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Optimizing Back Squat Performance

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OPTIMIZING BACK SQUAT PERFORMANCE

by

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ABSTRACT

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The back squat is a task commonly used to train and test performance levels in competitive sports and strength based performance events. The purpose of this study was to analyze the potential performance benefits for a 1-repetition max (1RM) back squat under conditions in which the three key factors of OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016) are present: Enhanced expectancies (EE), autonomy support (AS), and an external focus (EF) of attention. Participants (N = 23) were assigned to either an optimized condition, which included EE AS, and EF, or a control condition. They were asked to perform a 1RM back squat protocol on two days, one week apart. The first day of testing served to establish a baseline for both groups. Results demonstrated an increase in 1RM performance as well as an increase in self-efficacy relative to baseline in the optimized group. The control group demonstrated no changes in 1RM performance or self-efficacy. The findings reported in this study provide support for predictions of the OPTIMAL theory. They provide practitioners with practical information that may be beneficial for implementation in regular training for strength-based performance tasks or in competitive settings.

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CHAPTER 1

INTRODUCTION

Motor learning is understood to be a series of complex processes that occur in the brain in response to practice or experience of a certain skill (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2018). The premise in studying motor learning is to establish the most effective methods for producing a new motor skill. According to the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2019), three key factors make a positive impact on both performing and learning motor skills: Enhanced expectancies (EE), autonomy support (AS), and an external focus (EF) of attention.

Each of the three factors have been shown to improve performance of many tasks, including strength-related tasks. High levels of self-efficacy, or EE, have been shown to positively impact endurance and strength performance (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008). This impact on endurance and strength performance suggests that EE might also affect the performance of a maximal effort strength task. In addition to EE, giving individuals AS has been found to increase repeated maximum force productions (Iwatsuki, Abdollahipour, Psotta, Lewthwaite, & Wulf, 2017). AS has also been shown to enhance running efficiency (Iwatsuki, Navalta, & Wulf, 2018). EF has been shown to improve the performance of strength-related tasks such as the bench press and deadlift. For example, an EF has been shown to result in significantly more repetitions than a control condition or an internal focus of attention (Nadzalan, Low Food Lee, & Ikhwan Mohamad, 2015). Each one of the three key factors of the OPTIMAL theory of motor learning has been shown to lead to improvements in performance of strength and endurance tasks, as well as an increase in self-efficacy. Given the performance benefits seen when the factors are applied individually, the purpose of the present study is to examine combined effects of these factors when applied to a compound movement strength task, such as the back squat.

It has been shown that an EF requires less attentional capacity than an internal focus on body movements (Kal, Van Der Kamp, & Houdijk, 2013), AS leads to greater force production (Iwatsuki et al., 2017), individuals with EE may perceive task end-goals as being easier (Witt, Linkenauger, & Proffitt, 2012), and individuals with EF will also demonstrate improved performance with regard to maximal effort strength training (Nadzalan, Low Fook Lee, & Ikhwan Mohamad, 2015). The performance benefits of the three factors, EE, EF, and AS have been shown to be additive in nature (Pascua, Wulf, and Lewthwaite, 2014; Wulf, Chiviacowsky, and Cardozo, 2014; Wulf, Chiviacowsky, and Drews, 2015). In the present study, the effect of a combination of these factors on the performance of a 1-repetition maximum (1RM) back squat will be examined relative to a control condition. Given that they have already been shown to improve strength performance on sub-maximal strength tasks such as the bench press and deadlift (Nadzalan et al., 2015), and have been shown to increase self-efficacy (Hutchinson, et al., 2008), it is hypothesized that the three factors will have a significant impact on self-efficacy levels and the performance of a maximal-effort strength related task, such as the 1RM weighted back squat.

Purpose of the Study

The purpose of the present study is to examine whether performance of a maximal-effort strength task will be enhanced in a condition that incorporates EE, AS, and EF, with potential implications for applied settings. In this particular study, the maximal effort strength task will be a 1RM back squat with the use of a squat rack and free weights. I will be implementing the three key factors of the OPTIMAL theory and comparing the results of a maximal effort strength task for an intervention (optimized) group and a control group. I hypothesize that the optimized group will show an improvement in strength compared to the control group.

In line with the research previously discussed by Wulf and Lewthwaite (2016), I propose the following two hypotheses in this study:

Research Hypotheses

Hypothesis #1: Participants who perform under conditions that incorporate the three key factors of the OPTIMAL theory (EE, AS, EF) will demonstrate an increase in performance with regard to the greatest amount of resistance load (heaviest weight) they can move upon a 1RM attempt, whereas there will be no increase in the control condition.

Hypothesis #2: Participants in the optimized group will report an increased level of self-efficacy, whereas no increase will be seen in the control group.

