University of Alberta

Time-Motion Analysis and Heart Rate Response in University Women's Volleyball: A Descriptive Study

by

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Abstract

The purpose of this study was to determine the physiological demands of university women's volleyball utilizing heart rate response and time-motion analysis. Thirteen female CIS players were video recorded and had their heart rates (HR) monitored during 5 matches at a preseason tournament. Movements were coded into 19 different categories. Results showed that middle blockers spent the most time standing, but had the highest frequency of spike and block jumps. Outside hitters and setters in a 6-2 system showed similarities in movement and HR values. Setters spent the most time above 80% predicted MaxHR; Outside hitters averaged the highest MaxHR; Liberos had the lowest average HR values. Middle blockers had high HRs on the court, interspersed with long rest periods. University women's volleyball involves numerous movement patterns that vary by position. The HR profiles revealed the interval nature of volleyball and the necessity to develop position-specific training programs.

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TABLE OF CONTENTS

CHAPTER 4

RESULTS

CHAPTER 5

GENERAL DISCUSSION & CONCLUSIONS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 A Brief History of Volleyball

William G. Morgan invented volleyball in 1895 in Holyoke, Massachusetts. Originally dubbed “mintonette”, the intended purpose of the game was to provide an activity for older males at the YMCA that was less strenuous than basketball, but still required some athletic skill (Huff, 2000). Volleyball has since evolved into one of the most popular sports in the world. The Federation Internationale de Volleyball (FIVB) estimates that over 500 million people worldwide play volleyball (Volleyball Canada, 2012). The women’s game is especially popular. In Canadian Interuniversity Sport (CIS), the highest level of collegiate sport in Canada, 38 universities offer women’s volleyball (Canadian Interuniversity Sport, 2013). Women’s volleyball is also popular in Canada at the college level; the Canadian Collegiate Athletic Association (CCAA) includes 57 programs across the country that offer women’s volleyball. In the United States, more than 14 million women play volleyball recreationally, over 400,000 girls play high school volleyball, and more than 300 schools offer women’s volleyball at the collegiate level (Crisfield & Monteleone, 2010).

Not only has the popularity of the sport increased significantly since it became an Olympic sport in 1964, but the nature of the game has also changed drastically. What was once thought to be a leisurely activity has become a fast-paced, athletically demanding sport at the elite levels (Dyba, 1982). As rallies tend to last fewer than 10 seconds, volleyball is now "characterized as an anaerobic power sport" (Vescovi & Dunning, 2004, p.11). Some researchers refer to high-level volleyball as "power volleyball", consisting of numerous bouts of net play requiring fast reactions, agility, and muscular strength (Gionet, 1978, 1980).

Since 1998, changes were made to the game in order to make it more appealing for television, attempting to attract fans and sponsors (FIVB, 2011a). These changes included the introduction of a defensive specialist position, labeled the libero, and a "let ball in play" rule (FIVB, 2011a; FIVB, 2011b) designed to extend rallies and reduce stoppages in play, respectively. In addition, before 1999 volleyball sets were played to 15 points, with points only being scored when a team had the serve, which is known as side-out scoring. Thus, matches could last anywhere from 45 to 150 minutes (Dyba, 1982). In 1998, the FIVB approved changing the rules to rally-point scoring, (compulsory for all levels in the year 2000), meaning that a point is scored on each rally, with sets being played to 25 points. This change was made with the intention of adding excitement to the game, as well as shortening long matches (Volleyball World Wide, 1998).

1.2 Significance of Study

Despite the growing popularity of volleyball, there have been limited scientific studies examining the nature of the game and the physiological demands placed on athletes who compete in volleyball. There are even fewer studies examining women's volleyball. In 2007-2008, females comprised 89% of all high school volleyball players in the United States (Steinbach, 2009). The disparity exists at the collegiate level as well. There are 332 NCAA institutions that sponsor Division I women's volleyball, compared to only 22 for the men's game (Steinbach, 2009). In Canada, the province of Alberta alone has had a dramatic increase in female club volleyball participation over the last decade, with participation climbing from approximately 1200 girls in 2002, to approximately 6500 girls by 2012 (D. Hemsley, personal communication, December 3, 2012). With volleyball participation increasing for females, it is even more important to take a closer look at the women's game.

As women's volleyball has grown, the level and intensity of competition has also increased. Volleyball at the collegiate level is physically demanding and requires specific preparation on the part of the athlete to meet the demands of the sport (Hedrick, 2007). Physical fitness and training has become a concern for many volleyball coaches and sport scientists. However, there is very little data available to help coaches and trainers design appropriate training programs for their athletes. With recent technological advances, it is now possible to examine the physiological demands of volleyball using methods such as high definition video to record skills and movement, time-motion analysis, and heart rate measurements. These methods can be used to conduct a needs analysis of volleyball, allowing coaches to design conditioning programs that utilize relevant energy systems, incorporate certain movement patterns, and develop power (Carter, 2001). Furthermore, this information will aid coaches and sport scientists in the development of strength and conditioning programs that are position specific.

1.3 Purpose & Hypothesis

The purpose of this study was to measure the heart rates of elite female volleyball players during competition, as well as to conduct a time-motion analysis of their on-court movement patterns. The heart rate data was used to describe workload by position, and also to indicate exertion levels throughout the match based on a percentage of predicted maximum heart rate for each athlete. The time-motion analysis data was used to describe the types of movement patterns that are most frequently observed in CIS women's volleyball, the frequency at which these movements occurred, and the average amount of time per set that athletes spent performing each movement.

It was hypothesized that there would be differences in movement patterns and their frequency, as well as differences in heart rate response for the positions of libero, outside hitter, middle blocker, and setter.

1.4 Delimitations

The participant sample consisted of members of one university female volleyball team. Female athletes were chosen not only because they are underrepresented in the literature, but also because female participation in volleyball greatly outnumbers male participation. University athletes were the focus of the study because Canadian Interuniversity Sport (CIS) is the top competitive league within Canada. Teams within the CIS also have an extensive preseason, allowing for data collection at multiple matches.

In total, there were five matches from which data was collected. The number five was chosen because it is the typical number of matches played in one university tournament. It was predicted that five matches would be sufficient to collect consistent data for both the heart rate measurements and time-motion analysis.

1.5 Limitations

Collecting data from only one team was a limitation, as the team was coached to move in specific patterns, and had their own specific system and style of play. Collecting from only one team also limited the sample size and thus, the applicability of the data across the population. The team that was studied played a 6-2 system, which reduces the applicability of the study to teams that play a 5-1 system or otherwise. However, for this study it was not feasible to collect data during the preseason from multiple teams who play other systems.

In order to reduce seasonal effect, data was collected after the team had already completed 2 weeks of preseason training, as well as three preseason matches. With the heart rate monitors being a new experience for the players, it was considered best to collect the data early in the preseason. This prevented anxiety and distraction that could occur when matches are played closer to the regular season. Players might be more willing to wear a heart rate monitor when they were under less pressure.

Collecting the data during pre-season matches may have been a limitation. Data collected in the pre-season may not be completely reflective of data collected during league play. This was considered when analyzing the results.

The Polar Team2 heart rate monitoring system was not set up to transfer data to a computer in real time. Instead, data was collected on the heart rate monitors and was later uploaded to the computer. This proved to be a limitation if the heart rate monitor slipped out of place, or malfunctioned. The researchers were not aware of this problem until data was uploaded. Substitutions were also a limiting factor, as only 6 players (7 including the libero) were active on the court at one time. Coaches are restricted to 6 substitutions per set, and a similar line-up was on the court for all five matches. Any substitutions that were made also limited the number of full-set heart rate data charts. Of the 19 sets that were played, substitutions were made in 6 of these sets that prevented collection of full set heart rate data for at least one position.

Chapter 2

REVIEW OF LITERATURE

2.1 Physiology of volleyball players

The physical and physiological attributes of volleyball players have been studied sporadically over the past half-century. In its early days, volleyball was believed to be only moderately stressful on the body. This conclusion was derived by measuring the average heart rates of athletes competing in the sport (e.g. Skubic & Hodgkins, 1965; Walker, 1973). Heart rate has been found by numerous researchers to be a reliable measure of cardiac strain and physiological stress (e.g. Maxfield & Brouha, 1963). In fact, heart rate has quickly become the most commonly used method of assessing exercise intensity in the field, thanks to the development of portable, wireless heart rate monitors (Achten & Jeukendrup, 2003). Heart rate is relatively easy to monitor, and can provide athletes with immediate feedback that they can use to adjust exercise intensity (Achten & Jeukendrup, 2003).

In an early study of female volleyball players, Skubic and Hodgkins (1965) found an average heart rate of 133 beats per minute (bpm) during play, ranking volleyball relatively low in strenuousness when compared to sports such as basketball, field hockey, badminton, and tennis (as cited in Walker, 1973). Some researchers did not agree with this conclusion, however. Believing that this average heart rate did not reflect the true nature of the game, June Walker (1973) conducted a similar study with competitive female volleyball players. The study was conducted by attaching chest electrodes and ECG transmitters to five females throughout a competitive match. Using this technique, heart rates were recorded continuously during the match. The results showed an average heart rate of 155 bpm for the five participants. Walker (1973) concluded that volleyball is indeed more strenuous than previously thought, and is “a sport deserving of cardiovascular conditioning” (p. 39).

Before long, it was established that the game of volleyball requires athletes to have a high anaerobic capacity for energy production (Gionet, 1978), though there was still very little research to support this statement. The physiological demands of volleyball, including: muscular power and strength, speed, endurance, flexibility, agility, and the interval nature of the sport were the basis for these claims (Gionet, 1978). However, studies had yet to be conducted on the specific court movement patterns, physiological characteristics of volleyball players, or the heart rate values of competitive players.

Unfortunately, the samples used to study the strenuousness of volleyball have varied widely. Utilizing a sample of women’s intercollegiate players at Case Western Reserve University, volleyball was again found to be only moderately strenuous (Fardy, Hritz, & Hellerstein, 1976). The authors do note, however, that this specific team practiced merely twice a week, and their matches were a best of three. In addition, the team ended the season with an extremely poor record of two wins and twelve losses (Fardy et al., 1976). Thus, these were not highly skilled or highly competitive players, and their results may be more reflective of recreational players. Nonetheless, Fardy et al.'s (1976) study was also progressive in many ways. The researchers measured heart rate in both competition and practice, and also noted which actions produced the highest heart rates. Individual heart rates were found to range from 92 to 182 bpm during competition, slightly higher than in practice. Fardy and colleagues (1976) found that the highest heart rates occurred during or immediately after a jumping activity, while the lowest heart rates were observed during low level activity such as serving and receiving. Though the average heart rate throughout competition was measured at 139 bpm, the results still show that volleyball is an intermittent activity within which heart rates can escalate close to maximal range.

