A DESCRIPTIVE EVALUATION OF TWO RECOVERY METHODS ON PHYSIOLOGICAL AND PERFORMANCE FACTORS IN NCAA DIVISION II BASEBALL PITCHERS

By

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A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Exercise Science to the office of Graduate and Extended Studies of East Stroudsburg University of Pennsylvania

May 8, 2020

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ABSTRACT

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Exercise Science to the Office of Graduate and Extended Studies of East Stroudsburg University of Pennsylvania.

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Title: A Descriptive Evaluation of Two Recovery Methods on Physiological and Performance Factors in NCAA Division II Baseball Pitchers

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Abstract

Introduction: Injury rates in all levels of baseball pitchers have increased over the last two decades, while the knowledge behind the mechanics of pitching has increased as well. In-game recovery techniques have often been overlooked as possible methods of maintaining pitching performance, reducing injury, and decreasing fatigue. **Purpose:** The purpose of this study was to investigate the effects of two recovery methods on pitching performance in male NCAA division II baseball pitchers. **Methods:** Five male subjects on the East Stroudsburg University of Pennsylvania's pitching staff participated in 2 separate simulated bullpen sessions, where sessions were 7 days apart from one another. Recovery intervention consisting of Passive Recovery (PR) or Electrical Muscle Stimulation (EMS) occurred after the first 15 pitches. Velocity, spin rate, and release height were measured by the Rapsodo 2.0 Pitch Tracker. **Results:** Descriptive statistics showed EMS better maintained mean velocity over 2 innings of pitching when compared to PR. The results demonstrated that a greater number of subjects and innings thrown would be necessary to show significance between recovery methods and pitching measurables. **Conclusion:** In conclusion, no definitive recovery method was shown to be favorable over another.

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CHAPTER 1: INTRODUCTION

In baseball, just like any sport, the need for bigger, stronger, and faster athletes continually grows year in and year out. Over the past few decades, Major League Baseball (MLB) has seen a steady increase in average throwing velocity from pitchers, while consequently seeing an increase in elbow and shoulder injuries (Wilson et al., 2015). There have been many methods that are said to contribute to the increase in injuries, but no one factor has proven to be the root cause. Despite many advances in the analysis of throwing mechanics using biomechanical approaches i.e. 2-D and 3-D frame by frame analysis, injury rates rise year after year. Multiple areas of injury prevention have been examined, such as the use of radar guns in youth and adolescent facilities/games, exceeding pitch count restrictions, increases in off-speed pitches thrown, and sport specificity. Although a combination of the aforementioned methods may elicit injury, few studies have looked at in-game recovery methods to prevent/monitor injuries in all levels of pitchers. Because of the nature of a baseball game, pitchers can have an undetermined amount of rest in-between innings which makes it difficult to prescribe appropriate recovery methods in-game.

During competition, pitchers use an explosive delivery to generate the necessary speed/spin on each pitch to ultimately get the batter they are facing out. This motion needs to be repeated each pitch, with an undetermined amount of pitches that can be thrown each inning. At certain points during a game, a pitcher may need to produce maximal force/velocity in their motion to induce an out. A pitcher's level of physical strength/conditioning may be one of the determining factors on the speed of a pitcher's maximal velocity pitch. One measure of maximal force that may correlate to maximal velocity is the 1-Repetition Maximum (1-RM) Back Squat. With the obvious importance of lower body involvement/force development during the pitching delivery, pitchers with larger 1-RM back squats may be able to throw at higher velocities.

Anaerobic and ballistic in nature, the pitching delivery can cause muscular fatigue and a loss of control while the number of pitches thrown increases (Hackney, 1996). As the anaerobic system depletes without proper rest, the aerobic system becomes the main source of energy for a pitcher. As this occurs pyruvate is converted to blood lactate (HLa) and these concentrations rise in the bloodstream. Because elevated HLa levels are closely associated with muscular fatigue, a pitcher's performance in-game could decline rapidly if HLa levels stay elevated. Once a pitcher can rest between innings or batters, their body is able to clear lactate because the demand for immediate energy is low and oxygen is shuttled to working musculature. Different recovery protocols have been examined to see which is more efficient in clearing HLa at rest for baseball pitcher’s in-between innings, but HLa levels have not been recorded at high enough levels to induce muscular fatigue (Warren, Szymanski, & Landers, 2015).

Two researched recovery methods for pitcher’s in-between innings include passive recovery (PR) and electrical muscle stimulation (EMS). PR is a strategy commonly used in recovery for baseball pitchers at all levels of competition. PR is when a pitcher sits down between innings and wears a jacket either around their arm or on their body. A study by Monedero (2000) showed a decrease in HLa concentrations after a maximal incremental cycling protocol followed by 15 minutes of passive recovery. Although shown to be efficient with substantial rest, most pitchers will not have 15 minutes of time for rest between innings for HLa levels to return to resting. The EMS recovery method has not been examined as extensively as PR for in-game recovery for pitchers. EMS has been used frequently in rehabilitation processes for post-operative individuals, and for muscular repair. The theory behind EMS is that EMS induces muscle contractions through generating action potentials via external electrical stimulus; this process induces blood flow to working musculature and helps to clear lactate build up after strenuous exercise. As lactate is cleared during recovery, a subject may be able to compete for longer durations due to less built up fatigue. Determining which recovery method would best reduce the occurrence of injury and clear HLa between innings is crucial to prolonging optimal performance in pitchers at all levels of baseball.

Purpose

The purpose of the present study was to investigate the effects of two between-inning recovery methods on pitching performance in male NCAA division II baseball pitchers.

Delimitations

For the purpose of the present study, the following delimitations apply:

1) NCAA Division II, East Stroudsburg University of Pennsylvania baseball pitchers
2) Participants must be free from injury for the past 6 months
3) No heavy resistance training 24-48 hours prior to testing sessions

Limitations

For the purpose of the present study, the following limitations apply:

1) Compliance to preconditions of testing
2) Consistent effort throughout both testing sessions
3) Rapsodo technology error
4) Non-Randomized recovery method per session

Operational Definitions

The following definitions applied directly to the present study:

Spin Rate – the amount of spin of a baseball after it is released. Spin Rate is measured in revolutions per minute (rpm).

Electrical Muscle Stimulation – electrical impulses sent to muscle via electrodes. These impulses act as Action Potential's to induce the muscle to contract. The subject was sitting down for 6 minutes with electrodes placed on the Anterior and Posterior Deltoid muscle of the throwing arm. The stim machine was set at a frequency of 9Hz, with biphasic symmetry, and a pulse width of 250 milliseconds.

Passive Recovery – the subject sitting down with a jacket on for 6 minutes between the first and second simulated inning.

Release Height – the distance (m) from the bottom of the pitching mound to the pitcher's active hand when he releases the ball to the catcher.