CHAPTER 2

REVIEW OF RELATED LITERATURE

OPTIMAL Theory of Motor Learning

Skilled movement has been studied for many years in an attempt to determine conditions that will improve the automatization or the performance of a given task. Researchers have taken many approaches when looking at skilled movement, including social-cognitive, behavioral, and neurophysiological. These approaches have all been researched individually in order to examine skilled performance. Various results have been found from each of these approaches in relation to skilled task performance, but until recently, there has been limited research that looked at the combination of such approaches to motor learning. In their OPTIMAL theory of motor learning, Wulf and Lewthwaite (2016) identified key motivational and attentional variables that are necessary for optimal motor performance and learning. Specifically, there are three factors within the OPTIMAL theory, each making their own impacts upon motor learning and the improvement of skilled performance. These three factors are enhanced expectancies (EE), autonomy support (AS), and an external focus (EF) of attention. Conditions that include individual factors, and in particular combinations of all three factors, have been shown to improve the performance of many skills, including performance or learning of novice and advanced individuals (Bahmani, Wulf, Ghadiri, Karimi, & Lewthwaite, 2017; Wulf & Su, 2007). Therefore, it is expected that the performance of a weighted back squat will be enhanced by a combination of EE, AS, and EF as well.

Enhanced Expectancies

Over time, experience establishes certain expectations based upon previous performance. For example, if an individual consistently performs well at a throwing task, they will establish a high level of self-efficacy and a sense of confidence in their own ability to continue to perform well at the same or similar throwing tasks. In contrast, if prior experience has been negative, and performance of a throwing task has not been good in the eyes of the performer, there will be a predisposition to continue with poor performance with regard to throwing tasks. One of the purposes of enhancing the expectancies of an individual is to affect their performance by increasing their self-efficacy. In order to make a positive impact on an individual's self-efficacy, or to enhance their expectancies, that individual must believe that they are doing well, and that they are performing in a skilled manner with regard to the given task. That is, there must be some sort of feedback or observation that leads the performer to have an increased level of self-efficacy. The use of EE has been shown to be effective in studies that require varying levels of skill, and has been effective amongst a variety of different age groups within test populations. For example, performance benefits of EE were demonstrated with golf putting performance (Witt et al., 2012), performance in both adults and children (Bahmani et al. 2017 & Witt et al., 2012), balancing tasks in older adults (Wulf, Chiviacowsky, & Lewthwaite, 2012), movement efficiency in experienced runners (Stoate, Wulf, & Lewthwaite, 2012), and isometric handgrip endurance (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008).

Enhancing a performer's expectancies has been shown to positively impact motor learning and performance, for example, by providing (false) positive social-comparative feedback (Hutchinson et al., 2008), or by giving the performer on their best attempts (Clark & Ste-Marie, 2007). It has also been shown that verbal encouragement positively affects performance of an isometric strength task (Belkhiria, De Marco, & Driss, 2018). In this particular study, participants were instructed to perform a maximal voluntary isometric handgrip contraction under one of three conditions: verbal encouragement (VE), non-verbal encouragement (nVE), or non-concentration and non-motivation condition (nCM). Maximal voluntary force and maximal rate of force development were both significantly higher during VE, compared to the nVE and nCM conditions (Belkhiria et al. 2018). Thus, if an individual's expectancies were to be enhanced through verbal communication or encouragement, it is expected that there would be positive implications for the performance of a maximal effort strength task such as the back squat.

Research on EE has demonstrated improved performance for strength tasks as well as other tasks (for a review, see Wulf & Lewthwaite, 2016). Thus, it is expected that enhancing the expectancies of an individual would also make a positive impact on the performance of a maximal effort back squat. Enhancing expectancies is only one of the factors that leads to the expectation to improve 1RM back squat performance and to increase the level of self-efficacy.

Autonomy Support

Giving performers control over some aspect of their environment or the task being performed, gives them a sense of autonomy that satisfies a basic psychological need (Deci & Ryan, 2000; 2008). Research has consistently shown improvements in motor learning and performance when participants are given autonomy, or the freedom of choice (Iwatsuki, Navalta, & Wulf, 2018; Lemos, Wulf, Lewthwaite, & Chiviacowsky, 2017; Wulf, Raupach, & Pfeiffer, 2005). The concept of AS can be thought of as a sense of independence and trust that a researcher or practitioner instills in the individuals performing a skill or task. The goal of AS is to create a sense of ownership, independence, and trust for the individuals performing a given task.

Implementation of AS gives individuals the freedom to make their own decisions when given a number of options, rather than having their every move dictated or instructed to them with no freedom of choice. One example is a study in which participants performed basketball free throws (Wulf et al., 2005). Individuals in the intervention group were given freedom of choice, or AS, and were permitted to choose the number of times and the intervals of frequency at which they wished to watch a video demonstration of an expert performing a basketball jump shot. The control group was “yoked,” that is, they were instructed to watch the demonstration video at the same intervals as their counterpart in the intervention group. The purpose of that study was to assess the impact on basketball shooting form and accuracy. The results of the study demonstrated that AS positively impacted shooting accuracy, relative to the control group (Wulf et al., 2005). Freedom of choice, or AS, has also led to improved running efficiency (Iwatsuki et al., 2018), cricket bowling (Hooyman, A., Wulf, G., & Lewthwaite, R., 2014), and throwing performance (Chiviacowsky, Wulf, De Medeiros, Kaefer, & Tani, 2008). The choices provided to performers do not need to be large or major. In fact, even minor choices that would not be expected to have an impact, can affect the learning and performance of a given skill (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015). That is, the improvement in motor learning or performance are due to the motivational effects of AS and the support of participants' basic psychological need for independence which was discussed previously.

