Summer 2020

The Impact of a Division I Volleyball Season on Jumping Performance

Joshua R. Pascal

THE IMPACT OF A DIVISION I VOLLEYBALL SEASON ON JUMPING PERFORMANCE

by

JOSHUA PASCAL

(Under the Direction of Barry Munkasy)

ABSTRACT

Previous research has been conducted on different performance metrics in collegiate athletes in various sports, including volleyball. These metrics include strength, speed, power output, and jump height. However, little research has examined changes on seasonal jumping performance in volleyball athletes on a weekly basis. **Purpose:** To examine how Division I Volleyball jumping performance is affected by a competitive season. **Methods:** 11 female volleyball athletes from one NCAA Division I institution wore VERT sensors during practices for the entire 15-week competitive season. The athletes also completed countermovement Jump Mat testing on the first practice of the week, with the exception of 2 weeks, throughout the competitive season. Team averages were calculated according to period of the season for variables from the VERT sensors and the Jump Mat. **Results:** A significant difference between total number of jumps was found between preseason and the 1st half of conference play ($p=0.003$). No other significant differences were found in total jumps over 50.8 cm, average jump height, average highest overall jump, or countermovement jump height when comparing the periods of the season. **Conclusion:** The results indicate that jumping performance does not significantly increase or decrease over the course of an NCAA Division I volleyball season. This suggests that these volleyball athletes were able to sustain jumping performance throughout the competitive season.

INDEX WORDS: Jumping performance, Volleyball, Season

THE IMPACT OF A DIVISION I VOLLEYBALL SEASON ON JUMPING PERFORMANCE

by

JOSHUA PASCAL

B.S., Winthrop University, 2018

A Thesis Submitted to the Graduate Faculty of Georgia Southern University in Partial

Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

THE IMPACT OF A DIVISION I VOLLEYBALL SEASON ON JUMPING PERFORMANCE

by

JOSHUA PASCAL

Major Professor: Barry Munkasy
Committee: Stephen Rossi
Samuel Wilson

Electronic Version Approved:
July 2020

DEDICATION

My thesis is dedicated to my parents, Dan and Ina, who was always given me unconditional love and inspiration. They have always supported my decisions and have made me the person I am today. I would also like to thank my brother, Daniel, and my sister, Kia, for consistently pushing me and reminding me to never settle in life. I am grateful for the life lessons they have provided me with.

Next, I would like to dedicate this to my grandfather and my aunts, Deloris and Holly, for providing a source of inspiration and setting an example of striving for excellence in my career and any future endeavors.

Lastly, I would like to thank my close friends, Aaron, John, Kori, DeAnthony, DeShaun, Matt, Briana, and Vincent. They have given me endless laughter throughout the years and have always offered great advice and knowledge on different situations whenever I needed it.

ACKNOWLEDGMENTS

I would like to acknowledge my thesis chair and boss, Dr. Barry Munkasy, for his patience and commitment to helping me become the leader and researcher that I have become in my time at Georgia Southern. And I would like to thank him for giving me the opportunity to work at the Biomechanics Lab as a Graduate Research Assistant.

Next, I would like to thank my thesis committee, Dr. Stephen Rossi and Dr. Samuel Wilson, for the many hours dedicated to helping me. I would also like to acknowledge Dr. Siekirk for his guidance through the statistical analysis and other guidance he has provided me over the last 2 years. Also, I would like to thank Dr. Jessica Mutchler for her much needed emotional support and encouragement whenever I needed it.

Lastly, I would like to acknowledge the Georgia Southern University Volleyball coaching staff, managers, and athletes for allowing me to work with the team for my 2 years at the university. I thoroughly enjoyed the experience and memories created with the Volleyball program.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The impact of a NCAA Division I competitive season on body composition, mental health, as well as athletic performance in student-athletes has been examined in previous research. Previous studies have focused on changes in body composition associated with many sports. For example, research has indicated that body fat percentage, total fat mass, total lean mass, as well as total mass are all susceptible to increase in Division I men's soccer athletes over the course of a competitive season (Silvestre et al., 2006). Among football athletes, percent body fat may increase while weight and lean mass decrease during the season (Binkley, Daughters, Weidauer & Vukovich, 2015). In Division I female athletes, results vary across sports. Basketball athletes are prone to a significant decrease in total mass while swimming and track athletes may experience a significant decrease in fat mass and body fat percentage (Stanforth, Crim, Stanforth & Stults-Kolehmainen, 2014). Female soccer athletes, may either experience a significant loss in lean mass (Minett, Binkley, Weidauer & Specker, 2017) or no significant changes at all (Stanforth, Crim, Stanforth & Stults-Kolehmainen, 2014).

Previous research has been conducted on fatigue, recovery, and readiness in athletes during a competitive season. Among rugby athletes, countermovement jump (CMJ) performance was found to be significantly lower the day after a match when compared to baseline performance (Twist, Waldron, Highton, Burt & Daniels, 2012). Another study on rugby athletes concluded that CMJ performance is significantly lower than baseline values up to 48 hours after the conclusion of a match during a competitive season (McLean, Coutts, Kelly, McGuigan & Cormack, 2010). The same study also indicated that CMJ performance returned to baseline levels within four days after a match. In soccer athletes, total high-intensity running distance and perceived ratings of fatigue, muscle soreness, and sleep quality were measured during an in-season competitive phase. Results indicated that day-to-day total high-intensity running distance correlated with perceived fatigue, soreness, and sleep quality (Thorpe, Strudwick, Buchheit, Atkinson, Drust, & Gregson, 2015). The results from a study conducted on collegiate swimmers indicated high cumulative physiological fatigue across a 23-week season. (Kennedy, Tamminen & Holt, 2013). Other literature has examined the impact of a season from a psychological perspective. Weeks of high academic stress have been linked to increased injury and illness rate (Mann, Bryant, Johnstone, Ivey & Sayer, 2016). Academic performance has been shown to decline for athletes who are in the midst of their competitive season compared to off-season, with football, baseball, and softball athletes experiencing the greatest negative impact (Scott, Paskus, Miranda, Petr & McArdle, 2008). McAllister et al., (2012) studied how one season of head impacts can affect cognitive performance in collegiate contact sport athletes. This study concluded that repetitive head impacts may have a negative impact on learning capabilities for some athletes. Social support and negative social interactions have been shown to influence burnout and well-being among Division I athletes over the course of a season (DeFreese & Smith, 2014). While previous literature has focused on the influence of a Division I season on athletes from a variety of perspectives, it is crucial to continue to examine how athletic performance may be altered over the course of a season in order to maximize and sustain athlete performance.

Changes in conditioning over the course of a season among collegiate athletes have been evaluated using preseason and postseason testing. A study that evaluated power output and fatigue in Division I men’s hockey athletes during a repeated sprint test indicated that mean power was significantly higher in the preseason for the first, second, fourth, and fifth sprint (five total sprints) when compared to the postseason (Laurent, Fullenkamp, Morgan & Fischer, 2014). Sprint and vertical jump performance was measured in men's soccer athletes and no significant differences were found between preseason and postseason (Silverstre et al., 2006). Suggesting a decline in muscular strength during a competitive season, back squat and bench press strength in collegiate wrestlers was found to be significantly lower at midseason than pre- and post-season (Schmidt, Piencikowski & Vandervest, 2005). In addition to the various studies conducted on Division I sports; further examination needs to be conducted to understand the influence of a intercollegiate season on jumping performance.

Vertical jump performance in volleyball has been studied previously. Volleyball athletes jump higher than track and field, soccer, handball, basketball, and rowing athletes (Kollias, Panoutsakopoulos & Papaiakovou, 2004). The relative depth jump has been shown to be the best predictor for relative spike jump performance in volleyball (Sheppard et al., 2008). Links between flexibility and vertical jump approach have indicated that female volleyball athletes with less hip flexibility have better jump performances (Lee, Etnyre, Poindexter, Sokol & Toon, 1989). While jumping performance in volleyball has been examined, no literature was found that examined average jump height, the total number of jumps, total jumps over 50.8 cm, highest overall jump and jump mat performance during practices. A decline in performance in any of these variables could be indicative of fatigue (Chappell et al., 2005; Watkins et al., 2017).