Rapsodo 2.0 Pitch Tracker – a pitch tracking device that provides instant feedback as well as analyzes spin rate, command, velocity, movement, and mechanics of each pitch.

Summary

Along with the necessity of maintaining velocity during games for pitchers, comes the need to maintain other performance factors like accuracy, spin rate, and release height. The Rapsodo Pitching Unit allows researchers to track such performance measurables and has been used by numerous professional baseball organizations to monitor and track their pitcher's progress (Boddy, 2016). There has been no study to date that has combined the performance measurables recorded from the Rapsodo Pitching Unit with different between inning recovery methods. Lack of research examining in-game recovery methods in collegiate baseball warrants further study. The two methods this study examines is Passive Recovery (PR) and Electrical Muscle Stimulation (EMS). Therefore, finding the best recovery method during competition, while using the most up to date technology, could be key to maintaining performance for collegiate baseball pitchers.

CHAPTER 2: LITERATURE REVIEW

Biomechanics of the Throwing Motion

For years the throwing motion related to baseball pitching has been broken down and analyzed by coaches, scouts, and bio mechanists. Generally, the throwing motion can be divided into 6 sequential parts: windup, stride, arm cocking, acceleration, deceleration, and follow through; all of which piece together to form a ballistic yet fluid motion (Chu, Jayabalan, Kibler, & Press, 2016). The windup begins when the stride leg drifts back behind the mound and ends with the stride leg elevated and fully flexed while the stance leg is isometrically contracting (Chu et al., 2016). The stride represents the descending of the stride leg, the separation of the throwing hand and non-throwing hand, and the corresponding touchdown of the stride foot to the ground in full-stride (Chu et al., 2016). The arm cocking phase starts at the end of the stride phase, where the trunk and pelvis rotate towards the desired target and the throwing arm sets into maximal external rotation at the Glenohumeral joint (Chu et al., 2016). The acceleration phase begins when the arm is in maximal external rotation and ends with release of the ball (Chu et al., 2016). The trunk and pelvis continue rotating towards the target, and ultimately propel the torso over a flexed trunk and extended knee (Chu et al., 2016). The deceleration phase begins at the end of the acceleration phase when the ball leaves the hand, and ends when the throwing shoulder has reached peak internal rotation (Chu et al., 2016). Most of the forces slowing down the arm are absorbed by the group of muscles that make up the rotator cuff (supraspinatus, infraspinatus, teres minor, and subscapularis) at this time. The last phase is the follow-through, where the pitcher's stance leg flies forward and the throwing arm ceases movement (Chu et al., 2016). It is important to note that like many exact repetitive movements in sports, the throwing motion can become catastrophic to the individual performing it very quickly. One muscular imbalance or improper weight-shift can cause acute/chronic injury. Each phase of throwing must be so calculated that even slight error/deviation during a phase can cause injury to the athlete. Because of limb length discrepancies, mass differences, and muscular output differences between pitchers, there is no one motion that will work for every pitcher. Along with variations in mechanics, variations in pitching measurables exist between pitchers as well. One of the most recent variable studied for its use in professional baseball, and its use as a possible monitoring tool is spin rate.

Spin Rate

It has been well established that one of the main keys to success for a starting pitcher at any competitive level is for them to maintain the velocity of all pitches throughout the entirety of a baseball game. However, until recent, the importance of the rate of spin of a pitcher's different pitches has not been studied. Many pitchers ultimately may throw the same velocity on different pitches, but their actual spin rates in revolutions per minute (rpm) may be drastically different. Higuchi examined differences in batted balls with same velocities but different spin rates in elite level hitters (Higuchi, Morohoshi, Nagami, Nakata, & Kanosue, 2013). 30 pitches were thrown at a set speed of 81 miles per hour (mph), but the pitching machine they were propelled from would randomly select 1 of 3 different rates of spin (1800rpm, 2400rpm, or 3000rpm) for the pitch. There was a statistically significant correlation between rate of spin and deviation from the "sweet-spot" of the bat when hitters swung (Higuchi et al., 2013). As rate of spin increased, the distance between ball-center and the sweet spot of the bat increased, meaning less balls were batted on the sweet spot or barrel of the bat (Higuchi et al., 2013). One reason given as to why there was an increase of sweet spot misses was that the spin of pitches thrown with higher rpm's oppose the gravitational force acting on the ball, leading to less of a decrease in ball path height. This observation is called the Magnus Effect (Higuchi et al., 2013). This research explains that pitcher's with higher rpms on their fastballs may be harder to consistently contact because of the increased Magnus effect on their ball flight. Consistency in a pitcher's spin rate along with velocity throughout a game could be crucial to maintaining optimal performance. Since there would be an expected linear decline of spin rate and throwing velocity over multiple innings of pitching, pitchers' need for an efficient between inning recovery method is crucial. Finding the best recovery method to maintain performance would be vastly importantly to the performance of baseball pitchers at all competitive levels.

Increases in Injuries and Practical Assessments

Without knowledge or proper recovery techniques, pitchers can fatigue in-game rapidly. In baseball it is well known that frequent pitching, or overhead throwing in any manner, can lead to arm injuries. However, it has only been since the last decade or two where this growing epidemic of injury/overuse has been vigorously studied. A recent study by Wilson aimed to look at the incidence of Ulnar Collateral Ligament Reconstruction surgery (UCLR) among MLB baseball pitchers from 1974-2015. Data showed that from 1974-1995 there was an average of <2 UCLR surgeries per year in MLB pitchers, but from 2002-2012 there was an average of >14 UCLR surgeries per year with a peak of 33 UCLR in 2012 (Wilson, Pidgeon, Morrell, & DaSilva, 2015). Overuse injuries have been found to be even more common in youth baseball as of recent. A study by Lyman showed that in an increase in pitches thrown throughout the year and more than 75 pitches thrown per game led to an almost 52% increase risk of shoulder injury and a 35% increase in elbow pain across youth baseball pitchers (Lyman, Fleisig, Andrews, & Olsinski, 2002). An increase number of pitches has also been shown to disrupt repeatable mechanics (release height, stride length) in MLB pitchers, which is theorized to be caused by fatigue and may lead to an increase in injury rates (Whiteside, Martini, Zernicke, & Goulet, 2016).

