiguing condition before testing was administered for 30 minutes in a randomized and crossover manner. The conditions were also administered while the participants were cycling at 40% of their predetermined VO_{2max} at 60 rpm. The highly mentally fatiguing condition was an electronically administered 30-minute Stroop test (Cognition Laboratory Experiments, Hanover College, Stroop Experiment). Using a tablet (iPad mini, Apple Inc, Cupertino, CA) subjects were presented with 100 trials of all incongruent stimuli, using only the colors red, green, blue, and yellow. No time restraints were imposed and upon completion of all 100 trials, the test was reset until the 30-minute threshold had been reached. The low mentally fatiguing condition was watching a 30-minute segment of Seinfeld (S1;E1 & S1;E2). The segment was the same for all participants and was watched using the same tablet, in the Walker Human Performance laboratory, under hands-free stationary bike riding conditions on the same cycle ergometer used for the max test. The NASA TLX was administered immediately following the conditions to measure the degree of workload and mental fatigue. From this assessment a workload value is calculated and the individual AR results are used as VAS evaluation for mental demand, physical demand, temporal demand, performance, effort, and frustration with the tasks. Additionally, HR values were collected via a heart rate monitor strap (H10; Polar, Kempele, Finland) every 5 minutes during testing.

Participants then completed a to-failure leg press test at 50%1RM following a standardized 10 rpm cadence using an electronic metronome video (36). The researcher counted the number of repetitions and the subject reported RPE after every repetition to prevent participants from counting their repetitions. The test was terminated when the participant could no longer maintain the standardized cadence or reached failure.

Participants then repeated the 1RM midthigh pull protocol using the isometric dynamometer and EMG analysis to measure IMTP 1RM (N), IMTP RFD (msec), IMTP RT (msec), and EMG amplitude (mV).

Statistical Analysis

A power analysis conducted with G*POWER 3.1 (Universitat Kiel, Germany) (9), determined based on the effect size of changes in leg press repetitions (d = 0.91) following mental fatigue protocol (10), that 9 participants were needed in the present study for a power of 0.80, with an effect size of 0.91 and an α = 0.05.

All statistical analyses were conducted using JASP 18.3 (Amsterdam, Netherlands). Separate paired sample t-tests were used to assess the difference between the dependent variables between the mentally fatiguing session and the control session. Effect size was determined via Cohen's d with scores classified as small (d = 0.2), medium (d = 0.5), and large ($d \geq 0.8$)(32). Significance was set *a priori* at p = 0.05.

RESULTS

There was a significant difference ($t(6)$=-3.40, p = 0.02, d = 1.48) comparing the mean scores of NASA TLX Mental Demand AR for control (90.83 ± 141.33) and Stroop (292.50 ± 118.27) conditions (Figure 1). Additionally, there was a significant difference ($t(6)$ = -3.27, p = 0.03, d = -1.24) comparing the mean scores of NASA TLX Physical Demand AR control (190.83 ± 106.04) and Stroop (45.00 ± 74.57) conditions (Figure 2).

No significant differences were reported comparing the control condition versus the mentally fatiguing condition for NASA TLX score ($t(6)$ = -1.60, p = 0.23, d = 0.56; 35.81 ± 15.64 vs 46.24 ± 12.75, respectively), NASA TLX temporal demand AR ($t(6)$ = -2.22, p = 0.07, d = 0.96; 22.86 ± 36.95 vs 81.43 ± 81.69, respectively), NASA TLX performance AR ($t(6)$ = -1.91, p = 0.20, d = 0.61; 54.29 ± 48.69 vs 95.72 ± 50.37, respectively), NASA TLX effort AR ($t(6)$ = -0.40, p = 0.88, d = 0.07; 147.14 ± 123.12 vs 168.57 ± 100.40, respectively), or NASA TLX frustration AR ($t(6)$ = 2.27, p = 1.00, d = 0.00; 57.14 ± 84.99 vs 50.00 ± 88.88, respectively).