In addition to jumping performance, various other performance measures have been examined in volleyball athletes over the course of a competitive season. Jump spike ball speed and standing spike ball speed both increase throughout the season by 2.3% and 0.4%, respectively (Valades & Palao, 2015). While general strength and power has been found to increase during a season, contrary to what was found in the previous study, jump spike ball speed did not increase (Valades, Palao, Aunsolo, and Urena, 2016). A number of studies have investigated injury risk as well as common injury types during a volleyball season (Malliaras, Cook & Kent, 2006; Malliaras, Cook & Kent, 2007; Reeser et al., 2010; Verhagen, van der Beek, Bouter, Bahr & Van Mechelen, 2004; Agel, Palmieri-Smith, Dick, Wojtys & Marshall, 2007). Volleyball athletes with reduced ankle dorsiflexion range of motion are at an increased risk of patellar tendinopathy (Malliaras, Cook & Kent, 2006). In male volleyball athletes, those with waist girth greater than 83 cm are at a greater risk for developing patellar tendinopathy (Malliaras, Cook & Kent, 2007). Regarding shoulder injuries, attackers and "jump servers" are more likely to experience shoulder issues than defensive specialists and "float servers" (Reeser et al., 2010). Common volleyball injuries include ankle sprains and overuse injuries to the shoulder and back with ankle injuries being the most common (Verhagen, van der Beek, Bouter, Bahr & Van Mechelen, 2004; Agel, Palmieri-Smith, Dick, Wojtys & Marshall, 2007). Over the course of a season a resistance training program may lead to an increase in muscle mass, fat-free mass, power, and strength while simultaneously decreasing body fat percentage (Gonzalez-Rave, Arija & Clemente-Suarez, 2011). Many of the studies on volleyball performance are primarily focused on preseason and postseason testing. Little research, however, has been conducted on the weekly influence on volleyball jumping performance during the competitive season.

The purpose of this study was to examine how a Division I Volleyball jumping performance is affected across a competitive season. This study may provide additional insight into monitoring performance to ensure that the cumulative training load is not too high. Also, this study could potentially provide a performance variable to monitor seasonal fatigue.

CHAPTER 2

METHODS

2.1 Participants:

There was a total of 18 volleyball athletes at one NCAA Division I institution who volunteered for the study. However, only 11 were included in the study. All participants were members of the Georgia Southern University NCAA Volleyball team. All athletes' data were de-identified during processing, analysis, and interpretation to protect athlete privacy. As a normal part of practice, athletes wore the VERT sensors (VERT, Fort Lauderdale, FL) and Jump Mat (Probotics Inc, Huntsville, AL) testing was performed to monitor fatigue and performance. The researchers were provided access to the data after obtaining permission from each athlete. This study was approved by the institutional review board (Institutional Review Board: H18054).

Table 1: Participant Demographics

Position	Number	Height (range)	Age (range)
All Athletes	11	181 ± 7.5 (167.6 - 190.5)	19.7 ± 0.9 (18-21)
Back Row	2	172.7 ± 5.1 (167.6 - 177.8)	19.5 ± 0.5 (19-20)
Front Row	9	183.2 ± 6.6 (170.2 - 190.5)	19.7 ± 1.0 (18-21)

2.2 Protocol:

The study was designed to analyze jumping performance across a Division I volleyball competitive season. The Jump Mat was used in the study to assess maximal CMJ height performed by the athletes. VERT sensors were used to track various kinematic variables. Data collection lasted for 15 total weeks, starting from the first day of preseason practice through the final day of the competitive season. The data were evaluated and grouped together according to the period of the season. The periods of the season were preseason (PS), in-season non-conference (ISNC), 1st half of conference play (ISC1), and 2nd half of conference play (ISC2).

2.3 Collection:

Jump Mat testing was conducted on the first practice of the week with the exception of two weeks when testing was conducted on the second practice of the week. Permission to conduct the testing was obtained from the head coach before practice to ensure that testing would not interfere with or negatively impact the practice. Athletes jumped prior to (VERT, Jump Mat) and during practice (VERT). The Jump Mat measured time in the air via an electronic switch mat to a handheld monitor from the instant of takeoff to the instant of landing. Jump height was then calculated from the measured flight time. All jump mat testing consisted of an arm swing CMJ. Each athlete lined up in random order to jump and land on the mat. Each jump height was recorded with a corresponding identifier. VERT sensors were worn during practices starting from the first day of preseason through the final day of the season for a total of 15 weeks. The sensors are inertial measurement units (IMUs) with a 3-axis accelerometer and 3-axis gyroscope. Additionally, the sensors quantified vertical displacement through the use of an algorithm. The sensors were placed inside of the VERT Velcro strap and the straps were then placed around the lower lumbar region of the vertebrae underneath the spandex to minimize excess movement. Data were stored on the VERT sensor, downloaded to an IPad, and after practice were uploaded onto the VERT online database for storage.

2.4 Variables:

The variables from VERT for analysis were from practices and included the total number of jumps, average jump height, total high jumps (jumps of 50.8 cm or more), and highest overall jump. All variables were measured in centimeters (cm). VERT sensors have been validated as a tool for measuring jump height and jump count when compared to 3-D motion analysis (MacDonald, Bahr, Baltich, Whittaker & Meeuwisse, 2017). Total high jumps and highest overall jump were included to provide additional measures of any significant changes in jump performance during the season. The CMJ height recorded from the Jump Mat was also analyzed. The Jump Mat has been validated as a tool for measuring jump height when compared to a Vertec ($r = 0.967$) (Leard et al., 2007).

2.5 Processing:

Data from the 2019 preseason and season were downloaded from the VERT online database as Microsoft Excel spreadsheets (Microsoft, Redmond, WA). The data were categorized and grouped together according to the four periods of the season (PS, ISNC, ISC1, and ISC2). All practices were used which allowed for data from all 4 periods. Team averages were calculated for all variables for the period.

2.6 Statistical Analysis:

All statistical analyses were performed in SPSS Version 25 (IBM Corporation, Armonk, NY). A Repeated Measures ANOVA was utilized to compare the means of the different variables over the four periods of data collection. Variables included were the total number of jumps, average jump height, total high jumps, and highest overall jump from the VERT sensors and CMJ height from the Jump Mat. Alpha level was set to $\alpha \leq 0.05$

CHAPTER 3

RESULTS

Results

The mean and standard deviation values for all performance measures as well as data for all four periods of the competitive season can be found on tables 2, 3, 4, 5, and 6 and figures 1, 2, 3, 4, and 5. The performance measures were the total number of jumps, number of jumps over50.8 cm, average jump height, average highest jump, and CMJ height on the Jump Mat.

Total Number of Jumps

There was a significant difference in the total number of jumps during practice between preseason and the 1st half of conference play (PS = 88.7 ± 46.4, ISC1 = 61.6 ± 41.7, p-value = 0.003). There were no other significant differences found for the total number of jumps.

Average Jump Height, Total Jumps over 50.8 cm, Average Highest Jump, and Jump Mat

Comparisons of average jump height, total jumps over 50.8 cm, average highest jump, as well as jump mat jump height across periods of the season yielded no significant results. Therefore, the hypothesis was that there would be no significant difference in jumping performance must be accepted for these variables. Data on tables 3 and 4 show that both average jump height and average highest jump were greatest during the 2nd half of conference play, which was the final period of the season.

Table 2. Means and standard deviations of total number of jumps during all periods

Total Number of Jumps			P-value				
Period	Mean	Standard Deviation		PS	ISNC	ISC1	ISC2
PS	88.7	46.4	PS	x	0.164	0.003*	0.409
ISNC	73.4	45.4	ISNC	0.164	x	0.525	1
ISC1	61.7	41.7	ISC1	0.003	0.525	x	0.684
ISC2	70.5	40.1	ISC2	0.409	1	0.684	x

Legend: Preseason (PS), In-season non-conference (ISNC), 1st half of conference play (ISC1), 2nd half of conference play (ISC2). "X" depicts no interaction between variables. Significance (p-value) under 0.05 noted by*

Table 3. Means and standard deviations of number of jumps over 50.8 cm during all periods

Jumps over 50.8 cm			P-value				
Period	Mean	Standard Deviation		PS	ISNC	ISC1	ISC2
PS	9.1	10.6	PS	x	1	1	1
ISNC	7.5	7.4	ISNC	1	x	1	1
ISC1	6.7	5.8	ISC1	1	1	x	1
ISC2	8.5	5.6	ISC2	1	1	1	x

Legend: Preseason (PS), In-season non-conference (ISNC), 1st half of conference play (ISC1), 2nd half of conference play (ISC2). "X" depicts no interaction between variables

