FACULTAD DE CIENCIAS DE LA EDUCACIÓN

PROGRAMA DE DOCTORADO EN FORMACIÓN DEL PROFESORADO

ANALYSIS OF RALLY POINT SCORE SYSTEM (SET TO 21 POINTS) AND TIME REDUCTION OF 15 SECONDS BETWEEN SERVES IN HIGH-LEVEL MEN'S VOLLEYBALL: EFFECTS ON THE PERFORMANCE AND DYNAMIC OF THE VOLLEYBALL GAME

TESIS DOCTORAL

D. MLADEN STANKOVIĆ

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Título de la Tesis

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Las Palmas de Gran Canaria, a _____ de _____ de 20___

UNIVERSIDAD DE LAS PALMAS DE GRAN CANARIA

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TESIS DOCTORAL DEL LCDO. EN CIENCIAS DE LA ACTIVIDAD FÍSICA Y DEL DEPORTE

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LAS PALMAS DE GRAN CANARIA, 2017

Transport a handful of earth everyday and you will make a mountain.

~ Confucius ~

"Whatever you can do,
Or dream you can, begin it.
Boldness has genius, power, and magic in it."

~ Johann Wolfgang von Goethe ~

"Only as high as I reach can I grow
Only as far as I seek can I go
Only as deep as I look can I see
Only as much as I dream can I be"

~ Karen Ravn ~

Acknowledgments

Completing this Doctoral Dissertation means a great deal to me. A dissertation is not simply a scientific work carried out over four to five years during doctoral studies: it is a way of life. In my case, the dissertation is the realization of a dream I have had since I was 11 years old. My interest in the sport of volleyball began when I started playing at the age of 14. As a volleyball player, I improved myself, met so many people worldwide, and developed my career as an athlete, a coach and an academic.

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List of Abbreviations

FIVB: International Volleyball Federation

USAV: USA Volleyball

VIS: Volleyball Information System

IT: Information Technology

Resumen

Esta tesis doctoral tiene como objetivo primordial analizar y valorar el efecto de dos nuevas reglas introducidas en el voleibol en el año 2013 – la del set de 21 puntos (excluyendo el quinto set), debiendo tener una ventaja de dos puntos al final del set, y la de los 15 segundos entre rallies o jugadas (dividiéndose en 10 segundos después del punto terminado hasta la señal del árbitro para realizar el saque, teniendo desde ese momento 5 segundos para ejecutar el saque) –. Estas reglas influyen sobre la dinámica de los partidos, en cuanto al saque, el tanteo en las partes finales del set, el tiempo de juego y descanso, y en los saltos, golpeos y contactos.

El vóleibol ha tenido una constante evolución desde su invención en 1895. Desde 1947, la Federación Internacional de Voleibol (FIVB) se ha encargado del desarrollo y de la promoción de voleibol. Después de los Juegos Olímpicos en 1996 en Atlanta, la FIVB anunció varias reglas nuevas. Una de ellas era el set con 25 puntos, bajo el sistema de marcador "Rally Point" o punto por jugada. En octubre de 2013 la FIVB organizó el primer Campeonato Mundial de Vóleibol para hombres menores de 23 años en Uberlandia, Brasil, probándose las dos reglas novedosas: la del set de 21 puntos (excluyendo el quinto set) y 15 segundos entre rallies o jugadas. Con estos cambios se trataba de modernizar el vóleibol, haciéndolo más atractivo para los seguidores y aficionados y posibilitando o facilitando la audiencia de partidos, tanto por los que ven partidos en directo como los que los ven por la televisión.

Esta tesis doctoral, está compuesta por cuatro estudios en los que se observa la influencia de estas nuevas reglas en los partidos de voleibol. Para poder llevarla a cabo se ha realizado la observación de 12 equipos nacionales (Argentina, Australia, Brasil, Bulgaria, la República Dominicana, Egipto, Irán, México, Rusia, Serbia, Túnez, y Venezuela),

visualizándose y analizándose 36 partidos con 123 sets, en los cuales intervinieron 144 jugadores varones menores de 23 años (M = 21.1±1.4 años).

El primer estudio incluye 4588 saques, procesados utilizando el test estadístico Chi-Cuadrado de Pearson. Fueron estudiadas las siguientes variables: el rol del jugador, el tipo de saque, la calidad del saque, las tendencias de saque según la fase del set, la zona desde la que se realiza el saque, la zona a la que se dirige el saque y el resultado del set. Fueron observadas diferencias significativas entre: tipo de saque y fase del set, calidad del saque y resultado del set, zona de saque y resultado del set, zona a la que se saca y zona desde la que se saca, distribución de la calidad del saque y zona de saque, distribución de la calidad del saque y zona a la que se saca, distribución del tipo de saque y rol del jugador, distribución de la calidad del saque y rol del jugador y, distribución de la zona de saque y rol del jugador. Cabe señalar que el "Saque en Salto Flotante" fue el servicio dominante al tratarse de un saque seguro pero, a la vez, un arma compleja, cuya frecuencia aumenta hacia el final del set. Para ganar un set, el equipo no solo tiene que ejecutar saques controlados, sino también tiene que atacar cometiendo un mínimo de errores, asegurando que los saques den las menos posibilidades de ataques de primer tempo posible.

El segundo estudio aborda las acciones realizadas para ganar puntos en las partes finales del set. Se han considerado 1335 acciones finales que dieron como resultado puntos ganadores. Se aplicó la prueba de Chi-Cuadrado de Pearson para analizar los datos. Los resultados demuestran una disminución en la diferencia entre los sets ganados y perdidos en relación a la estructura de puntos ganados y perdidos cuando el set estuvo más duro y apretado. Se identificó al jugador atacante de zona 4 como el rol de jugador que finalizaba la mayoría de los puntos. Si se cambian las reglas, el desarrollo de los bloqueos, los saques y los ataques, podría tener mayor influencia en el resultado del set en el futuro.

El tercer estudio trata de los tiempos de juego y descanso, analizándose 36 horas de partidos, divididos en 123 sets y 4583 puntos. Se han usado las pruebas ANOVA unidireccional y no paramétricas de Kruskal-Wallis para el tratamiento estadístico. Entre los resultados obtenidos cabe señalar que la parte de juego real, o activa, del set y del partido entero se corresponde solo con un poco más de un tercio de la duración total. La duración más frecuente en un rally o jugada oscila entre 5 y 10 segundos (43,5% de los puntos). A medida que los sets se volvían más impredecibles y se acercaban hasta el final, el tiempo de descanso entre puntos se alargaba. El análisis de los partidos muestra que hay una base para limitar las pausas entre rallies hasta 10 segundos, lo que da a los jugadores el tiempo adecuado para llegar a la posición de saque y 5 segundos para ejecutar el saque.

En el cuarto estudio se analizaron 25930 saltos, 15706 contactos y 10224 golpeos realizados por los jugadores. Se ha utilizado la prueba de Chi-Cuadrado de Pearson para evaluar las diferencias significativas entre las frecuencias registradas en las muestras individuales y las pruebas T-test y ANOVA unidireccional para probar la significación entre las medias establecidas para los elementos específicos en submuestras específicas. Este estudio se dividió en dos investigaciones: en la primera se analizaron los saltos considerando el tipo de salto, el rol del jugador, y el nivel del set ganado. En la segunda se analizaron los contactos (recepción, colocación, bloqueo y defensa) y los golpeos (saque y ataque), considerando su tipo, el rol del jugador y el resultado del set. Se han encontrado diferencias significativas entre el rol del jugador y el tipo de salto, siendo identificado el jugador central como el rol que ejecutó la mayor cantidad de saltos. Al analizar la cantidad y el tipo de golpeos, se han encontrado diferencias significativas entre los equipos ganadores y perdedores del set solo en lo que respecta a los saques del colocador y del central. La investigación reveló grandes diferencias en cuanto a los saltos, golpeos y contactos si se considera el rol del jugador, destacando que el jugador que ocupa el rol de central tuvo, con diferencia, la mayor

frecuencia de salto, seguido del atacante de ala de la zona 4 y del colocador. El líbero mostró una nueva tendencia a colocar en salto después de la acción inicial defensiva del colocador.

Podemos decir que la aplicación de estas nuevas reglas sí condiciona el juego del voleibol desde diferentes perspectivas, revelando muchas diferencias significativas y que, además, su implantación influye en los resultados de los partidos, siendo un elemento nuevo a la hora de considerar el entrenamiento del voleibol.

Abstract

The aim of this Dissertation is to give detailed answers about how two new experimental rules introduced into the game of volleyball in 2013 – the 21-point set (excluding the fifth set) with a two-point lead required at the end of sets, and 15 seconds between rallies (10 seconds from the finished point until the referee's whistle to serve and five seconds for performing the serve) – have influenced the dynamic of the game related to serves, point-scoring plays in the final parts of the sets, work-rest time, and jumps, hits and contacts.

The game of volleyball has evolved since it was invented in 1895. In 1947, the Fédération Internationale de Volleyball (FIVB) was formed, tasked with developing and promoting the sport of volleyball. After the 1996 Olympic Games in Atlanta, FIVB announced several new rules. One of them was the 25-point set under the rally point score system. In October 2013, FIVB organized the first Volleyball Men's Under 23 World Championship in Uberlandia, Brazil, testing two new rules: the 21-point set (excluding the fifth set), and 15 seconds between rallies. The rule changes were intended to modernize volleyball and make it more appealing for fans, both present at games and watching matches on television.

For this Dissertation, four studies were conducted, involving the observation of 12 national teams (Argentina, Australia, Brazil, Bulgaria, Dominican Republic, Egypt, Iran, Mexico, Russia, Serbia, Tunisia, and Venezuela) that played 36 matches in 123 sets performed by 144 male players under 23 years of age (M = 21.1±1.4 years).

The first study, about serves, comprised 4588 serves processed using Pearson's Chi-Square statistical test. The following variables were examined: in-game role, serve type, serve quality, serve trend by set phase, serve zone, placement zone and set outcome. Significant differences were observed in serve type by set phase, serve quality by set outcome, serve zone

by set outcome, placement zone by serve zone, serve quality distribution by serve zone, serve quality distribution by placement zone, serve type distribution by in-game role, serve quality distribution by in-game role and serve zone distribution by in-game role. The Jump Float Serve was found to be the predominant serve type. It is a safe but complex weapon that becomes more frequent towards the end of the set. To win the set, the team not only has to perform controlled serves, but also attack with minimum errors, ensuring their serves result in as few first tempo attacks as possible.

The second study, about point-scoring plays in the final parts of the set, comprised 1335 final actions that led to winning points. Pearson's Chi-Square test was used to analyze the data. The results showed a decrease in the difference between winning and losing sets in relation to the structure of points won and lost as the set became tougher. The outside-hitter was identified as the in-game role that finished the most points. If the rules are changed, the development of blocks, serves and attacks may have greater influence on set outcome in the future.

A third study, about work-rest time, comprised 36 hours of matches, partially segmented into 123 sets and 4583 points played. One-Way ANOVA and Kruskal-Wallis nonparametric tests were used. The active part of the set and the whole match last slightly more than one third of the total time. The most frequent rally duration was 5 to 10 seconds (43.5% of points). As sets became more unpredictable and approached the end, rest time between points was longer. Game analysis shows there is a basis for limiting pauses between rallies to 10 seconds, giving players adequate time to reach the serving position and 5 seconds to perform the serve.

The fourth study comprised 25930 jumps, 15706 contacts, and 10224 hits. Pearson's Chi-Square test was used to evaluate significant differences between frequencies registered in individual subsamples. T-tests and One-Way ANOVA were used to test the significance

between means established for specific elements in specific subsamples. This final study was divided into two investigations: 1) jumps were analyzed by each type of jump, in-game role and level of set win; 2) contacts (reception, setting, block, and defense) and hits (serve and attack) were examined by type, in-game role and set outcome. Significant differences were found between in-game role and jump type, and middle blocker was identified as the position that performed the most jumps. Analysis of the number and types of hits showed significant differences between set winner teams and set loser teams only for serves by the setter and middle blocker. The investigation revealed a major difference in jumps, hits and contacts between in-game roles, identifying middle blocker as by far the most frequent jumping position, followed by outside hitter and setter. The libero in-game role showed a new tendency of being setter with jumps after the initial setter defense action.

The volleyball game analysis revealed many significant differences with the introduction of the two experimental rules, influencing the game from various perspectives. The new rules also affect match results and are a further element to take into consideration for volleyball training.

INTRODUCTION

Introduction

The game of volleyball is played by millions of people around the world (Huang & Hu, 2007; Kenny & Gregory, 2006; Lee & Chin, 2004; Tillman, Hass, Brunt, & Bennett, 2004). Today it is among the world's ten major sports (Humski & Skocir, 2011). Its origins go back to 1895 in Holyoke, Massachusetts, when William G. Morgan invented a new game called Mintonette (Lee & Chin, 2004; Matias & Greco, 2011; Fédération Internationale de Volleyball [FIVB], n.d.-b, Volleyball history – The origins; Pfeifer & Deutsch, 1981). In 1896, this game became known as volleyball (FIVB, n.d.-b, Volleyball history – The origins). From the moment of its creation, every sport goes through phases that shape its original constitution until a stable structure is reached (Ureña, Gallardo, Delgado, Hernández, & Calvo, 2000). Knowing the rules and being familiar with the changes to them gives us the opportunity to better understand volleyball, determine how changes have influenced the dynamic of the game, and predict how volleyball will continue to develop (González, Ureña, Santos, Llop, & Navarro, 2001). Nowadays, all changes mandated by Fédération Internationale de Volleyball (FIVB) are intended to make volleyball one of the most famous sports in the world, fulfilling a demand for modernized sports that offer a unique spectacle (Fraile, 1999; Ureña et al., 2000).

During the early years of volleyball, the scoring system was continually modified (Lee & Chin, 2004). The Side Out Scoring System (set to 15 with a difference of at least two points; the match is finished when one team wins 3 sets of a maximum of 5 played sets) came into force in 1925. In 1974 came the Fin-30 variation of the Side Out Scoring System, with a set to 30 points with a minimum two-point difference for set victory (Pfeifer & Deutsch, 1981). Volleyball rules went through various phases as the game evolved: the first period, 1947–1963, the second period, 1964–1979, the third period, 1980–1994, the fourth period, 1994–1998 (Ureña et al., 2000), the fifth period, 1999–2008, and the sixth and last period,

from 2009 until the present, January 2017.

During the first period, changes were designed to give more freedom to players. In the second period, volleyball became an Olympic sport; from that time, amendments to rules aimed to increase defense and decrease strong attacks. In the third period, the changes involved catering towards television, primarily to reduce the duration of games and make them more appealing for spectators. In the fourth period, changes dramatically influenced the structure of the game (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules; Ureña et al., 2000). Two changes greatly influenced the dynamic of the game: changing the scoring system from the Side Out (SO) to the Rally Point system (RPS) (Lee & Chin, 2004) and including a new player position in the game, called "libero" (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules; Mesquita, Manso, & Palao, 2007).

Many important changes were implemented in the fifth period. In particular, several rules were updated in 1998:

- Colored balls were introduced to help players and television viewers focus on the ball.
- The libero, a specialized defensive player, was introduced to improve the first pass"" and the defensive ""dig pass". The position was also intended to replace back-zone players (the principal attackers), who are generally weak in defense.
- The coach could now stand and move about during the rally and give instructions without taking a time-out.
- The 25-point rally point system was introduced for sets one to four, further emphasizing the need to perfect the skills of the game; when the team loses the point, the opponent is given the serve. This system is beneficial for scheduling the day's matches, with five-set matches lasting an average of 90-110 minutes.
- The players' uniform numbers were increased in size to 20 cm x 2 cm. This allows the

scorer to easily verify the next server on rotation and helps the media and television to capture the player number for statistical analysis.