There was no significant difference comparing the mean scores of 50% to-failure LP reps ($t(6)$ = 0.34, p = 0.99, d = -0.01), LP maximum RPE ($t(6)$ = -0.55, p = 1.00, d = 0.00), or LP average RPE ($t(6)$ = 0.51, p = 0.54, d = 0.27) for control and mentally fatiguing conditions. For the 50% to-failure LP reps, the mean of 63.14 ± 42.56 was not significantly different from 60.43 ± 43.75. The LP maximum RPE mean of 19.29 ± 1.11 was not significantly different from 14.38 ± 1.93. The LP average RPE mean of 14.92 ± 1.59 was not significantly different from 14.43 ± 1.77.

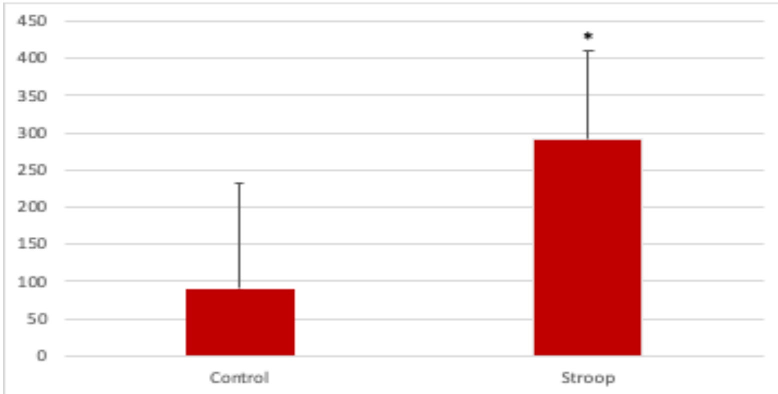

Figure 1. NASA TLX Mental Demand AR. *Stroop session was significantly ($p > 0.05$) greater that the Control session.

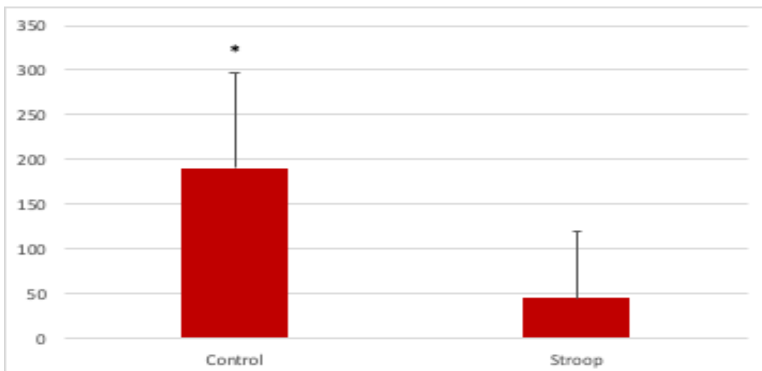

Figure 2. NASA TLX Physical Demand AR. *Control session was significantly ($p > 0.05$) greater than the Stroop session.

There was no significant difference comparing the mean scores of IMTP RFD ($t(6) = 0.52$, $p = 0.59$, $d = -0.24$) or IMTP RT ($t(6) = -0.26$, $p = 0.54$, $d = -0.27$) for control and mentally fatiguing conditions. The IMTP RFD mean of 182.14 ± 204.29 msec was not significantly different from 140.71 ± 66.45 msec. The IMTP RT mean of 627.71 ± 265.970 msec was not significantly different from 661.43 ± 235.16 msec.

There was no significant difference between IMTP Amp (V2-V1) ($t(6) = 1.01$, $p = 0.054$, $d = 0.27$), IMTP Max Amp ($t(6) = 0.99$, $p = 0.50$, $d = 0.30$) , or IMTP Maximum Force Production ($t(6) = 2.18$, $p = 0.10$, $d = 0.83$) for control and mentally fatiguing condition. The IMTP Amp (V2-V1) mean of 6.64 ± 4.53 mV was not significantly different than 3.80 ± 4.54 mV. The IMTP Max Amp means of 9.65 ± 4.59 mV was not significantly different from 5.55 ± 5.10 mV. The IMTP Maximum Force Production mean of 766.95 ± 271.42 N was not significantly different from 719.30.12 ± 306. N.