Table 4. Means and standard deviations of average jump height during all periods

Average Jump Height (cm)			P-value				
Period	Mean	Standard Deviation		PS	ISNC	ISC1	ISC2
PS	37.5	3.3	PS	x	1	1	0.221
ISNC	37.1	6.7	ISNC	1	x	1	1
ISC1	37.8	5.5	ISC1	1	1	x	1
ISC2	39.6	2.9	ISC2	0.221	1	1	x

Legend: Preseason (PS), In-season non-conference (ISNC), 1st half of conference play (ISC1), 2nd half of conference play (ISC2), centimeters (cm). "X" depicts no interaction between variables

Table 5. Means and standard deviations of average highest jump during all periods

Average Highest Jump (cm)			P-value				
Period	Mean	Standard Deviation		PS	ISNC	ISC1	ISC2
PS	56.1	7.8	PS	x	1	1	1
ISNC	58.2	10.2	ISNC	1	x	1	1
ISC1	58.2	12.3	ISC1	1	1	x	1
ISC2	59.9	8.4	ISC2	1	1	1	x

Legend: Preseason (PS), In-season non-conference (ISNC), 1st half of conference play (ISC1), 2nd half of conference play (ISC2), centimeters (cm). "X" depicts no interaction between variables

Table 6. Means and standard deviations of jump mat during three of the four periods

Jump Mat (cm)			P-value			
Period	Mean	Standard Deviation		ISNC	ISC1	ISC2
ISNC	55.2	6.4	ISNC	X	1	1
ISC1	54.9	6.4	ISC1	1	x	1
ISC2	54.9	6.5	ISC2	1	1	x

Legend: In-season non-conference (ISNC), 1st half of conference play (ISC1), 2nd half of conference play (ISC2), centimeters (cm). "X" depicts no interaction between variables

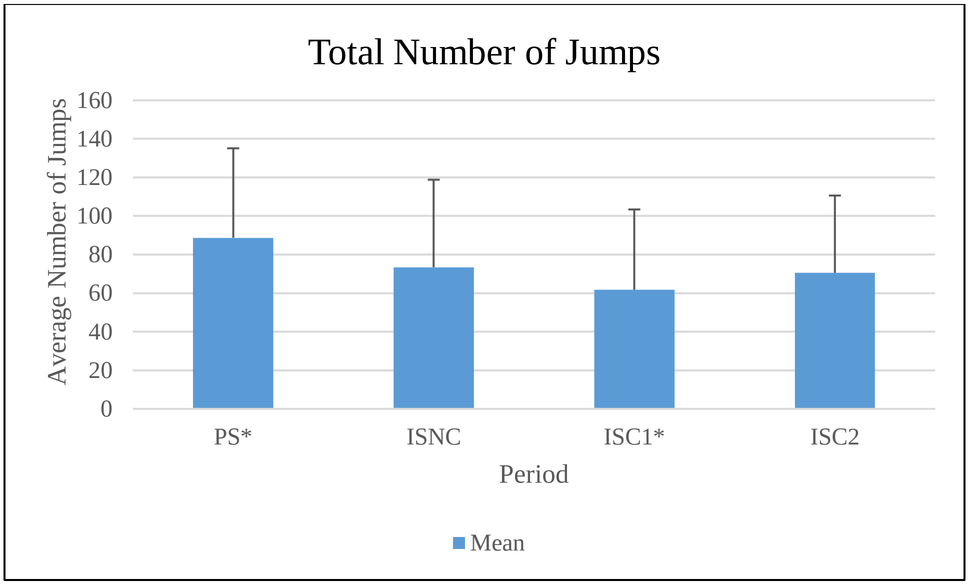

Figure 1. Total number of jumps per period. Significant difference found between preseason (PS) and 1st half of conference play (ISC1) (p-value = 0.003). * denotes significance

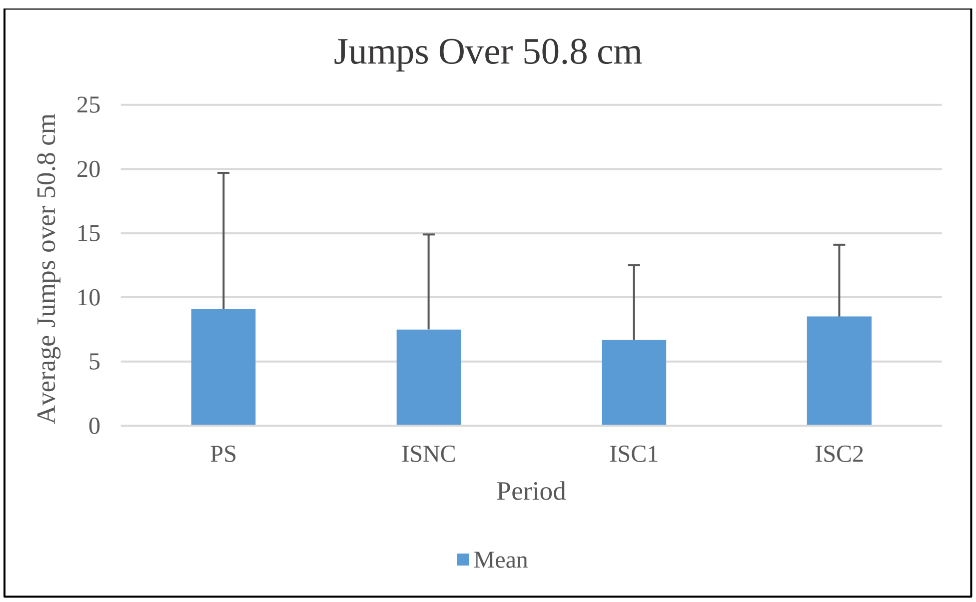

Figure 2. Total number of jumps over 50.8 cm per period. No significant differences found

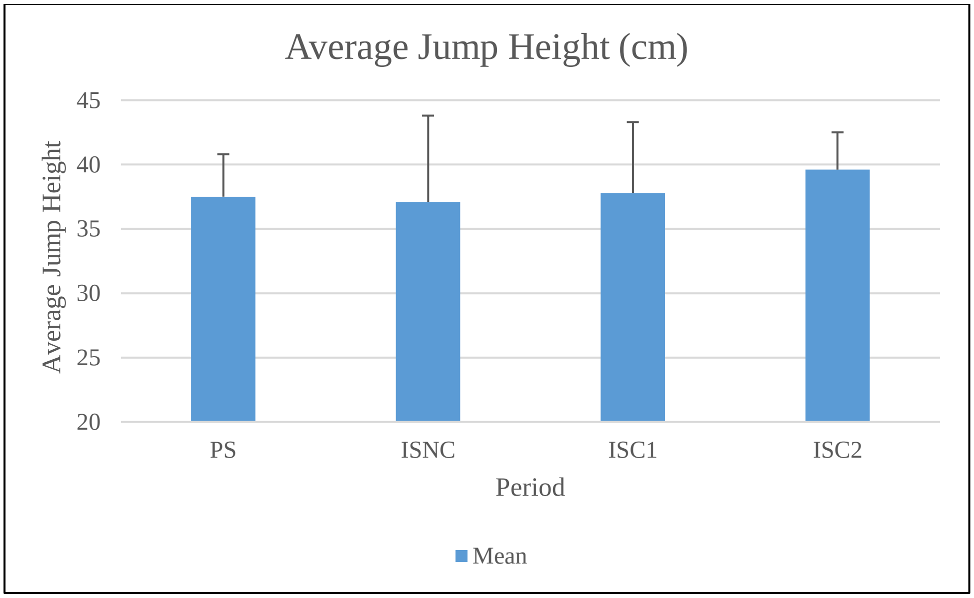

Figure 3. Average jump height per period. No significant differences found

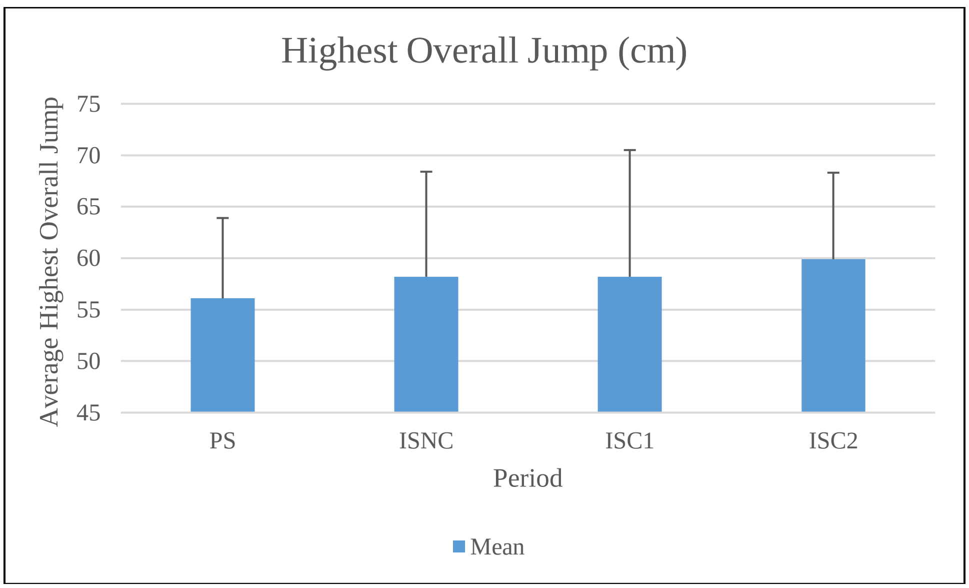

Figure 4. Average highest overall jump per period. No significant differences found