- Serve attempts were eliminated, reducing the duration of the match. Every player invariably delayed the serve, taking undue advantage of the "serve-attempt", taking a total of 5+3 seconds (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules).

Further changes were brought in each year after 1998. In 1999, the time allowed for serving was increased to eight seconds. One year later, the serve ball was allowed to touch the upper edge of the net while passing to the opponents' court (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules; Quiroga et al., 2012). From 2000, the libero was not permitted to be either team captain or game captain. Based on the 2001 rule for "Exceptional substitution," injured players could be replaced by other players without the switch qualifying as a regular substitution. The two rules added in 2005 defined the center line width as belonging equally to both courts and introduced an assistant scorer mainly to control libero replacement. In 2006, the coach restriction line was implemented to limit coach movements beyond the playing court. In 2007, rule 9.1.2.3 was revised and upgraded so that continuity of play would be upheld over the double fault. Four rules were implemented in 2008: a) introduction of a newly designed ball, featuring two colors on eight panels; b) the possibility of nominating 14 players on the team roster for FIVB and world events for senior teams, with the requirement of including two liberos, who can be exchanged only once during the match, if the team elects more than 12 players; c) implementation of the quick substitution system; and d) modification of net fault and center line rules (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules).

During the sixth period there have been several essential changes to the rules governing the international game, first introduced in 2014 and implemented for the 2015

FIVB Volleyball World League. The new team ranking was modified for all events, such that the Round Robin team ranking criteria was determined according to the number of victories (wins/losses) among the teams of the same pool or group. Simultaneously, the following critical rules were adopted: a) net contact; b) player's fault at the net; c) minor adaptation of rally point definition; d) libero; and e) total number of players.

Earlier research has demonstrated that excitement and interest in matches (especially where the point difference is minimal) are increased by the RPS, and this increases the number of sponsors involved in volleyball (Giatsis, 2003). The duration of volleyball matches has become more controlled with RPS.

From 6 to 14 October 2013, FIVB launched the first Under 23 (U23) Men's World Championships in Uberlandia, Brazil, where two new rules were tested: the Rally Scoring System (RS) set to 21 points (excluding the 5th set) with a minimum difference of two points, and 15 seconds before the referee whistles for serve; in addition, one Technical Time-Out of 60 seconds per set was applied automatically when the leading team reached the 12th point. The rules were tested with the aim of modernizing volleyball, making it more appealing to fans at the game or watching matches on television (FIVB, 2013). With the earlier changes in the scoring system from SO to RS, the players needed to adapt and coaches needed to consider the duration and number of repetitions during training sessions (Giatsis, 2003). As a result, if the new tested rules are approved in the future, the training process is likely to be similarly influenced by these modifications.

CHAPTER 1

THEORETICAL FRAMEWORK

Chapter 1

Theoretical Framework

The Serve in Volleyball

The history of serve rules. Each rally in a volleyball game is started with a serve, where the player has to hit the ball over the net, directed inside the lines of the court, exclusively with the arm (FIVB, n.d.-a, The Game - Volleyball - Service). The serve is introduced as one of the original volleyball skills in the first written rules by William G. Morgan, from 1897 (Giddens & Giddens, 2005; Kenny & Gregory, 2006; López, 2013; Palou, 1992; Ureña et al., 2000).

In 1897, the rules for serve were as follows: The serving player had two chances to serve, in case the first attempt resulted in a miss; the server had to have one foot on the back line, hit the ball with the hand, and the ball must go over the net without touching it; a partner could help the ball over the net with one touch; if the serve was correct there was no second serve; every "unreceived" serve was a point for the serving team, but if the opponent team scored, they earned the chance to serve. In 1920 the rules were modified and the server was not permitted to step on the back line of the court during the serve. In 1947 the server had to serve from the right side behind the court (back line), still with one foot on the ground (Fröhner, 1995; Santos, Viciana, & Delgado, 1996; Ureña et al., 2000).

From 1949 the server could run and jump before hitting the ball, and from 1951 the server could land in the court after jumping and hitting the ball. The serving zone was expanded to an unlimited area behind the line, but in 1953 it was limited to 20 cm behind the back line of the court (Ureña et al., 2000).

More than 40 years later, further new rules were added: in 1994 the serve zone was extended to nine meters to provide more options in serving (Ureña et al., 2000); from 1998

the server had only one attempt to serve, to reduce the duration of the match; and from 1999 the server had 8 seconds to serve. In 2000 the ball was allowed to touch the top of the net and pass over it without interrupting the continuity of the game (FIVB, 2015, The Game - Volleyball Rules; Major changes in volleyball rules).

The importance of the serve. The serve in volleyball is at once a defensive and an offensive element (Katsikadelli, 1997; Maia & Mesquita, 2006; Tsivika & Papadopoulou, 2008), evaluated as a strong weapon for directly scoring points (Monge, 2007; Wise 2002). After the presentation of the Rally Point Scoring System by the FIVB in 1998, the serve became a more important skill in volleyball (Alemany, 2000; Díaz Mariño, 2001; Hung & Hu, 2007; Ureña et al., 2001). Direct serve errors give the opponent points and the chance to attack with a serve.

In modern volleyball it is difficult to score directly from the serve, so the focus is on influencing the attack of the receiving team (Quiroga et al., 2010). A team that struggles to defend a good serve efficiently will drastically reduce its possibilities of winning the match (Patsiaouras, Moustakidis, Charitonidis, & Kokaridas, 2011). Because blocking efficiency depends on the quality of the serve (Drikos, Kountouris, Laios, & Laios, 2009), the serve strategy in elite volleyball is aimed at creating better conditions for team blocking, such as the formation of double or triple blocks and defense strategies (Papageorgiou & Spitzley, 2003). To avoid first-tempo attacks (Zetou, Moustakidis, Tsigilis, & Komninakidou, 2007) and quick attacks from the outside (Fellingham, Hinkle, & Hunter, 2013), the serving team has to take risks in its serve.

Characteristics of serves in men's elite volleyball. In volleyball there are two basic types of serve: the underhand (associated with young and beginner players) and the overhand,

used by most players (FIVB, n.d.-a, The Game - Volleyball - Service; Ruiz & Hernandez, 2003). Overhand serves include the following types: Standing Spin Serve, Standing Float Serve, Jump Float Serve, and Jump Spin Serve (USA Volleyball [USAV], 2009). In recent decades it has become obvious that two types of overhand serves are dominant in both male and female and elite volleyball: Jump Spin Serve and Jump Float Serve (Huang & Hu, 2007; Mackenzie, Kortegaard, Levangie, & Barro, 2012).

According to Agelonidis (2004); Häyrinen, et al. (2007); Huang and Hu (2007); Katsikadelli (1995, 1996); Mackenzie et al. (2012); Masumura, Marquez, Koyama, and Michiyoshi (2007); Moras et al. (2008); and Tsivika and Papadopoulou (2008), in men's volleyball the Jump Spin Serve is the technique predominantly used during competitions. More aggressive serves allow a shorter reaction time for receivers compared to less aggressive serves, and aggressive serves are usually performed during jumps, providing steeper flight paths and causing greater difficulty for the receivers (López, 2013; Strohmeyer, 1988).

With the Jump Spin Serve, a player performs a powerful movement and creates a strong force, giving the ball higher velocity after it is hit than in any other type of serve. However, the main disadvantage of the Jump Spin Serve is a higher percentage of errors than other serve types. In high-level volleyball, the high risk of error related to serve execution (1 in 5 serves is an error) is an acceptable part of the defensive strategy (Agelonidis, 2004). Because of its force and high speed, the Jump Spin Serve is a powerful offensive weapon that causes trouble for opponent reception. It is used frequently in elite volleyball despite its high percentage of error (Tsivika & Papadopoulou, 2008).

All rule changes and developments in volleyball have led to considerable changes in the serve and perfection of technique aimed at increasing the incisive and most commonly used Jump Float and Jump Spin Serve (Molina, Santos del Campo, Barriopedro, & Delgado,

2004). Since the introduction of the libero, teams have started to have three players specializing in reception, indirectly obliging servers to develop their serves. Approval of the rule that the ball can touch and pass over the net without stopping play, in 2000 (FIVB, 2015, The Game - Volleyball Rules; Major changes in volleyball rules), means the server has one aspect less to worry about. In today's elite volleyball, players try to hit the ball at the highest possible point during the serve to send the ball over the net as steeply as possible with small parabolas.

Winning Points in Volleyball

Points are scored in volleyball by serving, blocking, attacking, and from opponent's mistakes (Häyrinen, Hoivala, & Blomqvist, 2004).

Winning a point through a serve appears to be the fastest and most desirable method, and therefore the serve is performed by one key player on the team. The number of serve errors and the percentage of serve points are closely related to the team's final tournament ranking; it follows, then, that the best teams make more serve errors, but at the same time, they score more points by serves (Marcelino, Mesquita, & Afonso, 2008). In high level volleyball, the average number of points won by serve per game is 4.98 (Marcelino & Mesquita, 2006). Teams at this level are inclined to take high risks during the serve, with the intention of neutralizing the opponent's attack and increasing the probability of better blocking (Marelić, Rešetar, Zadražnik, & Đurković, 2005).

According to Patsiaouras et al. (2011), the block is the most difficult skill in volleyball. It is the first line of defense and its main aim is to stop the opponent's attack and often to score the point by simultaneous defensive and offensive movements (George, 1992). "Reading" the setter and attackers, quick lateral movements, experience, and correct timing in putting the arms up for blocks are crucial skills in elite volleyball for a successful block

(George, 1992). Blocking is one of the significant factors of final match outcome (Eom & Schutz, 1992a; Palao, Santos, & Ureña, 2004; Patsiaouras et al., 2011).

In the context of winning points, the setter has an important role as a player in the team and is typically found to be a key element for the team's victory (Bergeles, 1993; McGown, 1994; Stork, 1992; Zhang, 1996). Considering the setter's role as linchpin of the team and the involvement of this player in all actions, he or she has several tasks: to manage difficult situations, predict the opponent's team strategy, know the attacking abilities of both his or her own and the opposing team, bear in mind the capability of each blocker, communicate and organize his or her team, and intelligently pass all balls as adeptly as possible (Patsiaouras et al., 2011).

Many studies have proven that the attack is a decisive predictor of a team's success (Eom & Schutz, 1992a; Monteiro, Mesquita, & Marcelino, 2009; Rodriguez-Ruiz et al., 2011; Tsivika & Papadopoulou, 2008; Yiannis & Panagiotis, 2005; Zetou et al., 2007; Zetou, Tsigilis, Moustakidis, & Komninakidou, 2006). Two specific actions can be defined in volleyball attacks: the spike, or power attack, and the tip, or tipping, characterized as a slower attack (Castro, Souza, Mesquita, 2011; Lucas, 1985; McLaughlin, 2006; Neville, 1994; Paolini, 2001; Selinger & Ackermann-Blount, 1986; Weishoff, 2002). Tipping is a typical weapon for setters, while the spike pertains to all other attackers as the most commonly used weapon for attacking. In today's elite volleyball, quick attacks (first tempo) are mostly used, as they score the most points with minimum errors because the opponents do not have time to react and organize defense (Tsivika & Papadopoulou, 2008). An inseparable element of attacking is the attack error, which can be a decisive factor for the winning team (Patsiaouras et al., 2011). Higher level teams have less probability of unforced errors (Palao et al., 2004). To ensure fewer unforced errors during attacking, players should always be reminded by the coach to focus on proper technical execution in attacking rather than simply acting with

enthusiasm (Zetou et al., 2007).

Another way points can be scored during play is through opponent errors (Häyrinen et al., 2004; Marcelino et al., 2008). These include serve errors, attack and counter attack errors, and technical errors, such as touching the net, double touch, invasion, stepping on the serve line, back row players stepping on the attack line (3 meters from the center line), and long touches. Giatsis and Zahariadis (2008) found that opponent attack errors were the most important factor contributing to the *Winners*' win. A team's own errors (forced and unforced) can be controlled during training and competitions (Häyrinen et al., 2004).

Match Duration and Time Characteristics in Volleyball

Volleyball belongs to the group of sports without time limits, which also includes tennis, badminton and table tennis. The duration of a match is determined by the result of each set and the number of sets played. A volleyball match ends when a team wins three sets (FIVB, 2014). However, certain parts of the game are limited by time, such as the team time-out (30 seconds), technical time-out (60 seconds), serve time (8 seconds) and time between sets (3 minutes).

The total time of a volleyball match can be divided in two basic groups: work time and rest time. A rally is the period when the ball is in the game; it is the fundamental unit of the active game (Fellingham, Collings, & McGown, 1994) and of the whole game.

Rest time comprises a) the time after the whistle for a finished point until the whistle for a serve; b) team time-outs (time before the whistle for the beginning of team time-out, time between the two whistles for the time-out, time after the whistle for the end of team time-out); c) technical time-outs (time before the whistle to begin the technical time-out, time between whistles, time after the whistle for the end of the technical time-out); d) player sanctions (time before the whistle for the sanction, time between whistles, and time after the

whistle for the end of the sanction); e) time between sets (time after the whistle for the end of the last point until the whistle for the new set); and f) time for player injury.

Minimizing match length variability is of great advantage for the organizers in scheduling matches and gives broadcasting companies a better idea of the amount of time they need to reserve for an event (Fellingham et al., 1994).

Jumps, Contacts and Hits in Volleyball

The three main characteristics of the game of volleyball are specific jumps, specific contacts with the ball and hits.

Jumps. Because the net is set at a height of 2.43 meters in men's volleyball and 2.24 meters in women's volleyball, players are required to jump to score points. Volleyball has become a sport where the team result greatly depends on the athletic performance of each player (Vilamitjana et al., 2008). Jump ability is a decisive factor in the final score of a volleyball match, especially to gain greater height in bouts in order to attack from the highest point and achieve higher blocks in defense (Sheppard, Borgeaud, & Strugnell, 2008; Sheppard et al., 2008; Sheppard et al., 2007). Volleyball is characterized by various two-footed jumps and occasional one-footed jumps. The most commonly used two-footed jumps are during attack (spike and tipping), Jump Spin Serve, Jump Float Serve, setting and blocking. In women's volleyball, an attack from a one-footed jump is often seen, but this study will focus on men's volleyball. For male players, the one-footed jump is rarely used, in uncommon situations in attacking, setting, blocking and serving. Therefore, considering the jumps performed by elements of the game, all representative volleyball jumps can be grouped as follows: jumps for serves (float and top-spin serve), jumps for setting (two- and one-footed), jumps for attacks (two-footed, and one-footed only in women's volleyball) and jumps for blocks (with or without stepping).

Knowing the average number of jumps for a given role in the team per match or for a whole tournament makes it possible to physically prepare players appropriately for each competition (Vilamitjana et al., 2008).

Contacts and hits. The literature includes only written notions of touches in volleyball, without clearly defining types. Many authors use terms such as contacts and hits, without categorization. The purpose of this study is to decide on and demonstrate the correct usage of these terms. From numerous studies in volleyball it can be concluded that serves and attacks belong to hits (Almujahed, Ongor, Tigmo, & Sagoo, 2013; FIVB, 2014; Hummel, 1997; Lidor & Mayan, 2005; López, 2013), while the remaining elements, i.e., reception, set, block and dig-defense, belong to contacts (Afonso, Esteves, Araújo, Thomas, & Mesquita, 2012; Almujahed et al., 2013; FIVB, 2014; Hummel, 1997; Palao, Valadés, Manzanares, & Ortega, 2014). Therefore all touches of the ball in volleyball can be divided into two overarching groups: contacts and hits.

Rally Point System and Performances

Under the Rally Point System (RPS), each rally corresponds to a point for the serving or receiving team. A rally is a chain of playing actions, starting with a serve and continuing until the ball is out of play. If the serving team wins the rally, it wins the point and continues to serve until it loses a rally. When the receiving team wins the rally, it wins the point and takes the serve. Volleyball sets under RPS end when a team scores 25 points with a minimum difference of two points (except for the fifth set). In the case of a 24:24 tie, play continues until one team achieves a two-point difference (26:24, 27:25, 28:26, etc.). One team is the winner after winning three sets. In the case of 2:2 in sets, the fifth decisive set is played to 15 points, with a minimum lead of two points.