Establishing a sense of autonomy has been shown to be beneficial by means of demonstrating that a tester or practitioner has confidence in the participants and their ability to perform or make important decisions. That sense of independence will lead participants to feel a sense of trust and confidence that the tester has in them, which then leads to an improvement in task performance (Lewthwaite et al., 2015, Experiment 1). AS also reduces an individual's self-related concerns and conscious attempts at controlling their movements that hamper automaticity (Hooyman et al., 2014). This means the attention that would otherwise be required for conscious attempts of movement control can instead be directed toward the task being performed, without hindering automaticity. Therefore, an individual will not utilize their attentional capacity to consciously control movements or on controlling negative emotional responses to a denial of autonomy (Hooyman et al., 2014).

Force production was recently studied in relation to AS, specifically when looking at maintaining maximum force levels (Iwatsuki, Abdollahipour, Psotta, Lewthwaite, & Wulf, 2017). Participants were instructed to utilize a hand dynamometer and repeatedly produce maximum forces with both their dominant and non-dominant hand. On the last three of four trials, the intervention group was given AS by means of being able to choose the order in which to test each hand, either dominant or non-dominant. In the case of the control group, there was a consistent decrease in maximal force levels over the course of the trials. However, the AS group maintained the initial force levels (Iwatsuki et al., 2017). This demonstration of the effects AS has on force production in combination with the other performance benefits shown by implementation of AS, leads to the present hypothesis that there will be an improvement in performance of a 1RM back squat.

Focus of attention

Attentional focus is an important factor for motor learning and performance, and different instructions for attentional focus can affect an individual's level of performance. Attentional focus has been studied through instructions or feedback that direct an individual's attention either internally or externally. An internal focus (IF) is directed toward an individual's own body position and movements. An EF is directed toward the effects of an individual's movements or the movement goal. Over years of research on EF versus IF in relation to performance outcome, it has been shown that an EF is more beneficial for motor performance and learning than an IF (for a review, see Wulf, 2013).

Motor performance and learning have been studied in relation to an EF by utilizing various cues and directions for participants. For example, in one study, participants were directed to place their focus on an object external to their body, specifically by focusing on the pendulum-like motion of a club during a golf swing (Wulf & Su, 2007). Wulf, Weigelt, Poulter, and McNevin (2003) demonstrated an example of an EF of attention through means of having an individual standing on a stabilometer. The IF instruction given to participants was to keep their feet horizontal, thus focus on self and body position. Instructions for the EF of attention were to keep certain points on the stabilometer platform horizontal, thus a focus on movement effect. It was demonstrated that an EF led to more effective balance learning than that of an IF (Wulf et al., 2003). In addition to improved balance (Wulf, Höß, & Prinz, 1998; Wulf et al., 2003), utilization of an EF has been shown to improve golf stroke accuracy (Wulf & Su 2007), golf stroke movement form and carry distance of the ball (An, Wulf, & Kim, 2013), and gymnastics performance (Abdollahipour, Wulf, Psotta, & Palomo, 2015).

The means by which an EF of attention has been shown to be effective is through the promotion of automatic control processes. That is, an individual can perform a task without consciously controlling their movements, or without needing to utilize as much attentional capacity on the given task. A study by Wulf, McNevin, and Shea (2001) provided evidence for the constrained action hypothesis (CAH). According to the CAH, when trying to consciously control one's movements (IF), the motor system will be constrained, due to an interference with automatic control processes. When focusing on a movement effect (EF), automatic control processes are promoted, and superior motor performance is seen. An IF will constrain the motor system by interfering with automatic control processes and thus lead to the requirement of more attentional capacity that could be utilized elsewhere in a task or the surrounding environment (Kal et al., 2013; Wulf et al., 2001). Studies examining the CAH demonstrated that an EF resulted in faster reaction times, increased reflex utilization, greater movement fluidity, and more effective balance (Kal et al., 2013; Wulf et al., 2001).

Direction of attentional focus has also been shown to make an impact on strength related tasks. When compared to a control condition or an IF, an EF has been shown to significantly increase the number of repetitions that can be performed at a given resistance for strength related tasks, including the bench press, squat and deadlift

(Marchant, Greig, Bullough, & Hitchen, 2011; Nadzalan et al., 2015). These studies demonstrated an increase in number of repetitions to failure at a given percentage of 1RM, which indicates an increase in both strength and endurance when looking at compound or multi-joint resistance exercises. For this reason, it is hypothesized that an EF will also make a positive impact on the 1RM performance of a maximal effort free weight back squat.