DISCUSSION

The primary purpose of this study was to investigate the effect of mental fatigue on resistance training performance outcomes, such as muscular endurance, maximal isometric force production, power output, and neuromuscular activation. Results from the analysis showed no significant effects of mental fatigue on any of the resistance training-related performance outcomes evaluated in this study.

One of the primary goals of this study was to ensure that the Stroop test employed in the experimental condition was mentally fatiguing. Prior research indicated that a 30-minute Stroop test, regardless of its vigor, was a valid means of inducing mental fatigue (33). The current study applied this duration recommendation in the research design and utilized NASA TLX to evaluate workload and mental fatigue. The mental demand AR was significantly higher (p = 0.02) in the evaluation of the mentally fatiguing task compared to the control task. This indicated that participants felt the Stroop test was mentally fatiguing, suggesting that it was a valid modality for inducing the requisite mental fatigue to potentially impact psychobiology performance. Interestingly, physical demand AR was significantly higher (p = 0.03) in their evaluation of the control task compared to the mentally fatiguing task, despite the utilization of the same cycling resistance and rpm for both tasks. Additionally, the difference in the physical demand AR cannot be attributed to the training effect, due to the cross-over nature of the experiment design. This indicates that, in the absence of mentally fatiguing stimuli, participants perceived the task as more physically demanding, despite the physical demands of the task remaining constant between the two conditions. Despite the significant findings of these two adjusted ratings within the NASA TLX evaluation, the overall NASA TLX score, temporal demand AR, performance AR, effort AR, and frustration AR were not significantly different between the two tasks (p > 0.05). This indicates that, while the mentally fatiguing task was more mentally demanding than the control task, the overall workload, as evaluated by the NASA TLX, was the same between the two tasks.

Consistent with prior research, there was no significant difference between muscular endurance outcomes between the control and mentally fatiguing conditions as shown by the number of to-failure LP reps at 50% 1RM (p > 0.05). Brown et al. (3) found no significant difference between the number of to-failure bicep curl reps at 50% 1RM. The research design for Brown et al. (3) was comparable to the current investigation and it was thought that addressing the limitations of Brown et al. (3) would alter the significance of the findings; however, this was not observed. Van Cutsem et al. (33) suggested that a 30-minute Stroop is adequate for inducing mental fatigue regardless of the intensity of the test (33) and because the 10-minute Stroop test was employed in Brown et al. (3) in conjunction with the lack of a post-test mental fatigue evaluation, it was hypothesized that the high cognitive demand condition may not have been sufficiently mentally fatiguing. To address this potential limitation, the current investigators employed the NASA TXL to evaluate the workload and mental demand of the experimental and control conditions, and the experimental condition was significantly more mentally demanding (p = 0.01) than the control condition. While Brown et al. (3) indicated that the lack of any significant difference in performance outcomes between mental fatiguing and control conditions cannot be attributed to a general lack of induced mental fatigue, the current investigation found that muscle endurance was not impacted under mental fatigue.

Additionally, there was no significant difference in maximum or average RPE during the to-failure LP test between the mentally fatiguing condition and the control condition (p = 0.99).

Previous research, specifically investigating the effect of mental fatigue on aerobic performance, suggests that increased RPE following the completion of a mentally fatiguing task is a primary contributor to subsequent performance decrements (4, 30). This relationship between increased RPE and decreased performance is explained using a psychobiological model and motivational intensity theory, which indicates that the connection between RPE and task motivation yields significant influences on performance as they dictate the degree of exertion an individual is willing to express for a given task (3, 19, 20). Therefore, conditions that impact RPE and motivation would likely also impact performance variables within a given task. This model may explain why this current investigation yielded no significant difference in performance variables, based on the lack of significant difference in RPE, between the mentally fatiguing and control conditions. For example, in Marcora et al. (30) RPE was significantly higher following the mentally fatiguing condition, despite there being no significant difference in heart rate or blood lactate response, and significantly lower time to exhaustion during high-intensity anaerobic capacity cycling testing. In Brown et al. (3) there was no significant difference between RPE or number of repetitions during to-failure resistance training training at 50% 1RM between the high cognitive demand and low cognitive demand conditions similar to what was found in the current investigation. The differences between these results may stem from the exercise modality, whereas low-intensity muscular endurance may be less impacted by mental fatigue whereas high-intensity anaerobic capacity tests are blunted by mental fatigue to due being more neurophysiologically demanding.