In RPS to 21 points, the set has fewer total points. A set is played until one team scores 21 points with a minimum lead of two points. In the case of 20:20 play, the game continues until one team secures a two-point lead (22:20, 23:21, etc.). As a simple comparison, where RPS is to 25 points and the final set result is 25:21, the difference is four points and the total number of points played is 46; but where RPS is to 21 points and the final set result is 21:17, there is also a four-point difference but the total number of points played is 38. The simple conclusion would be that the set is shorter by 8 points and therefore the duration of each set and total match time is shorter. Fewer points played means shorter sets, resulting in a shorter match.

Claver, Jiménez, Gil, Moreno, and Moreno (2013) aimed to show the importance of performance in game actions as the determining factor of the match result, using the following variables: performance in game actions (serve, defense, setting and spike) and match result (win/loss). Marcelino and Mesquita (2015) examined the relation between performance indicators, specifically those indicated as "contacts" and "hits" in our study (number of spike points, spike errors, spike continuity, block points, block errors, block continuity, serve points, serve errors, serve continuity, dig excellent, dig errors, dig continuity, set excellent, set errors, set continuity, reception excellent, reception errors, and reception continuity) and overall performance in volleyball with respect to set result (set wins and losses).

Volleyball is one of several sports where the number of contacts with the ball is limited to a maximum of three (except for the case of a passive block contact within the opponent's court, causing a new attack cycle, again with a maximum of three possible contacts) (Sánchez-Moreno, Marcelino, Mesquita, & Ureña, 2015).

A rally is made up of a number of contacts and hits. The duration of each rally can have an impact on team success (Sánchez-Moreno et al., 2015). Long rallies, with a higher

than average number of contacts and hits, can considerably affect performance because of the additional physical and psychological influence on players, and can also lead to negative or positive outcomes in the subsequent rally (Sánchez-Moreno et al., 2015).

In terms of physical activity, volleyball can be defined by short, high-intensity, repetitive bouts with defensive and offensive jumping activities interspersed with low-intensity activities and recovery time (Dyba, 1982; Polglaze & Dawson, 1992; Viitasalo et al., 1987). Jumping activities include horizontal approach movements (spike jumps) and movements with no approach (jump setting, jousts and blocking) (Sheppard, Cronin, et al., 2008). These jumps and their frequency in relation to their tactical application in the match represent critical performance in volleyball games (Fry et al., 1991; Smith, Roberts, & Watson, 1992; Thissen-Milder & Mayhew, 1991). Specific movements by each player can impact the performance profile (Vilamitjana et al., 2008). Sheppard, Cronin, et al. (2008) researched potential strength, power and anthropometric contributors to vertical jump performances in relation to volleyball success.

With the new Rally Point System (RPS) to 25 points introduced in 2000, the jump serve became more important as a decisive factor in the final outcome of the match (Huang & Hu, 2007), and this trend is likely to continue and progress with RPS to 21 points because of the fewer total points.

Offensive Skills

The serve and passing an opponent's tough, controlled serve are important skills for scoring points. After the controlled serve-receive pass, offensive play depends on setting and attacking (Miller, 2005).

Serving. The serve is the first hit in the rally and puts the ball into play. It is performed by the back-right player, placed in the serve zone (FIVB, 2014). Quantifying serves is very important for each team, as the serve has become one of the main elements in a volleyball team's play (Quiroga et al., 2012). Quantification permits the study of the consequences on serves resulting from changes in rules, trends and serve development. Serve analysis shows that failed serves and aces are significant factors that directly lead to winning or losing the rally, set and match (Drikos et al., 2009; Marcelino et al., 2008; Marelić, Rešetar & Janković, 2004; Quiroga et al., 2012). Marcelino and Mesquita (2015) found that the possibility of winning increases with the improvement of one serve point while other variables are held constant.

Passing. This technique is mainly used to receive the serve. Serve reception is the second volleyball action in a rally and is used to control the first ball sent over the net by an opponent on a serve (Miller, 2005). It is understood as receiving and neutralizing tactical or strong serves (Palao, Manzanares, & Ortega, 2015). Reception is normally performed by a bump or overhead technique. Quantifying reception in volleyball is very important, as it provides clear insight into reception efficacy. Serve reception is of indisputable importance according to coaches (Marelić et al., 2004). With the Rally Point system, serve reception has become more important, as each reception error directly becomes a point for the opponent. Reception errors were found to be one of the decisive factors for winning or losing a match (Patsiaouras et al., 2011). Charitonidis, Patsiaouras and Charitonidi (2007) reported that successful serve reception was a predictive factor for winning a match. Marelić et al. (2004) found that reception is one of the variables that significantly differentiated set *Winners* and *Losers.*

Setting. Setting is the simultaneous use of both hands to direct the ball to a location where an attacker can hit it over the net. The action of setting occurs during the second contact in a team's transition to offense (Miller, 2005). It is normally performed by a finger technique, and in unspecific situations by the bump technique. Setting is the most frequent action in volleyball, as found in this study. It has been analyzed in many studies as an important part of attacking and of the blocking chain (Castro et al., 2011; Claver et al., 2013; Eom & Schutz, 1992a, 1992b; Häyrinen et al., 1999; Marcelino, Afonso, Moraes, & Mesquita, 2014). Because setting is one of the volleyball elements that greatly influences the final score (Claver et al., 2013; Eom & Schutz 1992a, Marelić, 1998), it warrants in-depth analysis. Knowing the number and variety of sets performed by the setter during a set, match or tournament gives coaches an idea of how to prepare setters and blockers while playing against the opposite setter. This makes it very important to quantify all the characteristics of setting: number of sets during set and match (frequency), type, speed, efficacy, errors, relationship to blocks and setting performance.

Attacking. All actions that direct the ball towards the opponent, except for the serve and block, are considered attack hits (FIVB, 2014). In a rally, the two preliminary contacts are designed to set up the third contact or attack (Miller, 2005). Spike and tipping belong to attack and are therefore the main point-scoring actions, especially the spike. The number of these actions is of great importance for the result in volleyball sets and matches. Both attacking actions can be performed by almost every in-game role in the team. Characteristics such as the in-game role performing the action, the court position of the acting player, the type of spike or tipping, the part of the set or match during which the spike or tipping is performed, and efficacy are important for the coach and the whole team. The spike is one of the most decisive factors in volleyball sets and the entire match (Cox, 1974; Eom & Schutz,

1992a; Marcelino, Mesquita, & Afonso, 2008; Marcelino & Mesquita, 2008; Palao et al., 2004; Vunić, Hraški, & Marelić, 2005). Marelić (1994) and Marelić et al. (2004) found the spike to have major importance in the phases of attack and counterattack. Marelić (1998) found the spike in attack to be a critical factor, whereas in the counterattack it had little influence.

Defensive Skills

According to Miller (2005), the most realistic method to score a point is a team's ability to block or dig and counter attack.

Blocking. Blocking is the action taken only by front-row players to obstruct the ball coming from the opponent, where some part of the body must be higher than the top of the net at the moment of contact with the ball (FIVB, 2014). Blocking in elite volleyball has been examined in several performance studies as one of the crucial elements (Häyrinen et al., 2004; Lobietti, 2009; Marcelino et al., 2008; Marcelino, Mesquita, Castro, Sampaio, 2008; Marelić et al., 2004; Marelić, Žufar, & Omrčen, 1998; Palao et al., 2004; Patsiaouras et al 2011; Peña, Rodriquez-Guerra, Busca, & Serra, 2013; Rodriguez-Ruiz et al., 2011). Analyzing the block in relation to all aspects (qualitative and quantitative) gives coaches the possibility of applying the right tactic during the game, adapting technical and tactical drills, and building new, appropriate exercises to develop players' blocking technique (Lobietti, 2009).

Defense. Defense (also called digging) is each action by the players on the court (except those not participating in blocking) in response to opponent attack. Contact with the ball in defense can be made with any part of the body. The angle of the ball, combined with topspin and increased speed, oblige players to lower their base and play from the floor

upward, and balls that are high, deep and inbounds must be played with open hands (Miller, 2005). Defense has been reported in numerous studies as an important element of the match, but not as significant a factor for winning the match (Claver et al., 2013; Häyrinen, Hoivala, & Luhtanen, 1999; Zetou et al., 2006). Mesquita et al. (2007) and Monteiro et al. (2009) found dig efficacy an insignificant element of set outcome, but Monteiro et al. (2009) reported that attack efficacy greatly depends on dig efficacy. Marcelino, Mesquita, Sampaio, and Moraes (2010) found dig efficacy a decisive factor for winning the set and reported that winning teams have lower percentages of dig errors than losing teams, which Claver et al. (2013) similarly argued. Mesquita et al. (2007) described the significant increasing trend of dig efficacy since the libero in-game role was introduced.

Overview of Dissertation

The main objective of this Dissertation is to fully explain, give insight into and identify the influence of the new rules tested on the game of volleyball in relation to a) point-scoring plays; b) duration of the volleyball match; c) serves; and d) number of hits and contacts, using notational analysis, video analysis and appropriate statistical packages to achieve an applicable approach to this study.

The purpose of the results and the knowledge presented in this thesis is to help further development of the volleyball game. The FIVB development board can use all the findings to develop volleyball appropriately. Volleyball coaches, university lecturers, instructors and teachers, as experts who instruct others about the game and help to spread it, can better understand how volleyball has developed and improve their strategic and tactical systems within the competition and training process to individually prepare each player. With this knowledge, volleyball players can implement strategies within their individual abilities and build their own tactic as part of the team tactic. Using knowledge from this thesis, experts and

players can adapt their development in terms of strategy, tactic and technique in time for rule changes. As Information Technology (IT) becomes more connected to professional sports, the best results should be more closely linked to scientific research applied to the training process and competitions.

The volleyball serve has been analyzed from several aspects and has been found to be one of the most important skills that distinguish winning and losing teams. This work is the first study of the effect of the new rules tested (set to 21 points, excluding the fifth set; 15 seconds between points). We have compiled a model with considerable information about the serve under the two new rules tested. When FIVB launched the testing of the new rules at the Volleyball Men's U23 World Championship, several questions were raised: How do the 15 seconds influence the serve? Which type of serve is mostly used and by which in-game role? From which zone is the serve performed, and to which zone? What is the efficacy of the serve? How do players and the whole team behave under these rules in relation to the serve? Comparing behavior from the 25-point set and the 21-point set, the obvious difference is that in the 21 point set the player who is about to serve runs to pick up the ball and prepares for the referee's signal to execute the serve right after the point is finished, whereas in the 25 point set, the same player briefly celebrates the point scored and then goes to prepare for the serve. All the statistical series had characteristics of a nominal scale and therefore Pearson's Chi-Square test was used as an appropriate data analysis procedure. The Jump Float Serve was found to be the most executed serve. This serve type is a safe, but at the same time powerful, weapon. Significantly, the Jump Float Serve was performed more frequently as teams approached the end of the sets. It is obvious that the set *Winner* teams executed more controlled serves, while trying to attack with minimum errors and causing as few first tempo attacks as possible. To safely continue the set after both technical and team time-outs, the Jump Float Serve was performed in most cases. Most serves were performed from behind

zone 1 to zones 6 and 5.

For the sport of volleyball to be appealing to spectators, the way in which point-scoring plays are performed is important. If the style is more flashy, the sport becomes more attractive. This aspect is of great importance for the FIVB development board. For coaches, knowledge of how points are scored is useful in preparing a model of point-scoring plays. In our research, we analyzed all point-scoring plays in the *Final* phase of the sets (from the 16th point in the first four sets and from the 10th point in the fifth set). These particular plays were chosen for analysis mainly because closer to end of the set or the whole match, psychological pressure causes players to use their best skills and give their best performance. In addition to the main question about the type of point-scoring plays, several other questions were raised: What is the distribution of point-scoring plays by each in-game role related to *Level of Set Win* and *Set Outcome*? How do point-scoring plays change according to *Score Fluctuation?* This study affirmed the results of other authors who found that the attack-spike is the main point-scoring play in volleyball. All numerical data are presented by frequency, separated into each volleyball element analyzed. Because all the statistical series had the characteristics of a nominal scale, Pearson's Chi-Square test was used as an appropriate data analysis procedure. The high amount of point-scoring plays, attack-block outs and attack-tipping performed by set *Loser* teams indicate the possibility of developing these elements as winning actions. To work on polishing attack-spike ability, coaches have significant scope to work with their attackers on attack-block outs and attack-tipping. The outside hitter was identified as the dominant position for scoring points, followed by opposite and middle blocker. As a high-demand position, the outside hitter needs extensive physical preparation, with adequate technical training from an early age. Analysis of results by *Level of Set Win* showed the tendency of individual players being constantly forced to score points because of the quality imbalance of players in the team.

Volleyball does not have a time limit, but the work and rest time for each physical activity is very important in the physical and tactical preparation of players. With the development of IT and the vast range of sports on TV, FIVB has aimed to find the best model of volleyball match for duration to keep fans watching volleyball matches. It is obvious that in general, as people's lives becomes faster in tempo, they have less time to spend a couple of hours watching one thing, such as a volleyball match that lasts about two to three hours. From our results, it can be concluded that FIVB intends to equalize the duration of the volleyball match without notable variation, making the organization of live streaming of events easier and less costly. With regard to the rules tested, the following questions were raised: Are these changes the right way of reducing and equalizing match duration? Is volleyball more attractive because of the new rules? How do these rules influence specific time periods, such as *work time* (time between the referee's whistle for serve and the end of the point), *rest time* (time after the whistle for the finished point until the whistle for the next serve), and all the individual components belonging to *rest time*, such as the *team time-out* (time before the whistle for the beginning of team time-out, time between the two whistles for time-out, and the time after the whistle for the end of team time-out), *technical time-out* (time before the whistle for the beginning of technical time-out, time between whistles, time after the whistle for the end of technical time-out), *player substitutions* (time before the whistle for substitution, time between whistles, time after the whistle for the end of substitution), *player sanctions* (time before the whistle for sanction, time between whistles, time after the whistle for the end of sanction), *time between sets* (time after the whistle for the end of the last point until the whistle for the new set), *player injury time, time for other technical aspects* (e.g. fixing a fallen antenna, problem with a referee's chair; this includes time before the whistle for fixing the technical problem, time between whistles, and time after the whistle for the end of the technical problem). One-way ANOVA was applied to test the significance of

differences between the arithmetic means at different phases of the set and in sets with different levels of win. Because of a small number of unbalanced observations in different categories of "time between sets," the Kruskal-Wallis nonparametric test was used for a more in-depth analysis.

Game analysis verifies the positive influence of the 15 seconds rule between rallies, with 10 seconds for the player to reach the serving position and 5 seconds to execute the serve. Both types of time-outs were found to be periods that can influence volleyball to make it a more dynamic sport. Applying the technology used for technical time-outs to team time-outs could improve team time-outs. The time period after the whistle for the end of both time-outs should be 10-12 seconds, after which all players must be ready on the court with the server in position. Under the rule of 15 seconds between rallies, the time for calling a team time-out is indirectly limited to about 5 seconds. Both of these time limits will increase the dynamics of the game and decrease rest time. The 21-point set could also positively influence the dynamics of the game if technical time-outs are eliminated and replaced with two one-minute team time-outs, with an optional TV technical time-out (if neither team calls a time-out). Rest time between rallies in the *Early* and *Middle* phases was very similar, but shorter than in the *Final* periods, with a difference of only 0.3 seconds. Without the 15 seconds between rallies rule, the pause would be much longer. Given the uncertainty in the *Final* phases of the sets, most teams naturally try to take advantage of the longer rest time between rallies. With respect to the time limits between points, the libero and middle blocker in-game roles need to be more focused and synchronized for on-the-fly substitutions. Analyzing the timing of volleyball matches provides significant insight for both players and coaches in creating a system of physical training. Beyond bodily training, coaches could also prepare players to react and to process situations quickly. This study could therefore also serve to bring about future amendments to the structure of the volleyball game.