As the sport progressed, the interest in the physiological demands of volleyball increased. A study of women's intercollegiate volleyball at the NCAA Division 1 level investigated exercise intensity, heart rates, and rally-to-rest ratios during a mock competition (Harbour, 1991). The subjects' heart rates ranged from 138-170 bpm when playing the in frontcourt, 133-160 bpm in the backcourt, and 130-172 bpm during timeouts. Also, four of the six players in the study maintained a heart rate of a least 60% of their maximum for over half of the total match length. The rally to rest ratio was found to be approximately 1:1.09-1.3. These results demonstrated that volleyball at such a level provides an interval training effect and requires high levels of aerobic and anaerobic fitness (Harbour, 1991).

A comprehensive study by Wally Dyba (1982) examined the physiological characteristics of men's volleyball in terms of its aerobic and anaerobic requirements, as well as the activity characteristics of the game, including skill execution, frequencies, and time durations. Results showed that heart rate was reflective of the number of net encounters within a given rally. Rallies that ended on the first net encounter revealed an average player heart rate of 141 bpm, whereas a rally with five or more net encounters increased the heart rate up an average of 152 bpm (Dyba, 1982, p. 50). Also of significance were the differences in heart rate depending on court position. Heart rates were highest in the frontcourt, and reflected the cyclical nature of the game of volleyball. Heart rates were lowest in position five, and were highest immediately after rotating out of the front row, into position 1. Thus, heart rate decreased as a player moved through the backcourt, and increased once higher demands, such as spiking and blocking, were placed on the athletes (Dyba, 1982). The average rally length was a mere 7.0 seconds, while rest durations averaged 13.3 seconds, indicating that many rallies ended on the first net encounter. Dyba also noted that the matches did not utilize the three-ball system, which is a system wherein specific individuals are designated to retrieve balls and ensure that one is always ready to be put into play. He predicted that the use of this system would reduce the rally to rest ratio (Dyba, 1982, p. 50).

Lecompte and Rivet (1979) studied the duration of exchanges and stops in competitive women's volleyball, finding the average duration of an exchange to be 9.79 seconds. They found that 45.4% of match time was spent on rallies and 65.5 % was spent at rest or on stoppages in play. These matches did not utilize the three-ball system, and were studied prior to rally point scoring.

It is clear from the above data that there is a difference between the physiological demands of women's volleyball versus the demands of men's volleyball, and the two must be studied as separate entities.

As a result of the rule changes mentioned previously, studies conducted after the year 2000 are of particular interest. After the introduction of the libero position, researchers became interested in the effects the change would have on the player in that role, as well as the players being replaced by the libero. One study of men's volleyball sought to determine the levels of lactic acid concentration in the blood, along with variations in heart rate for the libero and the middle players (Gonzalez, Urena, Llop, Garcia, Martin, & Navarro, 2005). Gonzalez et al. (2005) found the average heart of liberos on court to be 137 bpm, while the average heart rate of frontcourt middle players was measured at 148.5 bpm. As predicted, the heart rates of players in both positions decreased while off the court; however, the libero had a much shorter rest period, thus his heart rate did not decrease as drastically as that of the middle players. Gonzalez and colleagues (2005) also found high blood lactate concentrations in all players, especially the middles. Therefore, they concluded that high levels of lactate are produced in volleyball, despite its intermittent nature.

A recent study was conducted on the load intensity of men's volleyball in game-like drills (Lehnert, Stejskal, Hap, & Vavak, 2008). The researchers measured player heart rates in a wash drill, as well as in straight game play. Average heart rate for the players during the wash drill was found to be 157.5 bpm, and the average maximum heart rate was measured at 175.3 bpm (Lehnert et al., 2008). In contrast, average heart rate during the straight game play was found to be 145.5 bpm, with an average maximum of 166.8 bpm.

Given the variability of the results in the studies above, more research is required on the physiological demands of elite volleyball. Specifically, the women's game should be a primary focus, as it has not been studied since the rule changes in 1998.

2.2 Time-Motion Analysis

Not only has there been a call for more research on the physiological demands of volleyball, but there is also a demand for research using time-motion analysis (TMA) (Lidor & Ziv, 2010). TMA entails "the quantification of movement patterns involved in sporting situations, thus providing speeds, durations, and distances of various locomotor patterns during the course of a game" (Dobson & Keogh, 2007, p. 48). Time-motion analysis has been used to study many sports, including but not limited to: field sports such as rugby (Deutsch, Maw, Jenkins, & Reaburn, 1998; Virr, Game, Bell, & Syrotuik, 2013), soccer (Hill-Haas, Dawson, Coutts, & Rowsell, 2009), and field hockey (Lythe

& Kilding, 2011); court sports such as basketball (Matthew & Delextrat, 2009); sports in an alternate environment such as ice hockey (Bracko, Fellingham, Hall, Fisher, & Cryer, 1998) and water polo (D'Auria & Gabbett, 2008); individual activities such as dance (Wyon et al., 2011) and mixed martial arts (Del Vecchio, Hirata, & Franchini, 2011).

Volleyball has been largely neglected in the time-motion analysis research. No studies that analyze all of the game movement patterns have been conducted on volleyball, and few studies have been done since the rule changes. The only studies on volleyball that have utilized TMA have focused on the characteristics and frequency of jumping, and even those are few in number. Vescovi & Dunning (2004) conducted a positional analysis of jumping in collegiate women's volleyball. The researchers compared two elite (top 25) NCAA women's volleyball teams with two non-elite (held only regional rankings) NCAA women's volleyball teams, analyzing three positions, including outside hitter (OH), middle (MID), and setter (SET). Vescovi and Dunning (2004) analyzed the frequency of 5 jumping movements: spike, block, jump set, jump serve, and dive. They found that elite OH performed significantly more spikes than MID and SET; MID performed significantly more blocks than OH and SET; SET performed significantly more jump sets than OH and MID; SET performed significantly less jump serves than MID and OH. They found no significant differences between positions for the dive. Their results showed that 44% of OH jumps were spikes, 55% of MID jumps were blocks, and 47% of SET jumps were jump sets (Vescovi & Dunning, 2004,). SET had the highest overall jumping volume, as a result of the amount of jump sets. However, the researchers noted that: "jump sets are typically sub-maximal and appear less intense than either spike or maximal block jumps" (p. 15). Thus, the total jump volume could be misleading. MID was found to be an interesting position, performing more spikes than SET, but less than OH, and more blocks than both OH and SET. Vescovi and Dunning (2004) stated that this indicates a "unique contribution to the game of volleyball both on offense and defense, whereas OH and SET seem to split the responsibility to assist MID defensively" (p.15). The researchers concluded that one third of exercises in a training program designed for MID should focus on spiking ability, whereas this should be the primary focus for a training program for OH. This study was one of the first of its nature on women's volleyball and will be of critical importance to the current investigation.

One TMA study of men's volleyball has been conducted since the rule changes (Sheppard, Gabbett, & Stanganelli, 2009). Sheppard et al. (2009) focused specifically on the demands of the three positions (middle, outside, and setter) in international men's volleyball matches. Eight matches from the 2004 Olympic Games, along with eight international test matches, were analyzed. The frequency of all the major activities a player would perform was analyzed in order to determine any difference between the demands of middle players, outsides, and setters. Sheppard et al. (2009) considered the major activities to be spike jumps, block jumps, dives, and jump serves. The most significant findings were revealed in the categories of block jumps and spike jumps. Middle players averaged approximately 11 block jumps per set, with setters and outsides averaging just over 6. Middle players also performed more spike jumps per set than did outsides and setters (7.75 to 5.75 to 0.38 respectively). Sheppard and colleagues (2009) concluded that the spike and blocking jumping demands of middle players are the greatest compared to all other positions. They are also required to perform a considerable amount of lateral movement in the frontcourt. However, it is noted that since the middle player is removed for most of backcourt play (replaced by the libero), this jumping demand does not necessarily equate to the highest total physiologic stress (Sheppard et al., 2009, p. 1864). The researchers also recognized that the setter has a different kind of demand placed on the body, performing 20 or more submaximal jumps (jump sets) per set. These findings are important for both coaches and sport scientists to consider when designing training programs and practice sessions.

It is evident from the above information that there is a need for more studies on the sport of volleyball, specifically the women's game. In a review of the physical and physiological attributes of female volleyball players, Lidor and Ziv (2010) suggest that athletes' heart rates should be measured under field conditions, providing coaches with relevant information about the demands of match play. They also state "information on patterns of movements and actions performed by volleyball players during the game should be also collected and analyzed (p. 1970)." Lidor and Ziv (2010) go on to recommend the use of time-motion analysis to collect such information.

Therefore, the current study recorded athlete heart rate during match play, and a time-motion analysis of each playing position was conducted using the game tape. The workload and movement patterns of collegiate female volleyball players was determined, providing useful information to both coaches and sport scientists who must design practice plans and training programs to optimize athletic performance.