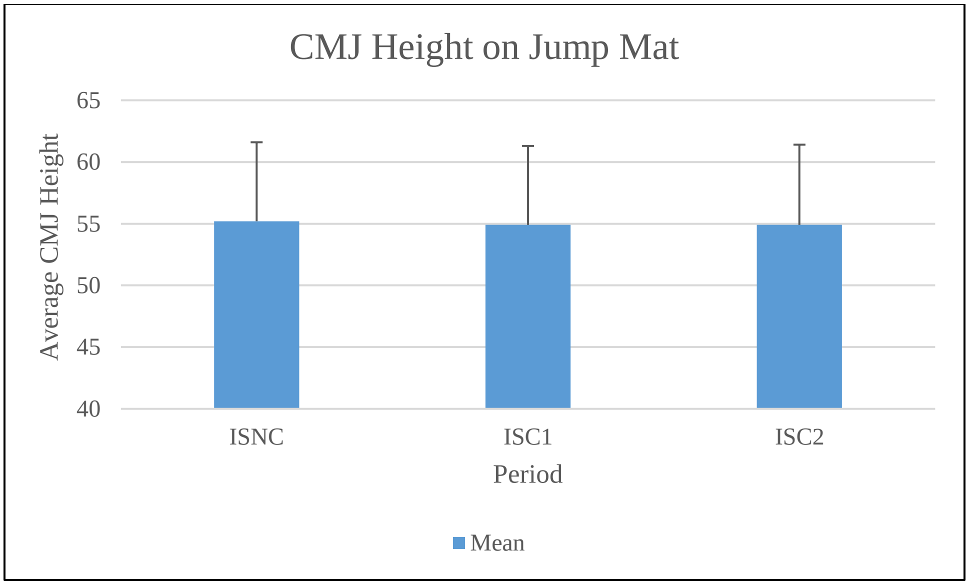

Figure 5. Average CMJ height on jump mat per period. No significant differences found

CHAPTER 4

DISCUSSION

The purpose of this study was to examine how a Division I Volleyball season impacts jumping performance. It was hypothesized that there would be no significant difference in jumping performance over the course of the season. This study may provide additional insight into various strategies that can be utilized to monitor performance. Analyzing the results provided information on an athlete's ability to maintain jumping performance as well as indicated if performance declines during specific periods of the season. Using this data can assist the coaching staff in designing the training schedule to allow for adequate rest throughout the competitive season.

Total Number of Jumps

There was a significant difference in the total number of jumps in the preseason and the 1st half of conference play. Because of this, the hypothesis was rejected. Cumulative training loads are expected to be at the highest during the preseason compared to other periods of the season in competitive sports (Gabbett & Domrow, 2007; Jeong, Reilly, Morton, Bae & Drust, 2011). This is because the majority of work in preseason training is aimed towards developing the physiological requirements of the competitive season whereas training sessions in-season are often more focused on tactical strategy and technical skill (Bangsbo, 1994). Although this concept is common, coaches on the collegiate level should be wary of the impact this may have on their student-athletes.

Based on previous research, student-athletes are at the highest risk of injury as well as illness during the preseason due to a sudden increase in training load (Hamlin, Wilkes, Elliot, Lizamore & Kathiravel, 2019). A potential explanation for this link is the concept of “detraining”, the partial or total loss of training adaptations due to inadequate training stimulus which typically begins to occur after four weeks (Mujike & Padilla, 2000). Detraining decreases cardiorespiratory performance as well as muscular performance and this impact becomes greater as more time passes. The decline in muscular performance can lead to strength and flexibility imbalances in the lower extremities which elevates injury risk in female collegiate athletes (Knapik, Bauman, Jones, Harris & Vaughan, 1991). These athletes often return to campus for preseason training after limited training and supervision over their summer break from school. Injury rates were not tracked as a part of this study. However, further examining the team’s injury records and incidence over the course of a few years could indicate which periods of the season pose a higher injury risk. Understanding that athletes are more prone to injury during specific periods of the season will allow coaches and strength and conditioning coaches to structure a practice schedule that minimizes the risk of injury.

Several limitations are present in the study. One is that no athlete participated in all 45 practice sessions throughout the season. Also, only 11 of the 18 athletes on the team were included in the study. 9 of the 11 athletes were front row athletes. Additionally, front row athletes jump more as their positions are spiking and blocking more often. Because of this, the study does not truly represent an entire volleyball team.

Jumps Over 50.8 cm

There was no significant change in the number of jumps over 50.8 cm throughout the competitive season. This suggests that the athletes were able to maintain jumping performance across the different periods of the season. The hypothesis that there would be no significant difference in jumping performance was accepted. Further results indicate that the number of jumps over 50.8 cm was approximately 10% of the total number of jumps. Previous research has not examined the total number of jumps of over a specific height. Additionally, previous research has not explored a minimum threshold regarding percentages of jumps over a specific height. However, a decline in jumping performance could be indicative of fatigue. Monitoring any trends that show a decreased percentage of jumps over a certain height could be beneficial in analyzing progressive fatigue in athletes.

Several limitations are present in this current study. First, no athlete participated in all 45 practice sessions throughout the season. This indicates that the data may not truly indicate an entire competitive season. Also, only 11 of the 18 athletes on the team were included in the study. 9 of the 11 athletes were front row athletes. Because of this, the study does not truly represent an entire volleyball team.

Average Jump Height

There was no significant change in average jump height over the course of the competitive season. This suggests that these volleyball athletes were able to sustain jump height despite training, games, and injuries that may have occurred. The hypothesis that there would be no significant difference in jumping performance was accepted. Although there was no statistical significance in average jump height, it is worth noting that that the greatest average jump height was achieved during the 2nd half of conference play, which was the last period of the season. Examining the differences in values between the four periods and nature of practice during these periods can provide evidence on which practice format may induce fatigue slightly more than other practice formats.

The results of the current study differed from another study that examined jumping performance in women volleyball athletes. Jumping performance significantly increased over the course of the competitive season (González-Ravé, Arija & Clemente-Suarez, 2011). However, these athletes were at the professional level. Future literature on seasonal monitoring should be conducted on athletes at the collegiate level for more comparable results. Additionally, further research should explore differences in athletic performance between class status (Freshman, Sophomore, Junior, or Senior) or playing position.

One limitation of the current study was that no athlete participated in all 45 practice sessions that took place during the season. Because of this, the data may not adequately the average jump height over a season. Next, only 11 of the 18 athletes on the team were included in the study. 9 of the 11 athletes were front row athletes. Therefore, the data is not truly indicative of an entire volleyball team.

Highest Overall Jump

The results of this study suggest that there was no significant change in the highest overall jump across the different periods of the season. This accepts the hypothesis that there would be no significant difference in jumping performance over the course of the season. Previous research has not sought to isolate the single highest jump height achieved during practice. However, previous research has suggested that a decrease in the force of a maximal voluntary contraction is the cause of a decrease in vertical jump height (Skurvydas, Jascaninas & Zachovajevas, 2000). Additionally, fatigue is defined as “any reduction in the maximal capacity to generate force or power output” (Vøllestad, 1997). It can be hypothesized that a significant decrease in the highest overall jump achieved could be indicative of fatigue.