Another cause for injury in pitchers, and athletes alike, is lack of physical conditioning. Baseball pitcher's motions are a detailed, complex, multi-step process that allow little room for error. Even if the mechanics of a certain pitcher is flawless, the stress a pitcher places on their body during this motion becomes greater as pitch counts rise. Most pitchers not only need to maintain longevity in each performance, but they must be able to throw maximally at certain points as well. Without proper strength, a pitcher may not be able to throw with enough velocity to get batters they're facing out. Secondly, without proper strength, a pitcher may fatigue faster. Knowledge of a pitchers strength/conditioning may be key to maintaining optimal performance throughout a baseball season, which is why testing measures like the 1-RM back squat could be important. The 1-RM back squat is a test of maximal strength of the lower body and has been correlated to various performance measures like jumping and sprinting (Chelly, Chérif, Amar, Hermassi, Fathloun, Bouhlel, Tabka, & Shephard, 2010). Being that the amount of force produced from the lower body segments during the pitching delivery is high, the velocity at which a pitcher can throw may be influenced by the amount of weight they can squat. A recent study highlighted lower extremity muscle activation during the pitching motion through EMG analysis in 11 highly skilled baseball pitchers (Campbell, Stodden, Nixon, 2010). The muscles marked for analysis during this study were the Vastus Medialis, Rectus Femoris, Biceps Femoris, Gluteus Maximus, and Gastrocnemius on both the stride leg and the trail leg of each subject (Campbell, Stodden, Nixon, 2010). Researchers broke down the pitching motion for analysis into 4 distinct phases; phase 1 was the initiation of the pitching motion until the stride knee was completely vertical, phase 2 was peak stride knee flexion until the stride foot contacted the ground, phase 3 was stride foot contact until the ball was released, and phase 4 was ball release until 0.5 seconds after release (Campbell, Stodden, Nixon, 2010). Mean EMG percentage values were highest during phase 3 for both the stride leg and trail leg, with the largest values observed from the vastus medialis (166 ± 47), rectus femoris (167 ± 38), and gluteus maximus (108 ± 33) via the stride leg, and the largest values from the gastrocnemius (172 ± 57) and gluteus maximus (141 ± 71) via the trail leg (Campbell, Stodden, Nixon, 2010). When comparing the muscle activation during the phases of pitching with the muscle activation during the barbell back squat, there are several similarities. A study by Yavuz on back squat EMG analysis during maximum loads shows muscle activations for the quadriceps and hamstrings groups. During the back squat, the highest EMG activities were observed from the vastus medialis (48.3 ± 14.3), vastus lateralis (45.9 ± 13.9), rectus femoris (37.9 ± 12.1), and gluteus maximus (28.8 ± 18.9) during the descending phase, and from the vastus medialis (49.3 ± 13.9), vastus lateralis (48.5 ± 17.2), rectus femoris (36.0 ± 13.8), and gluteus maximus (47.3 ± 27.7) during the ascending phase (Yavuz, Erdag, Amca, Aritan, 2014). With the observed correlation between muscle activation in the lower extremities during the pitching motion and the barbell back squat, the 1-RM back squat would be a valid assessment of pitchers' strength in relation to their sport.

Although having a strong base of strength to support the pitching delivery is vital, pitchers must also be able to recover from training before, after competition, and try to even during competition. Being that the most important aspect of any athletes' career is actually their time competing, being able to recover as efficiently as possible will allow for not only longer bouts of competition, but also more frequent ones. Finding an optimal recovery method that allows for the highest degree of recovery for pitchers between innings is therefore a necessity.

Electrical Muscular Stimulation

Electrical muscle stimulation (EMS) is a therapeutic modality used to enhance muscular activation and promote blood flow to affected areas of the body. Electrical impulses are sent through electrodes placed on the skin of the subject which mimic action potentials at the neuromuscular junction. EMS has been widely used as a form of therapy post-injury to promote blood flow to injured areas when patients cannot perform proper range of motion or strength tasks. Recently, EMS has been researched for its possible uses in sports performance enhancement/recovery. A study by Neric looked at different recovery methods (passive recovery and EMS) in 30 competitive swimmers post-exercise. Both passive recovery and EMS were administered randomly, and total recovery time was 20 minutes. HLa levels were compared from rest, 10 minutes into recovery, and 20 minutes into recovery (Neric, Beam, Brown, & Wiersma, 2009). HLa levels decreased significantly from rest during both recovery methods after 10 minutes, but only continued to decrease after 20 minutes when EMS was administered (Neric et al., 2009). With the continued decrease in HLa levels after 20 minutes of recovery EMS showed to be an optimal method of recovery for swimmers, especially because of the possibility of competing multiple times within a 30-minute time period (Neric et al., 2009). Comparably, swimmers may have to compete in multiple events during a single meet just like baseball pitchers may have to throw multiple innings in a single game. For the majority of a competition, the rest between the next race/inning is unknown, so finding a recovery method that decreases fatigue/maintains performance optimally is imperative.

Passive Recovery

Passive Recovery (PR) is one of the most widely used methods of recovery in many sports, especially baseball. A typical PR protocol consists of having a subject sit down, stand, or stretch immediately following exercise/competition. Many pitchers during baseball games use PR as their main method of recovery between innings pitched, except most times the pitcher is wearing a jacket while resting. Many times during competition a pitcher will have unknown periods of rest in-between innings, which makes it very difficult to establish an exact between-inning recovery protocol. Even with other recovery methods being researched in sports today, PR is still extensively used because of its simplicity and economical advantage (no equipment is necessary). One study on recovery methods looked at correlations between in-game recovery methods, one of which being PR, and HLa, RPE, heart rate, and range of motion in 21 intercollegiate Division I pitchers (Warren., Szymanski., Landers., 2015). After pitchers threw a simulated inning of 15 pitches (entirely fastballs) they would perform a 6-minute PR protocol before their next simulated inning. Results showed that HLa levels did not change significantly when compared pre-recovery to post-recovery, however RPE decreased when compared pre-recovery to post-recovery (Warren., Szymanski., Landers., 2015). Although biological evidence like HLa testing has shown PR to be a slower means of lowering fatigue, PR has been established as a reliable protocol that consistently lowers RPE and heart rate.

Research on Recovery Methods

There are various recovery methods used by athletes before and after performance to decrease fatigue. Therefore, finding an optimal recovery method between innings for pitchers could allow them to maintain increased performance levels for longer durations. Although research is minimal, Warren was able to examine the effects of passive recovery and electrical muscle stimulation on pitchers during a simulated game (Warren et al., 2015). 21 Pitchers from a division I university participated in the study. Each pitcher was required to throw 15 pitches per inning, for 5 innings, for a total of 75 pitches. Each pitch thrown was a fastball, and each pitcher was asked to throw at or above 95% effort. Before each pitcher started throwing, one of three recovery methods were randomly selected for that specific testing day. All recovery protocols lasted 6 minutes and were administered following the 15th pitch of each inning. Before and after recovery protocols were administered, the subject's heart rate and HLa were recorded. PR was explained as sitting down and wearing a jacket for the entirety of the recovery time, and the EMS protocol had practitioners administer electrodes on the triceps and biceps brachii, anterior and posterior deltoid, and the anterior and posterior upper trapezius of each subject's throwing arm (Warren et al., 2015). EMS was shown to decrease HLa concentrations significantly ($p<0.001$) from post-pitching to post-recovery, whereas passive recovery did not change ($p = 0.04$) (Warren et al., 2015). While HLa levels decreased significantly, HLa accumulation was never high enough to decrease velocity or induce skeletal muscle fatigue (Warren et al., 2015). Although Warren's study showed a significant decrease in HLa concentrations for the EMS protocol, there may be a limitation in the experimental design that could have skewed the results. One major limitation is that subjects were only instructed to throw fastballs during testing. Although this method may assure little variation in throwing velocity across the entirety of the study, it does not match the purpose of a "simulated" inning. Pitchers during competition throw many more pitches per inning besides fastballs i.e. changeups, curveballs, sliders, etc., thus having multiple innings of only fastballs may not elicit the same physiological effects that would occur during real competition. To have a better understanding of the physiological toll that is placed on a pitcher during competition, a study where pitchers throw all their respective pitches during simulated innings is necessary.