Chapter 3

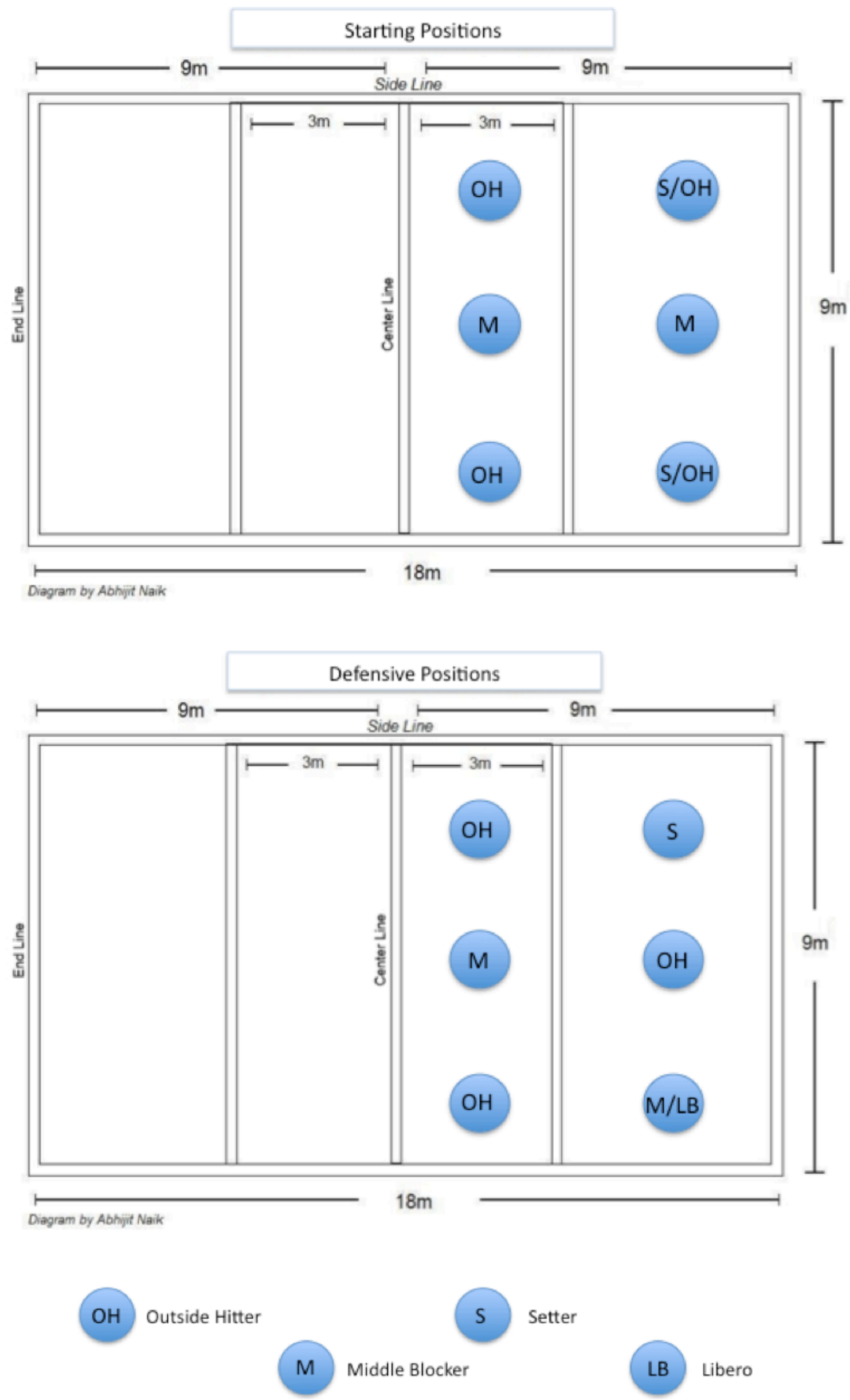
METHODS AND PROCEDURES

3.1 Participants and Experimental Design

A team of 14 university level female volleyball players between the ages of 17-24 years were the participants in this study. The participants competed at a pre-season volleyball tournament in a total of 5 matches. 13 players opted to wear heart rate monitors, however only the 6 players on the court were video recorded. The positions observed were outside hitter, middle blocker, setter in a 6-2 system, and the libero. The team played a modified 6-2 system, meaning that they played with 2 setters on the court, both of which performed as attackers in either the right-side or left-side position when they were front row (see Figure 1). Therefore, the setter who was in the back-row was most often the setter and the setter in the front-row played as an outside hitter. However, there are certain situations where the right-side hitter performed as the setter in the front row. Figure 1 displays the starting positions for the team studied, as well as the positions played defensively. In volleyball, rotation for service occurs counterclockwise, and the players switch into their respective offensive or defensive positions upon service contact, or when time is sufficient during a rally.

Ethics approval for the study was granted one month prior to data collection, and informed consent was received from the participants 1 week prior to game-day data collection. At this time, they had the option to complete one practice session wearing the heart rate monitors and become familiar with the procedure and the use of the transmitters.

Figure 1. Volleyball court and positioning.



3.2 Game Day Data Collection

Approximately 1-1.5 hours before the match, participants were given a Polar Team2 (Polar Electro Oy, Kempele, Finland) heart rate monitor, and instructed as to how to wear the chest strap. The participants wore the monitors during warm-up to ensure that their pre-game routine was not disturbed. Heart rate values were measured throughout the entire match. At the end of each match, the monitors were removed and the data was uploaded to the computer.

It is notable that the matches used for data collection employed the three-ball system. The three-ball system is used in CIS league play, and is necessary to ensure that the rally to rest ratio is kept as low as possible. If the three-ball system were not used, the data would not be a true reflection of the demands placed on these athletes in league matches.

3.3 Camera Locations

To record the matches, there were 2 cameras on tripods located at elevated positions above the court. One camera was a Sony HDR-XR160 the other camera was a Sony HDR-XR350V and both cameras recorded in high definition. The cameras were placed at the center of each baseline, 8-10 meters from the baseline, elevated approximately 5 meters above the court. This ensured a full court rear view of the participants, regardless of which side they were playing on. Also, two cameras were used in the event of a technological malfunction.

3.4 Time-Motion Analysis

The participants' movement patterns were coded into 19 different movement categories by the principal researcher. The movement patterns were treated as separate entities, rather than categories of locomotion as seen in previous studies (eg. Deutsch et al, 1998; Virr et al., 2013) because limited jogging, striding or sprinting occurs in the sport of volleyball. There was no basis or previous research conducted to determine which movement patterns would be considered high, moderate, or low intensity. The movement patterns included: standing, walking, service reception, standing serve, jump float serve, dig, dig with recovery, running pass/dig, transition to set, standing set, jump set, setter dump, transition to attack, transition to defensive position, transition to attack coverage, spike approach and jump, spike, lateral movement to block jump, and stationary block jump. The activities were recorded in frequency of occurrence throughout each set. Total and mean duration, as well as the percentage of time each position spent performing each activity was also measured. Work to rest totals, percentages, and ratios were calculated for each set, as well as the average length of the rallies in each set. The movement categories of standing and walking were considered low intensity rest activities in previous studies (Deutsch et al., 1998; Virr et al., 2013) and were treated as such in the current study. The measurement of time spent standing and walking served as the rest component of the work to rest calculation.

Using the application *Quicktime* (Apple Inc.), a frame-by-frame analysis was conducted on the movements, allowing the researcher to analyze the movements at 30 frames per second. The duration of each movement pattern was then calculated by dividing the respective number of frames by a value of 30, resulting in the number of seconds spent in each category. The running time on the video camera was used to sync the heart rate data with the movement patterns. The movement patterns were then color-coded and graphed along a timeline with the heart rate data. Time between sets was not used in the time-motion analysis because data was analyzed set by set. Data was analyzed set by set because volleyball matches can vary in length anywhere from 3 to 5 sets (Sheppard et al., 2009).

3.5 Heart Rate

The participants' heart rates were recorded and stored in a Polar Team2 heart rate monitor beat-by-beat throughout the game, and the data was downloaded to a computer after each match. An estimation of maximum heart rate was determined using the formula for age-predicted maximum heart rate: HR maximum=(220-age). This formula has proven to be accurate for establishing training programs for healthy people, though there can be significant variances among individuals (McArdle, Katch, & Katch, 1996). In the event a higher heart rate was recorded during match play, that value was used as the maximum heart rate.

Ideally, a VO2 max test would have been conducted and a true maximum heart rate obtained, but this was not possible given the time limitations of the current study. Minimum, maximum, and mean heart rates for each set were recorded for each player and position. Percentage of set time spent above 80% maximum heart rate was also calculated, indicating time spent in moderate to high exertion (Deutsch et al., 1998). This is a common value used in other time-motion analysis research (Deutch et al., 1998; Virr et al., 2013) and also examines the assertion that volleyball requires a high anaerobic capacity (Gionet, 1978). The heart rate data was placed on a timeline corresponding to the movement patterns in order to observe the variations in player heart rates throughout the match.

The above measurements of heart rate were used to describe workload for outside hitters, middle blockers, setters in a 6-2 system, and the libero. In the event of player substitutions, the substitutes' HR data was only used if the substitute played a minimum of 60% of the total set time. As with the time-motion data, heart rate data collected between sets was not included for analysis.

3.6 Definition of Movement Categories

1) **Standing:** no locomotor movement.
2) **Walking:** slow locomotor movement in any direction without a flight phase (Virr et al., 2013).

3) **Service reception**: the use of a forearm or overhead pass to direct a served ball toward one's setter. Measurement began at the referee's whistle, and ended when the athlete began movement to the next phase, regardless of whether or not contact was made with the ball.

4) **Standing overhead serve**: the initiation of play with an overhead action wherein both feet remain in contact with the ground. Measurement began from the moment the ball was tossed, and ended after contact, when the athlete began to take a step towards entering the court for defense.

5) **Jump float serve:** the initiation of play with an overhead action wherein both feet leave the ground to contact the ball. Measurement began when the athlete started their approach, and ended after contact, when the athlete began to take a step towards entering the court for defense.

6) **Dig**: the movement to receive an opponent's attack. Measurement began at the moment when the opponent attacked the ball, and ended after the athlete either contacted the ball or the ball hit the floor in an attempted dig, and the athlete began movement to the next phase.

7) **Dig with recovery**: the movement to receive an opponent's attack, requiring the body to make contact with the ground in either a diving or sliding action. Measurement began at the moment when the opponent attacked the ball, and ended when the athlete completed the recovery and began movement towards the next phase.

8) **Running pass/dig:** the use of an overhead or forearm pass while moving through the ball (feet do not get planted) in order to set up an attack or prevent the ball from hitting the floor. Measurement began after the previous contact, when the athlete made her first movement towards the ball, and ended after contact or recovery, immediately when the athlete began to move to the next phase.

9) **Transition to set:** the movement of an athlete to set the ball. Measurement began as the athlete made her first movement towards the setting position, and ended when she began to move to the next phase.

10) **Standing set:** the use of an overhead or forearm pass from a standing position to set up an attack. Measurement began when the athlete moved their hands/arms up to contact the ball, and ended after contact, immediately when the athlete began to move to the next phase.

11) **Jump set:** the use of an overhead pass wherein both feet leave the ground prior to contacting the ball. Measurement began when the athlete began her jump, and ended immediately when the athlete began her movement towards the next phase.

12) **Setter Dump:** a front row attack completed by the setter on the second contact. Measurement began when the setter started her jump, and ended after the setter had contacted the ball and both feet were in contact with the ground, ready to move to the next phase.

13) **Transition to attack:** transitional movements from service reception, defense, or attack coverage that prepare the athlete to attack. Measurement began as the athlete took her first step following reception, defense, or coverage, and ended immediately when the athlete started the first step of the spike approach, or began movement towards the next phase.

14) **Transition to defensive position**: movement of a player to defensive position, whether in the front court or back court. Measurement began as the athlete took her first step towards defensive position, and ended when the athlete began movement towards the next phase. Movements when the athlete was in the ready position making adjustments to the play of the opponent were also included in this category.

15) **Transition to attack coverage:** low ground movement towards a teammate who is spiking the ball. Measurement began as the athlete made her first movement towards her teammate who was attacking, and ended immediately as she made her first movement towards the next phase (regardless of whether or not contact was made with the ball).

16) **Spike approach and jump**: dynamic steps towards the net with a vertical jump. Measurement began as the athlete took her first step in the spike approach, and ended when she landed with both feet contacting the ground, and began movement towards the next phase.

17) **Spike**: an overhead attack that is completed while in the air, directing the ball towards the opponent's court. Measurement began as the athlete took her first step in the spike approach, and ended when she landed with both feet contacting the ground, and began movement to the next phase.

18) **Lateral movement to block jump**: a defensive movement that involves the athlete jumping off of two feet after moving laterally along the net, extending the arms up and forwards, attempting to prevent the ball from crossing the net. Measurement began as the athlete started her lateral movement, and ended when she has landed with both feet contacting the ground, beginning movement to the next phase.

19) **Stationary block jump**: a defensive movement that involves the athlete jumping off of two feet from a stationary position, extending the arms up and forwards, attempting to prevent the ball from crossing the net. Measurement began as the athlete started her jump, and ended when the athlete had landed with both feet contacting the ground.