Volleyball is characterized by specific jumps during serving, attacking and blocking. In high-level volleyball, all movements apart from defense are almost always performed using jumps. Given the lack of studies about jumps in volleyball in relation to in-game roles, this study came up with a new approach of defining the effects of the new rules tested on jumps. The variables that were analyzed in relation to in-game roles (setter, outside hitter, middle blocker, opposite, libero) were Jumps for Jump Float Serve (JFS), Jumps for Jump Spin Serve (JSS), Jumps for attacks, Jumps for setting and Jumps in blocks. The analysis was also performed according to *Level of Set Win* (*Walkover, Balanced, Tough* set). *Level of Set Win* showed no notable effect on the distribution of the various jump types. The jumps performed in order of highest to lowest frequency were: *attacking* (33%), *blocking* (32%), *setting* (16%), JFS (12%) and JSS (7%).Significant differences (p = .000) were observed according to in-game role: middle blocker performed the most jumps (34.7%), followed by outside hitter (24.9%), setter (24.6%) and opposite (15.8%). Sheppard et al. (2007), Sheppard, Gabbett, and Stanganelli (2009), and Vilamitjana et al. (2008) found that middle blocker jumped most frequently in blocks and attacks, which is consistent with our study. Similarly, Vilamitjana et al. (2008) found the highest percentage of jumps in blocks (37.9%) and attacks (21.7%), also in agreement with our study. As the age group of players analyzed competes successfully in the most selective men's volleyball leagues worldwide, these games are at a similar degree of skill to elite men's volleyball. Jump analysis is of great importance for head volleyball coaches, such as the coaches for the physical preparation of players. Knowledge about the total number and type of jumps by in-game role gives appropriate insight into the physical and technical requirements for a match and for the whole tournament.

Although there are a few studies on contacts and hits in volleyball, there is a clear need to explain these technical elements in order to obtain a complete overview of the volleyball game. The purpose of this kind of research is to initiate the analysis of contacts and

hits and determine how the two new rules tested (21-point set excluding the fifth set, and 15 seconds between rallies; 10 seconds from the finished point until the referee's whistle for the serve, and five seconds for performing the serve) have influenced the number and types of jumps, contacts and hits related to each in-game role and set outcome. Reception, setting, block and defense were the variables analyzed for contacts, while serve and attack were studied for hits. The following statistical packages were used to analyze jumps, contacts and hits: 1) Pearson's Chi-Square test, to test for significant differences between frequencies registered in individual subsamples, and 2) T-test and One-Way ANOVA, to test significance between the means established for specific elements in specific subsamples. Analysis of the number and types of *Hits* showed that there were differences only between the *Winner* and *Loser* teams for the set for serves by the setter ($p < .001$) and middle blocker ($p < .05$). For set *Winners*, the setter and middle blocker hit the ball four to five times more than players with the same roles for the *Losers* of the set. Significant differences were observed for the opposite ($p < .05$) and middle blocker ($p < .05$) in block, and for libero in reception ($p < .05$). Marcelino and Mesquita (2006) found the following average values per match: attack (M = 97.09±20.25 hits), serve (M = 88.15±16.17 hits), block (M = 48.30±14.93 contacts), dig (M = 55.63±16.48 contacts) and reception (M = 70.82±14.59 contacts). This study revaled a significant difference in jumps, hits and contacts between in-game roles, with the middle blocker identified as the position with most frequent action, followed by outside hitter and setter. The libero tended to be the setter with jumps after the initial setter defense action. These results can be used in other studies to relate all jumps, contacts and hits to explain the trends underlying these elements.

If the new rules tested become part of the official volleyball rules, this study can help guide team tactics, strategies and physical preparation programs in relation to serves, time, point-score plays, hits and contacts. Further study can also be carried out for women's

volleyball to determine the effect of the new rules on this category. Since the beginning of the Championship where the new rules were tested, it has been clear that FIVB intends to bring volleyball closer to the spectator and make it easier to stream by shortening matches to make the length of the match predictable and more uniform.

CHAPTER 2

STUDY 1

Chapter 2

Study 1. Analysis of Serve Characteristics under Rules Tested at Volleyball Men's Under 23 World Championship

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KEYWORDS*:* In-game role, server's zone, receiving zone, serve quality, set phase, type of serve.

Abstract

The aim of this study was to analyze the characteristics of the volleyball serve with the new rules tested at the inaugural Volleyball Men's Under 23 World Championship (set to 21 points, excluding the fifth set; 15 seconds between points). In a sample of 36 matches played in 123 sets, 4588 serves were studied. The variables used were serve type, serve quality, serve zone, placement zone, in-game role, score trend and set outcome. Pearson's Chi-Square test was used for data analysis. Significant differences were observed in the following variable relations: serve type by in-game role (p = .000), serve type by score trend (p = .000), serve quality by serve zone (p = .039), serve quality by in-game role (p = .000), serve quality by set outcome (p = .000), serve zone by in-game role (p = .000), serve zone by set outcome (p = .000), placement zone by serve quality (p = .000) and placement zone by serve zone (p = .004). If these changes become part of the official volleyball rules, this study will be a useful guide for building team tactics and strategy. It also provides insight for FIVB about the effect of the tested rules for further developments in the game.

Introduction

Volleyball is a team sport that has been played since 1895. Because of the many changes and developments introduced, it has become a dynamic, popular sport throughout the world (Claver, Jiménez, Gil, Moreno, & Moreno, 2013; Huang & Hu, 2007; Tillman, Hass, Brunt, & Bennet, 2004). In 2013, Fédération Internationale de Volleyball (FIVB) organised the inaugural Men's U23 World Championship, where the main goal was to test new rules intended to modernize volleyball and make it more appealing for fans both at matches and watching television (Fédération Internationale de Volleyball [FIVB], 2013b, Twenty-one point rule to be tested at U23 World Championships).

Many of the changes in the history of volleyball have affected the first element in the

game: the serve (García-Tormo, Redondo, Valladares, & Morante, 2006; Molina, Santos, Barriopedro, & Delgado, 2004). In 1897, William G. Morgan introduced the serve as the first written rule (Giddens & Giddens, 2005; Kenny & Gregory, 2006; López, 2013; Ureña, Gallardo, Delgado, Hernández, & Calvo, 2000). In the earliest rules, the following applied to the serve: 1) the serving player had two attempts, in case the first serve failed; 2) the server had to have one foot on the back line and use his hand to hit the ball, which had to go over the net without touching; 3) a partner could help the ball over the net using one touch; 4) if the serve was correct there was no second serve; and 5) every "unreceived" serve was a point for the team who served, but if the opponent team scored, they earned the chance to serve. In 1920 the rules were modified and the server was not permitted to step on the back line of the court during the serve. In 1947 the server had to serve from the right side behind the court (back line), still with one foot on the ground (Ureña et al., 2000). In 1949 the server could run and jump before hitting the ball, and in 1951 the server could land inside the court after jumping and hitting the ball. The serving zone was expanded to an unlimited area behind the line, but in 1953 it was limited by two lines of 20 cm behind the back line of the court (Ureña et al., 2000). More than 40 years later, further new rules for serving were added: in 1994 the serve zone was extended to 9 m to provide more options in serving (Ureña et al., 2000); from 1998 the server had only one attempt to serve, to reduce the duration of the match; and from 1999 the server had 8 seconds to serve. In 2000 the ball was allowed to touch the top of the net and pass over it without interrupting the continuity of the game (FIVB, 2015, The Game – Volleyball Rules; Major changes in volleyball rules).

The serve is the action of hitting the ball with the arm and directing it over the net into the opponent's court by the server placed in the serve zone (Conejero, Claver, Fernández-Echeverría, Gil-Arias, & Moreno, 2017), who has 8 seconds from the first referee's signal for serve (FIVB, 2012). The volleyball serve is a technical skill (Parisi, & Raiola, 2014a) and a

complex individual skill that can be adapted depending on the match situation, the player's capabilities and tactical needs (Moras et al., 2008). In volleyball, each team has four options (Häyrinen, Hoivala, & Blomqvist, 2004) for scoring points: by serving, blocking, attacking and from opponent error. As the first offensive action (Raiola, Altavilla, De Luca, & Di Tore, 2016) through which a point can be scored, the volleyball serve is an essential element of today's elite volleyball (Asterios, Kostantinos, Athanasios, & Dimitrios, 2009; Dávila-Romero, García-Hermoso, & Saavedra, 2012; Drikos, Kountouris, Laios, & Laios, 2009; Huang & Hu, 2007; Masumura, Marquez, Koyama, & Michiyoshi, 2007; Moras et al., 2008). The primary goal of the serve is to score a direct point (ace) or to prevent the opponent making a good attack (Claver et al., 2013; MacKenzie, Kortegaard, LeVangie, & Barro, 2012; Raiola et al., 2016). The serve action directly depends on one player (Marcelino, Mesquita, & Afonso, 2008; Raiola et al., 2016) and the player's technical, physical and psychological preparation.

Serve and reception are related elements that determine the continuation or the end of the point. When the serve is better than the reception, the serving team can score a direct point or disrupt the opponent's attack (Rentero, João, & Moreno, 2015). The attack has changed over time because reception has been constantly forced to adapt to changes in the serve (Ureña et al., 2001). In the last 15 years, Jump Spin Serve (JSS) and Jump Float Serve (JFS) have become the predominant serve types in men's volleyball (Agelonidis, 2004; Häyrinen, Lahtinen, Mikkola, Honkanen, Paananen, & Blomqvist, 2007; Moras et al., 2008; Tsivika & Papadopoulou, 2008). Because of the importance of the serve and its relation to the final outcome, it is important to train and develop serve efficacy (João, Silva, Lacerda, & Vaz, 2012).

Many researchers have studied the serve action in relation to the following aspects: serve type, serve zone, reception zone, effectiveness, in-game role of the receiver, serve

direction and timing (Gil-Arias, Claver, Fernández-Echeverría, Moreno, & Moreno, 2016); serve type and serve direction in men's volleyball (Moreno, García de Alcaráz, Moreno, Molina, & Santos, 2007); serve technique, zone from where the player serves, serve direction and serve efficiency (Callejón-Lirola, 2006); serve type, in-game role, quality of serve, serve outcome, placement zone (Ciuffarella, Russo, Masedu, Valenti, Izzo, & De Angelis, 2013); effectiveness of the serve in a high-level volleyball tournament (Moras et al., 2008); and positive serve and negative serve (Dávila-Romero et al., 2012).

At the inaugural Volleyball Men's Under 23 (U23) World Championship, in Brazil (Uberlandia), two new rules were tested (FIVB, 2013a, New rules test to be held in Brasil only). The first was directly connected to the serve and the second was indirectly connected to the serve. The 15 second rule for serve means that the player hears the referee's signal to serve within 10 seconds of the point finishing and has 5 seconds to perform the serve. With the second rule, the set is won by the first team to win 21 points with a minimum difference of 2 points, except the final fifth set, which is unchanged (FIVB, 2013b, Twenty-one point rule to be tested at U23 World Championships). The aim of this study was to analyze the characteristics of the volleyball serve (Serve type, Serve zone, Placement zone, In game-role, Score trend and Set outcome) during new rules tested at the inaugural Volleyball Men's Under 23 World Championship (set to 21 points, excluding the fifth set; 15 seconds between points).

Methods

Participants. The sample comprised 36 matches played in 123 sets by the 144 players from the 12 national teams participating at the Men's U23 World Championships in Uberlandia (Brazil). An analysis was made of 4588 serves. The national teams participating in the study were from Argentina (6 matches analysed), Australia (5 matches), Brazil (7

matches), Bulgaria (7 matches), Dominican Republic (5 matches), Egypt (5 matches), Iran (7 matches), Mexico (4 matches), Russia (7 matches), Serbia (7 matches), Tunisia (6 matches) and Venezuela (6 matches).

Variables. Several studies have used similar variables to those in this study. In the study by Fernández-Echeverria, Gil, Moreno, Claver, and Moreno (2015), the independent variables were serve zone, serve type, striking technique, in-game role of the server, reception zone, receiver player and serve direction, and the dependent variable was serve efficacy. Callejón-Lirola (2006) used the categories and variables of: 1) Serving technique: Jump Spin Serve, Jump Float Serve, Overhead Float Serve; 2) Areas from where the serve is made: behind zone 1, behind zone 6, behind zone 5; 3) Qualitative measure of serve efficiency: six different values; and 4) Zone of impact of the serve: nine zones.

In this study, the serve variables were divided into 7 categories:

I. Type of serve:

Overhead Float Serve (OFS).

Jump Float Serve (JFS).

Jump Spin Serve (JSS).

II. Serve quality, divided into 5 levels (López-Martínez & Palao, 2009):

0 = error.

1 = maximum opponent attack options (action was easily passed and allowed the opponent to attack).

2 = limited attack options for the opponent (action was passed and opponent attacked with some attack options - “second tempo” actions).

3 = no opponent attack options (action was passed but opponent could not attack;

they simply passed the ball - free ball).

4 = Point (ace).

III. Serve zone (Zone from where the player serves) (Callejón-Lirola, 2006):

Serve execution behind zone 1 (BZ1).

Serve execution behind zone 6 (BZ6).

Serve execution behind zone 5 (BZ5).

IV. Placement zone on the opponent's court (divided into 9 equal fields) (Figure 1).

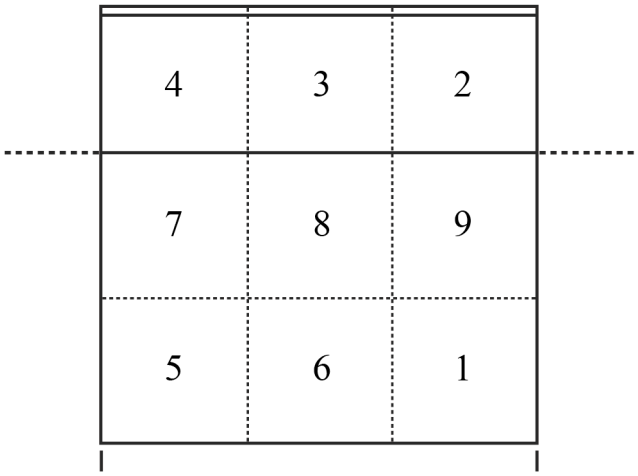

Figure 1. Serve placement zones.

V. In-game role: 1 = setter; 2 = outside hitter; 3 = middle blocker; 4 = opposite.

VI. Score trend (*Early*, *Middle*, and *Final phase*). *Early* phase is from the start of the set to the 8th point (6th point in the fifth set), *Middle* phase from 9th to 16th point (7th to 12th point in the fifth set), and *Final* phase from the 17th point to the end of the set (from 13th point to the end of the set in the fifth set).

VII. Set outcome: set *Winner* and set *Loser* (Gónzález-Silva, Moreno, Fernández-Echeverría, Conejero, & Moreno, 2016).

The Volleyball Information System (VIS), created by the Technical Commission of the FIVB (FIVB, 2000), was used to collect data from the matches. FIVB's Volleyball Information System is used to calculate points scored for individual skills of volleyball players (FIVB, n.d., Volleyball Information System). This software is accepted as a valid tool in volleyball research and has been used in many studies (João, Leite, Mesquita, & Sampaio, 2010; Marcelino et al., 2008; Marcelino, Mesquita, Sampaio, & Anguera, 2009). Because of its efficiency, simplicity and accuracy, VIS is the software FIVB uses most frequently for collecting data. It is also the method most used by coaches and observers to assess individual and collective performance of players in each phase of the volleyball game (FIVB, 2000). VIS calculates the following serve values (FIVB, n.d., Volleyball Information System): Aces (the number of points directly scored by the serve); Faults (number of serve mistakes); Serve hits (number of serves played when the rally continues); and Total attempts (total number of serves). From all the data collected by the FIVB technicians specially trained for VIS, who are approved, supervised and appointed by the FIVB Technical Commission, only data referring to the competition phase was used.