Optimizing Performance

Research on the three factors of the OPTIMAL theory has demonstrated more positive thoughts about task performance (Lemos et al., 2017), greater self-efficacy (Witt et al. 2012), and improved performance in maximum strength training (Nadzalan et al. 2015), among other things. Research has consistently demonstrated improvement in motor learning and performance when testing each of the three factors in the OPTIMAL theory, AS (Wulf, 2007), EE (Chiviacowsky & Wulf, 2007), and EF (Wulf, 2013), are implemented. Researchers also studied the effects of conditions in which two or more of the key factors were present. It was found that these conditions with two or more of the factors present is beneficial for motor learning and performance in a number of different applications discussed below. In 2015, Pascua, Wulf and Lewthwaite demonstrated an improvement in non-dominant hand throwing performance by combining an EF with EE. Although both EF and EE groups showed improved learning when compared to a control group, learning was enhanced with the presence of both EF and EE relative to either EF or EE alone (Pascua, Wulf, & Lewthwaite, 2015). Further support of the benefits found for conditions in which two or more factors are present has been demonstrated by improved learning when combining an EF and AS (Wulf, Chiviacowsky, & Drews, 2015) and an improvement when combining AS and EE (Wulf, Chiviacowsky, & Cardozo, 2014). Three studies demonstrated improved motor learning and performance when combining any two of the three factors of the OPTIMAL theory of motor learning; the improvement in motor learning and performance was demonstrated when combining AS/EE, AS/EF, and EE/EF, in comparison to the performance shown in a control group or when one of the factors was applied alone (Pascua et al., 2015; Wulf et al., 2014; Wulf et al., 2015). It has already been shown that each of the three factors of the OPTIMAL theory have demonstrated an improvement in motor learning and performance when applied on their own. However, the three aforementioned studies found that an even greater improvement in motor learning and performance will take place under conditions in which two or more of the factors are present at the same time (Pascua et al., 2015; Wulf et al., 2014; Wulf et al., 2015).

Given the improvement in motor learning and performance demonstrated through conditions with the presence of more than one factor, the next step is to examine the impact of all three factors when implemented at the same time. In a recent study, it was shown that the greatest improvement in performance for a given task are seen when combining all three components of the OPTIMAL theory at the same time (Lewthwaite & Wulf, 2017). The improvements in motor learning and performance that were demonstrated were more significant than those seen when implementing AS, EE, or EF of attention alone or in any combination. Additionally, it was demonstrated that the combination of all three factors at the same time was the only condition in which higher throwing accuracy or performance was shown on a retention test (Chua, Wulf, & Lewthwaite, 2018; Wulf et al., 2018). Due to the greatest improvements for motor learning and performance being shown when applying all three factors of the OPTIMAL theory in combination, the present study was designed to examine the effects on a maximal-effort strength task, 1RM weighted back squat, and self-efficacy when implementing all three factors of the OPTIMAL theory simultaneously.

CHAPTER 3

METHODS

Participants

All participants had a minimum of six months resistance training experience prior to participation in the study. A minimum of six months of experience was selected in order to minimize the risk of injury for participants. There were 12 participants in the optimized group (female n = 6, male n = 6). The average age was 24.2 ± 3.0, average number of years of experience 6.3 ± 4.9, and on average they performed resistance training 3.67 ± 1.44 times per week. There were 11 participants in the control group (female n = 5, male n = 6). The average age was 23.36 ± 2.98, average number of years of experience 6.36 ± 3.93, and on average they performed resistance training 3.55 ± 1.70 times per week.

Apparatus and Task

All participants performed 1RM attempts of a free-weight back squat. A 1RM was defined as the greatest resistance load under which a participant could successfully perform a weighted back squat. The back squat task was performed in a controlled lab setting, utilizing a barbell, weight plates, and a squat rack. Proper safety spotting procedures were followed for all participants. Spotting was done by the researcher and two assistants from behind the participant and at both ends of the barbell. Specific shoes were not required; however, all participants were instructed to wear the same shoes on both testing days in order to avoid any potential effects on performance.

Procedure

All participants performed 1RM attempts of a free-weight back squat under two experimental conditions, a control condition and an optimized condition. The conditions/sessions were separated by one week in order to attain proper recovery before the next testing day. Testing days were only one week apart in order to minimize any potential effects caused by physiological adaptations. Testing times were at the same time of day for day 1 and day 2. All participants were instructed not to participate in resistance training of the lower extremities for at least two days (48 hours) prior to each session. Prior to participation in the first session, participants were asked to sign a consent form. During this time, they were given the opportunity to ask questions about the study, or to withdraw from the study without penalty. The experimenter addressed any questions they had at this time. Participants were then provided with a demonstration of proper squat form by the experimenter (see Haff & Triplett, 2016).