3.7 Reliability

In order to establish intra-rater reliability, the primary researcher analyzed all playing positions during one full set, on two different occasions. The coefficient of correlation for intra-rater reliability was found to be 0.999 for all four positions. Inter-rater reliability was established by the primary researcher and an expert in the field each coding one full set, observing the movement categories for the four different playing positions. The coefficient of correlation for inter-rater reliability was found to be r=0.999 for outside hitters, r=0.999 for middle blockers, r=0.998 for setters in a 6-2 system, and r=0.999 for the libero.

3.8 Validity

Time-motion analysis (TMA) has been proven to be a valid method of assessing movement patterns in sport. However, with each different sport studied, it is necessary to define movement patterns that are sport-specific (Dobson & Keogh, 2007). Given that volleyball actions and movement patterns have not been defined in any study using TMA, the definitions used in the current study were developed by the primary researcher. The foundation for these definitions was the basic cycle of actions for the game of volleyball (Baudin & Anton, 2011).

To establish a form of content validity for the movement categories, CIS volleyball coaches were asked in survey form to identify and rate the importance of movement patterns necessary to succeed in volleyball. The twelve coaches who agreed to complete the content validity survey (Appendix A) had a mean of 16.3 years of experience coaching women's volleyball, 9.9 years coaching CIS women's volleyball, and an average NCCP certification of level 3. The results showed that the coaches considered all movement patterns included in this study to be at least somewhat important to the success of a CIS female volleyball athlete. It should be noted that some of the movement pattern titles and definitions were altered at the start of data input, and thus, the patterns used in the survey appear slightly different than the actual movement categories used for analysis.

3.9 Statistical Analysis

The time and frequency of each movement pattern performed by each player was recorded. The mean time spent performing each movement in a set, as well as the frequency of each movement pattern was reported according to position. The percentage of set time each player spent performing each movement was then calculated in Excel Mac 2008 (Apple Inc.), and these values were averaged. Work and rest percentages were also calculated in order to determine work to rest ratios for each set. The values for each set were averaged and reported.

Heart rate measures were reported on a timeline for each set. Minimum heart rate, maximum heart rate, and mean heart rate for each set was reported for each player and position; the percentage of time each athlete spent above 80% maximum heart rate was also calculated. The means and standard deviations of these values were calculated using Excel Mac 2008 and reported for each position across all sets studied.

A Pearson's product moment coefficient of correlation was used to determine both inter and intra-rater reliability.

Chapter 4

RESULTS

4.1 Subject Characteristics

The sample used in this study had a mean age of 19.7 years, with the average CIS eligibility of the athletes being 2.9 years.

4.2 General Game Characteristics

Five total matches were investigated, resulting in a 3-2 win/loss record, as well as a 12-7 record of sets won and lost (Table 1). All matches were best of 5 sets.

Table 1. General game characteristics and results of the 5 matches investigated.

Match	Result	Score	Total Match Time [hr:min:sec]
1	**Won**	**3**-0 (25-23, 25-22,25-15)	1:14:46
2	**Won**	**3**-0 (25-23,25-21,26-24)	1:22:26
3	**Won**	**3**-1 (25-16, 28-26, 23-25, 25-22)	1:41:02
4	**Lost**	**1**-3 (22-25, 25-19, 20-25, 21-25)	1:35:20
5	**Lost**	**2**-3 (19-25, 25-17, 25-19, 23-25, 11-15)	1:53:04

4.3 Time-Motion Analysis

Movement categories

Standing

Standing did not vary among positions, with the exception of middle blockers. Middle blockers spent considerably more time, and thus, percentage, of each set standing (Table 2 & 8). However, the frequency of standing was lowest for middle blockers (Table 3).

Walking

Outside hitters and setters spent the most time walking and also had the highest frequency of walking. Liberos returned slightly lower values. Middle blockers spent less time walking and had a lower frequency of walking compared to the other 3 positions (Table 2 & 3).

Service Reception

Middle blockers never took part in service reception, while outside hitters and the libero returned very similar values for frequency and time spent in service reception (Table 2 & 3). Setters, being in the 6-2 system, spent more time in service reception than middle blockers, but less time than outside hitters and the libero (Table 2).

Table 2. Time (min:sec) spent in specific movement categories throughout one set.

Set Duration: 22:37 ± 2:57	**Libero**	**Middle Blocker**	**Outside Hitter**	**Setter in 6-2**
Standing	11:27 ± 2:13	16:08 ± 2:19	9:28 ± 1:30	10:25 ± 1:44
Walking	4:23 ± 0:59	3:05 ± 1:04	5:04 ± 1:09	5:05 ± 0:59
Service Reception	2:38 ± 0:52	0	2:31 ± 0:44	1:14 ± 1:00
Standing Overhead Serve	0	0:06 ± 0:05	0:01 ± 0:03	0:00 ± 0:01
Jump Float Serve	0	0:02 ± 0:05	0:09 ± 0:07	0:10 ± 0:07

Values are means ± standard deviation.

Table 3. Total frequency of occurrence of specific movement categories during a set.

	Libero	**Middle Blocker**	**Outside Hitter**	**Setter in 6-2**
Standing	45 ± 5	33 ± 6	52 ± 4	52 ± 5
Walking	45 ± 5	32 ± 6	52 ± 4	52 ± 4
Service Reception	22 ± 3	0	23 ± 3	12 ± 5
Standing Overhead Serve	0	3 ± 2	0 ± 1	0 ± 1
Jump Float Serve	0	1 ± 2	4 ± 3	4 ± 2

Values are means ± standard deviation.

Standing Overhead Serve

Middle blockers more frequently performed a standing overhead serve in comparison to outside hitters and setters (Table 3). Liberos never completed a standing overhead serve.

Jump Float Serve

Outside hitters and setters more frequently performed a jump float serve in comparison to middle blockers (Table 3). Liberos never completed a jump float serve.

Dig

Liberos had the highest frequency of digs and spent the most time performing digs per set, but only marginally more than outside hitters and setters. Middle blockers attempted the fewest digs and spent much less time performing this movement (Table 4 & 5).

Dig with Recovery

Liberos had the highest frequency and time spent performing digs with recovery each set, but again, only marginally more than outside hitters and setters. Middle blockers, on average, did not execute any digs with recovery in a set (Table 4 & 5).

Running Pass/Dig

Setters spent the most time and had the highest frequency of running passes/digs per set. Liberos and outside hitters performed fewer running passes/digs, whereas the middle blockers, on average, did not perform any in a set (Table 4 & 5).

Table 4. Time (min:sec) spent in specific movement categories throughout one set.

Set Duration: 22:37 ± 2:57	**Libero**	**Middle Blocker**	**Outside Hitter**	**Setter in 6-2**
Dig	0:08 ± 0:05	0:01 ± 0:01	0:06 ± 0:04	0:06 ± 0:03
Dig with Recovery	0:04 ± 0:03	0:01 ± 0:01	0:02 ± 0:03	0:03 ± 0:04
Running Pass/Dig	0:02 ± 0:03	0	0:02 ± 0:02	0:06 ± 0:05
Transition to Set	0:01 ± 0:01	0	0	0:43 ± 0:42
Standing Set	0:03 ± 0:02	0:01 ± 0:01	0:01 ± 0:01	0:05 ± 0:03
Jump Set	0	0	0	0:10 ± 0:05
Setter Dump	0	0	0	0:00 ± 0:01

Values are means ± standard deviation

Table 5. Total frequency of occurrence of specific movement categories during a set.

	Libero	**Middle Blocker**	**Outside Hitter**	**Setter in 6-2**
Dig	5 ± 3	1 ± 1	4 ± 2	4 ± 2
Dig with Recovery	2 ± 1	0	1 ± 1	1 ± 2
Running Pass/Dig	1 ± 1	0	1 ± 1	3 ± 2
Transition to Set	1 ± 1	0	0	20 ± 9
Standing Set	2 ± 1	0	1 ± 1	4 ± 2
Jump Set	0	0	0	9 ± 5
Setter Dump	0	0	0	0 ± 1

Values are means ± standard deviation

Transition to Set

Setters had the highest frequency and spent the most time performing transitional setting movements. Outside hitters and middle blockers did not perform this movement pattern, while liberos sporadically engaged in transitional setting movements (Table 4 & 5).

Standing Set

Setters spent the most time performing standing sets and had the highest frequency of standing sets. Liberos also performed standing sets, though less than setters. Outside hitters and middle blockers rarely performed a standing set (Table 4 & 5).

Jump Set

The only position that performed a jump set was the setter, averaging approximately 9 per set (Table 5).

Setter Dump

The setter dump was only performed by the setter, and very rarely in the 6-2 system.

Transition to Attack

Outside hitters had the highest frequency of transition to attack, and also spent the most time performing transitional attacking movements. Middle blockers and setters returned similar values for both frequency and time spent in transition to attack. Liberos did not transition to attack (Table 6 & 7).

Table 6. Time (min:sec) spent in specific movement categories throughout one set.

Set Duration: 22:37 ± 2:57	**Libero**	**Middle Blocker**	**Outside Hitter**	**Setter in 6-2**
Transition to Attack	0	0:39 ± 0:22	1:03 ± 0:48	0:40 ± 0:41
Transition to Defensive Position	2:19 ± 0:57	1:15 ± 0:52	2:54 ± 0:46	2:55 ± 0:59
Transition to Attack Coverage	1:26 ± 0:37	0:27 ± 0:12	0:43 ± 0:33	0:37 ± 0:21
Spike Approach and Jump	0	0:12 ± 0:06	0	0
Spike	0	0:07 ± 0:04	0:15 ± 0:07	0:13 ± 0:07
Lateral Movement to Block Jump	0	0:20 ± 0:07	0:02 ± 0:03	0:01 ± 0:02
Stationary Block Jump	0	0:08 ± 0:05	0:08 ± 0:05	0:09 ± 0:04

Values are means ± standard deviation

Transition to Defensive Position

Outside hitters and setters spent the most time transitioning to defensive position, and also returned very similar frequencies. Liberos spent a considerable amount of time in transition to defensive position, whereas middle blockers spent the least amount of time and had the lowest frequency of this movement pattern (Table 6 & 7).

Table 7. Total frequency of occurrence of specific movement categories during a set.

	Libero	Middle Blocker	Outside Hitter	Setter in 6-2
Transition to Attack	0	21 ± 6	34 ± 8	19 ± 9
Transition to Defensive Position	30 ± 5	29 ± 8	48 ± 9	49 ± 7
Transition to Attack Coverage	19 ± 3	13 ± 5	22 ± 6	20 ± 6
Spike Approach and Jump	0	7 ± 4	0	0
Spike	0	3 ± 2	8 ± 3	6 ± 4
Lateral Movement to Block Jump	0	10 ± 3	1 ± 1	1 ± 1
Stationary Block Jump	0	6 ± 3	6 ± 3	6 ± 3

Values are means ± standard deviation

Transition to Attack Coverage

Liberos spent the most time in transition to attack coverage (Table 6). However, outside hitters, setters, and liberos had similar frequencies of transition to attack coverage, with outside hitters averaging the highest frequency (Table 7). Middle blockers had the lowest values for both time spent and frequency of transition to attack coverage.