One limitation is that no athlete practiced during all 45 practice sessions during the competitive season. Because of this, the data may not truly represent an entire season of practice sessions. Next, only 11 of the 18 athletes on the team participated in the study. Nine of the athletes played on the front row. Therefore, the population in this study did not represent an entire volleyball team.

Countermovement Jump

There was no significant change in CMJ performance over the course of the season. This indicates that the athletes were able to sustain their CMJ. The hypothesis that there would be no significant difference in jumping performance was accepted. Previous research examining CMJ performance across a competitive season has revealed either no significant difference (Thomas, Mather, Comfort, 2014) or significant improvements (Häkkinen, 1993; Stodden & Galitski, 2010). However, these studies were not conducted on the collegiate women's volleyball population. Future research should explore CMJ in this population.

One limitation is that only 11 of the 18 athletes on the team participated in the study and 9 of the 11 athletes played in the front row. All 18 athletes would be needed to produce results that are truly representative of a Division I volleyball team. Another limitation was that Jump Mat data was not collected during the preseason. Collecting data for all four periods of the season would allow for more complete results when analyzing an entire season. Also, Jump Mat testing was not conducted on the first practice of every week. There were two weeks when the testing occurred in the second practice of the week. Additionally, the CMJ was a clinical measure of jumping performance and did not represent "in-game" conditions as the other variables in the study did. Lastly, the study assumed that the athletes jumped with maximal effort while performing the CMJ on the Jump Mat.

Clinical Significance

While the study yielded very little statistical significance, the results can be used for practical application. As mentioned above, the study suggests that the volleyball athletes were able to sustain jumping performance throughout the four periods of the season. This indicates that the training schedule throughout the season was programmed at an appropriate load that did not induce fatigue. Additionally, the coaching staff can utilize this study as additional support for monitoring athletic performance as well as minimizing fatigue. Monitoring athletic performance can be based on jumping performance, such as this study, or through various other performance measures.

It is important to note, however, that this study only provided data on a handful of performance measures. Data on force plate jumping would offer more detail for monitoring seasonal performance as it would provide a way to analyze power output in the athletes. Also, this study did not include data on the duration of each practice. This would help the researchers understand how the duration of practices could have affected jumping performance. Additionally, the athlete's perception of training load and recovery was not recorded. This could be collected through the use of the Perceived Recovery Score (PRE) before practice and the Rating of Perceived Exertion (RPE) scale after practice. Collecting data on a greater variety of variables would provide more support for effective performance monitoring strategies for coaching staffs.

This study was similar to another study that also monitored volleyball athletes over the course of a competitive season. However, the researchers utilized ball speeds of the standing spike and jumping spike as their performance measures (Valades & Palao, 2015). The study was conducted by taking repeated measures weekly throughout the competitive season. The results indicate that ball speeds of both the standing and jumping spike increase over the course of the competitive season by 0.4% and 2.3%, respectively. While the team average increased, speeds decreased for four out of the ten athletes who participated. This study provides another reliable measure of monitoring seasonal performance as well as highlighting the importance of individualized monitoring to maintain athletic performance.

Assumptions and Limitations

There were several limitations to this study. There were 45 total practices recorded in the study. However, none of the athletes included in the study participated in all 45 practices. Reasons for missed practice include injury and suspension. Another limitation was that only 11 of the 18 athletes on the team were included in the study. This is due to the limited numbers of available VERT sensors. Additionally, nine of the volleyball athletes included in the study played positions on the front row. This was done upon the request of the coaching staff as front row athletes jump more often (blocks and spikes) than back row athletes. A study including an equal mix of front and back row athletes would be truly representative of a volleyball team. The assumption in this study is that the athletes are completing the CMJ on the Jump Mat with maximal effort.

CHAPTER 5

CONCLUSION

The results indicated that jumping performance did not significantly increase or decrease over the course of an NCAA Division I volleyball season. This study shows the viability of utilizing jumping measures to provide objective information to coaches and strength and conditioning coaches to monitor the performance of their volleyball athletes. Monitoring performance will provide insight into the impact of training and overload on the athletes. This current study suggests that the athletes were able to maintain jumping ability throughout the competitive season.

REFERENCES

Agel, J., Palmieri-Smith, R. M., Dick, R., Wojtys, E. M., & Marshall, S. W. (2007). Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988–1989 through 2003–2004. *Journal of athletic training*, *42*(2), 295.

Bangsbo, J. (1994). The physiology of soccer--with special reference to intense intermittent *Acta Physiologica Scandinavica. Supplementum*, *619*, 1-155.

Binkley, T. L., Daughters, S. W., Weidauer, L. A., & Vukovich, M. D. (2015). Changes in body composition in Division I football players over a competitive season and recovery in off season. *The Journal of Strength & Conditioning Research*, *29*(9), 2503-2512.

Chappell, J. D., Herman, D. C., Knight, B. S., Kirkendall, D. T., Garrett, W. E., & Yu, B. (2005). Effect of fatigue on knee kinetics and kinematics in stop-jump tasks. *The American journal of sports medicine*, *33*(7), 1022-1029.

DeFreese, J. D., & Smith, A. L. (2014). Athlete social support, negative social interactions, and psychological health across a competitive sport season. *Journal of sport and exercise psychology*, *36*(6), 619-630.

Gabbett, T. J., & Domrow, N. (2007). Relationships between training load, injury, and fitness in sub-elite collision sport athletes. *Journal of sports sciences*, *25*(13), 1507-1519.

González-Ravé, J. M., Arija, A., & Clemente-Suarez, V. (2011). Seasonal changes in jump performance and body composition in women volleyball players. *The Journal of Strength & Conditioning Research*, *25*(6), 1492-1501.

Häkkinen, K. (1993). Changes in physical fitness profile in female basketball players during the competitive season including explosive type strength training. *The Journal of sports medicine and physical fitness*, *33*(1), 19-26.

Hamlin, M. J., Wilkes, D., Elliot, C. A., Lizamore, C. A., & Kathiravel, Y. (2019). Monitoring training loads and perceived stress in young elite university athletes. *Frontiers in physiology*, *10*, 34.

Jeong, T. S., Reilly, T., Morton, J., Bae, S. W., & Drust, B. (2011). Quantification of the physiological loading of one week of "pre-season" and one week of "in-season" training in professional soccer players. *Journal of sports sciences*, *29*(11), 1161-1166.

Kennedy, M. D., Tamminen, K. A., & Holt, N. L. (2013). Factors that influence fatigue status in Canadian university swimmers. *Journal of sports sciences*, *31*(5), 554-564.

Knapik, J. J., Bauman, C. L., Jones, B. H., Harris, J. M., & Vaughan, L. (1991). Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes. *The American journal of sports medicine*, *19*(1), 76-81.

Kollias, I., Panoutsakopoulos, V., & Papaiakovou, G. (2004). Comparing jumping ability among athletes of various sports: vertical drop jumping from 60 centimeters. *The Journal of Strength & Conditioning Research*, *18*(3), 546-550.

Laurent, C. M., Fullenkamp, A. M., Morgan, A. L., & Fischer, D. A. (2014). Power, fatigue, and recovery changes in national collegiate athletic association division I hockey players across a competitive season. *The Journal of Strength & Conditioning Research*, *28*(12), 3338-3345.

Leard, J. S., Cirillo, M. A., Katsnelson, E., Kimiatek, D. A., Miller, T. W., Trebincevic, K., & Garbalosa, J. C. (2007). Validity of two alternative systems for measuring vertical jump height. *The Journal of Strength & Conditioning Research*, *21*(4), 1296-1299.

Lee, E. J., Etnyre, B. R., Poindexter, H. B., Sokol, D. L., & Toon, T. J. (1989). Flexibility characteristics of elite female and male volleyball players. *The Journal of sports medicine and physical fitness*, *29*(1), 49-51.

MacDonald, K., Bahr, R., Baltich, J., Whittaker, J. L., & Meeuwisse, W. H. (2017). Validation of an inertial measurement unit for the measurement of jump count and height. *Physical Therapy in Sport*, *25*, 15-19.

Malliaras, P., & Cook, J. (2006). Patellar tendons with normal imaging and pain: change in imaging and pain status over a volleyball season. *Clinical journal of sport medicine*, *16*(5), 388-391.

Malliaras, P., Cook, J. L., & Kent, P. (2006). Reduced ankle dorsiflexion range may increase the risk of patellar tendon injury among volleyball players. *Journal of science and medicine in sport*, *9*(4), 304-309.

Malliaras, P., Cook, J. L., & Kent, P. M. (2007). Anthropometric risk factors for patellar tendon injury among volleyball players. *British journal of sports medicine*, *41*(4), 259-263.