CHAPTER 3: METHODOLOGY

The purpose of this study was to investigate the effects of two between-inning recovery methods on pitching performance in male NCAA division II baseball pitchers. This chapter will present the participants, inclusion requirements, procedures, and data analysis.

Subjects

Six male college-aged NCAA Division II pitchers volunteered to participate in this study during the non-competition part of their baseball season. Out of the six pitchers, only five pitchers completed the study due to technological errors associated with the Rapsodo 2.0 Pitching Unit. This study received approval by the Institutional Review Board for the Protection of Human Subjects at East Stroudsburg University (Appendix A). All (5) pitchers read and signed an informed consent form and a Physical Activity Readiness Questionnaire Plus (PAR-Q+) (Appendix B & C) approximately a week before the start date of the study. Table 1 reports descriptive data for all demographic variables. Each subject reported to be free from injury during the time of the study, and at full health. All subjects had thrown for the past 5 weeks during their collegiate fall baseball season before the 2 weeks of testing occurred.

Table 1. Subject Demographics

Subjects	Age	Height (cm)	Weight (kg)	BMI (% Fat)	Years College of Experience
Subject 1	20	187.9	93.2	26.4	2
Subject 2	19	182.9	82.8	24.8	1
Subject 3	19	195.6	104.1	27.3	1
Subject 4	19	190.5	95.9	26.5	1
Subject 5	22	188.0	88.2	25.0	3
Mean	19.8	189.0	92.8	26.0	1.6
SD (±)	1.2	4.1	7.2	1.0	0.8

Values were rounded to 1 significant figure.

Procedures

The subjects underwent a familiarization session with all equipment being used for pitching purposes. All subjects underwent 1-RM back squat testing prior to the study commencing. The 1-RM testing design was as follows: The subjects were taken through a dynamic warmup, which started as dynamic stretching and ended with ballistic movements i.e. bounds and skips. All subjects had previously undergone a familiarization session in back squatting and had established proper back squat technique, as per their Strength and Conditioning coach. Each subject was instructed to follow the protocol of 8-10 repetitions as a warmup set, 6 reps as their first set, 2-4 as a second set, 1-2 reps as their third set, and then from there on they were instructed to do no more than 1 repetition per set, with the ultimate goal as achieving their 1-RM back squat at no more than 5-6 sets. The weight increased after each set was dictated by the subject and the Strength and Conditioning staff during testing. Termination of testing happened when the subject could either not lift the loaded bar back up from the down position, or when a member of the Strength and Conditioning staff saw a flaw in proper technique of a subject i.e. lack of proper depth (90 degrees at hip, knee, and ankle), excess knee valgus. Once each subject attained their 1-RM back squat, their testing numbers were recorded.

This study aimed to simulate a normal (in-game) pitching environment for all subjects. The subject testing sessions for pitching occurred individually on 2 separate occasions, where environmental conditions were similar, every 7 days. Pitchers were tested every 7 days because it followed their throwing schedule for the Fall season. Testing sessions ran for approximately 30 minutes and were designed as follows: Practitioner's placed Polar Heart Rate monitors directly below the subject's sternum and had them rest for 5 minutes to acquire resting heart rate levels. Subjects' baseline HLa, Local and Overall RPE were taken after 5 minutes of resting. HLa was acquired by a Lactate Pro Analyzer on the non-dominant fingertips of each subject. The Lactate Pro Analyzer was calibrated before each testing session. Once baseline data was recorded, the subjects completed a dynamic upper and lower body warm-up and started a light catch for 10-15 minutes. After their catch, pitchers threw 5-10 warmup pitches from the mound to simulate a bullpen before throwing in a game. After the simulated bullpen warmup pitches, pitchers threw 5 pitches to simulate the amount of pitches thrown before an inning commences. After 5 warm-up pitches were thrown, inning 1 commenced. During inning 1, subjects threw 15 pitches (with multiple variables being measured after each pitch (heart rate, velocity, release height, spin rate, accuracy). There was not a set script on what pitch/number of pitch types were thrown in the set of 15 because of the necessity of the subjects' pitching coach calling out pitches. This allowed for randomization of pitch types, which made the testing session as close to a real game scenario as possible. These 2 testing sessions were used as bullpen sessions for the pitcher's that threw in this study, so pitch type was called out by the pitching coach. Each subject threw different totals of each pitch throughout the testing sessions, but every subject threw 30 pitches total in each testing session. Ball and strike calls were given by the catcher and were not told to the subject throwing. Velocity, Release Height, and Spin Rate were all recorded by the Rapsodo 2.0 Pitching Unit, a high-speed camera used for pitch tracking purposes. After 15 pitches, Local and Overall RPE were recorded, and subjects were then given one of two recovery methods (EMS or PR) for 6 minutes (Warren et al., 2015). On day 1 of testing all the subjects were administered the PR protocol, and on day 2 the EMS protocol. HLa was taken at the beginning of the 6-minute recovery protocol to determine pre-recovery HLa, and immediately post-recovery. Heart Rate was recorded every 30 seconds during recovery (Warren et al., 2015). Local and Overall RPE were recorded post-recovery as well. After the 6 minutes of recovery was completed, the subjects threw 5 warmup pitches and then completed their 2nd inning. 15 more pitches were thrown during the 2nd inning, with Heart Rate being recorded after each pitch, as well as the pitching measurables from the Rapsodo

2.0 Pitch Tracker. After the 15 pitches were thrown, Local and Overall RPE were recorded as well as HLa. Once the last HLa was drawn, the subjects performed their normal cool down method which involved light jogging and static stretching.

Data Analysis

Descriptive data was collected for all variables. Mean, standard deviation, and delta scores were collected across conditions (PR, EMS). Microsoft Excel 2016 was used for all analysis

CHAPTER 4: RESULTS

The purpose of the study was to describe fatigue and overall pitching performance (Velocity, Strikes thrown, Spin Rate, and Release Height) across two recovery techniques in NCAA division II collegiate pitchers. This chapter will present descriptive statistics for accuracy, HLa, heart rate, local/overall RPE, velocity, spin rate, and release height.