Spike Approach and Jump

Middle blockers were the only position to perform spike approach and jump, averaging 7 per set (Table 7).

Spike

Outside hitters and setters spent similar amounts of time spiking (Table 6). However, outside hitters had a higher frequency of spikes in a set. Middle blockers also performed the spike, but spent less time and had a lower frequency of this movement. Liberos did not spike (Table 6 & 7).

Lateral Movement to Block Jump

Middle blockers spent the most time laterally moving to block jump, and also had the highest frequency of lateral movement to block jumps. Outside hitters and setters also performed lateral movement to block jump, though very rarely in comparison to middle blockers. Liberos did not laterally move to block (Table 6 & 7).

Stationary Block Jump

The frequency and time spent performing stationary block jumps was similar for outside hitters, middle blockers, and setters (Table 6 & 7). Liberos did not perform stationary block jumps.

Table 8. Percentage (%) of time spent performing each movement during a set.

	Libero	Middle Blocker	Outside Hitter	Setter in 6-2
Standing	50.6 ± 4.6	71.3 ± 5.6	41.9 ± 3.0	46.0 ± 4.2
Walking	19.4 ± 2.7	13.7 ± 3.1	22.4 ± 2.4	22.5 ± 2.6
Service Reception	11.7 ± 2.5	0	11.1 ± 2.0	5.5 ± 2.3
Standing Overhead Serve	0	0.5 ± 0.4	0.1 ± 0.2	0.0 ± 0.1
Jump Float Serve	0	0.1 ± 0.4	0.7 ± 0.5	0.7 ± 0.6
Dig	0.6 ± 0.4	0.1 ± 0.1	0.4 ± 0.3	0.4 ± 0.2
Dig with Recovery	0.3 ± 0.2	0.1 ± 0.1	0.2 ± 0.2	0.2 ± 0.3
Running Pass/Dig	0.2 ± 0.2	0.0 ± 0.1	0.1 ± 0.1	0.4 ± 0.3
Transition to Set	0.1 ± 0.1	0	0	3.2 ± 1.5
Standing Set	0.2 ± 0.1	0.0 ± 0.1	0.1 ± 0.1	0.4 ± 0.2
Jump Set	0	0	0	0.7 ± 0.4
Setter Dump	0	0	0	0.0 ± 0.1
Transition to Attack	0	2.9 ± 0.9	4.6 ± 0.9	2.9 ± 1.6
Transition to Defensive Position	10.2 ± 2.2	5.5 ± 1.4	12.8 ± 1.7	12.9 ± 1.8
Transition to Attack Coverage	6.3 ± 0.9	2.0 ± 0.7	3.1 ± 0.9	2.7 ± 0.6
Spike Approach and Jump	0	0.9 ± 0.5	0	0
Spike	0	0.5 ± 0.3	1.1 ± 0.5	0.9 ± 0.5
Lateral Movement to Block Jump	0	1.5 ± 0.4	0.2 ± 0.2	0.1 ± 0.1
Stationary Block Jump	0	0.6 ± 0.3	0.6 ± 0.3	0.6 ± 0.3

Values are means ± standard deviation.

4.4 Heart Rate Analysis

Given the age range of the participants in this study, the predicted maximum heart rate is very similar across the group. The maximum heart rate reached in a set varied across positions, with outside hitters at the highest value and liberos at the lowest value. Minimum heart rate also varied across positions, with liberos and middle blockers averaging significantly lower values than both setters and outside hitters.
A similar pattern was found in the average heart rate over a set: liberos and middles had much lower average heart rates than both outsides and setters, who attained similar values. Outside hitters and setters spent significantly more time above 80% of their maximum heart rate when compared to liberos and middles. Liberos spent the least amount of time with heart rate values exceeding 80% of their predicted maximum.

Table 9. Heart rate measurements (b· min).

	Libero (n=2)	Middle Blocker (n=3)	Outside Hitter (n=4)	Setter in a 6-2 (n=2)
Predicted MaxHR	201 ± 2	201 ± 2	200 ± 2	199 ± 1
Set MaxHR	168 ± 7	172 ± 17	182 ± 5	177 ± 6
Set Min HR	88 ± 20	87 ± 19	121 ± 9	125 ± 10
Set Avg.	133 ± 14	133 ± 20	159 ± 6	157 ± 7
80% MaxHR	161 ± 2	161 ± 1	160 ± 2	159 ± 1
% set >80% MaxHR	12 ± 13	21 ± 24	48 ± 16	52 ± 22

Values are means ± standard deviation

4.5 Work and Rest Intervals

Outside hitters spent the most time, per set, at work; however, similar numbers were found for setters and liberos. Middle blockers spent a substantial amount of time at rest when compared to the other three positions (Table 10).

The average rally lasted approximately 10.54 ± 1.13 seconds (Table 11). This calculation is based on the movements performed by the athletes, rather than on the referee's whistle. In this calculation, walking and standing between rallies was considered rest, and all other movements were considered work.

Table 10. Work and rest variables.

	Libero (n=2)	**Middle Blocker (n=3)**	**Outside Hitter (n=4)**	**Setter in a 6-2 (n=2)**
% set at work	29.6 ± 4.2	14.6 ± 3.3	35.2 ± 2.8	31.8 ± 3.0
% set at rest	70.0 ± 4.3	85.0 ± 3.3	64.3 ± 2.8	68.5 ± 4.9
Total work time [min:sec]	6:42 ± 1:07	3:19 ± 0:51	7:57 ± 1:05	7:12 ± 1:01
Total rest time [min:sec]	15:50 ± 2:05	19:13 ± 2:03	14:32 ± 1:40	15:30 ± 1:47

Values are means ± standard deviation.

Table 11. Rally lengths (s).

	Match 1	**Match 2**	**Match 3**	**Match 4**	**Match 5**
Set 1	8.6 ± 5.1	10.1 ± 5.0	8.9 ± 7.3	10.6 ± 6.6	10.7 ± 5.0
Set 2	10.4 ± 6.5	12.6 ± 9.1	9.5 ± 5.2	10.4 ± 5.3	10.7 ± 6.0
Set 3	9.9 ± 6.9	11.7 ± 7.3	11.7 ± 7.0	8.9 ± 5.2	12.6 ± 10.7
Set 4	/	/	11.2 ± 8.0	10.2 ± 5.1	10.3 ± 5.2
Set 5	/	/	/	/	11.2 ± 6.1
Longest Rally	38.4	37.4	45.8	32.1	58.2
Shortest Rally	1.1	1.3	1.3	1.1	1.4
Average Rally Length	**10.54 ± 1.13**				

Values are means ± standard deviation.

Chapter 5

GENERAL DISCUSSION & CONCLUSIONS

5.1 Discussion

The purpose of this study was to use time-motion analysis to identify and quantify movement patterns, as well as to examine heart rate response in order to describe the physical demands of women's volleyball at the University level.

5.2 Time-Motion Analysis

Middle blockers spent the most time standing because they were replaced by the libero for 2.5 rotations across the backcourt. Therefore, middle blockers were resting on the sidelines for a large portion of each set. In fact, middle blockers spent an average of 71.3% of set time standing, which is at least 20% more than the other three positions. The libero rested on the sidelines while the middle blockers were executing service, and therefore spent more time standing than outside hitters and setters. Outside hitters and setters also spent more time walking than the other two positions, for the same reasons. These two positions did not leave the court, and thus the frequency and time spent walking was higher.

The libero and outside hitters spent the most time in service reception, attempting to receive all serves by the opponent. In the 6-2 system, the setter in the front row played as an outside hitter, and thus, averaged half the time and frequency of service reception compared to the libero and outside hitters. Middle blockers did not participate in service reception, as they were constantly approaching for first tempo attacks.

On the specific team examined, middle blockers utilized the standing overhead serve more often compared to the other positions. Setters and outside hitters had a higher frequency of jump float serves. This is in contrast to the results of Vescovi and Dunning (2004), who found that elite level middle blockers and outside hitters performed more jump serves than setters. It should be noted that choice of serve is often based on personal preference of the athlete as well as coach discretion.

The libero averaged the most digs per set, as well as the most digs with recovery. Since the movement patterns of this position have not been studied in the past, it is difficult to be certain as to the reason behind this. However, since the libero is a "specialized defensive player" (FIVB, 2011b), it can be assumed that they would be placed in a location on the court that would receive the most attacks, and therefore have the most opportunities to execute digs. Also, the libero plays more rotations across the backcourt than any other position, providing them more opportunities to play defense in the backcourt than other positions. Given that that the libero is "pivotal in backcourt defense" (FIVB, 2011b), it is no surprise that this position completes the most digs and digs with recovery.

Predictably, the setter spent the most time performing setting movement patterns. Setters had the highest frequency of running passes/digs, standing sets, jump sets, and transitional setting movements. It is important to note that these values would have been much higher for a team using the 5-1 system of play, since one player would perform all of the setting duties, as seen in Sheppard et al. (2009). Vescovi and Dunning (2004) found that setters perform approximately 60-80 jump sets per 3-4 set match, reflective of a 5-1 system. In the current study, setters performed an average of 9 ± 5 jump sets per set. Though these are submaximal jumps, they must be considered in the overall jumping load of setters (Sheppard et al., 2009; Vescovi & Dunning, 2004).

The setter dump proved to be of little importance in this study. However, one can assume that it would be more of a factor for teams using a 5-1 system, as the setter would be in the frontcourt for 3 rotations. The team participating in this study had only one rotation wherein the setter was frontcourt.

Transition to attack proved to be a critical movement pattern for both middle blockers and outside hitters, occurring in almost every rally, often multiple times per rally. Hitters spent a substantial amount of time getting into position to attack the ball. This movement pattern has not been studied in any other research; however, from this data it can be concluded that transitional attacking movements are an important part of the game that coaches should consider when planning training sessions.

Transition to attack coverage was also shown to be an important movement pattern for all positions, but especially for the libero. Since the libero is not an attacking player, she does not perform transition to attack, and instead moves immediately to attack coverage. Immediately following service reception or defense, the libero is the first position to move to attack coverage, and therefore spends the most time performing this movement.

Transition to defensive position was relative to the time each position spent on the court; thus, the outside hitters and setters had the highest frequency of transitional defensive movements. Nonetheless, every position performed transition to defensive position for a large portion of each set. Therefore, coaches and trainers must consider incorporating these movement patterns when planning training sessions.

Middle blockers were the only position to perform spike approach and jump. In the offensive system used by the team studied, middle blockers were the only position that attempted first tempo attacks. First tempo attacks require the athlete to be in the air as the set is being made, and therefore they always jump but do not always spike. Combining the values for *spike* with the values for *spike approach and jump* shows that middle blockers perform the highest frequency of spike jumps in total, similar to the results found by Sheppard et al. (2009) in their study on elite men's volleyball. However, this is in contrast to previous results which found that outside hitters performed more total spike jumps than middle blockers per match (Vescovi & Dunning, 2004).