Mann, J. B., Bryant, K. R., Johnstone, B., Ivey, P. A., & Sayers, S. P. (2016). Effect of physical and academic stress on illness and injury in division 1 college football players. *The Journal of Strength & Conditioning Research*, *30*(1), 20-25.

McAllister, T. W., Flashman, L. A., Maerlender, A., Greenwald, R. M., Beckwith, J. G., Tosteson, T. D., ... & Grove, M. R. (2012). Cognitive effects of one season of head impacts in a cohort of collegiate contact sport athletes. *Neurology*, *78*(22), 1777-1784.

McLean, B. D., Coutts, A. J., Kelly, V., McGuigan, M. R., & Cormack, S. J. (2010). Neuromuscular, endocrine, and perceptual fatigue responses during different length between-match microcycles in professional rugby league players. *International journal of sports physiology and performance*, *5*(3), 367-383.

Minett, M. M., Binkley, T. B., Weidauer, L. A., & Specker, B. L. (2017). Changes in body composition and bone of female collegiate soccer players through the competitive season and off-season. *Journal of musculoskeletal & neuronal interactions*, *17*(1), 386.

Mujika, I., & Padilla, S. (2000). Detraining: loss of training-induced physiological and performance adaptations. Part I. *Sports Medicine*, *30*(2), 79-87.

Reeser, J. C., Joy, E. A., Porucznik, C. A., Berg, R. L., Colliver, E. B., & Willick, S. E. (2010). Risk factors for volleyball-related shoulder pain and dysfunction. *Pm&r*, *2*(1), 27-36.

Schmidt, W. D., Piencikowski, C. L., & Vandervest, R. E. (2005). Effects of a competitive wrestling season on body composition, strength, and power in National Collegiate Athletic Association Division III college wrestlers. *Journal of Strength and Conditioning Research*, *19*(3), 505.

Scott, B. M., Paskus, T. S., Miranda, M., Petr, T. A., & McArdle, J. J. (2008). In-season vs. out of-season academic performance of college student-athletes. *Journal of Intercollegiate sport*, *1*(2), 202-226.

Sheppard, J. M., Cronin, J. B., Gabbett, T. J., McGuigan, M. R., Etxebarria, N., & Newton, R. U. (2008). Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. *The Journal of Strength & Conditioning Research*, *22*(3), 758-765.

Silvestre, R., Kraemer, W. J., West, C., Judelson, D. A., Spiering, B. A., Vingren, J. L., ... & Maresh, C. M. (2006). Body composition and physical performance during a National Collegiate Athletic Association Division I men's soccer season. *Journal of Strength and Conditioning Research*, *20*(4), 962.

Skurvydas, A., Jascaninas, J., & Zachovajevas, P. (2000). Changes in height of jump, maximal voluntary contraction force and low-frequency fatigue after 100 intermittent or continuous jumps with maximal intensity. *Acta Physiologica Scandinavica*, *169*(1), 55 62.

Stanforth, P. R., Crim, B. N., Stanforth, D., & Stults-Kolehmainen, M. A. (2014). Body composition changes among female NCAA division 1 athletes across the competitive season and over a multiyear time frame. *The Journal of Strength & Conditioning Research*, *28*(2), 300-307.

Stodden, D. F., & Galitski, H. M. (2010). Longitudinal effects of a collegiate strength and conditioning program in American football. *The Journal of Strength & Conditioning Research*, *24*(9), 2300-2308.

Thomas, C., Mather, D., & Comfort, P. (2014). Changes in sprint, change of direction and jump performance during a competitive season in male lacrosse players. *Journal of Athletic Enhancement*, *3*(5), 1-8.

Thorpe, R. T., Strudwick, A. J., Buchheit, M., Atkinson, G., Drust, B., & Gregson, W. (2015). Monitoring fatigue during the in-season competitive phase in elite soccer players. *International journal of sports physiology and performance*, *10*(8), 958-964.

Twist, C., Waldron, M., Highton, J., Burt, D., & Daniels, M. (2012). Neuromuscular, biochemical and perceptual post-match fatigue in professional rugby league forwards and backs. *Journal of Sports Sciences*, *30*(4), 359-367.

Valades, D., & Palao, J. (2015). Monitoring ball speed of the volleyball spike throughout the season for elite womens volleyball players. *J Sport Hum Perf*, *3*(2), 1-11.

Valadés, D., Palao, J. M., Aúnsolo, Á., & Ureña, A. (2016). Correlation between ball speed of the spike and the strength condition of a professional women's volleyball team during the season. *Kinesiology: International journal of fundamental and applied kinesiology*, *48*(1), 87-94.

Verhagen, E. A. L. M., Van der Beek, A. J., Bouter, L. M., Bahr, R. M., & Van Mechelen, W. (2004). A one season prospective cohort study of volleyball injuries. *British journal of sports medicine*, *38*(4), 477-481.

Vøllestad, N. K. (1997). Measurement of human muscle fatigue. *Journal of neuroscience methods*, *74*(2), 219-227.

Watkins, C. M., Barillas, S. R., Wong, M. A., Archer, D. C., Dobbs, I. J., Lockie, R. G., ... & Brown, L. E. (2017). Determination of vertical jump as a measure of neuromuscular readiness and fatigue. *The Journal of Strength & Conditioning Research*, *31*(12), 3305 3310.

APPENDIX A: LIMITATIONS

LIMITATIONS

1. No athletic participated in all 45 practices
2. There were 18 athletes on the team but only 11 included in the study, 9 of which played on the front row
3. Jump Mat testing not conducted the first practice of every week

DELIMITATIONS

1. The study only examined collegiate athletes from one NCAA Division I institution

ASSUMPTIONS

1. Athletes jumped with max effort during the CMJ on the Jump Mat

HYPOTHESIS

It was hypothesized that there would be no difference in jumping performance over the course of the NCAA Division I season.

APPENDIX B: LITERATURE REVIEW

Athletic performance can be influenced by a variety of factors (Blomqvist & Saltin, 1983; Jaric, 2002; Harman, 1993; Udermann, Mayer, Graves, & Murray, 2003) like physical capability, fatigue, and psychological status can be used to predict the success of an individual athlete as well as the team (Worthen & Wade, 1999; Terry, Walrond, & Carron, 1998). For example, athletes subjectively feel more tense, anxious, and fatigued and less confident while playing away games compared to playing at home (Terry, Walrong & Carron, 1998).

Fatigue causes decreases in performance and causes of fatigue are numerous such as accumulation of lactic acid in skeletal muscles, serotonergic activity, and intense exercise (Newsholme, 1987; Allen, Lamb, & Westerblad, 2008). Previous research has cited travel as a cause of fatigue for numerous reasons. These include a shift in the “biological clock” and circadian peak window and jet lag, which cause sleepiness, lethargy, and a decline in mental performance (Manfredini, Manfredini, Fersini, & Conconi, 1998; Comperatore & Krueger, 1990).

In this review of literature, the component of athletic performance, definition and causes of fatigue, the relationship between travel and fatigue, and the impact of jet lag on athletic performance will be discussed. Athletic performance has been evaluated in a plethora of studies yet, there is not a clear cut definition for “athletic performance”. The literature, however, acknowledges that physiological measures and performance can be used as a tool to predict the success of an individual athlete as well as the team. Strength is one of these physiological measures. Strength is defined as the “maximum force or torque developed during a maximal voluntary contraction” (Jaric, 2002). Jaric then goes on to discuss various methods to test strength. These tests are performed under conditions where a single muscle group is in action and the force or torque is recorded. Testing can also include the contraction of multiple muscle groups (Jaric, 2002). In addition to strength, power is another physiological measure in athletic performance and is closely associated with strength. Harman (1993) defines power as "the product of the force exerted on an object and the velocity of the object in the direction in which the force is exerted". In simpler terms, power equals force times velocity. Tests of power include vertical jump, squat jump, and power cleans (Harman, 1993).