During exercise, no feedback was given with regard to form, unless it was deemed necessary for the safety of the participant. Participants were instructed to perform a specific warm-up protocol prior to a 1RM attempt. Prior to this warm-up protocol, all participants were asked to estimate what their 1RM would be, based upon past experience. This estimated 1RM value would be used to determine percentages for the warm-up sets. The warm-up protocol began by instructing participants to walk for three minutes at three miles per hour on a treadmill, followed by 15 repetitions squatting a 45 pound barbell. A one minute rest period was provided. The next step in the warm-up was for participants to perform eight repetitions squatting 50% of their estimated 1RM. A one minute rest period was provided. Following the rest period, participants were instructed to perform four repetitions at 70% of their estimated 1RM. A two-minute rest period was provided. Following this, participants were instructed to perform 2 repetitions at 90% of their estimated 1RM. A three-minute rest period was provided. Upon the conclusion of this warm-up protocol, resistance load was then increased to the estimated 1RM load. Participants were instructed to perform a maximal effort attempt that would be recorded as their first 1RM attempt. Following the first 1RM attempt, participants were instructed to rest for three minutes. A three-minute rest period was provided between all 1RM attempts.

Upon completion of a successful maximal effort attempt, resistance load was increased by 10 pounds or 0-10%. If the attempt following this increase was failed, resistance load was reduced by 5 pounds or 0-10%, and participants were instructed to complete another attempt. Resistance load continued to be increased or decreased until the participant could complete one repetition with proper exercise technique. All participants were permitted three to five testing sets in order to attain a 1RM (see Haff & Triplett, 2016).

In the optimized condition, participants were given positive feedback (EE) two times during the three warm-up sets, and after each maximal effort attempt (e.g., “nice job,” “you did well”). AS was provided by allowing participants to choose the amount of load to increase or decrease the resistance by after each maximal effort attempt (0-10%). An EF was implemented by instructing participants to concentrate on the movement path of the barbell. Reminders of this EF were given before each warm-up set and before each maximal effort attempt.

In the control condition, participants followed the protocol utilized during the baseline 1RM testing. However, they were yoked to the participants in the optimized condition with regard to percentage of resistance load increase or decrease between maximal effort attempts. Participants were yoked by gender and similar 1RM values. If a participant in the optimized group chose to increase resistance load by 10% (AS), the individual yoked to them was instructed to increase resistance load by 10% as well during the same maximal effort attempt. Participants were given no enhanced expectancy feedback nor any feedback that was not pertinent to their safety in the control condition. Additionally, no instructions were given with regard to attentional focus during the warm-up and during each maximal effort attempt.

Participants' self-efficacy was measured after the completion of all warm-up sets, prior to the first 1RM attempt. This timing was selected because participants would have established a given level of self-efficacy with regard to squat performance during the warm-up sets. The questionnaire was five questions long and asked participants to rate how confident they were that they would be able to increase the resistance load by either 1-2%, 2-3%, 3-4%, 4-5% or >5% upon completion of a successful 1RM attempt. Self-efficacy was rated on a scale of 1-10, with 1 being "not confident at all" and 10 being "extremely confident".

Data Analysis

Statistical analysis was performed using SPSS software (Version 25.0 for Windows, IMB, Inc., Chicago, IL, USA). Self-efficacy was analyzed as the average value between all five questions. Both self-efficacy and 1RM back squat performance were analyzed in 2 (group: optimized, control) x 2 (testing time) analyses of variance (ANOVAs) with repeated measures on the last factor.. The Shapiro-Wilk test of normality was performed for each of the outcome variables at each time point.

CHAPTER 4

RESULTS

Self-Efficacy

Descriptive statistics for self-efficacy on day 1 and day 2 can be found in Table 1 and Figure 1. Self-efficacy passed the assumption of normality with the Shapiro-Wilk test statistic. The main effect of time was not significant, F (1, 21) = 1.056, p = 0.316, η^2 = 0.048. The ANOVA revealed a significant Group x Time interaction, F (1, 21) = 8.57, p = 0.008 η^2 = 0.290. Follow-up tests for each group showed that self-efficacy increased for the optimized group from day 1 to day 2, F (1, 11) = 15.54, p = .002, η^2 = 0.586, whereas the control group showed no change, F (1, 10) = 1.14, p = .31, η^2 = 0.102.

1RM Performance

Descriptive statistics for 1RM performance can be seen in Table 1 and Figure 2. The assumption of normality was met for 1RM performance. The main effect of time was significant, F (1, 21) = 11.362, p = 0.008. The interaction of Group x Time was significant, F (1, 21) = 4.32, p = 0.05. Follow-up tests indicated that 1RM performance increased significantly for the optimized group, F (1, 11) = 19.462, p = 0.001. There was no significant change in performance for the control group, F (1, 10) = 0.654, p = 0.437, η^2 = 0.061.

Table 1. Descriptive statistics (mean, SD) of self-efficacy and 1RM performance on days 1 and 2

Group	SE Day 1	SE Day 2	1RM Day 1	1RM Day 2
Optimized	5.2 ± 1.5	7.0 ± 2.3	230.8 ± 75.67	240.42 ± 76.38
Control	6.8 ± 2.1	6.0 ± 2.3	242.27 ± 81.10	244.55 ± 80.67

Figure 1. Self-efficacy on days 1 and 2 for optimized and control groups. *indicates significant difference between optimized vs. control on day 2.