Procedure. The 36 games were videotaped and evaluated. Video/match analysis in volleyball is of great importance for qualitative and quantitative performance assessment (Parisi, & Raiola, 2014b; Raiola et al., 2016; Raiola, Parisi, Giugno, & Di Tore, 2013). All games were filmed using the same PANASONIC HC-V720 HD digital camcorder in AVCHD format. The camera was always located at the same position, behind the court at a height of 5 m above floor level (Claver et al., 2013) to obtain an optimal angle of view. Once the different categories and their corresponding variables had been established, they were

studied and analysed from a quantitative and a qualitative point of view, following the principles established in the observational investigation (Callejón-Lirola, 2006).

FIVB officially authorised this study and the use of all match videos and data from the VIS statistical recording program and the FIVB website. The study was performed in accordance with the Helsinki Declaration of 1975.

Reliability. The observer was trained to achieve consistency in the criteria and quality in coding the data. The training comprised a briefing on the definition of the variables and a data recording period of two weeks until he achieved a Cohen's Kappa value higher than .90. The observer had at least three years' experience in data logging during volleyball research and extensive experience as a volleyball scout and coach.

To ensure reliability of the calculation to avoid any learning effect, 12% of the serves were re-analyzed after a six-week interval, exceeding the reference value of 10% (Tabachnick & Fidell, 2007). Two additional volleyball researchers and national coaches who had received 10 hours of training in data collection conducted secondary observation of the data. Cohen's Kappa ranged from .84 to .91 for inter-observer reliability and from .82 to .92 for intra-observer reliability. All values fulfilled the criterion of .75 suggested in the literature (Fleiss et al., 2003).

Statistical analysis. All numerical data are expressed in frequencies, specified for each volleyball element analysed. As all the statistical series had characteristics of nominal scale, Pearson's Chi-Square test was used as an appropriate data analysis procedure. The results were calculated using IBM SPSS v.19 software. The statistical inferences were performed at the significance level of .05 ($p < .05$).

Results

Serve type was analyzed in relation to two criteria: in-game role and score trend.

SERVE TYPE by IN-GAME ROLE - Contingency analysis showed that different in-game roles used significantly different types of serve (p = .000). Comparison of relative frequencies showed that setters and middle blockers mainly used Jump Float Serve (77.3% and 71.6%), whereas opposite players performed Jump Spin Serve (72.0%) more often. Outside hitters also frequently used Jump Float Serve (54.9%), closely followed by Jump Spin Serve (44.7%) (Figure 2). Outside hitters performed the most serves (1531), followed by middle blocker (1411), setter (953) and opposite (692).

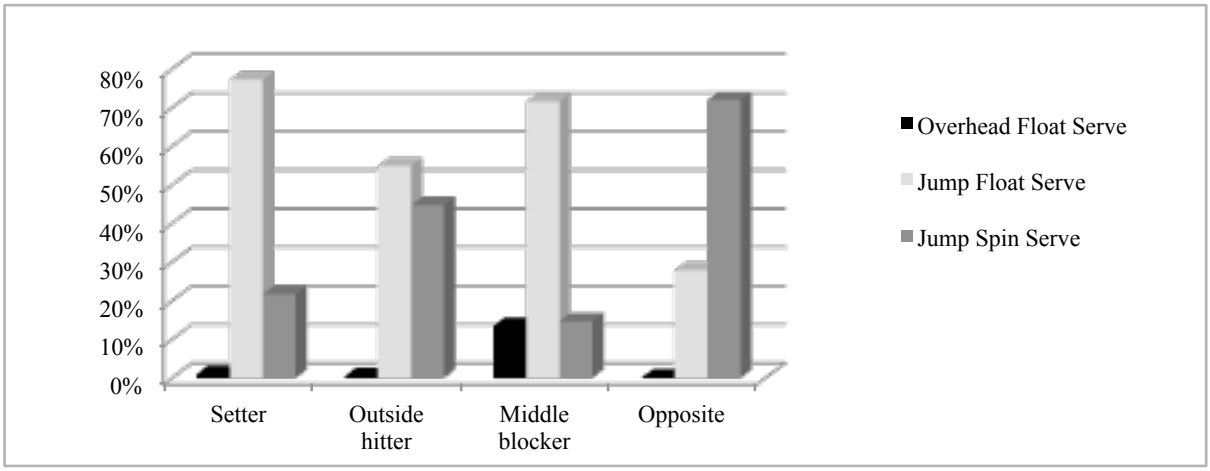

Figure 2. Serve type distribution by in-game role.

SERVE TYPE by SCORE TREND - The statistical analysis showed a significant difference between serve type and set phase (p = .000). Comparison of relative frequencies in all phases of the set showed that the most used serve type was Jump Float Serve (60.6%) and the least used was Overhead Float Serve (4.6%). Jump Spin Serve was performed for about a third of all serves (34.9%). In most sets, Jump Float Serve was used more in the *Final* phase (64.0%) than in the *Middle* phase (62.9%) and the *Early* phase (55.8%). In contrast, the frequency of Jump Spin Serve (40.2%) in the *Early* phase was greater than in the *Final* phase

(30.6%), while in the *Middle* phase the value was 32.6%. Overhead Float Serve was performed with the following values: *Early* phase 3.9%, *Middle* phase 4.5%, *Final* phase 5.4%.

Serve quality was analyzed in relation to four criteria: serve zone, in-game role, score trend and set outcome.

SERVE QUALITY by SERVE ZONE – A significant difference (p = .039) was found between serve quality and serve zone. Relative frequency analysis showed that most serves related to serve quality were performed from BZ1 (54.6%), followed by BZ5 (26.3%) then BZ6 (19.1%). Almost 60.0% of aces were served from BZ1 (59.7%), compared to 22.0% from BZ5 and 18.3% from BZ6. Serve errors were predominant in serves from BZ1 (58.6%), compared to values of 21.3% from BZ5 and 20.1% from BZ6. Although serves resulting in *Free ball* had the lowest percentage (51.7%) among all serves from BZ1, the percentage from this zone was higher than from BZ5 (26.0%) and BZ6 (22.3%). Serves resulting in *Free ball* performed from BZ6 had the highest percentage among all serves from BZ6. From BZ5 the most frequent serves were those that resulted in first (27.8%) and third (26.9%) tempo attack and *Free ball* (26.0%).

SERVE QUALITY by IN-GAME ROLE - A significant difference (p = .000) was observed in the contingency analysis of serve quality by in-game role (Table 1). Analysis of descriptive characteristics and relative frequencies showed that most serves by all in-game roles gave the opponent the opportunity to organise all types of attack. Opposite is the in-game role with the lowest number of serves at the tournament (n=692), although these players accounted for the highest number of aces (7.4%) and the highest number of serve errors (22.5%), undoubtedly causing the greatest trouble for receivers. Serves by setter in-game role (n=953) resulted in the highest number of opponent third-tempo attacks and free balls. From a

total of 1412 serves, middle blocker position had the highest relative frequency of serves that allowed a first-tempo attack (58.5%), followed by outside hitter with 54.7% from 1531 serves.

Table 1

Serve quality distribution by in-game role

Serve quality	Setter		Outside hitter		Middle blocker		Opposite	
	Count	%	Count	%	Count	%	Count	%
Serve error	82	8.6	243	15.9	147	10.4	156	22.5
First tempo	484	50.8	838	54.7	826	58.5	277	40.0
Third tempo	244	25.6	270	17.6	288	20.4	138	19.9
Free ball	105	11.0	121	7.9	108	7.6	70	10.1
Ace	38	4.0	59	3.9	43	3.0	51	7.4
Total	953	100	1531	100	1412	100	692	100

Note. Chi-Square = 156.213*, (p = .000).

*Asterisk indicates a statistically significant difference.

SERVE QUALITY by SCORE TREND - It was found that serve quality is not significantly different in the various set phases.

SERVE QUALITY by SET OUTCOME - Contingency analysis (*Chi-Square test*) revealed statistically significant differences (p = .000) between set *Winners* and set *Losers* by serve quality. Relative frequencies showed that both *Winner* and *Loser* groups of teams were able to organize all attacks on most serves (*Winner* teams 49.8%, *Loser* teams 56.6%), and on a small percentage it was possible to organise only a third tempo attack (*Winner* teams 21.3%, *Loser* teams 19.4%). The same comparison of the *Winner* and *Loser* groups showed that the winning group significantly made fewer serve errors (13.0% compared to 14.6%), executed

fewer serves that permitted all types of attack, performed more serves that compelled the opponent to organise a third tempo attack, provoked more free balls from the opponent (10.4% compared to 6.8%), and made more aces (5.4% compared to 2.6%).

Serve zone was analyzed in relation to three criteria: in-game role, score trend, and set outcome.

SERVE ZONE by IN-GAME ROLE – A significant difference (p = .000) was observed in the contingency analysis of serve zone by in-game role (Figure 3). Relative frequencies indicate that from behind zone 1, the most used zone, opposite performed 69.2% of total serves by this in-game role, setter 63.2% and outside hitter 64.4%, whereas middle blocker in-game role had the lowest percentage of serves from this zone (30.9%). Middle blocker was unique in performing the highest percentage of serves from BZ5 (46.9%) and the lowest percentage from BZ1.

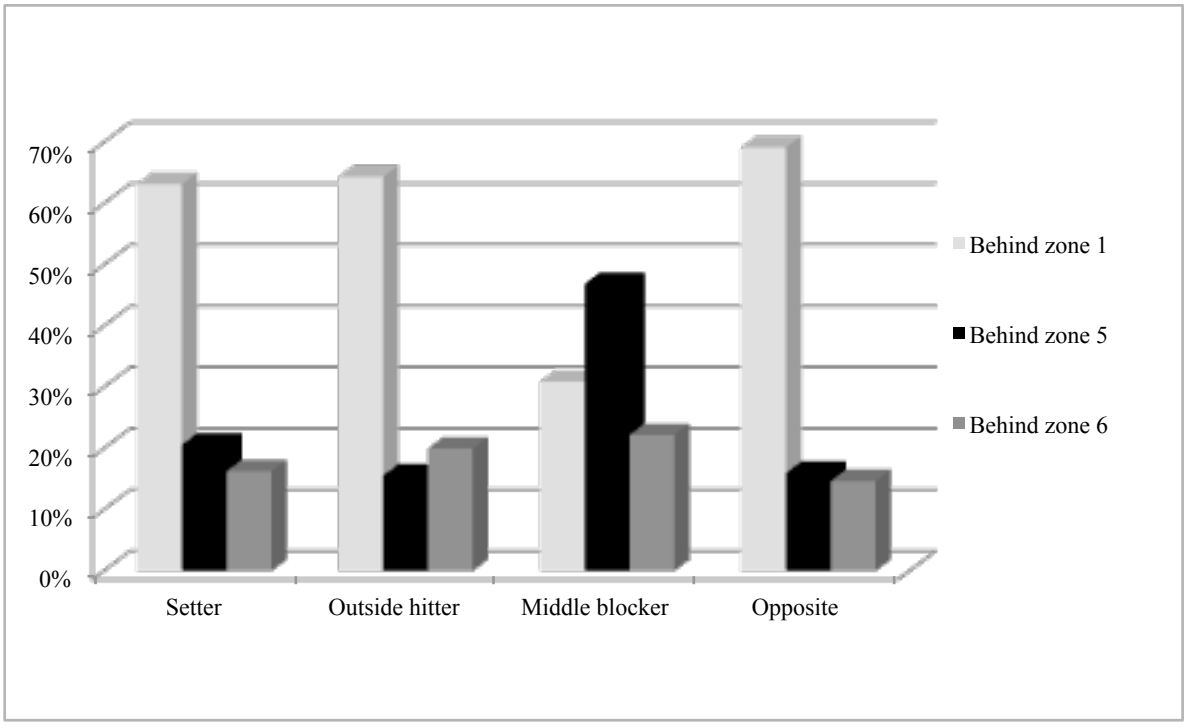

Figure 3. Serve zone distribution by in-game role.

SERVE ZONE by SCORE TREND – The choice of serve zone did not change significantly during the various set phases.

SERVE ZONE by SET OUTCOME - Set *Winner* and set *Loser* groups showed significant differences (p = .000) in the zones they served from. Set *Winner* group performed 2554 serves, compared to 2034 serves by set *Loser* group. In terms of relative frequencies, in all phases the set *Winner* and set *Loser* teams performed 54.6% of serves from BZ1, 26.3% from BZ5 and considerably fewer from BZ6 (19.1%). Set *Winner* teams performed considerably more serves (21.5%) from BZ6 than set *Loser* teams (16.2%). As a rule, set *Loser* teams executed more serves (57.2%) from BZ1 than set *Winner* teams (52.4%). Both groups performed almost the same number of serves from BZ5 (*Winner* teams 26.1%, *Loser* teams 26.6%).

Placement zone was analyzed in relation to three criteria: serve quality, serve zone and set outcome.

PLACEMENT ZONE by SERVE QUALITY – Statistical analysis showed a significant difference between placement zone and serve quality (p = .000). Relative frequency analysis revealed that zones 1, 5 and 6 were the most frequent placement zones (Table 2). The highest number of *Serve Errors* were made in serves to zone 6 (39.6%), compared to values of 25.0% for *Serve Errors* to zone 1 and 22.6% to zone 5. The easiest serves were performed to zone 6 (35.6%), followed by zone 5 (29.0%). Serves that triggered opponent third tempo attack were directed to zones 5 (31.3%) and 6 (32.7%). The highest number of free balls (34.4%) and aces (28.8%) resulted from serves to zone 5.

Table 2

Serve quality distribution by serve placement zone

Placement zone	Serve error		First tempo		Third tempo		Free ball		Ace	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
1	157	25.0	497	20.5	206	21.9	83	20.5	44	23.0
2	1	.2	4	.2	6	.6	1	.2	4	2.1
3	3	.5	3	.1	7	.7	8	2.0	7	3.7
4	2	.3	4	.2	2	.2	1	.2	3	1.6
5	142	22.6	703	29.0	294	31.3	139	34.4	55	28.8
6	249	39.6	863	35.6	307	32.7	122	30.2	43	22.5
7	25	4.0	89	3.7	34	3.6	18	4.5	9	4.7
8	25	4.0	167	6.9	55	5.9	25	6.2	16	8.4
9	24	3.8	95	3.9	29	3.1	7	1.7	10	5.2
Total	628	100	2425	100	940	100	404	100	191	100

Note. Chi-Square = 139.760*, (p = .000).

*Asterisk indicates a statistically significant difference.

PLACEMENT ZONE by SERVE ZONE – Contingency analysis showed a significant difference between placement zone and serve zone (p = .004). In table 3, relative frequencies show that from BZ5 to zone 5 (32.9%) and zone 6 (31.9%), and from BZ6 to zone 5 (32.0%) and zone 6 (32.3%), players served in almost the same percentage. For serves executed from BZ5 to zone 1 the value was 19.5% and from BZ6 to zone 1 the value was 20.4%, whereas from BZ1, players mostly served to zone 6 (36.6%), then to zone 5 (26.1%) and zone 1 (22.9%).

Table 3

Serve placement zone by serve zone

Placement zone	BZ1	BZ1	BZ5	BZ5	BZ6	BZ6	Total	Total
	Count	(%)	Count	(%)	Count	(%)	Count	(%)
1	573	22.9	235	19.5	179	20.4	987	21.5
2	8	.3	6	.5	2	.2	16	.3
3	13	.5	9	.7	6	.7	28	.6
4	7	.3	1	.1	4	.5	12	.3
5	654	26.1	398	32.9	281	32.0	1333	29.1
6	916	36.6	385	31.9	283	32.3	1584	34.5
7	92	3.7	49	4.1	34	3.9	175	3.8
8	156	6.2	80	6.6	52	5.9	288	6.3
9	84	3.4	45	3.7	36	4.1	165	3.6
Total	2503	100	1208	100	877	100	4588	100

Note. Chi-Square = 34.880*, (p = .004).