Table 2. Fastball Pitch Totals and Differences in Accuracy Across Recovery Methods

Passive Recovery	# of Pitches	EMS	# of Pitches
Pre PR Strikes	25	Pre EMS Strikes	28
Pre PR Balls	23	Pre EMS Balls	20
Post PR Strikes	24	Post EMS Strikes	22
Post PR Balls	16	Post EMS Balls	19
PR Difference in Strikes	-4%	EMS Difference in Strikes	-21.5%
PR Difference in Balls	-30.5%	EMS Difference in Balls	-5%

Table 2 depicts fastball pitch totals and differences in accuracy across PR and EMS. The difference in strikes thrown for PR was (-4%), while balls thrown was (-30.5%). The difference in strikes thrown for EMS was (-21.5%), while balls thrown (-5%).

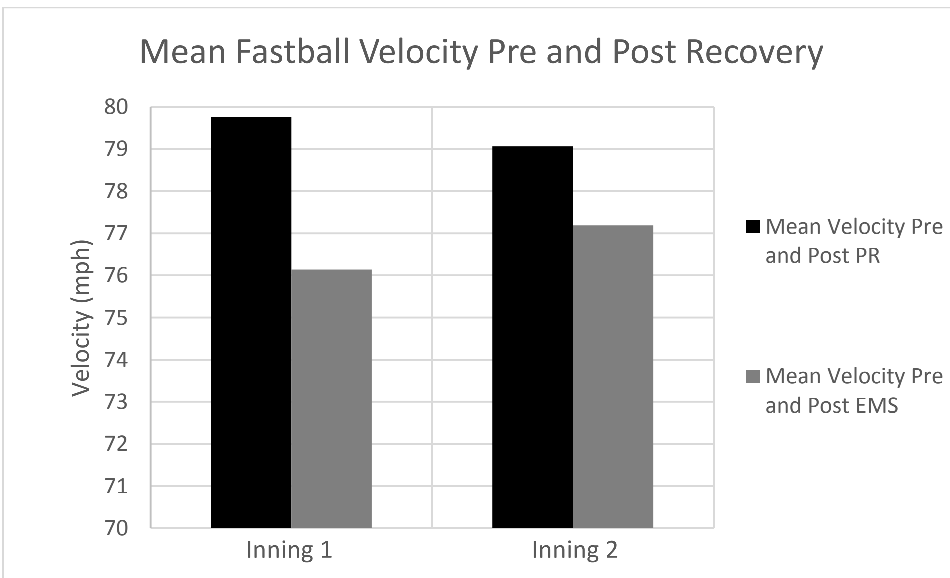

Figure 1: Mean Fastball Velocity Pre and Post Recovery

Figure 1 depicts mean fastball velocity (mph) pre (Inning 1) and post (Inning 2) PR and EMS. Mean velocity during inning 1 for Pre PR was 79.8 mph, while mean velocity for Pre EMS was 76.1 mph. Mean velocity during inning 2 for Post PR was 79.1

mph, while mean velocity for Post EMS was 77.2 mph. A 0.8% decrease in velocity was shown pre-recovery to post-recovery for the PR session, while an increase of 1.4% was shown pre-recovery to post-recovery for the EMS session.

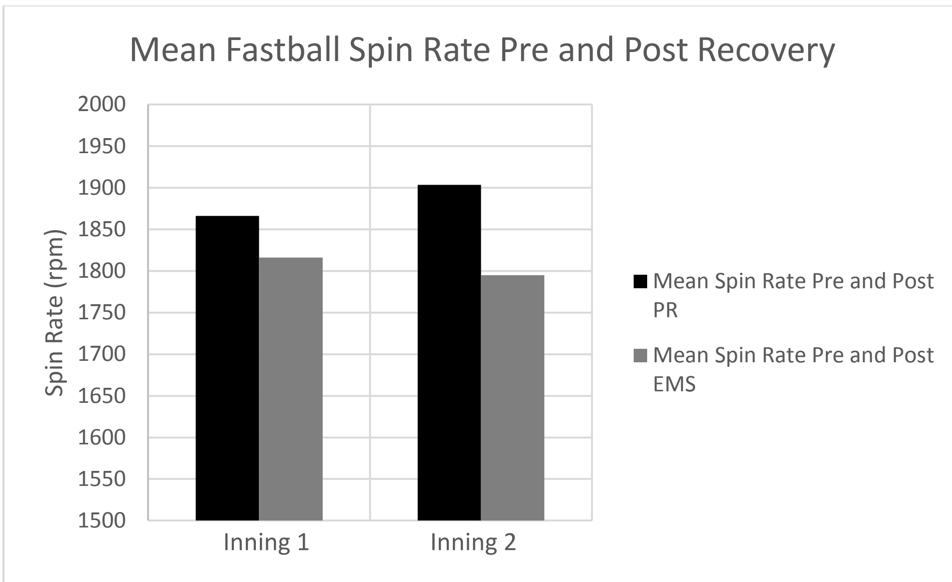

Figure 2: Mean Spin Rate Pre and Post Recovery

Figure 2 depicts mean fastball spin rate (rpm) pre (Inning 1) and post (Inning 2) PR and EMS. Mean Pre PR spin rate for inning 1 was 1866 rpm, while mean Pre EMS spin rate for inning 1 was 1815 rpm. Mean Post PR spin rate for inning 2 was 1903 rpm, showing a 2% increase from inning 1. Mean Post EMS spin rate for inning 2 was 1794 rpm, showing a 1.1% decrease from inning 1.

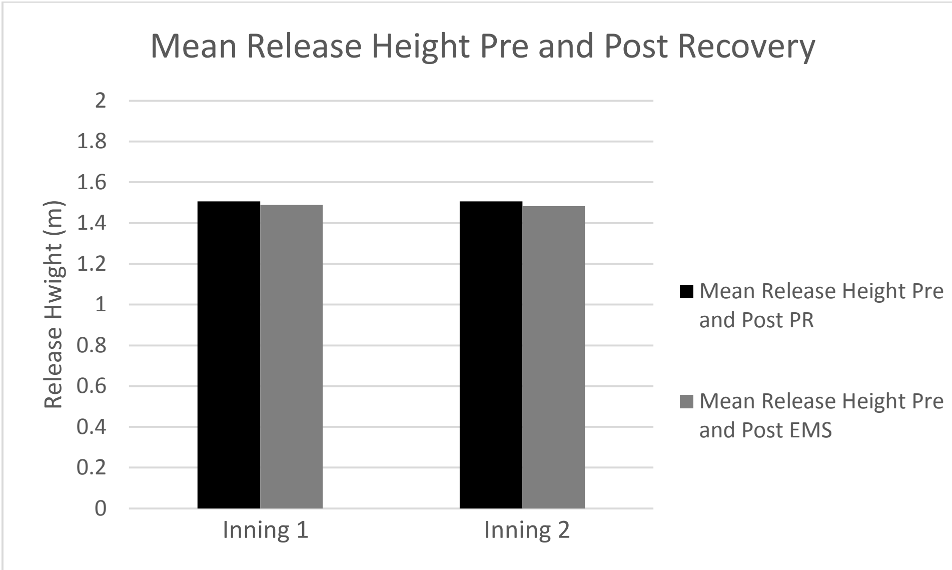

Figure 3: Mean Release Height Pre and Post Recovery

Figure 3 depicts mean release height (m) pre (Inning 1) and post (Inning 2) PR and EMS. There was no change in release height across pre to post recovery, but the PR session averaged a higher release height (1.50m) compared to the EMS session (1.48m).