Endurance is a third physiological measure to predict athletic performance. It is studied in two ways, cardiovascular (endurance capacity) and muscular endurance. Endurance capacity is defined as "time to exhaustion at submaximal workload levels" while muscular endurance is explained as "the ability to produce work over time or the ability to sustain effort (Blomqvist & Saltin, 1983; Udermann, Mayer, Graves, & Murray, 2003). The Pacer Test, Mile Run/Walk Test, and VO_{2max} Test are all methods used to determine endurance capacity. Muscular endurance can be measured through any test that requires continued repetitions until exhaustion. Lastly, agility can be used as a fourth physiological measure to determine the performance of an athlete. It is defined as "a rapid whole-body movement with change of velocity or direction in response to a stimulus" (Sheppard & Young, 2006). An example of an agile athlete is a football wide receiver. The receiver must be able to run at full speed then cut to change direction while maintaining their speed. Methods of measurement include change of direction tests such as the 5-10-5 Shuttle, T-Test, Shuttle Run Test, and Illinois Test. Strength, power, and agility are all important skills for athletes in any sport to possess. Additionally, endurance (cardiovascular and muscular) allows the athlete to utilize their skills throughout the course of the practice and competition. Athletes who are able to perform at an elite level often are superior in these categories when compared to athletes of the same sport and position.

Overtraining, sometimes referred to as staleness, is defined as a “state of reduced performance in concert to train at customary levels” (Morgan, Brown, Raglin, O’Connor, & Ellickson, 1987). This occurs when athletes train above the optimum level. In other words, the athlete has trained too much without being given an adequate rest period. This occurs frequently in athletes with less training experience because they are not accustomed to training at a certain load level. Their bodies need more time to recover from weekly training than an athlete with more training experience.

Fatigue ties into overtraining because fatigue is defined as “the reduction in the force generating capacity of the neuromuscular system that occurs during sustained activity” (Bigland-Ritchie, Johansson, Lippold, & Woods 1983). As an athlete becomes fatigued during a game or practice, their performance suffers for several reasons. Altered hormonal processes, decreased neuromuscular function and psychomotor speed, and delayed heart rate recovery are all symptoms of fatigue. Regarding an altered hormonal process, this refers to the central fatigue hypothesis which centers around serotonin. Serotonin is a neurotransmitter that has previously been linked to fatigue due to its effects on lethargy, sleepiness, and mood (Newsholme, 1987). The central fatigue hypothesis states that prolonged exercise causes serotonergic activity which then causes lethargy and a decline in motor unit recruitment (Newsholme, 1987).

Neuromuscular function (NMF) refers to the ability to control muscles and make coordinated movements. Muscular fatigue is one factor that can influence NMF. As muscles become more fatigued, there is a decrease in maximal voluntary force as well as an alteration to mechanical movement patterns (Bigland-Ritchie, Johansson, Lippold, & Woods 1983; Sanderson & Black, 2003). On the playing field, this may translate to a decline in jumping ability, slower sprinting, or a decrease in overall strength and control with movements. Other factors that can impact NMF are narcotics, which can impair NMF, and caffeine, which can increase maximal voluntary contraction (Ensrud et al., 2002; Kalmar & Cafarelli, 1999).

One other main cause of fatigue is the accumulation of lactic acid (Allen, Lamb, & Westerblad, 2008). Lactate and H^+ are produced in the muscles during exercise which leads to a decrease in muscle force (Allen, Lamb, & Westerblad, 2008). Repetitive and intense exercise can speed up the rate of lactate and H^+ accumulation and lead to quicker fatiguing of the muscles.

Volleyball is a sport in which both teams are separated by a net and the possession of the ball changes constantly. The playing field is a clearly defined court. Athletes can only venture outside of the boundary lines once the ball has been touched by a teammate. The game has defensive formations and offensive plays. The defense attempts to cover as much of the court as possible and the offense tries to deceive the defense regarding the direction of attack (Allard & Starkes, 1980). Various studies on volleyball performance evaluated sport specific skills such as serves, spikes, kills, blocks, etc. The results suggest that teams who display the better block, dig, setting, and spike performance are more likely to be successful (Eom & Schutz, 1992). Athletes who are better equipped to handle general stress are better able to manage potentially stressful in-game situations and subsequently enhance performance (Crocker, Alderman, Murray, & Smith, 1998). In addition to the game-specific tasks, several studies on strength and conditioning in volleyball athletes have been conducted.

Kutzer (1995) created a training program based on multi-joint and multi-muscle coordination and focused on shoulder, back, and knee integrity to assist in injury prevention. Gadeken (1999) utilized a training program that focused on increasing power and strength using free weights. Other focus points of this training program were improving spike velocity while minimizing rotator cuff injuries and improving agility performance without losing balance or speed. Both programs incorporated multi-joint movements to replicate sport-specific tasks. Creating a training program at the collegiate is a challenge because coaches work with numerous sports for men and women. Also, the class schedule varies from player to player so each player may not have the same availability which can cause training sessions to be rushed. Lastly, the game schedule for an NCAA Division I team requires frequent travel. The Georgia Southern University volleyball team, for example, played games in Minnesota, West Virginia, Louisiana, North Carolina, South Carolina, and Alabama. Collegiate teams of every sport may be required to travel frequently throughout their season.

There are various definitions of travel depending on the context. The Merriam-Webster online dictionary defines travel as “to move or undergo transmission from one place to another” (Gove). In our context, travel will be defined as “any trip, through air or ground that requires going to another location for athletic competition”. NCAA regulations state that a team may not travel earlier than 48 hours before the start of the competitions and must leave within 36 hours after completion (University of Georgia Athletic Compliance, 2019). Regardless of the regulations set in place, this does not take away from the amount of travel that is required for collegiate athletes. Collegiate teams are required to travel to various locations for competitions throughout the course of their season. Before the 2018 college football season, the total amount of distance traveled in miles was calculated for 40 football teams (Ndjrs, 2018). The average distance traveled was 7,025.3 miles for each of the 40 teams. To calculate total mileage, the road miles between home stadiums of the home and away teams were taken.

One study examined the psychological status of 100 male rugby athletes (Terry, Walrond, & Carron, 1998). The Profile of Mood States questionnaire (POMS), a 65-item questionnaire was given to the athletes one hour before the game. Pre-competition anxiety was measured through the Competitive State Anxiety Inventory-2 (CSAI-2). 50 athletes took the POMS first then the CSAI-2 before the competition. The other 50 athletes took the CSAI-2 first then the POMS. This was done to balance how the questionnaires were presented to the athletes. Results indicated that athletes rate themselves at high levels of vigor and self-confidence when they are playing at home. While playing on the road, the athletes felt more tense, anxious, and fatigued. The physiological aspect of traveling has also been investigated in numerous studies.

Jet lag is the term that applies to a “desynchronization of the circadian rhythm” and lasts until the rhythm is re-phased to the new environmental conditions” (Manfredini, Manfredini, Fersini, & Conconi, 1998). Circadian rhythm is from the Latin “circa diem”, meaning about 24 hours (Manfredini, Manfredini, Fersini, & Conconi, 1998). Previous research has indicated that rapid air travel through time zones can lead to a shift in the “biological clock” and circadian peak window (Manfredini, Manfredini, Fersini, & Conconi, 1998). Symptoms of jet lag include fatigue, lethargy, sleepiness, and a decline in mental performance (Comperatore & Krueger, 1990). Additionally, the desynchronization of physiological and behavioral rhythms has been linked to the circadian timing system (Comperatore & Krueger, 1990). Symptoms of jet lag may last up to 48 hours after the flight (Manfredini, Manfredini, Fersini, & Conconi, 1998). While many studies have established that travel causes short term fatigue in the general population, previous research has also looked at how athletic performance may be impacted by fatigue.

Worthen and Wade (1999) examined the influence of directional travel on team performance in college football. The researchers obtained game data from 333 regular-season games with the visiting team crossing over one or more time zones. The study found that visiting teams score fewer points and allow more points than home teams. This suggests a decline in performance that can be attributed to jet lag. Physiological performance has also been measured.

A previous study examined fatigue and recovery in beach volleyball athletes (Magalhães, Inácio, Oliveira, Ristö & Ascensao, 2011). In this study, the researchers evaluated countermovement jump (CMJ), sprint ability (7.5m and 15m), and maximal isometric voluntary contraction (MVIC) for 16 male elite volleyball athletes. These measures were evaluated at baseline, immediately before (0h) and three hours after each match. There was no significant difference in CMJ performance immediately before and three hours after the game when compared to baseline values (Magalhães, Inácio, Oliveira, Ristö & Ascensao, 2011). MVIC in the knee extensor and flexor muscles were decreased in comparison to the baseline values immediately before the match. Sprint performance was only slightly impaired at zero hours and was returned to baseline 3h after the match. Results of the study indicate that lower limb strength is at a deficit before matches but all performance values are recovered after 3 hours (Magalhães, Inácio, Oliveira, Ristö & Ascensao, 2011).