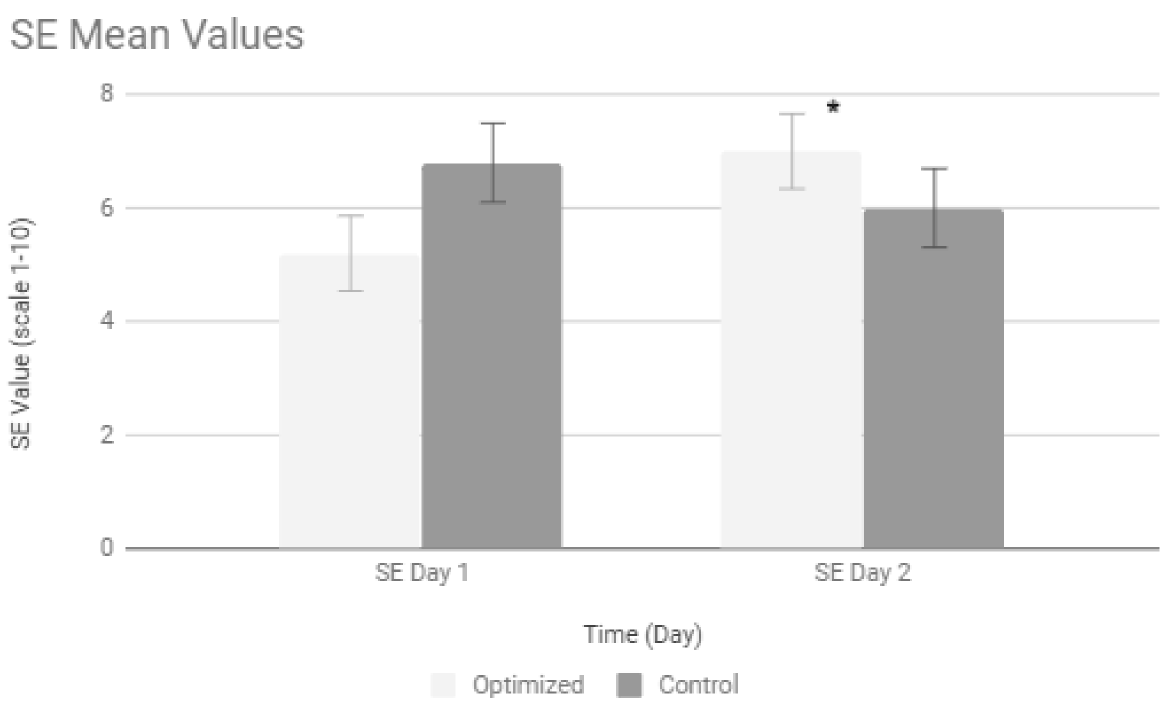
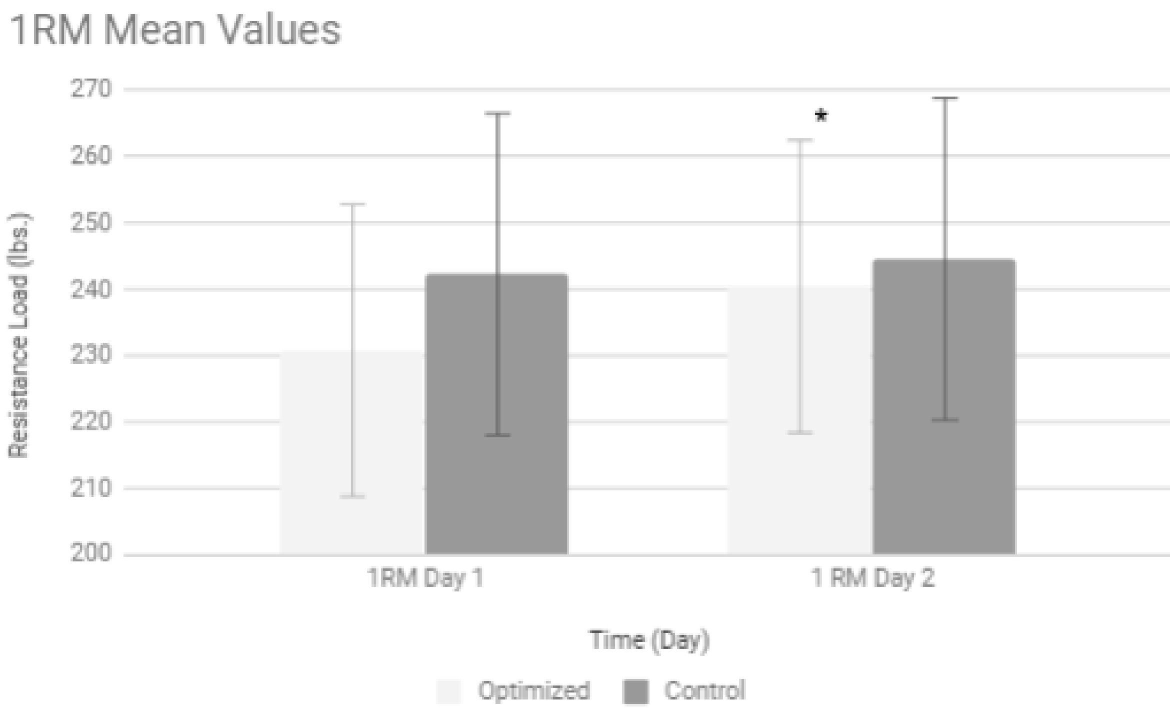