There was no significant difference in the IMTP RFD, IMTP RT, IMTP EMG amplitude, or IMTP EMG maximal amplitude between the control and experimental conditions ($p > 0.05$). This indicates that the time from baseline to peak neuromuscular activation, as well as from onset of the stimulus to peak neuromuscular activation during IMTP were not significantly influenced by the degree of mental fatigue. Additionally, the maximal electrical activity within the recruited muscle group for completion of the IMTP was not significantly impacted by the presence of mental fatigue. While there is minimal research investigating the relationship between neuromuscular activation and mental fatigue, this is a finding that has been consistently reported to exist. Silva-Calvacante et al. (28) found that there was no significant difference in EMG M-wave amplitudes of the quadricep muscle groups, specifically targeting the Vastus Lateralis, between mentally fatiguing and control conditions both before and after the completion of a 4 km cycling time trial test. The lack of significance regarding the effect of mental fatigue in neuromuscular activation has been reported previously, using tests of isometric contraction (14,24), anaerobic performance (28), aerobic performance (25), and muscular endurance (3). The consistency of this insignificant relationship between mental fatigue and neuromuscular activation suggests that any physiological decrements observed in response to mental fatigue are likely not attributed to changes in the peripheral nervous system, but more likely due to changes in task motivation as a result of increased mental load.

Similarly, there was no significant difference in maximal force production during IMTP between the mentally fatiguing condition and the control condition ($p > 0.05$). This finding was not expected as the task being performed was isometric, and previous literature indicates that mental fatigue reduced the overall duration of sustained isometric contraction at a given resistance (1, 4). It was suspected that this performance decrement would also extend to maximal force production during isometric testing. However, upon further investigation, previous research showed no effect of mental fatigue on maximal force production using a series of isometric and anaerobic testing modalities, including maximal voluntary contraction of the knee extensors, elbow flexors, Wingate testing, and countermovement vertical jump (23). This is thought to be due to the short duration and neurophysiological simplicity of the IMTP task. While there is minimal research investigating the effect of mental fatigue on force production, the findings of the current investigation are consistent with the currently available literature.

This study was not without limitations that may impact the generalizability and reliability of findings. First, the smaller-than-expected sample size considering the predetermined power prediction may have limited the statistical power of the analysis. Second, the all-female participants may affect the extent to which the result can be applied to a broader population. Additionally, the experimental design lacked an initial assessment of mental fatigue levels before the administration of the control or experimental conditions. By failing to evaluate mental fatigue at the onset of each visit, baseline levels of mental fatigue due to daily stressors were not established or taken into consideration during analysis. Lastly, as subjects were tested in the late afternoon, there is a potential limitation as fatigue may be impacted by the time of day of the data collection.

In conclusion, the present study investigated the effects of mental fatigue on resistance training performance outcomes, such as muscular endurance, power output, and neuromuscular activation. Additionally, the study evaluated the effect of mental fatigue on perceived rates of exertion during an exercise bout and established that the administered Stroop test was sufficiently mentally fatiguing as compared to the control condition. It was determined that, while the Stroop test utilized in the mentally fatiguing condition was significantly more mentally fatiguing than the control condition, mental fatigue had no significant impact on the performance outcomes that were being evaluated. These findings indicate that mental fatigue, a common symptom of cognitive stress, does not appear to affect resistance-training-related performance outcomes. However, accumulative cognitive stress, like seen in a college environment, may still be a concern to consider for student-athletes, and its impact on performance needs to continue to be explored. With the ever-growing awareness that is being brought to the stress that athletes are under, exercise professionals must understand the potential effects that this may have on performance to train successful and healthy athletes.

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