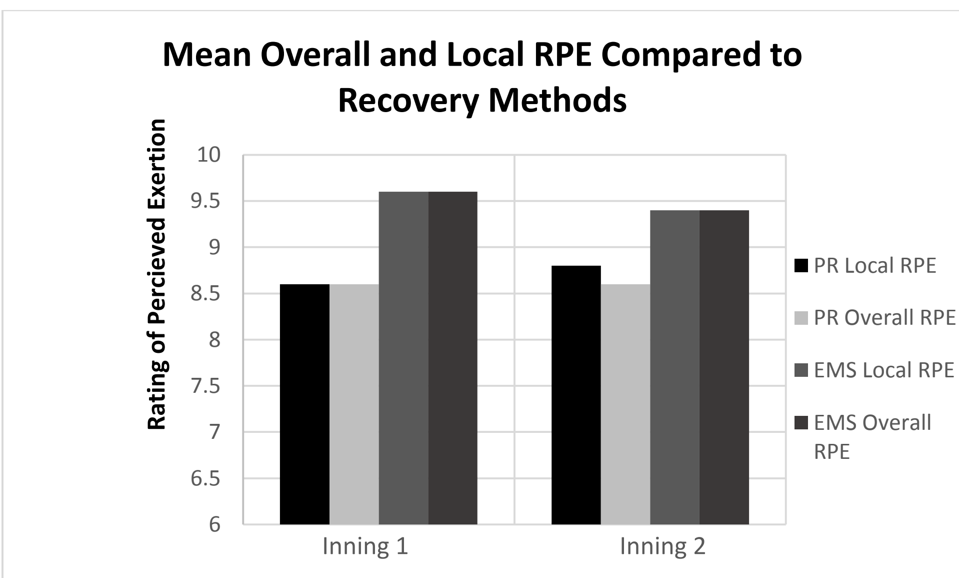

Figure 4: Mean Overall and Local RPE Compared to Recovery Methods

Figure 4 depicts the mean local and overall RPE values pre (Inning 1) and post (Inning 2) recovery. Both local and overall RPE decreased .2 after the EMS recovery. PR local RPE increased .2 after recovery, while overall RPE for PR stayed constant at 8.6. The Borg RPE scale (6-20) was used to measure both local and overall RPE.

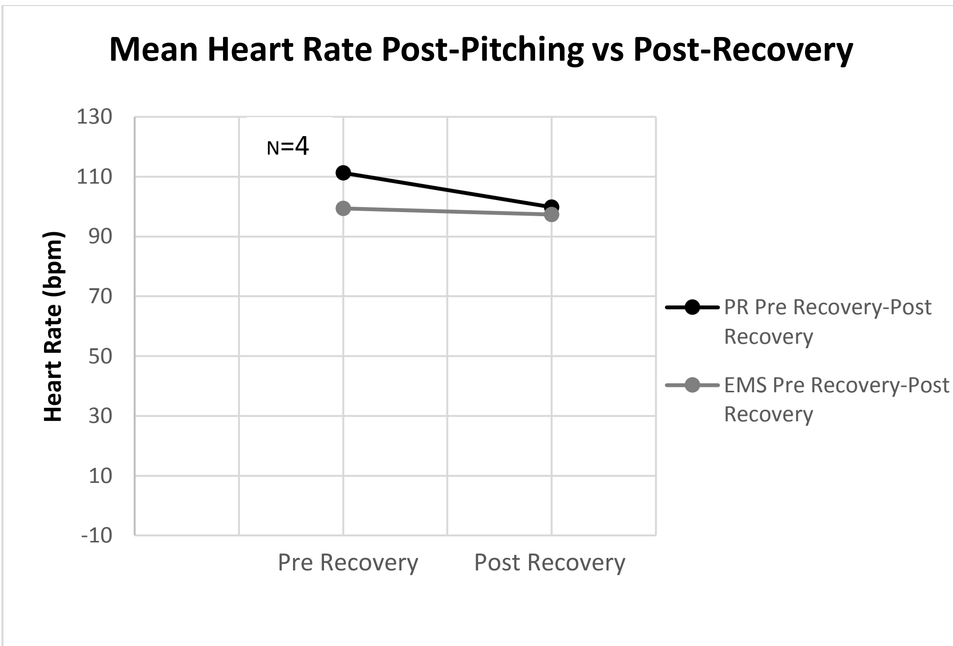

Figure 5: Mean Heart Rate Pre-Recovery vs Post-Recovery

Figure 5 depicts mean heart rate Pre and Post PR and EMS. PR mean heart rate decreased after the 6-minute recovery by 10% (11.5 bpm), while EMS mean heart rate decreased only by 2% (2.0 bpm). Data from 4 subjects was analyzed from the PR session because of an outlier.

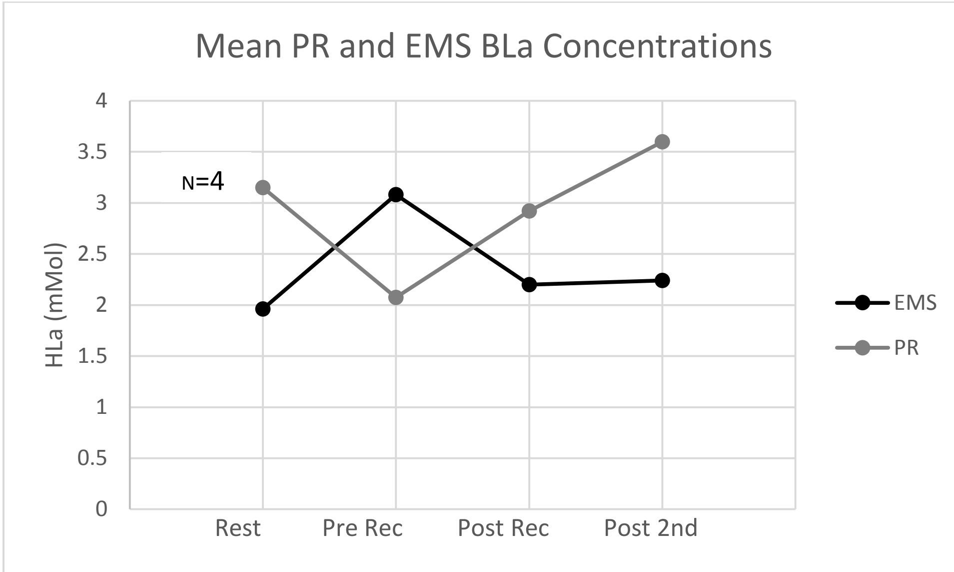

Figure 6: Mean PR and EMS HLa Concentrations

Figure 6 depicts mean HLa concentrations during rest, pre-recovery, post-recovery, and post 2nd inning of pitching. Mean PR HLa concentrations increased 40% (0.85 mMol) from pre-recovery to post-recovery. Mean EMS concentrations decreased 29% (0.88 mMol) from pre-recovery to post-recovery. Data from 4 subjects (n=4) was analyzed from the PR session because of an outlier.