Outside hitters had the highest frequency of spikes, reflective of results from a previous study which established that elite female outside hitters perform approximately 50-67 spikes per 3-4 set match (Vescovi and

Dunning, 2004). The current study found that outside hitters perform 8 ± 3 spikes per set. It must be considered that the team studied played a 6-2 system and thus had 3 attackers in the front row for 5 of 6 rotations. This resulted in a more even distribution of sets to outside hitters and setters. Also, set distribution is likely a result of the quality of service reception. As middle blockers often run first tempo attacks, it is difficult to set these players up to attack if the pass is away from the net. Also, outside sets are often a simpler play for the setter. Thus, outside hitters perform the most spikes.

Middle blockers performed far more lateral movements to block than any other position. In order to have two blockers on the opposing hitters, middle blockers must be able to move rapidly in both directions across the net in order to assist outside hitters and setters with blocking duties (Sheppard et al., 2009). This is a very important skill for coaches and trainers to consider when designing training plans for middle blockers.

All positions (with the exception of the libero who cannot legally perform blocks) performed an equal amount of stationary block jumps. Therefore, this is an important movement pattern to train for all frontcourt positions. When combining the data for *stationary block jumps* with *lateral movement to block jump*, middle blockers had the highest frequency of block jumps (16 ± 3 per set) reflective of data found in previous studies (Sheppard et al., 2009; Vescovi & Dunning, 2004). It is significant to note that middle blockers not only perform the most block jumps, but also the most spike jumps. The jumping load is very high for middle blockers (Sheppard et al., 2009) despite the fact that they are standing off the court for 2.5 rotations every set. This must be considered when training athletes in this position. In fact, Vescovi and Dunning (2004) note that the training program for a middle blocker should focus one third on spiking ability, and the majority of the program should focus on training the block. These researchers found that 55% of jumps for middle blockers are, unsurprisingly, blocks; these numbers are similar compared to the current study.

It is evident that the movement requirements for volleyball are very position-specific. In an early study, Dyba (1982) claimed, "all skills are performed by all players regardless of specialization" (p.50). As a result of increasing positional specialization, specifically the introduction of libero position, it is clear that this statement no longer rings true. In fact, middle blockers rarely perform any type of dig, and the libero never performs spikes, serves, or blocks. Given the changes in the game, coaches and trainers need to assess the physical demands placed on the athletes of each position and adjust training accordingly.

5.3 Heart Rate

Outside hitters and setters had the highest heart rate values in the four categories measured (Table 9), similar to results found by Harbour (1991). Outside hitters had the highest maximum heart rate values at 182 ± 5 bpm, and the highest average heart rate values at 159 ± 6 bpm. Setters had the highest minimum heart rate values at 125 ± 10, and spent the most time over 80% of their age-predicted maximum heart rate. The heart rate values for outside hitters and setters were very similar overall, demonstrating that these positions have similar workload demands. In fact, the heart rate profiles for setters and outside hitters show similar patterns throughout a set (Figure 2 & 3). Setters and outside hitters remained on the court at all times (except mandatory time-outs), and performed many of the same movements. Thus, a similar heart rate profile was the result.

Liberos and middle blockers had similar heart rate values, averaging 133 bpm in a typical set (Table 9). However, the heart rate profile for the two positions was very different as a result of the length of time the middle blockers rest on the sidelines. The middle blocker profile shows large dips during the rest period wherein they were replaced by the libero (Figure 5). The libero profile shows similarities to the outside hitters and the setter, but at lower values (Figure 4). It can be inferred that the values are lower for the libero due to the fact that liberos do not perform any jumping activities, which have been shown in previous studies as movements that result in the highest heart rates (Fardy et al., 1976). It must also be considered that the libero is resting on the sideline when the middle blocker is serving, which can extend for one rally or multiple rallies. Typically, the rest period for the libero was much shorter than for middle blockers, similar to the results found by Gonzalez et al. (2005), which accounts for the choppy nature of the libero profile in comparison to the large dips seen in the middle blockers' profile.

These charts illustrate that the athletes, regardless of position, maintained elevated heart rates for minutes at a time throughout a match, despite the fact that the average rally lasted only 10.54 seconds. In the past, volleyball has been thought to be purely anaerobic in nature; however, these heart rate values support the assertion that volleyball also involves the aerobic system to a greater degree than found in previous research (Gionet, 1980).

Figure 2. An example of a heart rate profile for a setter in a 6-2 system.

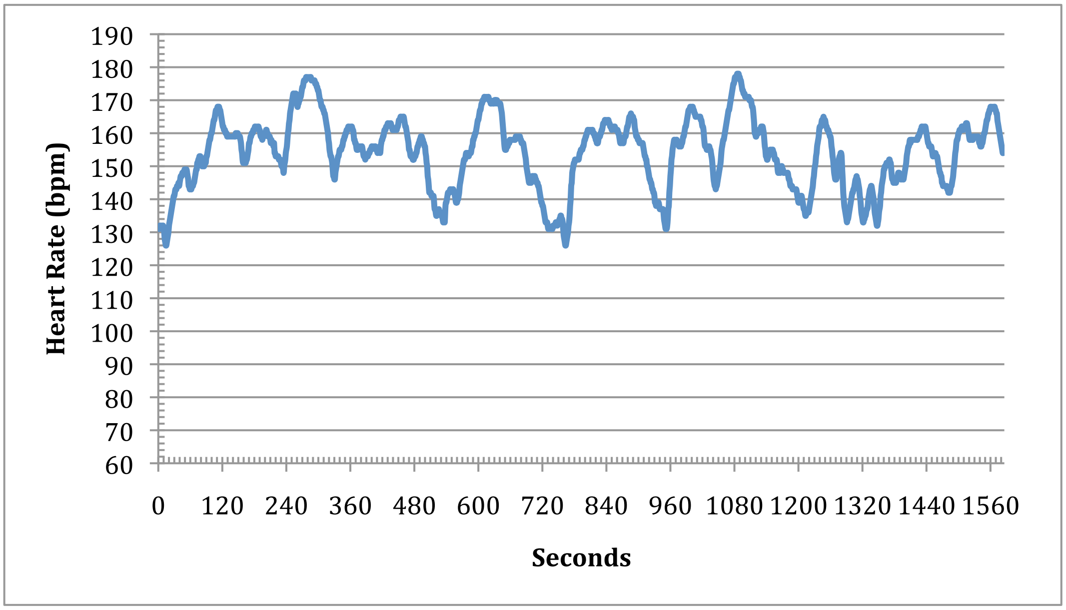


Figure 3. An example of a heart rate profile for an outside hitter.

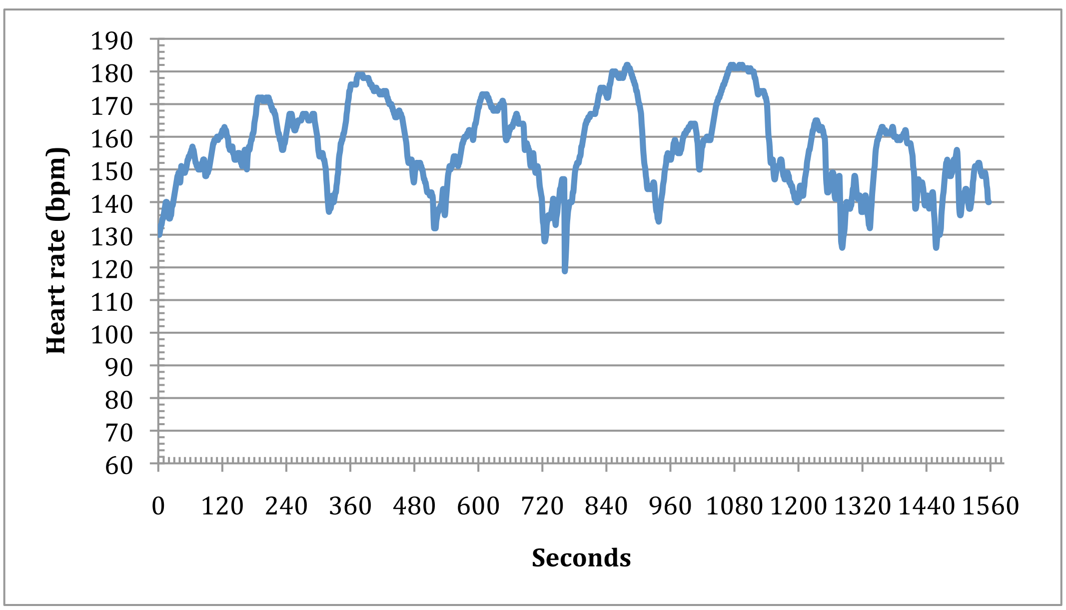


Figure 4. An example of a heart rate profile for a libero.

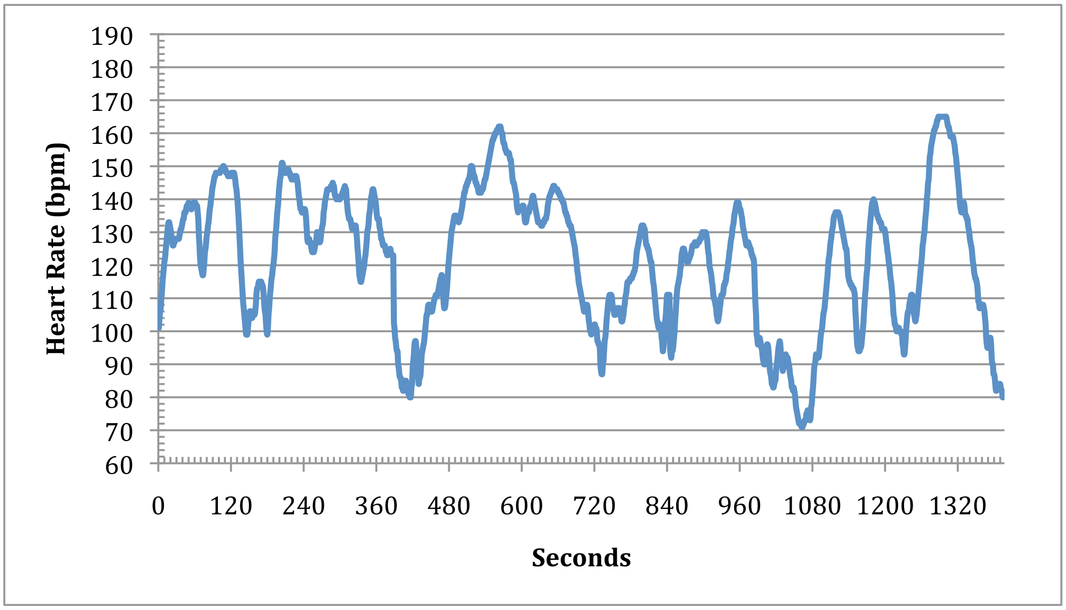
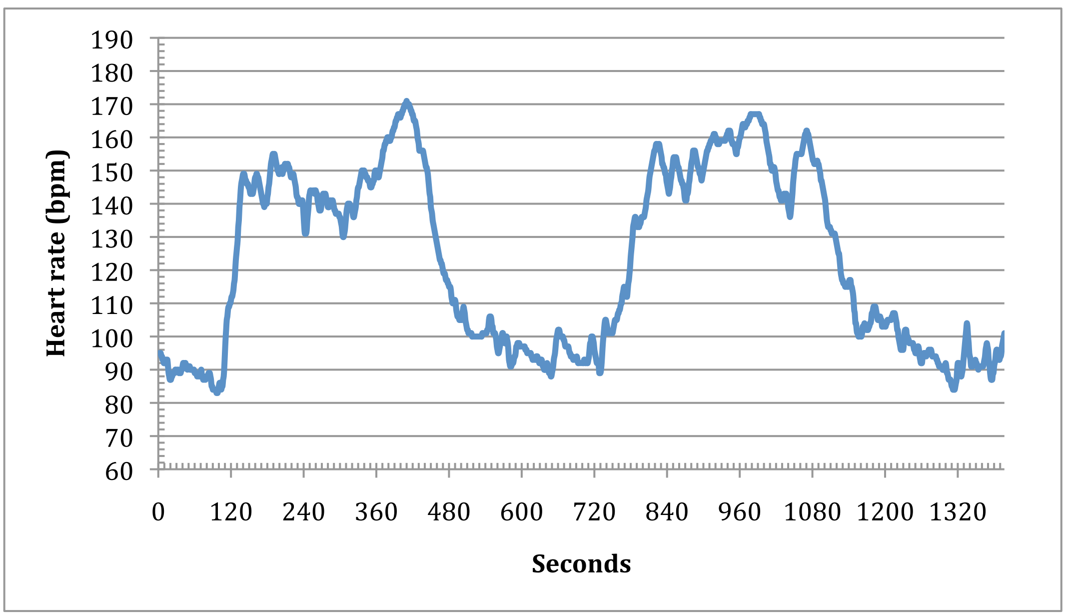