*Asterisk indicates a statistically significant difference.

PLACEMENT ZONE by SET OUTCOME – The only data for which no significant differences were found between the *Winner* and *Loser* groups of teams in any set phase were for serve placement zone.

Discussion

Analysis of relations between the variables used in this study revealed many significant results. For serve type, a clear trend of an increase in the use of JFS was observed, in agreement with the study by Moreno et al. (2007). Jump Float Serve was used in more than 60.0% of serves, followed by a value of 34.9% for JSS and only 4.6% for OFS, indicating that the new rules tested probably caused the predominance of JFS. This concurs with studies by Häyrinen et al. (2007) and Tsivika and Papadopoulou (2008), who found JFS to be the

predominant serve type. In contrast, Mackenzie et al. (2012) identified JSS and JFS as the main serve types in elite volleyball. Other authors (Callejón-Lirola, 2006; Ciuffarella et al., 2013) reported JSS as the most frequent serve, followed by JFS and OFS. Analysis of male players under 16 years of age in the study by Gil-Arias, Claver, Fernández-Echeverría, Moreno, and Moreno (2016) showed a higher value for serve with jump (56.6%) than serve from the ground with no jump (43.4%).

Analysis of SERVE TYPE by IN-GAME ROLE revealed the following trend of relative frequencies for each in-game role: setters and middle blockers had a higher use of JFS (77.3% and 71.6%) while the most frequent serve by opposite players was JSS (72.0%). Outside hitters frequently served using JFS (54.9%), closely followed by JSS (44.7%). Outside hitter and middle blocker were the only in-game roles to perform a similar number of serves (1531 and 1411). The lowest number of serves (692) performed by opposite can be explained by the high number of serve errors and the lack of opportunity to serve several times in a row, for example like the setter (953 serves). Middle blocker was the leader in executing OFS, which made up 13.5% of total serves by this in-game role. The literature includes several studies about the serve and in-game role, but they are not comparable with this study because they are about women's and youth volleyball. Fernández-Echeverria et al. (2015) compared in-game role and serve. Although their study was about U14 and U16 female players, it is interesting to note the tendency among younger players. It seems that most teams decide to try to attack with JFS, which statistically provokes fewer errors but still creates problems for receivers.

For the relation between SERVE TYPE and SCORE TREND, there is no parallel literature for comparison. It was found that in most sets, the frequency of JFS increased (*Early* phase 55.8%, *Middle* phase 62.9%, *Final* phase 64.0%). In contrast, the frequency of JSS decreased with the approach to the *Final* phase (*Early* phase 40.2%, *Middle* phase 32.6%,

Final phase 30.6%). Overhead Float Serve showed a similar trend to JFS, increasing in frequency with the approach to the *Final phase* (*Early* phase 3.9%, *Middle* phase 4.5%, *Final* phase 5.4%).

The third correlation between SERVE QUALITY and SERVE ZONE showed that the highest quality serve was from BZ1 (54.6%), with the highest number of aces and free balls, followed by BZ5 (26.3%), while BZ6 was the zone from where fewest serves were performed (19.1%). Callejón-Lirola (2006) and Moreno et al. (2007) found that the highest percentage of serves (46.7% and 67.2%) are performed from BZ1, concurring with this study. Moreno et al. (2007) reported that the lowest percentage of serves (7.40%) are performed from BZ5, and Callejón-Lirola (2006) reported 21.0% for the same serve zone. In the study by Gil-Arias, Claver, Fernández-Echeverría, Moreno, and Moreno (2016), the most performed serve (35.7%) at the Championship in 2005 was with maximum opponent attack options, whereas the most performed serve (37.3%) at the Championship in 2010 was with limited attack options for the opponent.

From the analysis of SERVE QUALITY by IN-GAME ROLE, the results for outside hitter and middle blocker in-game roles indicate that these positions are safe servers, because their serves led to the highest percentage of *First tempo* attacks (54.7% and 58.5%) and achieved the lowest percentage of aces (3.9% and 3.0%) and *Free balls* (7.9% and 7.6%). Outside hitter was responsible for more serve errors (15.9%) than middle blocker (10.4%) because of the higher relative frequency of JSS (44.7% compared to 14.7%). The term constantly offensive serve can be applied to setter in-game role, as their serves resulted in the most *Third tempo* attacks (25.6%) and *Free balls* (11.0%). Opposite in-game role caused the lowest percentage of *First tempo* attack (40.0%) and the highest percentage of *aces* (7.4%). Opposite in-game role can be described as a highly offensive serving position, because these players achieved most aces, caused a high number of free balls (10.1%) and third tempo

attacks (19.9%) and made the minimum number of serves that let the opponent organize a *First tempo* attack. Because of this highly offensive serve, opposite in-game role made the most serve errors (22.5%). According to Callejón-Lirola (2006) and Ciuffarella et al. (2013), JSS is the serve with the most errors but also the most aces. Raiola et al. (2016) found no dependence between the relative number of aces and serve type.

For SERVE QUALITY by SET OUTCOME, set *Winner* teams had clearly better results in all serve aspects, concurring with the study by Marcelino et al. (2008), who found that the number of serve errors and percentage of serve points are associated with the team's tournament ranking. Claver et al. (2013) found the same trend of *Winner* teams showing higher performance in the serve. In this study the total points won by serve were 4.2%, compared to the findings of Marcelino and Mesquita (2006) in their study of high level volleyball, who reported only a mean value of 4.98±2.87 points won by serve per match. In their study of men's volleyball Palao, Manzanares, and Valadés (2015) found, as a rule, that the set *Winner* teams score 1-2 points per set. Set *Winner* teams had a lower percentage of serve errors (13.0% compared to 14.6%) and a higher percentage of aces (5.4% compared to 2.6%), partly concurring with Marcelino et al. (2008), who found that the best teams fail a higher number of serves but win more points with this action. In this study, set *Winner* teams made slightly fewer serve errors (13.0%) than the value of 14.6% found by Häyrinen et al. (2004), who reported more serve errors for the *Loser* teams (16.6% compared to 18.6%). This study showed that all types of attack could be organized (first tempo attack) from 52.9% of serves performed. Moreno et al. (2007) found a value of 52.4%. Further differences between the two studies were 19.2% for serve error reported in this study compared to 13.7% by these authors, 5.8% for aces compared to 4.2%, and 5.3% for serves resulting in a free ball compared to 8.8%.

For SERVE ZONE by IN-GAME ROLE, it was found that opposite players, with the

highest percentage of JSS (72.0%), performed most serves from BZ1 (69.2%), probably because it is directly in front of the area where this position plays (zones 2 and 1). Also, immediately after the powerful jump and hit during the serve, it is usual for these players to land in their defence zone (zone 1), otherwise they would need to make additional movements to reach this zone. Opposite is the in-game role with minimum zone change. The small percentage of serves from BZ5 (16.0%) and BZ6 (14.7%) could be from left-handed opposite players. Setter and outside hitter varied serve zones much more than opposite. Outside hitter in-game role served slightly more from BZ6 (20.0%), probably because of the move to the usual defence zone of this position immediately after the serve. Middle blocker in-game role showed the most variety in serve zones, with the highest percentage from BZ5 (46.9%), where this player is in the right defence zone (zone 5) after landing. The high percentage of JFS performed from BZ1 (30.9%) by middle blocker in-game role indicates that these players did not find it difficult to move to their defence zone (zone 5). Gil-Arias et al. (2016) found the highest percentage of serves were performed from BZ1 (51.6% in 2005, 50.8% in 2010), followed by BZ6 (33.5% in 2005, 27.3% in 2010) and BZ5 (14.9% in 2005, 21.9% in 2010).

For SERVE ZONE by SET OUTCOME there is no literature for comparison. This analysis showed that, as a rule, both *Winner* and *Loser* group of teams served mostly from BZ1, followed by BZ5 and BZ6. Set *Winner* performed 520 more serves than *Loser* group. In percentages, *Loser* teams performed more serves from BZ1 (57.2% compared to 52.4%) and BZ5 (26.6% compared to 26.1), whereas set *Winner* teams performed more serves from BZ6 (21.5% compared to 16.2%).

For PLACEMENT ZONE by SERVE QUALITY, the total of 4.2% aces performed is divided as follows: 28.8% to zone 5, 23% to zone 1 and 22.5% to zone 6. Ciuffarella et al. (2013) reported 5.62% of aces, divided as follows: 35.5% to zone 6, 18.4% to zone 5 and 16.4% to zone 1. The 22.5% of aces in zone 6 confirms that most *Serve Errors* (39.6%) were

made by serving to this zone. The results indicate that zone 5 is the most effective zone to serve to. Gil-Arias et al. (2016) found that the zone most served to was zone 6 (53.9% in 2005, 49.5% in 2010), followed by zone 5 (24.0% in 2005, 31.3% in 2010) and zone 1 (17.82% in 2005, 15.8% in 2010). Other authors reported the equivalent zones most served to. Callejón-Lirola (2006) indicated the following order: zone 6 (33%), zone 1 (15.2%), zone 5 (16.0%), zone 8 (14.8%), zone 9 (8.3%) and zone 7 (9.5%). Ciuffarella et al. (2013) found that in zone 6, the most hit zone, 83.5% of serves were directed by JSS, 14.2% by JFS and 2.3% by OFS. Moreno et al. (2007) reported that most serves (36.45%) go to zone 6, followed by zone 5 (21.8%) and zone 1 (17.73%). In this study the following values were found for serving to zones 7 (3.8%), 8 (6.3%) and 9 (3.6%), and Moreno et al. (2007) reported a value of 23.94% for all three zones.

Analysis of PLACEMENT ZONE by SERVE ZONE, also known as serve direction, showed that the most frequent serve direction from BZ1 was to zone 6 (36.6%), followed by zone 5 (26.1%). From BZ5 the most frequent serve direction was to zone 5 (32.9%), followed by zone 6 (31.9%), and from BZ6 it was to zone 6 (32.3%) and zone 5 (32.0%). The value for serves performed from BZ1 to zone 1 was 22.9%, from BZ5 to zone 1 19.5% and from BZ6 to zone 1 20.4%, which partially agrees with the results from the study by Moreno et al. (2007), who found almost half this value for serves from BZ1 to zone 1 (12.76%) and almost the same from BZ5 and BZ6 to zone 1, at about 20.0%. Gil-Arias et al. (2016) found medium diagonal to be the most frequent serve direction (57.7% in 2005, 53.0% in 2010), followed by parallel (28.4% in 2005, 31.6% in 2010) and long diagonal (13.9% in 2005, 15.3% in 2010).

No significant differences were found for the relations SERVE ZONE - SCORE TREND, SERVE QUALITY - SCORE TREND and PLACEMENT ZONE - SET OUTCOME and no studies analyzing the relations between these variables were found.

Conclusions

At the Volleyball Men's U23 World Championship, Jump Float Serve was the predominant serve type under the new rules tested. Setter, middle blocker and outside hitter in-game roles mostly used Jump Float Serve, whereas opposite in-game role mostly performed Jump Spin Serve. This serve type appears to be a safe but complex weapon that becomes more frequent towards the end of the set, compared to Jump Spin Serve, which decreased in frequency with the approach to the *Final* phase. The highest quality serves were performed from behind zone 1, resulting in the greatest number of aces and free balls. Outside hitter and middle blocker were found to be safe servers, whereas setter was a constantly offensive server. Opposite was a highly offensive serving position, with the most aces and errors. To win the set, the team has to perform controlled serves but also attack with minimum errors, ensuring their serves result in as few first tempo attacks as possible. It was observed that most servers performed the Jump Float Serve after both types of time out, indicating that most teams wanted to ensure a safe serve inside the court. Set *Winner* teams had clearly better results in all serve aspects than set *Loser* teams. Middle blocker was found to be the in-game role that used the greatest combination of serving zones, followed by both setter and outside hitter, whereas opposite in-game role mostly served from behind zone 1. Serving more from behind zone 6 and slightly less from behind zones 1 and 5 were significant characteristics for set *Winners* compared to set *Losers*. Set *Winners* often deployed their servers among three serving zones. Most serves were executed from behind zone 1 to zone 6 (medium diagonal) and zone 5 (parallel). If these rules become part of the official volleyball rules, this study will be a helpful guide for building team tactics and strategy. It also provides insight for FIVB about the effect of the tested rules for further developments in the game.

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References

Agelonidis, Y. (2004). The jump serve in volleyball: From oblivion to dominance. *Journal of Human Movement Studies, 47*(3), 205–213.

Asterios, P., Kostantinos, C., Athanasios, M., & Dimitrios, K. (2009). Comparison of technical skills effectiveness of men's National Volleyball teams. *International Journal of Performance Analysis in Sport, 9*(1), 1–7.

Callejón-Lirola, D. (2006). Estudio y análisis del saque en el voleibol masculino de alto rendimiento. [Research and analysis of the serve in the current high performance Men's Volleyball]. *RICYDE. Revista Internacional de Ciencias del Deporte, 2*(5), 12–28.

Ciuffarella, A., Russo, L., Masedu, F., Valenti, M., Izzo, R. E., & De Angelis, M. (2013). Notational Analysis of the Volleyball Serve. *Timisoara Physical Education and Rehabilitation Journal, 6*(11), 29–35.

Claver, F., Jiménez, R., Gil, A., Moreno, A., & Moreno, M. P. (2013). Relationship between performance in game actions and the match result: a study in volleyball training stages. *Journal of Human Sport and Exercise, 8*(Proc3), S651–S659.

Conejero, M., Claver, F., Fernández-Echeverría, C., Gil-Arias, A., & Moreno, M. P. (2017). Toma de decisiones y rendimiento en las acciones de juego intermedias y finalistas en voleibol, en sets con diferente resultado [Decision-making and performance in intermediate and terminal actions in volleyball, according to the set result]. *Retos - Nuevas Tendencias en Educación Física Deporte y Recreación, 31*, 28-33.

Dávila-Romero, C., García-Hermoso, A., & Saavedra, J. M. (2012). Poder discriminatorio de las acciones finales de voleibol en etapas de formación [Discriminatory power of final game actions volleyball in formative stages]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 12*(48), 745–755.

Drikos, S., Kountouris, P., Laios, A., & Laios, Y. (2009). Correlates of team performance in volleyball. *International Journal of Performance Analysis in Sport, 9*(2), 149–156. Fédération Internationale de Volleyball. (2000). *VIS (Volleyball Information System) STAFF Guidelines - Evaluation Criteria 2000.* Lausanne, Switzerland.

Fernández-Echeverria, C., Gil, A., Moreno, A., Claver, F., & Moreno, M. P. (2015). Analysis of the variables that predict serve efficacy in young volleyball players. *International Journal of Performance Analysis in Sport, 15*(1), 172–186.

FIVB. (n.d.). *Volleyball Information System (VIS)*. Retrieved October 1, 2013, from http://www.fivb.org/en/volleyball/VIS.asp

FIVB. (2000). *VIS (Volleyball Information System) STAFF Guidelines - Evaluation Criteria 2000.* Lausanne, Switzerland: FIVB.

FIVB. (2012). Official volleyball rules 2013-2016. In *33rd FIVB Congress.* Anaheim, CA: FIVB. Retrieved from http://www.fivb.org/EN/Refereeing-Rules/documents/FIVB-Volleyball_Rules2013-EN_20121214.pdf

FIVB. (2013a). *New rules test to be held in Brazil only*. Retrieved October 1, 2013, from http://www.fivb.org/viewPressRelease.asp?No=43147&Language=en#.VMOwz8aI9YE

FIVB. (2013b). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved October 1, 2013, from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2015). *The Game - Volleyball Rules; Major changes in volleyball rules*. Retrieved January 1, 2015, from http://www.fivb.org/TheGame/TheGame_VolleyballRules.htm

Fleiss, J. L., Levin, B. A., & Paik, M. C. (2003). *Statistical Methods for Rates and Proportions (3rd ed.)*. Hoboken, NJ: John Wiley & Sons.