Table 3. 1-RM Squat Compared to Highest Fastball Velocity

Subjects	1RM Back Squat (kg)	Highest FB Velo (mph)
P1	165.2	84
P2	151.6	84
P3	144.8	75
P4	142.5	82
P5	122.2	86

Table 3 depicts each subjects 1-Repetition Maximum (1-RM) back squat and each subjects' highest recorded fastball velocity. P5 recorded the highest fastball velocity at

86mph, while also recording the lowest 1-RM back squat value at 122.2kg. P1 and P2 recorded the second highest fastball velocities at 84mph, and both also recorded the two highest back squat values (P1=165.2, P2=151.6).

CHAPTER 5: DISCUSSION, CONCLUSION, FUTURE RECOMMENDATIONS

The purpose of this study was to describe which recovery method may better sustain velocity, spin rate, release height, and accuracy. Because the time a pitcher has to rest between innings constantly varies, it is essential to find a recovery method that best decreases fatigue and maintains performance measurables (i.e. velocity, spin rate) throughout a game. This chapter will present a discussion, conclusion and future recommendations.

Discussion

An important aspect of pitching that has been shown to be influenced by fatigue is accuracy. An increase in fatigue can lead to a decrease in sensorimotor function (Warren et al., 2015). From a pitching perspective, a loss in sensorimotor function could affect the amount of balls and strikes thrown in a pitching performance. The accuracy of pitches was totaled for both PR and EMS sessions, and then grouped into pre-recovery and post-recovery groups (table 2). The results show that 4% less strikes were thrown after PR was performed, compared to 21.5% less strikes when EMS was administered. Snyder, 2013 had results that showed EMS, not PR, being the recovery method that better maintained strikes thrown across multiple innings of recovery. This is theorized to be because of EMS' ability to better clear lactate than PR, subsequently decreasing fatigue. It is believed that the present study showed a greater decrease in accuracy after EMS because of the small number of subjects, and the limit of only 2 simulated innings thrown (30 pitches). With more pitches thrown per subject, and additionally more subjects, there may be a difference in which recovery method would better maintain accuracy across innings.

Results suggest that EMS may better sustain velocity during performance but may also reduce spin rate. Figure 1 shows mean fastball velocity pre-recovery to post-recovery for EMS increasing 1.1 mph (1.4%), while mean velocity for PR decreased 0.8 mph (8%). On the other hand, in figure 2, mean spin rate decreased 1.1% (1815rpm to 1794rpm) after EMS, and increased 2% (1866rpm to 1903rpm) after PR. Velocity may have been maintained better during the EMS session because of an overall larger decrease in mean HLa concentrations after EMS, when compared to PR. Mean HLa concentrations decreased 29% (.88mmol) post-EMS recovery, and actually increased 40% (.85mmol) post-PR (figure 6). However, only data from 4 of the 5 subjects were analyzed for PR HLa concentrations because of a present outlier. This decrease in HLa for EMS recovery is consistent with previous research shown by Warren et al. 2015, where EMS showed larger decreases in post-recovery HLa when compared to active recovery (AR) and PR. Larger decreases in HLa during the EMS recovery method are understandable because of the promotion of new blood flow to the electrically stimulated areas, which causes HLa to clear more rapidly. Because of the clear link between fatigue and performance, and an increase in HLa corresponding to an increase in fatigue, higher HLa levels may reduce pitching measurables like velocity. Because EMS was able to clear HLa more effectively than PR, subjects were able to maintain velocity. It is important to note that one pitching measurable that did not change after PR, and changed only minimally (.02) after EMS was mean release height (figure 3). Research by Whiteside et al.2016 demonstrated that release height did not decrease until the 6th inning in a random selection of MLB pitchers across a 9-inning pitching performance. It is theorized that because the subjects were only required to throw two simulated innings per recovery session in this study, no decrease in mean release height was found.

Although velocity was found to decrease less after EMS than PR, the subjects' mean pitch velocities were significantly less on the EMS testing session day when compared to the PR testing session day. The mean velocity for the first simulated inning was 76.1mph for the PR session, and was only 73mph for the EMS session. The second simulated inning for PR showed a decrease of 1.1mph with a mean velocity of 75mph while the second inning for EMS showed a decrease of only 0.2mph with a mean velocity of 72.8mph. The apparent difference in velocity could potentially be the reason behind a shown decrease in spin rate during the EMS protocol, and in increase in spin rate during the PR protocol (figure 2). This difference of 3.1mph on testing days could be multifactorial, but one greater possibility is noncompliance to preconditions i.e. effort.

All subjects were told to throw their simulated innings at “game speed”, and many pitchers velocities decreased from the PR session to the EMS session. For future recommendations, phrases like “Throw at 95% of your best pitch” should be used, because it has shown to effective in pitching research (Warren et.al, 2015).

Mean local and overall RPE (pre-recovery and post-recovery) barely changed (figure 4). The EMS session reported a mean decrease in overall/local RPE by 0.2 after recovery, while the PR session reported a mean increase in local RPE of 0.2 and no change in overall RPE (figure 4). Because the subject amount was only 5 pitchers, it would be difficult to see a true subsequent change in RPE across various recovery methods. This is comparative to a study done by Snyder, 2013 on the effects of recovery methods on collegiate pitching performance. Snyder found no significant difference for overall and local RPE across various recovery methods (Snyder, 2013).

Mean heart rate pre-recovery to post-recovery exhibited one of the largest changes across recovery methods. After PR, mean heart rate decreased 10% (11.5bpm), compared to after EMS when heart rate decreased only by 2% (2.0 bpm). This is not comparative to research done by Warren et al. 2015. Warren showed no change in mean heart rate when comparing EMS and PR (both measures decreased by 29%). One possible explanation for the larger decrease in heart rate from PR to EMS is the difference in post-pitching heart rate values from subjects on the different testing sessions. When subjects P1 and P2 finished their first simulated inning on their PR testing session, they reported post-pitching heart rates of 101bpm and 128bpm, respectively. After recovery, their heart rates decreased to 83bpm and 95bpm (-18bpm and -33bpm). However, when subjects P1 and P2 finished their first simulated inning on their EMS testing session, they reported post-pitching heart rates of 82bpm and 91bpm, respectively. After recovery, their heart rates increased to 93bpm and 98bpm (+11bpm and +7bpm). With the drastic differences in post-pitching heart rate for the PR and EMS sessions, a larger possible decrease in post-recovery heart rate was to be expected.