Petrie, Conaglen, Thompson, and Chamberlain (1989) studied melatonin as a potential intervention. Melatonin is a pineal hormone that is secreted at night. Results indicated that melatonin can be used to alleviate the symptoms of jet lag. This is because melatonin can act as a synchronizer of other body rhythms and reverse, or at least limit, the impact of jet lag.

Monitoring training load is a strategy that can be used to reduce injury risk while still eliciting the desired training outcomes. A very common method of monitoring training load is the Borg Rating of Perceived Exertion Scale (RPE). The Borg scale ranges from 6 to 20 with 6 being “very, very light” and 20 being “very, very hard”. Research has indicated that RPE measurements show a discrepancy in perceived practice intensity between athletes and coaches (Foster, Carl, Kara, Esten, & Brice, 2001). In the study, 15 volunteer competitive runners participated in a 5-week training period designed by professionally trained coaches and recorded their RPE rating after each training session. The athletes perceived training sessions that were scheduled to be low intensity to be higher than intended and vice versa (Foster, Carl, Kara, Esten, & Brice, 2001). The use of RPE provides subjective feedback to the coaching staff from the athletes which can then be used to structure the training sessions accordingly.

Another form of monitoring training load is performance tracking. In a study of elite women's volleyball athletes, jumping and standing spike speed was tracked over the course of a competitive season (Valades & Palao, 2015). The spikes were recorded two times every week through a series of five trials. The testing lasted for the entire 23-week season and was incorporated in the practice schedule. Jumping and standing spike speed increased by 2.3% and 0.4%, respectively (Valades & Palao, 2015). This study serves as a template for other forms of performance tracking to measure fatigue.

The literature has established that fatigue causes a decline in athletic performance. The causes of fatigue, the impact of travel, and intervention methods to preserve athletic performance are also well documented. Previous research has examined the training requirements for volleyball. However, there is limited research on weekly jumping in volleyball athletes over the course of a season. The purpose of this study is to examine the impact of an NCAA Division I Volleyball season on jumping performance.

APPENDIX C: LITERATURE REVIEW REFERENCES

Allard, F., & Starkes, J. L. (1980). Perception in sport: Volleyball. *Journal of Sport psychology*, *2*(1), 22-33.

Allen, D. G., Lamb, G. D., & Westerblad, H. (2008). Skeletal muscle fatigue: cellular mechanisms. *Physiological reviews*, *88*(1), 287-332.

Berry, M. J., & McMurray, R. G. (1987). Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise. *American journal of physical medicine*, *66*(3), 121-132.

Bigland-Ritchie, B., Johansson, R., Lippold, O. C., & Woods, J. J. (1983). Contractile speed and EMG changes during fatigue of sustained maximal voluntary contractions. *Journal of neurophysiology*, *50*(1), 313-324.

Blomqvist, C. G., & Saltin, B. (1983). Cardiovascular adaptations to physical training. *Annual review of physiology*, *45*(1), 169-189.

Davis, J. M., Alderson, N. L., & Welsh, R. S. (2000). Serotonin and central nervous system fatigue: nutritional considerations. *The American journal of clinical nutrition*, *72*(2), 573S-578S.

Dorel, S., Drouet, J. M., Couturier, A., Champoux, Y., & Hug, F. (2009). Changes of pedaling technique and muscle coordination during an exhaustive exercise. *Medicine & Science in Sports & Exercise, 41*(6), 1277-1286.

Comperatore, C. A., & Krueger, G. P. (1990). Circadian rhythm desynchronosis, jet lag, shift lag, and coping strategies. *Occupational medicine (Philadelphia, Pa.), 5*(2), 323-341.

Ensrud, K. E., Blackwell, T. L., Mangione, C. M., Bowman, P. J., Whooley, M. A., Bauer, D. C., ... & Study of Osteoporotic Fractures Research Group. (2002). Central nervous system–active medications and risk for falls in older women. *Journal of the American Geriatrics Society*, *50*(10), 1629-1637.

Foster, J. P., Carl, H., Kara, M., Esten, P. L., & Brice, G. (2001). Differences in perceptions of training by coaches and athletes. *South African Journal of Sports Medicine*, *8*(2), 3-7.

Gove, P. B. (n.d.). Travel. In *Merriam-Webster*. Retrieved from https://www.merriam-webster.com/dictionary/travel

Gadeken, S. B. (1999). Off-season strength, power, and plyometric training for Kansas State volleyball. *Strength & Conditioning Journal*, *21*(5), 49.

Harman, E. (1993). Strength and Power: A Definition of Terms. *National Strength and Conditioning Association Journal*, *15*(6), 18-21.

Jaric, S. (2002). Muscle strength testing. *Sports Medicine*, *32*(10), 615-631.

Kalmar, J. M., & Cafarelli, E. (1999). Effects of caffeine on neuromuscular function. *Journal of Applied physiology*, *87*(2), 801-808.

Kutzer, B. (1995). Volleyball: strength training periodization through volume control. *Strength & Conditioning Journal*, *17*(3), 34-39.

Kraemer, W. J., Bush, J. A., Bauer, J. A., Tripleft-McBride, N. T., Paxton, N. J., Clemson, A., … & Newton, R. U. (1996). Influence of compression garments on vertical jump performance in NCAA Division I volleyball players. *Journal of strength and conditioning research*, *10*, 180-183.

Magalhães, J., Inácio, M., Oliveira, E., Ristö, J. C., & Ascensao, A. (2011). Physiological and neuromuscular impact of beach-volleyball with reference to fatigue and recovery. Age (yr), 23, 3.

Manfredini, R., Manfredini, F., Fersini, C., & Conconi, F. (1998). Circadian rhythms, athletic performance, and jet lag. *British journal of sports medicine*, *32*(2), 101-106.

Morgan, W. P., Brown, D. R., Raglin, J. S., O'connor, P. J., & Ellickson, K. A. (1987). Psychological monitoring of overtraining and staleness. *British journal of sports medicine*, *21*(3), 107-114.

Ndjrs. (2018, August 10). College Football 2018: Here's How Many Miles 40 Top Teams Will Have To Travel. Retrieved from https://www.onefootdown.com/2018/8/10/17665212/college-football-2018-how-many-miles-40-top-teams-travel-alabama-clemson-ohio-state-georgia-oklahoma

Newsholme, E. A. (1987). Amino acids, brain neurotransmitters and a functional link between muscle and brain that is important in sustained exercise. *Advances in myochemistry*.

Parekh, A. L. P. A., & Lee, C. M. (2005). Heart rate variability after isocaloric exercise bouts of different intensities. *Medicine and science in sports and exercise*, *37*(4), 599-605.

Petrie, K., Conaglen, J. V., Thompson, L., & Chamberlain, K. (1989). Effect of melatonin on jet lag after long haul flights. *Bmj*, *298*(6675), 705-707.

Sanderson, D. J., & Black, A. (2003). The effect of prolonged cycling on pedal forces. *Journal of Sports Sciences*, *21*(3), 191-199.

Sheppard, J. M., & Young, W. B. (2006). Agility literature review: Classifications, training and testing. *Journal of sports sciences*, *24*(9), 919-932.

Terry, P. C., Walrond, N., & Carron, A. V. (1998). The influence of game location on athletes' psychological states. *Journal of Science and Medicine in Sport*, *1*(1), 29-37.

Udermann, B. E., Mayer, J. M., Graves, J. E., & Murray, S. R. (2003). Quantitative assessment of lumbar paraspinal muscle endurance. *Journal of Athletic Training*, *38*(3), 259.

University of Georgia Athletic Association Compliance Department. (2019). *Permissible Expenses for Travel, Practice & Away-from-home Competition*. Retrieved from https://compliance.sports.uga.edu/coaches-staff/ncaa-rules-for-administrative-coaching-staff/permissible-expenses-for-travel-practice-away-from-home-competition/.

Watkins, C. M., Barillas, S. R., Wong, M. A., Archer, D. C., Dobbs, I. J., Lockie, R. G., ... & Brown, L. E. (2017). Determination of vertical jump as a measure of neuromuscular readiness and fatigue. *The Journal of Strength & Conditioning Research*, *31*(12), 3305-3310.

Worthen, J. B., & Wade, C. E. (1999). Direction of travel and visiting team athletic performance: support for a circadian dysrhythmia hypothesis. *Journal of Sport Behavior*, *22*(2), 279.