García-Tormo, J. V, Redondo, J. C., Valladares, J. A., & Morante, J. C. (2006). Análisis del saque de voleibol en categoría juvenil femenina en función del nivel de riesgo asumido y su eficacia [Analysis of volleyball serve in junior female category by risk taken and efficiency]. *Motricidad. European Journal of Human Movement, 16*, 99–121.

Giddens, S., & Giddens, O. (2005). *Volleyball: Rules, Tips, Strategy, and Safety.* The Rosen Publishing Group.

Gil-Arias, A., Claver, F., Fernández-Echeverría, C., Moreno, A., & Moreno, M. P. (2016). Análisis comparativo del saque en voleibol entre los Campeonatos de España 2005-2010 [Comparative Analysis of the Serve in Volleyball between the Spanish Championships 2005-2010]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 16*(62), 439-456.

Gónzález-Silva, J., Moreno, A., Fernández-Echeverría, C., Conejero, M., & Moreno, M. P. (2016). Características de la colocación en voleibol, en etapas de formación, en sets ganados y perdidos [Characteristics of the set in volleyball, in formative stages, in set win and lost]. *Retos - Nuevas Tendencias en Educación Física Deporte y Recreación, 30*, 43-47.

Häyrinen, M., Hoivala, T., & Blomqvist, M. (2004). Differences between winning and losing teams in men's European top-level volleyball. In P. O'Donoghue, & M. Hughes (Eds.),

Proceedings of VI Conference Performance Analysis of Sport (pp. 491–496). Belfast, Northern Ireland: University of Wales Institute Cardiff.

Häyrinen, M., Lahtinen, P., Mikkola, T., Honkanen, P., Paananen, A., & Blomqvist, M. (2007). Serve speed analysis in men's volleyball. *Science for Success II,* 10–11.

Huang, C., & Hu, L. H. (2007). Kinematic analysis of volleyball jump top spin and float serve. In H. J. Menzel, & M. H. Chages (Eds.), *XXV International Symposium on Biomechanics in Sports* (pp. 333–336). Ouro Preto – Brazil.

João, P., Leite, N., Mesquita, I., & Sampaio, J. (2010). Sex differences in discriminative power of volleyball game-related statistics. *Perceptual and Motor Skills, 111*(3), 893–900.

João, P., Silva, M., Lacerda, D., & Vaz, L. (2012). The scoring skills which discriminate result, according set number in World Championship volleyball 2010. In R. Meeusen, J. Duchateau, B. Roelands, M. Klass, B. De Geus, S. Baudry, & E. Tsolakidis (Eds.), *XVII annual Congress of the European College of sport science* (Vol. 30, pp. 149–150). Bruges, Belgium: European College of Sport Science.

Kenny, B., & Gregory, C. (2006). *Volleyball: Steps to success*. Campaign, IL: Human Kinetics.

López, J. P. (2013). *Analysis of the service as a performance factor in high-level volleyball and beach volleyball* (doctoral dissertation). University of VIC – Central University of Catalonia, Barcelona, Spain.

López-Martínez, A., & Palao, J. M. (2009). Effect of serve execution on serve efficacy in men's and women's beach volleyball. *International Journal of Applied Sports Sciences, 21*(1), 1–16.

MacKenzie, S., Kortegaard, K., LeVangie, M., & Barro, B. (2012). Evaluation of two methods of the jump float serve in volleyball. *Journal of Applied Biomechanics, 28*(5), 579–

586.

Marcelino, R., Mesquita, I., Sampaio, J., & Anguera, M. T. (2009). Ventaja de jugar en casa en voleibol de alto rendimiento [Home advantage in high-level volleyball]. *Revista de Psicología del Deporte, 18*(2), 181–196.

Marcelino, R. Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1–7.

Masumura, M. Marquez, W. Q., Koyama, H., & Michiyoshi, A. E. (2007). A biomechanical analysis of serve motion for elite male volleyball players in official games. *Journal of Biomechanics, 40*(S2), S744.

Molina, J. J., Santos del Campo, J. A., Barriopedro, M. I., & Delgado, M. A. (2004). Análisis de juego desde el modelo competitivo: un ejemplo aplicado al saque en voleibol [Game analysis from the competitive model: an example applied to the volleyball serve]. *KRONOS, III*(5), 37–45.

Moras, G., Buscà, B., Peña, J., Rodríguez, S., Vallejo, L., Tous-Fajardo, J., & Mujika, I. (2008). A comparative study between serve mode and speed and its effectiveness in a high-level volleyball tournament. *Journal of Sports Medicine and Physical Fitness, 48*(1), 31–36.

Moreno, M. P., García de Alcaráz, A., Moreno, A., Molina, J. J., & Santos, J. A. (2007). Estudio de la dirección del saque en la superliga masculina de voleibol [Study of serve direction in elite men's volleyball]. *Motricidad. European Journal of Human Movement, 18*, 111–134.

Palao, J. M., Manzanares, P., & Valadés, D. (2015). Way of scoring of Spanish first division volleyball teams in relation to winning/losing, home/away, final classification, and type of confrontation. *Journal of Human Sport & Exercise, 10*(1), 36-46.

Parisi, F., & Raiola, G. (2014a). The serve in under 12-13 Italian volleyball team.

Journal of Human Sport & Exercise, 9(Proc1), S588-S591.

Parisi, F., & Raiola, G. (2014b). Video analysis in youth volleyball team. *Journal of Human Sport & Exercise, 9*(Proc1), S584-S587.

Raiola, G., Altavilla, G., De Luca, C., & Di Tore, P. A. (2016). Analysis on some aspects of the service in volleyball. *Sport Science 9*(1), 74-77.

Raiola, G., Parisi, F., Giugno, Y., & Di Tore, P. A. (2013). Video analysis applied to volleyball didactics to improve sport skills. *Journal of Human Sport & Exercise, 8*(Proc2), S307-S313.

Rentero, L., João, P. V., & Moreno, M. P. (2015). Análisis de la influencia del líbero en diferentes fases del juego en voleibol [Analysis of the influence of the líbero in different phases of game in volleyball]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 15*(60), 739-756.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics (6th ed.).* Boston, MA: Pearson Education.

Tillman, M., Hass, C., Brunt, D., & Bennet, G. (2004). Jumping and landing techniques in elite women's volleyball. *Journal of Sports Science and Medicine 3*, 30–36.

Tsivika, M., & Papadopoulou, S. D. (2008). Evaluation of the technical and tactical offensive elements of the Men's European Volleyball Championship. *Physical Training*. Retrieved from http://ejmas.com/pt/2008pt/ptart_tsivika_0812.html

Ureña, A., Gallardo, C., Delgado, J., Hernández, E., & Calvo, R. (2000). Estudio sobre la evolución de las reglas de juego en voleibol [Study on the evolution of game rules in volleyball]. *Habilidad motriz: Revista de Ciencias de la Actividad Física y del Deporte, 16*, 32-39.

Ureña, A., Santos, J. A., Martínez, M., Calvo, R., Hernández, E., & Oña, A. (2001). El principio de variabilidad como factor determinante en la táctica individual del saque en

voleibol masculino de nivel internacional [Variability principle as a determining factor in individual tactics of male volleyball serve of an international level]. *Revista Motricidad, 7*, 63–74.

CHAPTER 3

STUDY 2

Chapter 3

Study 2. Point-Scoring Plays Related to Level of Set Win and In-Game Role During Volleyball Rules Testing

Abstract

This study determines how experimental rules first tested at the U23 Men's Volleyball World Championship (21-point set, 15 seconds between points) influenced point-scoring plays from the 16th point in the first four sets and the 10th point in the fifth set. The analysis comprised 1335 points from 123 sets in 36 matches played by 144 males (average age 21.1±1.4 years). Analysis included statistical procedures of in-game role (setter, outside hitter, middle blocker, opposite, libero), final score and finishing point actions (serve-ace, three attack types, three counter attack types, block). Pearson's *Chi-Square* test was used as for data analysis. The results showed a decrease in the difference between winning and losing sets in relation to the structure of won and lost points as the set becomes tougher. Outside-hitter was identified as the in-game role that finished more points. If the rules are changed, development of block, serve and attacks may have greater influence on set outcome in the future.

Introduction

Volleyball is a popular sport worldwide, with more than 221 associated federations in the International Volleyball Federation (Fédération Internationale de Volleyball [FIVB], n.d.-b, The Federation). Over time, volleyball rules have changed to make the game a more exciting spectator sport (Ureña, Gallardo, Delgado, Hernández, & Calvo, 2000). Point scoring has changed several times throughout the history of volleyball and the last change was from Side Out to Rally Point (FIVB, n.d.-a, FIVB History; FIVB, n.d.-c, The Game – Volleyball

Rules; Major changes in volleyball rules; Marelić, Rešetar, & Janković, 2004; Mesquita, Manso, & Palao, 2007). Points per set were also changed, from an initial set to 15 points (side out), then to 25 points (rally point), and more recently in Brazil at the Under 23 (U23) Men's World Championship, in 2013, when the FIVB tested a new scoring system: playing sets to 21 points (excluding the fifth set, which remained at 15) with a two-point lead required at the end of sets. The rule changes were intended to modernize volleyball and make it more appealing for fans both present at games and watching matches on television (FIVB, 2013b, Twenty-one point rule to be tested at U23 World Championships).

Analyzing the actions of both teams at a match, whole tournaments and in competitions is common in volleyball. Match analysis considers an objective recording and detailed examination of each game action during the competition (Lago, 2009). Each team is able to score points by serving, blocking, attacking and from the opponent's mistakes (Häyrinen, Hoivala, & Blomqvist, 2004). Generally all methods of scoring have their own importance, influence and terminating effect (Marcelino & Mesquita, 2006; Moreno, Moreno, Julián, & Del Villar, 2005). Various studies have addressed each scoring element: serve (Asterios, Kostantinos, Athanasios, & Dimitrios, 2009; Joao, Silva, Lacerda, & Vaz, 2012; Marelić et al., 2004; Moras et al., 2008), block (Araújo, Castro, Marcelino, & Mesquita, 2010; Palao, Santos, & Ureña, 2004) and spike (Häyrinen et al., 2004; Palao et al., 2004; Tsivika & Papadopoulou, 2008).

Every analysis of actions is research pertaining to notational analysis (Dávila-Romero & García-Hermoso, 2012). Notational analysis basically considers analysis of movement, technical and tactical evaluation, and statistical compilation (Hughes, & Franks, 2004). This technique is used to analyze various performance parameters by producing a permanent record of the events (Hughes, & James, 2008). This type of analysis is used in many sports such as soccer (Hughes, & James, 2008), tennis (O'Donoghue, & Ingram, 2010), water polo

(Escalante, Saavedra, Mansilla, & Tella, 2011), handball (Gruić, Vuleta, & Milanović, 2006), volleyball (Marcelino, Mesquita, & Sampaio, 2011) by coaches and sport scientists to obtain objective, reliable and valid data (Sampaio, Godoy, & Feu, 2004). Dávila-Romero & García-Hermoso (2012) analyzed the variables positive and negative serve, attack, positive block and technical error (touching the net, double touch, invasion, stepping on serve line, second line attacker stepping on the three-meter line and long touch). Some of the variables used by Palao, Manzanares, and Ortega (2015) in their analysis of the effects of team level on skills performance were technical actions of the serve, reception, set, attack, block, and court defense in relation to the player who intervenes; in-game role; manner of execution and execution zone; efficacy and result of the play; and how the point was scored. As performance in attack, serve, block and number of points won by opponent error are the variables in top-level men's volleyball that decisively explain the difference between teams (Rodríguez-Ruiz et al., 2011), these variables were chosen for this study as the only direct-scoring volleyball elements. For greater insight into the executors of final actions and which in-game role scores the points in the last part of the sets, it was necessary to include in-game role (Palao et al., 2015) as well. Including in-game role in the analysis gives the most detailed information about how each in-game role executes the points. To determine a trend of final actions in the last parts of the sets and clearly differentiate between the sets, it was necessary to include score fluctuation as a final variable (Palao et al., 2015). The parameters of each category of variables used in the study were attack-spike, as the action most correlated with the success of the team (Eom & Schutz, 1992a, 1992b; Grgantov, Dizdar, & Janković, 1998; Häyrinen et al., 2004; Marelić, Žufar, & Omrčen, 1998; Palao et al., 2004), attack-tipping, also known as the tip (Marcelino et al., 2011), and attack-block out and counter attack, as analyzed by Zetou, Tsigilis, Moustakidis and Komninakidou (2006).

The results of set analysis can help coaches design appropriate physical preparation,

determine adequate defense strategies and the best types of attack, avoid common mistakes, increase the general effectiveness of a team and develop a training system for any age. When the time between two points is limited, as with the 15 seconds rule, it should bring structure to the serve execution, which we aim to define in this study. Having sets to 21 points instead of 25 means fewer points are won and finishing actions that score points have a unique model. The purpose of this analysis is to define that model. The aim of this study was to determine which final actions by in-game role lead to winning points in the final part of sets, defined as points 16 to 21 in the first four sets and points 10 to 15 in the fifth set, relating this to level of set win, with reference to the two new rules tested: 21 point set (excluding the fifth set) and 15 seconds between rallies (10 seconds from the finished point until the referee's whistle for the serve and five seconds for performing the serve).

Methodology

Data were collected from the matches played at the U23 Men's World Championships in Uberlandia (Brazil) in October 2013, where 12 teams participated. Variables were analyzed after the Championships had ended, from recorded matches. Analysis included statistical procedures of in-game role (setter, outside hitter, middle blocker, opposite and libero), final score and finishing point actions (serve-ace, three attack types, three counter attack types and block).

Participants. The study involved observation (Anguera & Hernández-Mendo, 2013) of 123 sets and 1335 finishing actions delivered during 36 matches played by 144 male players under 23 years of age. The average age of players was 21.1±1.4 years. This age group currently competes successfully in the highest men's volleyball leagues around the world and therefore the games have a similar level to elite men's volleyball.

Ethical approval. The study was performed in accordance with the Helsinki Declaration of 1975 and approved by the Ethics Committee of the University of Las Palmas de Gran Canaria. FIVB officially authorized this study and the use of all match videos and data from the VIS statistical recording program and the FIVB website.

Procedure and measures. All 36 games studied were recorded from the same position, behind the court from a height of 5 m above floor level (Claver, Jiménez, Gil, Moreno, & Moreno, 2013), to obtain the best view of the whole court. All games were filmed using the same PANASONIC HC-V720 HD digital camcorder in AVCHD format.

The matches followed the competition system organized by the Fédération Internationale de Volleyball (FIVB). Competitions had two rounds, with 30 matches played in the first round (group phase) and eight in the second (Semi-final and Finals). The 12 teams were divided into two groups of six (A and B) and all teams played according to the round-robin system to determine the ranking and were classified from 1st to 6th. The team ranked 3rd in Pool A after the preliminary round played the team ranked 4th in Pool B. The team ranked 3rd in Pool B after the preliminary round played the team ranked 4th in Pool A. The losers of these semi-final matches played for 7th and 8th final places. The winners of the semi-final matches played for 5th and 6th places. The team ranked 1st in Pool A played the team ranked 2nd in Pool B. The team ranked 1st in Pool B played the team ranked 2nd in Pool A. The losers of the semi-final matches played for 3rd and 4th place. The winners of the semi-final matches played for 1st and 2nd place (FIVB, 2013a, Competition formula).