Lastly, no comparison was shown between max fastball velocity and 1-RM back squat. There ae many factors that go into allowing a pitcher to throw hard, so basing high velocity off of one (like 1-RM back squat) did not turn out feasible. Further studies with EMG analysis may be better to show muscle recruitment patterns during pitching and may be pinpoint active musculature better than a 1-RM test comparison.

Future Recommendations

The number of simulated innings pitched during this study was 2 per recovery session, with a total of 15 pitches thrown each inning. Further studies with more innings thrown, closer to 6-9, should elicit greater differences in HLa, spin rate, release height, accuracy, and many other variables tested. Also, data was collected towards the end of the subjects Fall baseball season. For more accurate/valid results, having testing sessions held in the subjects competitive Spring season may increase variables like accuracy and velocity. In terms of data collection, multiple errors were reported when using the Rapsodo Pitching Unit for pitch tracking (collecting spin rate & release height). Many spin rates and release heights never registered for multiple pitches per subject, so looking at comparisons between individual data became unreliable. With the amount of pitches that were subsequently “missed” by the Rapsodo Pitching Unit, each subject’s off-speed pitches that were thrown i.e. sliders, curveballs, changeups had to be omitted from data reporting purposes. The only pitch type that was able to be used for the purposes of this study was the fastball, because of the higher number that was able to be recorded for each subject. In the future, multiple weeks of possible testing sessions would be available in case such errors were to occur again.

Lastly, the number of type of pitches thrown per subject was not consistent in this study. The subjects used these testing sessions as their “bullpens” to prepare for weekend competitions in their Fall season, meaning the number of pitch types was dictated by their respective pitching coach. In one aspect, having a different amount of pitch types makes the present study more game specific, and allows researchers the ability to observe and collect data from subjects in the closest “in-game” like scenario. However, this also made the present study impossible to compare subject to subject. For future studies the number of pitch types being thrown should remain consistent across all subjects. It would be easiest to make a script that all subjects had to follow, which would make results more valid.

CONCLUSION

Despite limitations, this study shows importance to further investigate in-game recovery methods for pitchers. Increases in pitching injuries over the past two decades in baseball has made research on finding an optimal in-game recovery method a necessity. This study does not show favor of one recovery method over another in all aspects of pitching performance (velocity, spin rate, accuracy). However, further research involving EMS and PR could be potentially show one method as an optimal recovery modality.

APPENDICES

APPENDIX A IRB FORM

APPENDIX B INFORMED CONSENT FORM

Informed Consent for Scientific Study

Title of Investigation: The Effects of Two Recovery Methods on Physiological and Performance Factors in NCAA Division II Baseball Pitchers.

Principle Investigator: Brandon Snyder

Overview of Study

Understanding fatigue is extremely important when determining continuation of competition in all sport athletes, especially in baseball pitchers. This fatigue may be able to dissipate with adequate rest between innings, but the average rest varies drastically because of unpredictability in game situations. Current research varies support between multiple methods of recovery, but the two this study will focus on is Passive Recovery (PR), and Electro muscular Stimulation (EMS). Along with the necessity of maintaining velocity during games for pitchers comes the need to maintain other performance factors (i.e. Spin Rate, Spin Direction, Release Height, Vertical and Horizontal Break). The Rapsodo Pitching Unit allows researchers to track such performance measurables and has been used by numerous professional baseball organizations to monitor and track their pitcher's progress. There has not been a study to date that has combined the performance measurables recorded from the Rapsodo Pitching Unit with different between inning recovery methods. Therefore the purpose of this study is to investigate the effects of two between inning recovery methods on pitching performance in male NCAA division II baseball pitchers.

Testing Sessions

There will be 2 total testing sessions during this study, and they will occur in the Arena of Koehler Fieldhouse located on the campus of East Stroudsburg University of Pennsylvania. The testing sessions will occur 1 week apart (7 days) and will follow the subsequent format:

<u>Session 1:</u> Electrical Muscular Stimulation

Subjects weight and height will be recorded 15 minutes prior to their individual testing session. Polar heart rate monitors will then be placed along the distal aspect of the subject's sternum, and resting heart rate will be recorded. After heart rate is recorded, subject's resting BLa will be taken from their non-dominant hand via lancet. BLa will be analyzed using a Lactate Pro Analyzer. Resting local and overall RPE will then be acquired via the Borg RPE Scale (6-20). After all resting measurements are recorded, subject's will warmup and start to throw. Subject's will throw 5 warmup pitches prior to their first simulated inning. The first inning consists of 15 pitches, where pitch type will be dictated by the East Stroudsburg University pitching coach for each subject. After the 15^{th} pitch is thrown, HLa, RPE, and heart rate are taken again. The subject will then undergo electrical muscular stimulation (EMS) for 6 minutes, with electrodes being placed on the anterior and posterior aspect of the throwing shoulder. After the 6-minute recovery, HLa, RPE, and heart rate are recorded again. The second simulated inning will then commence, and 15 more pitches will be thrown. After the 15^{th} pitch, HLa, RPE, and heart rate will be recorded for a final time. During all 30 pitches thrown, the Rapsodo Pitching Unit will be recording velocity, spin rate, and release height. Catcher's will be recording accuracy.

<u>Session 2:</u> Passive Recovery

Session 2 is the exact same testing procedure as Session 1, except the 6-minute recovery protocol is Passive Recovery (PR) instead of EMS. The PR protocol calls for subjects to sit in a chair with a jacket on for 6 minutes.

As a collegiate pitcher, the volume of throwing associated with this study should raise little possibilities of musculoskeletal injuries. All individual information and will remain anonymous. The data collected from this study will be used for presentations with the possibility of scientific publications. You may withdraw from this study at any time. Any additional questions before signing this consent form can be directed to Brandon Snyder.

If any additional questions arise during or after the study, please contact Brandon Snyder at:

Email: bsnyder12@esu.edu

YOU ARE NOW MAKING A DECISION ON WHETHER OR NOT TO PARTICIPATE IN THIS STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED AND WISH TO PARTICIPATE IN THIS STUDY.

I have read and understood the above explanation of the purpose and procedures for this study and agree to participate. I also understand that I am free to withdraw my consent at any time.

____

PRINT NAME

__________________________ __________________________ ____________

SIGNATURE WITNESS SIGNATURE DATE

APPENDIX C PAR-Q+

2019 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ______	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ______	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION

If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

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11-01-2018

APPENDIX D BORG RPE SCALE

Rating	Perceived Exertion
6	No exertion
7	Extremely light
8	
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

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