Figure 5. An example of a heart rate profile for a middle blocker.



5.4 Heart Rate and Time-Motion Analysis Combined

Displaying the heart rate values on graphs along with time-motion analysis charts provides a good indication of what movements were occurring during periods of lower or higher exertion. It is apparent that heart rate values decreased dramatically during long periods of standing. The long periods of standing are indicative of time-outs for all positions, or periods of rest on the sidelines for the middle blockers and the libero. It is interesting to note that the heart rate can increase drastically (over 40 bpm) even after a longer rest period, and that it is often jumping movements that are associated with this increase in heart rate. The ability for volleyball athletes to transition from standing to dynamic, intense movements is apparent when looking at the combined graphs (Figures 6 to 9).

It is evident that the rest times between rallies are not long enough to substantially decrease heart rate values. Athletes must maintain moderate to high rates at all times within and between rallies. Heart rate is only shown to decrease substantially during periods of rest lasting 30 seconds or more.

Figure 6. An example of a heart rate profile and the movement patterns of a setter in a 6-2.

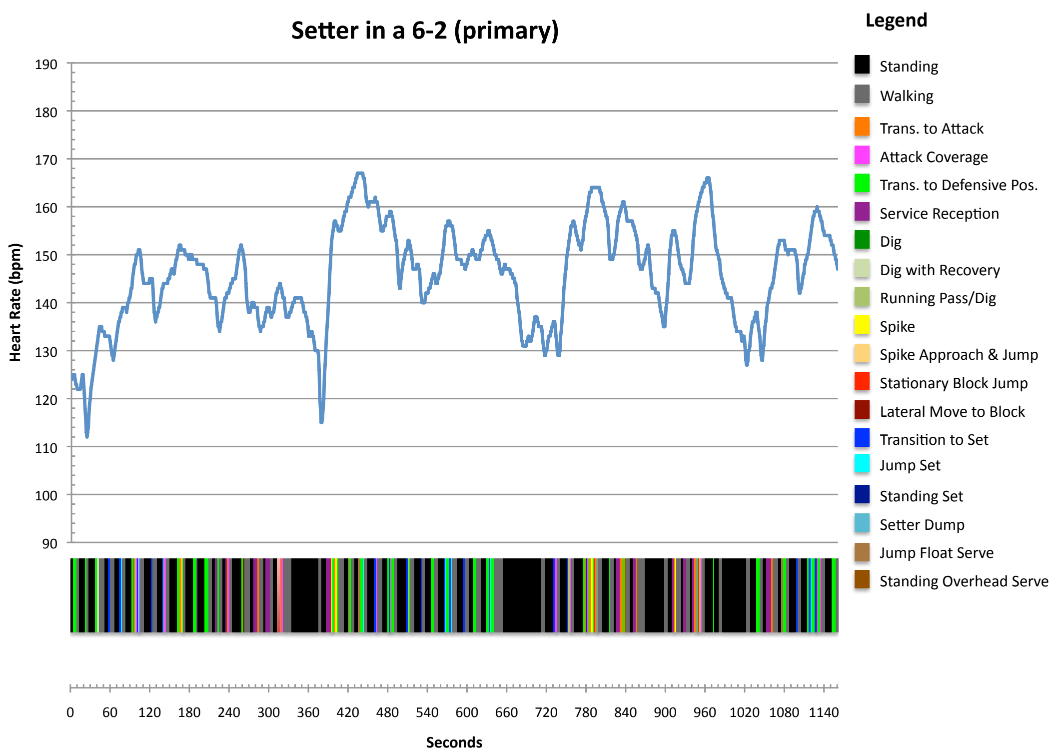


Figure 7. An example of a heart rate profile and the movement patterns of an outside hitter.

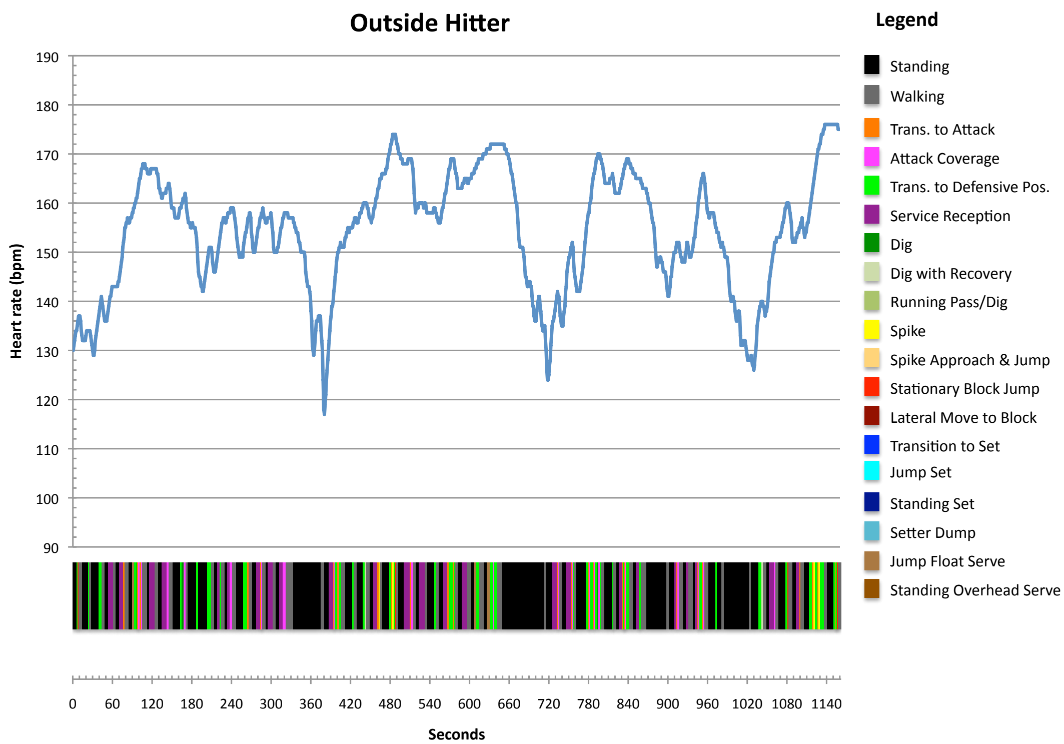


Figure 8. An example of a heart rate profile and the movement patterns of a libero.

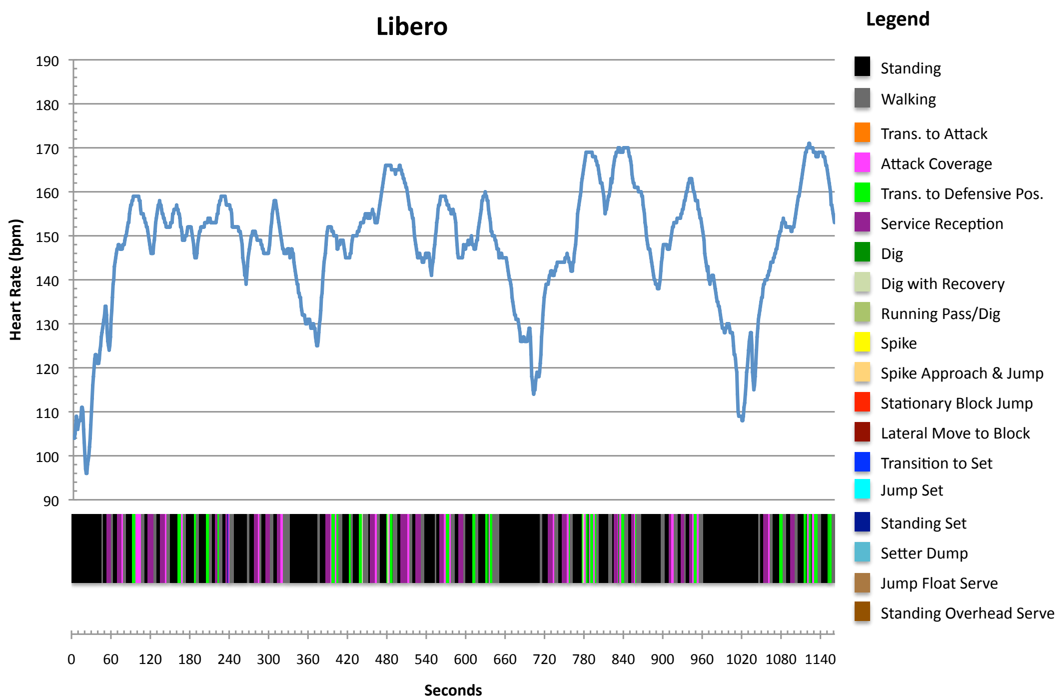
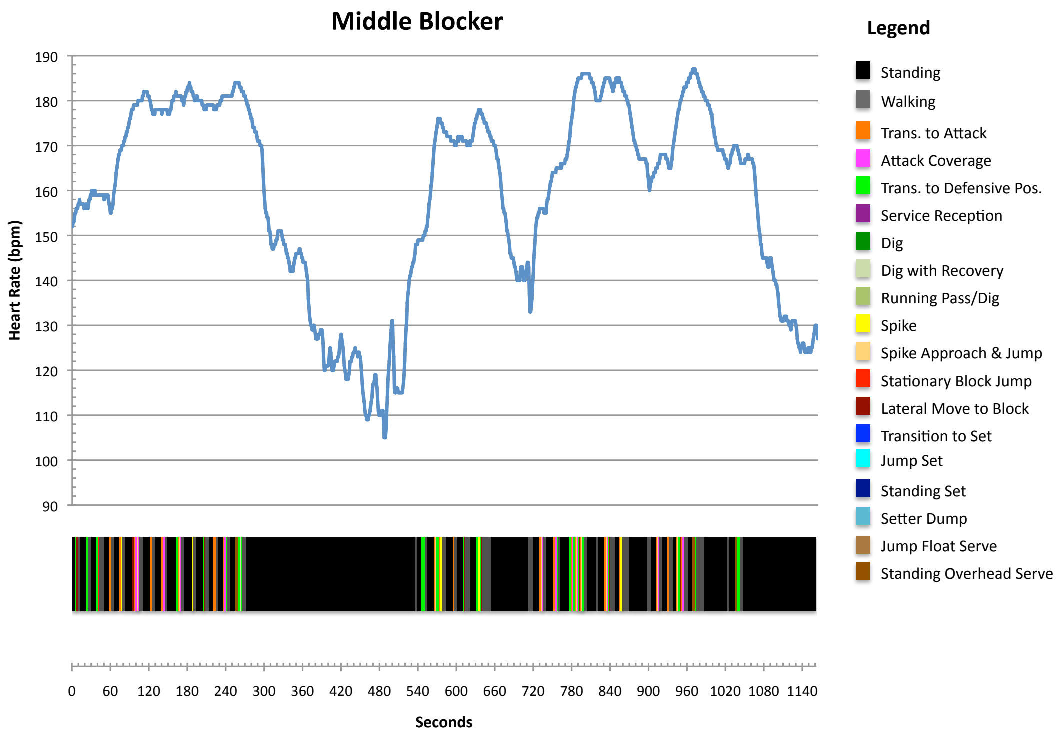