Figure 2. 1RM performance on days 1 and 2 for optimized and control groups.

*indicates significant difference between day 1 and day 2 under optimized conditions.



CHAPTER 5

SUMMARY, CONCLUSIONS,

AND RECOMMENDATIONS

The present study investigated whether performance levels and self-efficacy could be improved in relation to a 1RM back squat under conditions that incorporate the three key factors of the OPTIMAL theory (Wulf & Lewthwaite, 2016). A 1RM back squat is a maximal effort strength task that can be tested by researchers in the lab setting and by practitioners alike. Given that previous studies have shown performance improvements for the deadlift, back squat, and bench press with an EF, improved isometric grip strength performance with EE, and improved running efficiency with AS (Hutchinson et al., 2008; Iwatsuki et al., 2017; Marchant et al., 2011; Nadzalan et al., 2015), the purpose of the present study was to examine whether 1RM performance could be enhanced by incorporating all three factors (EE, AS, EF) in an optimized condition. The present results demonstrated a significant improvement in 1RM back squat performance under optimized conditions. This finding is in line with a previous study in which a performance condition that included EE, AS, and EF resulted in superior maximum (vertical jump) performance relative to a control condition (Chua et al., 2018). Additionally, the results demonstrated a significant increase in self-efficacy for the optimized group.

The increased self-efficacy and 1RM performance seen in optimized conditions fulfill the expectations for improved motor learning and performance based upon previous benefits seen with AS, EE, and EF (Wulf et al., 2018). The motor learning and performance benefits that have been seen under conditions that incorporate these three key factors can be thought of as more efficient goal-action coupling (GAC). GAC refers to the relationship between a task goal and the translation to actual performance of that task. It has been shown that all three factors play a role in the establishment of GAC and improved motor learning and performance (Wulf et al., 2017). This translation of a task goal to the performance seen with GAC can be attributed to the "stamping in" of memory that is brought about by a dopamine response to unconditioned rewards, or in this case, successful attempts (Wise, 2004). In addition, high-reward contexts modulate structural and neurological adaptations that increase learning and retention with regard to memory consolidation (Gruber, Ritchey, Wang, Doss, & Ranganath, 2016). Thus, the good performance seen in optimized conditions will lead to a dopamine response in a high-reward context, which modulates structural and neurological adaptations over time that will further improve performance due to increased learning and retention (Gruber et al., 2016; Wise, 2004).

The 1RM back squat was analyzed since it is a task commonly used to test fitness and performance levels in competitive sports and other similar events. The performance benefits for the back squat that were demonstrated in this study lead to implications for performance increases in other areas of fitness and performance testing. One of the purposes in studying the benefits of OPTIMAL theory with regard to a back squat is to be able to show the potential for application in the practitioner setting for strength coaches and trainers focusing on the most effective methods for fitness training and performance. For practitioners working with strength and performance based individuals, there are many additional applications for each key factor of

OPTIMAL theory. Just a few examples of these would be giving autonomy (AS) to choose the length of rest periods, an EF that focuses on direction of forces being applied on the ground, and EE through means of positive verbal cues or visual feedback such as a video playback of good performance of a specific participant performance of a strength task. Then, as it has been shown, performing under conditions in which all three factors are present will lead to optimized performance conditions (Wulf & Lewthwaite, 2016; Lewthwaite & Wulf, 2017; Wulf et al., 2018).

Nutrition or dietary intake is another aspect to consider when looking at strength performance. The present study did not include any physiological components such as dietary intake tracking to ensure participants consumed the same quantity and type of food and water on both testing days.

Given that increased 1RM performance was demonstrated, it is evidence for the benefits of optimized conditions in a lab setting. These performance benefits then have potential to translate to traditional training and performance settings in which maximal effort strength tasks are tested and performed, thus demonstrating that optimized conditions are beneficial for performance when looking at strength based tasks. This particular application would be beneficial for practitioners, including trainers and coaches in competitive sports - specifically sports and events that require a great deal of strength training.

Optimized conditions can lead to increased self-efficacy and greater maximal strength as has been demonstrated in this study. The advantageous performance seen under optimized conditions demonstrates the practicality of applying the three key factors of OPTIMAL theory to the back squat as well as additional strength-based tasks.

These performance benefits seen with the OPTIMAL theory will make for a favorable addition to strength training performance when studied and conscientiously implemented by coaches, instructors and all other practitioners working in fields that require strength training and performance.

APPENDIX I

UNLV

INFORMED CONSENT

Department of Kinesiology and Nutrition Sciences

TITLE OF STUDY: Squat 1RM Study

INVESTIGATOR(S): Arthur Hockwald and Gabriele Wulf

For questions or concerns about the study, you may contact Dr. Gabriele Wulf at **702-895-0938**.

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted, contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794 or via email at IRB@unlv.edu.**

Purpose of the Study
You are invited to participate in a research study. The purpose of this study is to examine the effects of a theory of motor learning on a back squat one repetition maximum (1RM).

Participants
You are asked to participate in the study because you fit this criterion: You are a healthy adult between the ages of 18 and 45 years. You have a minimum of six months experience with resistance training.

Procedures
If you volunteer to participate in this study, you will be asked to do the following: Perform a warm-up consisting of a standardized back squat lifting routine, prior to attempting a weighted 1RM back squat. The standardized warm-up includes incremental increases in weight, so as to reduce the risk of injury. Proper form will be demonstrated at the beginning of each session for the safety of all participants. Equipment will include the use of a squat rack and a barbell for each trial. There are two sessions, one week apart, each of which will take approximately 30 minutes.

Benefits of Participation
There may be no direct benefits to you as a participant in this study. However, we hope to learn more about factors that influence motor performance and maximal effort strength tasks.

Risks of Participation

There are risks involved in all research studies. In this study, there may be risks that include the possibility of experiencing some fatigue, soreness, or tenderness in your leg muscles and lower back on the days following each session. Participants will be spotted from three points, from behind and at both ends of the barbell, to ensure that proper form is maintained and risk of injury is kept minimal.

Cost/Compensation

There will not be any financial cost to you to participate in this study. The study will take approximately 30 minutes of your time today as well as another 30 minutes on the second day. No extra credit will be provided for participation; participation is completely voluntary. You may withdraw from the study at any time without penalty.

Confidentiality

All information gathered in this study will be kept as confidential as possible. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After this storage time, the information gathered will be destroyed.

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with the university. You are encouraged to ask questions about this study at the beginning of or any time during the research study.

Participant Consent:

I have read the above information and agree to participate in this study. I have been able to ask questions, if any, about the research study. I am at least 18 years of age. A copy of this form will be given to me upon my request.

_______________________________________ ______________________

Signature of Participant: ______________________________ Date: ______________

____

Name of Participant (Please Print): ____

APPENDIX II

Self-Efficacy Questionnaire

Please answer the following questions:

1. How confident are you that you will be able to increase resistance load by 1-2% after a successful 1RM attempt?

1	2	3	4	5	6	7	8	9	10
Not confident at all									Extremely confident

2. How confident are you that you will be able to increase resistance load by 2-3% after a successful 1RM attempt?

1	2	3	4	5	6	7	8	9	10
Not confident at all									Extremely confident

3. How confident are you that you will be able to increase resistance load by 3-4% after a successful 1RM attempt?

1	2	3	4	5	6	7	8	9	10
Not confident at all									Extremely confident

4. How confident are you that you will be able to increase resistance load by 4-5% after a successful 1RM attempt?

1	2	3	4	5	6	7	8	9	10
Not confident at all									Extremely confident

5. How confident are you that you will be able to increase resistance load by >5% after a successful 1RM attempt?

1	2	3	4	5	6	7	8	9	10
Not confident at all									Extremely confident

APPENDIX III

UNLV Biomedical IRB - Expedited Review

Approval Notice

DATE:	March 7, 2019
TO:	Gabriele Wulf, Ph.D.
FROM:	UNLV Biomedical IRB
PROTOCOL TITLE:	[1372074-3] Squat 1RM study
SUBMISSION TYPE:	Revision
ACTION:	APPROVED
APPROVAL DATE:	March 6, 2019
NEXT REPORT DATE:	March 5, 2021
REVIEW TYPE:	Expedited Review

Thank you for submission of Revision materials for this protocol. The UNLV Biomedical IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a protocol design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

PLEASE NOTE:

Upon approval, the research team is responsible for conducting the research as stated in the protocol most recently reviewed and approved by the IRB, which shall include using the most recently submitted Informed Consent/Assent forms and recruitment materials.

Should there be any change to the protocol, it will be necessary to submit a Modification Form through ORI - Human Subjects. No changes may be made to the existing protocol until modifications have been approved.

ALL UNANTICIPATED PROBLEMS involving risk to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NONCOMPLIANCE issues or COMPLAINTS regarding this protocol must be reported promptly to this office.

All approvals from appropriate UNLV offices regarding this research must be obtained prior to initiation of this study (e.g., IBC, COI, Export Control, OSP, Radiation Safety, Clinical Trials Office, etc.).

If you have questions, please contact the Office of Research Integrity - Human Subjects at IRB@unlv.edu or call 702-895-2794. Please include your protocol title and IRBNet ID in all correspondence.

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