Figure 9. An example of a heart rate profile and the movement patterns of a middle blocker.



5.5 Work and Rest Intervals

This study is unique in that the work and rest intervals were calculated using the start of movement patterns, rather than the referee's whistle. The results show that the athletes spend considerably more time at rest than they do at work (Table 10). In fact, the current results revealed even less time spent at work than studies conducted before rally-point scoring that did not utilize the three-ball system (e.g. Dyba, 1982; Lecompte & Rivet, 1979). This is an interesting finding, and there are several possible explanations for this outcome. Lecompte & Rivet (1979) note that the matches studied averaged "2 off-times and 3 change-overs per game" (p.89). This is equivalent to 2 time-outs and 3 substitutions in the current format. Currently in the CIS, each team is allowed 2 time-outs per set and there is a technical time-out included at 16 points. This would be 5 off-times using Lecompte and Rivet's terminology. Given this information, it is little wonder that the results of the current study show more time spent at rest. Also, as mentioned above, work and rest intervals were measured using actual movement in this study, rather than using the referee's whistle. Using the latter method incorporates time spent standing after the referee's whistle but prior to movement to execute service.

The average length of a rally was found to be 10.54 ± 1.13 seconds. This is slightly longer than what was found previously. Lecompte and Rivet (1979) found the average duration of an exchange to be 9.67 seconds. It is difficult to make comparisons here, as the level of play may have been significantly different. Today's game has sometimes been referred to as "power volleyball", played at the net and incorporating several blocks and spikes (Gionet, 1980). This change in the nature of the game may also account for the length of the rallies found in the current study.

The longest rally across all matches studied was 58.2 seconds, and the shortest rally was 1.1 seconds (Table 11). This demonstrates the need for volleyball players to train different energy systems. These results appear to support Gionet's (1980) assertion that power volleyball is not only anaerobic in nature, but also relies on the aerobic system. Therefore, it is clear that interval training aimed to improve the cardiovascular system is crucial for competitive female volleyball players.

5.6 Limitations

The results found in this study are specific to the investigated population of CIS female volleyball players at the start of the 2012/2013 season. The time-motion analysis applied to this population was developed by the primary researcher and has not been proven valid across other populations. Some of the time-motion results may be dependent on the tactics and systems employed by the specific team examined. Additionally, conclusions about the energy systems involved cannot be considered 100% accurate without the use of system-specific tests (Foran, 2001).

5.7 Conclusions

This is the first study to examine both the heart rates and the movement patterns of female university volleyball players. The results indicate that competitive women's volleyball is a multifaceted sport incorporating a multitude of movement patterns and skills. Movement patterns were found to vary across positions, including some skills and movements that are specific to one position only. A complete time-motion analysis of volleyball has never been done, and thus these results may serve as a catalyst for future research.

Women's volleyball at this level is composed of intermittent high intensity work periods, requiring heart rates to be maintained at a high level for minutes at a time. Results indicate that competitive female volleyball players, regardless of position, not only require a trained anaerobic system, but also rely on the aerobic system to maintain a high intensity throughout a set. These results are consistent with the most recent study examining heart rate response in NCAA women's volleyball (Harbour, 1991), demonstrating that collegiate women's volleyball provides an interval training effect and requires both aerobic and anaerobic fitness.

5.8 Practical Applications

Considerable differences were found between positions in regards to both movement patterns and heart rate response. Given that the middle blockers were found to spend considerably more time standing than any other position, but also performed the most spike jumps and block jumps, training for this position should involve periods of rest coupled with periods of high intensity jumping work. Training for the libero position should involve longer periods of moderate intensity, and incorporate movements that require low ground movement such as transition to attack coverage, transition to defensive position, service reception, and defensive skills such as the dig and dig with recovery. Undoubtedly, setters must spend more time training transitional setting movements, jump sets, and running passes than any other position. Setters and outside hitters must train at similar intensities, and aim to achieve heart rate values averaging just below 80% predicted maximum heart rate throughout a set. Outside hitters must train the majority of movement patterns (excluding setting movements), but extra time should be spent training the spike, given the frequency of occurrence of this skill.

All positions should utilize interval training and vary the length of the intervals in order to train the ATP-PC system, the anaerobic system, and the aerobic system (Virr et al., 2013). Outside hitters and setters must be able to maintain high heart rates for longer periods of time than middle blockers or liberos, and the training program should reflect this. An example cardiovascular training program that mimics the results found in this study for a middle blocker would be a 3-4 minute high intensity work period, followed by a 3-4 minute rest period, repeated 2-3 times within the length of a set (about 22 minutes). Within the work period, intense bursts of 10-20 seconds should be incorporated, followed by 10-15 seconds of recovery. This would mimic the high intensity movements in the front court that are followed by short periods of walking and standing. Heart rate should be monitored by the athletes at the end of work periods to ensure the values are over 80% predicted max heart rate; heart rate should also be monitored during the rest period, as results showed that heart rate should lower by a minimum of 30 bpm in one minute. An example program for an outside hitter would incorporate shorter rest periods in comparison to a middle blocker. The longest rest period within a 22-minute set or training session should be 1 minute for both outside hitters and setters, representing a time-out. For example, outside hitters should train for 3-4 minutes at 70-80% max heart rate, followed by a one-minute rest period wherein the heart rate should drop by 30bpm from the value measured at the end of the high intensity work period. As with the middle blockers (and all positions), short bursts of high intensity work should be incorporated within the 3-4 minute work period, mimicking the heart rate spikes found interspersed throughout rallies. Liberos can train in a similar way to outside hitters, but the high intensity bursts are not required in the same volume, and the heart rate is not required to be as high during the work period.

The frequency of jumping movements recorded in this study demonstrates the importance of strength training and plyometric training for volleyball athletes. The frequencies of these types of movements found during match play should be reflected in training programs that incorporate speed, power, and agility training (Hedrick, 2007). In comparison to traditional strength training, Olympic lifting has proven a successful method for increasing both strength and power (Hoffman, Cooper, Wendell, & Kang, 2004), and thus, could be utilized by volleyball athletes in their strength training programs. There is much biomechanical similarity between performing vertical jumps and performing Olympic lifting exercises such as cleans, jerks, and snatches (Hedrick, 2007). Therefore, training in this fashion simulates some on-court movements in volleyball.

Although volleyball participation has increased drastically over the past decade, few studies have examined movement patterns and heart rate response. In fact, no study on the sport of volleyball has ever combined the two forms of analysis. This study serves to increase the knowledge base for coaches, fitness professionals, and athletes as they strive to develop appropriate, position-specific training programs.

5.9 Future Directions

Future research should utilize the movement patterns developed in this study, in order to validate the importance of these skills and movements for university women's volleyball players. Studies should be done with teams that utilize various systems, specifically the 5-1 system of play. Also, it is important to study the highest level of competition and extend this research to the international women's game. Heart rate response should be analyzed in international competition. Heart rate monitors could also be used in training to assess the demands of practice in comparison to the demands of match play. It would be interesting to study the physiology of elite female volleyball players along with their anthropometric characteristics, separating this information by position. Such a study would provide a more detailed description of the demands of each position and very specific training programs could be developed.

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Appendix A

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Dear Coach:

We are seeking your feedback concerning the importance of specific movement patterns in the overall success of the female volleyball athlete. Our inquiries are part of a research study concerning the workload and movements of CIS women's volleyball players. The major benefit of your participation in this study will be to help the researchers create an accurate set of movement pattern categories that will be used to analyze the movement of CIS female volleyball athletes.

Thank you for considering completing this survey. All completed surveys can be returned to Jocelyn Blair in person or via email at jocelynb@ualberta.ca. If you have any questions or concerns about this research project please do not hesitate to contact Jocelyn Blair by email at jocelynb@ualberta.ca.

Many thanks,

Jocelyn Blair, Graduate Student
Pierre Baudin, PhD

PART ONE- COACHING HISTORY

1. Name (optional):

2. Total number of years coaching women's volleyball:

3. Total number of years coaching CIS women's volleyball:

4. Highest level coached:

5. NCCP certification:

PART TWO- MOVEMENT PATTERNS

***6. On a scale from 1-4, please rate the importance of each movement pattern in the overall success of a CIS female volleyball athlete. Please select the most appropriate number:**

	Not at all Important	Somewhat Important	Very Important	Vital
Dig	◯	◯	◯	◯
Dig with recovery (eg. stride slide)	◯	◯	◯	◯
Jump float serve	◯	◯	◯	◯
Jump set	◯	◯	◯	◯
Lateral movement to block (eg. middle closing to outside)	◯	◯	◯	◯
Retreat to attack (transition off of the net)	◯	◯	◯	◯
Running set (eg. setter has to chase down the ball)	◯	◯	◯	◯
Service reception	◯	◯	◯	◯
Setter dump	◯	◯	◯	◯
Spike	◯	◯	◯	◯
Spike approach and jump (eg. middle approaches, but is not set)	◯	◯	◯	◯
Standing overhead serve	◯	◯	◯	◯
Standing set	◯	◯	◯	◯
Stationary block jump	◯	◯	◯	◯
Transition to attack coverage	◯	◯	◯	◯
Transition to defensive home	◯	◯	◯	◯

7. Please identify any other movement patterns or actions not listed in the previous question, that you think are necessary to succeed in the sport of volleyball.

THANK YOU for your participation in this survey.