To analyze each game, a data recording form and analysis scheme are required, as well as a graphic representation of the playing area, so the variables can be defined and examined (Tsimpiris, Tsamourtzis, Sfingos, Zaggelidis, & Zaggelidis, 2006). To analyze point-scoring plays related to level of set win and in-game role during volleyball rules testing, the variables

were chosen according to extensive literature and objective volleyball analysts' validation of the research problem. Eleven volleyball elements had the status of dependent variables. Their empirical frequencies are analyzed in relation to the three independent variables: set outcome (Win-Lose), level of set win (*Walkover-Balanced-Tough*) and in-game role.

In-game role – This variable considers the role of each player in the team, classified by numbers: 1 = setter, 2 = outside hitter, 3 = middle blocker, 4 = opposite, 5 = libero.

Score fluctuation – This refers to each winning point in the final part of sets, defined as points 16 to 21 in the first four sets and points 10 to 15 in the fifth set, with reference to one of the two new rules tested: 21 point set (excluding the fifth set).

Serve-Ace – The final action that leads to point scoring. Both types of Serve-Ace were taken into consideration: 1) Serve-Ace point scored after the ball directly touches the court, and 2) Serve-Ace point scored after the final touch by the serve receiver.

Attack – This volleyball element is termed attack hit by FIVB (2014) and is defined as all actions where the ball is sent towards the opponent, excluding serve and block. Attack corresponds to three basic parameters: spike, tipping and block out.

Counter attack – Volleyball element also known as attack after defensive action (Sánchez-Moreno, Marcelino, Mesquita, & Ureña, 2015). This variable similarly considers three parameters: spike, tipping and block out.

Block – This variable takes into consideration all types of blocks that score points, i.e., individual, double, and triple block.

Opponent/unforced error – As a terminating action (Rodríguez-Ruiz et al., 2011), this considers the following parameters: unforced error by serve, attack/counter attack and technical fault (defined in this study as touching the net, double touch, invasion, stepping on the serving line, second line attacker stepping on the three-meter line and long touch).

Data analysis. These variables were assessed by methodical observation of all game actions. To achieve consistency in the criteria and quality in coding the data, the observer was given 20 hours' training consisting of instruction on the definition of the variables and a two-week data recording period until he obtained a Cohen's Kappa value higher than .90. The observer had at least three years' experience in data logging during previous volleyball research and six years' extensive experience as a volleyball scout and coach.

To ensure reliability of the calculation to avoid any learning effect, 12% of the rallies were re-analyzed after a six-week interval, exceeding the reference value of 10% (Tabachnick & Fidell, 2007). Two additional volleyball researchers and national coaches who had received 10 hours of training in data collection conducted secondary observation of the data. Cohen's Kappa ranged from .84 to .91 for inter-observer reliability and from .82 to .92 for intra-observer reliability. All values fulfilled the criterion of .75 suggested in the literature (Fleiss, Levin, & Paik, 2003).

All numerical data are presented by frequency, separated into each volleyball element analyzed. Because all the statistical series had the characteristics of a nominal scale, Pearson's *Chi-Square* test was used as an appropriate data analysis procedure. Statistical analysis was conducted using IBM SPSS Statistics V19 software. Statistical inference was performed at the level of significance of $p < .05$.

For a clearer view of the results, all data were analyzed using two criteria - set outcome (*Winner vs. Loser*) and level of set win (*Walkover-Balanced-Tough*). *Walkover* was defined as set results of 21:15 (and less than 15 points), *Balanced* as set results of 21:16, 21:17 and 21:18, and *Tough* as set results with a two-point difference (21:19, 22:20… or 15:13, 16:14… in the fifth set).

Results

Results of the statistical analysis showed that between set *Winners* and set *Losers* in relation to the structure of won and lost points, the differences decrease as the set becomes tougher. Overall, calculating all matches without dividing sets by *Level of Set Win*, the set *Winner* and *Loser* groups executed similar actions in each set (Figure 4). In all matches and in all teams the most frequently executed technical element was attack-spike (8.58±4.44), followed by block (5.06±3.22). Errors, mostly in serve and attack, also had a high contribution to the way points were finished.

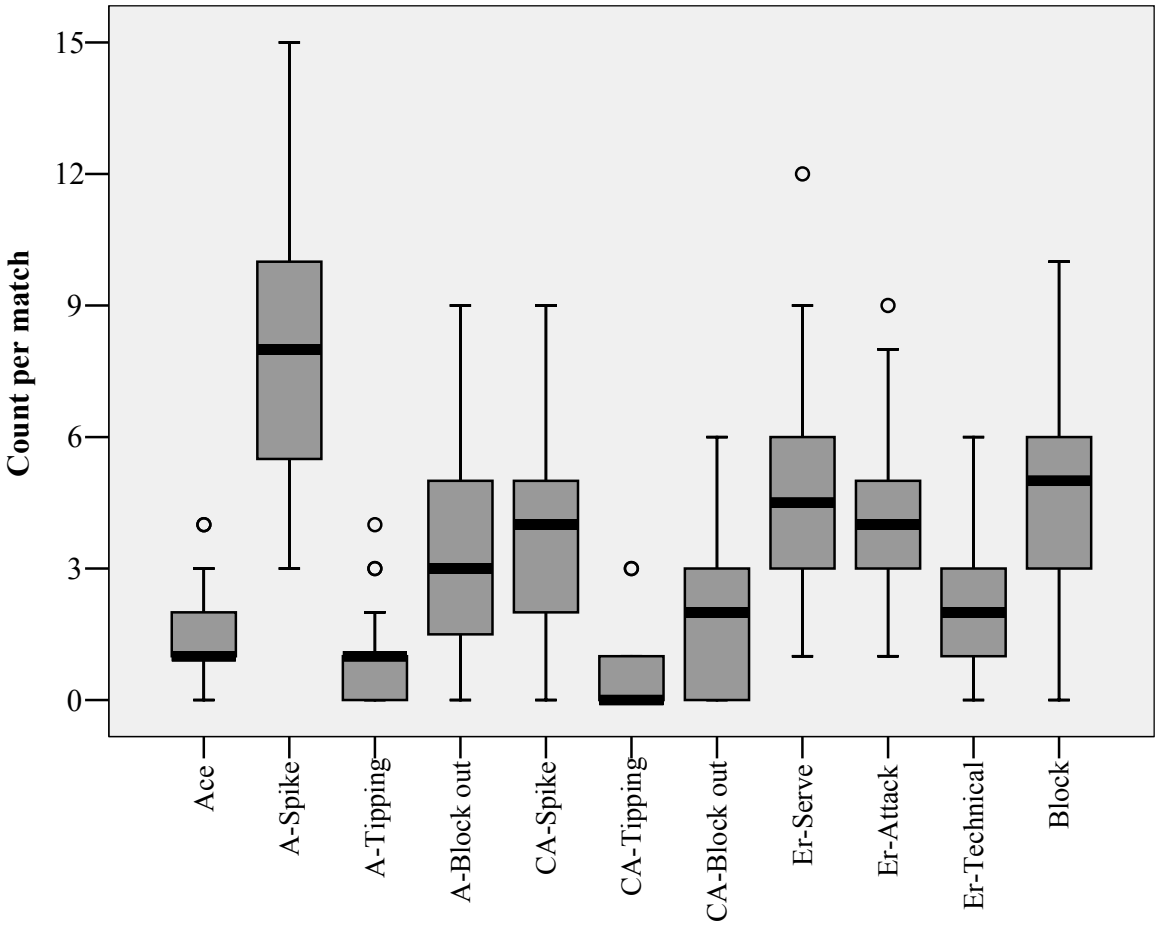

Figure 4. Average number of finishing volleyball elements registered per match.

Note. A = Attack; CA = Counter Attack; Er = Unforced Error

°Circles above the bars represent individual extreme values that exceeded 3 standard deviations and are excluded from the analysis as parasitic data.

Regarding *Level of Set Win, a* significant difference in the structure of winning and losing points (Chi-Square$_{10}$ = 75.476; p = .000; Cramer's V = 0.410) was found mainly in *Walkover* sets (Table 4).

Table 4

Point-scoring plays by winning and losing teams for walkover sets

Variables	Winner		Loser		Total	
	Count	(%)	Count	(%)	Count	(%)
Serve (Ace)	22	8.2	3	1.6	25	5.6
Attack-Spike	57	21.3	34	18.6	91	20.2
Attack-Tipping	12	4.5	2	1.1	14	3.1
Attack-Block out	16	6.0	15	8.2	31	6.9
Counter-Spike	31	11.6	15	8.2	46	10.2
Counter -Tipping	4	1.5	3	1.6	7	1.6
Counter -Block out	22	8.2	8	4.4	30	6.7
Unforced Error-Serve	45	16.9	30	16.4	75	16.7
Unforced Error-Attack	9	3.4	41	22.4	50	11.1
Un. Error-Technical fault	8	3.0	22	12.0	30	6.7
Block	41	15.4	10	5.5	51	11.3
Total	267	100	183	100	450	100

Note. Chi-Square = 75.476* (p = .000), Cramer's V = 0.410.

*Asterisk indicates a statistically significant difference.

A slightly lower significant difference (Chi-Square$_{10}$ = 23,154; p = .010; Cramer's V = 0.230) was found in *Balanced* sets (Table 5).

Table 5

Point-scoring plays by winning and losing teams for balanced sets

Variables	Winner		Loser		Total	
	Count	(%)	Count	(%)	Count	(%)
Serve (Ace)	11	4.2	4	2.2	15	3.4
Attack-Spike	68	26.3	44	24.6	112	25.6
Attack-Tipping	5	1.9	5	2.8	10	2.3
Attack-Block out	20	7.7	19	10.6	39	8.9
Counter-Spike	28	10.8	15	8.4	43	9.8
Counter -Tipping	6	2.3	0	0	6	1.4
Counter -Block out	14	5.4	8	4.5	22	5.0
Unforced Error-Serve	27	10.4	20	11.2	47	10.7
Unforced Error-Attack	22	8.5	32	17.9	54	12.3
Un. Error-Technical fault	13	5.0	16	8.9	29	6.6
Block	45	17.4	16	8.9	61	13.9
Total	259	100	179	100	438	100

Note. Chi-Square = 23.154* (p = .010), Cramer's V = 0.230.

*Asterisk indicates a statistically significant difference.

Tight sets (*Tough*) showed no significant differences between set *Winners* and set *Losers*. In close sets (*Tough*), both groups scored most points by Attack-Spike and made a similar number of unforced errors. The second most frequent method of winning points was by block, where set *Winners* obtained a slightly better result.

In unequal sets (*Walkover*), the *Winner* group had a significantly higher number of winning points by block, first attack and counter-attack, and then by serve (ace). The *Loser* group had a significantly higher number of unforced errors in attack and unforced technical mistakes. The significant impact of the independent variables in unequal sets also confirms *Cramer's V* because it exceeds the theoretical limit proposed by Gravetter and Wallnau (2004).

In equal sets (*Balanced*), the main reasons for the difference were a significantly higher number of blocks for winning teams and a higher number of unforced errors during attack for the *Loser* group. The significant impact of the independent variables in equal sets also confirms *Cramer's V* because it exceeds the theoretical limit proposed by Gravetter and Wallnau (2004).

Comparison of points won or lost by in-game role between set *Winners* and set *Losers* showed no significant differences in any of the three models – *Walkover*, *Balanced* and *Tough* sets.

In most sets, both the *Winner* and *Loser* groups had similar values for in-game role from the 16th point to the end of sets. Outside hitters were the players who finished the highest number of points, followed by opposites and middle blockers (Figure 5). As expected, libero was found as a point executor only infrequently.

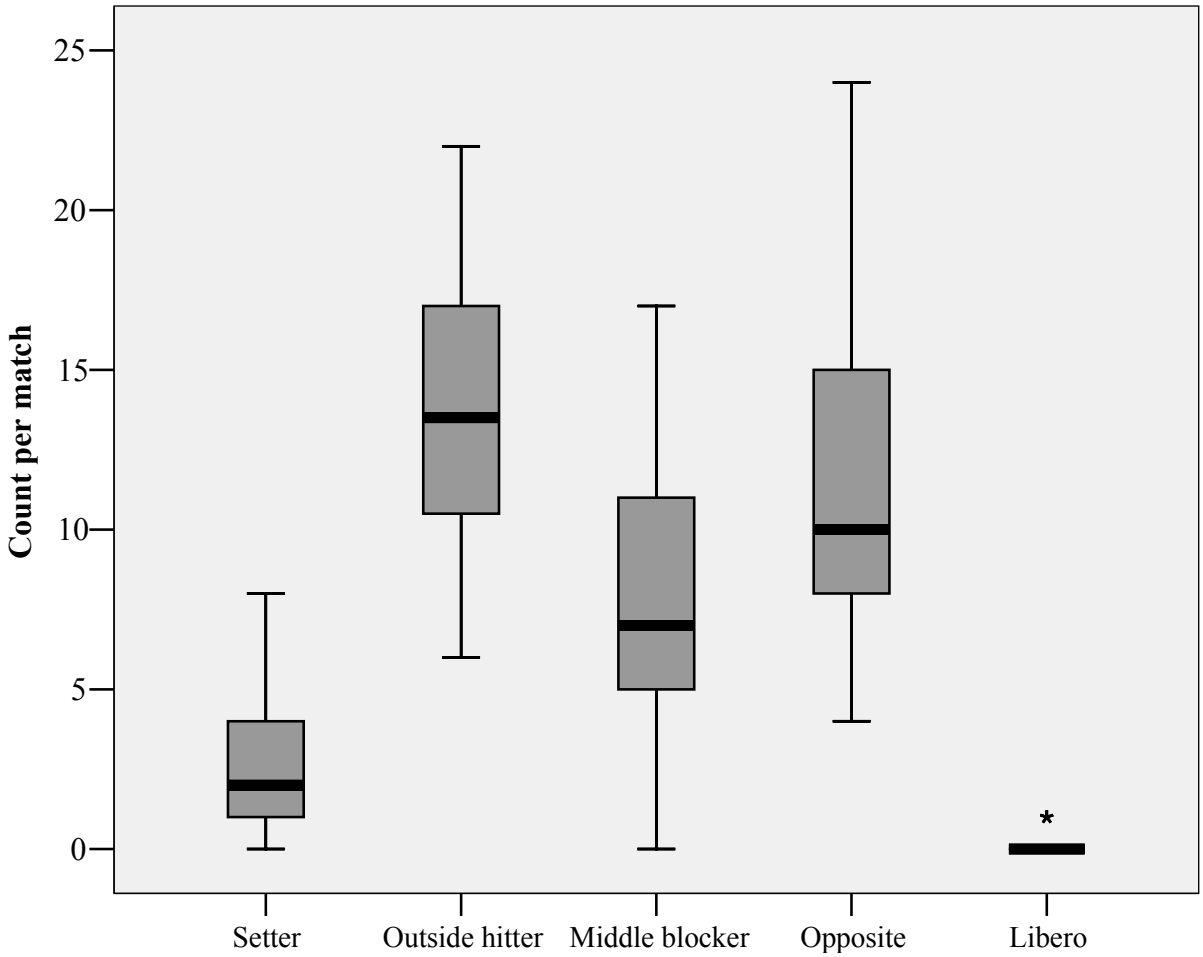

Figure 5. Average number of each in-game role in finishing points per match.

Note. *Asterisk above the bar (Libero) represents a single participation at the end of the point; this made it impossible to calculate the dispersive elements (Std. deviations and Std. Error).

In unequal and equal sets, the opposite role in the losing team decided more points than the same position in the winning team, indicating a major difference between player quality in the team losing the set. In contrast, in unpredictable sets, outside hitters and opposite players from both groups (*Winner* and *Loser*) finished almost the same number of points, with normal outcomes of other roles. Logically, it follows that for *Tough* sets, the roles in each team were qualitatively equal.

As expected, setter had the lowest percentage of point finishes. In both equal and

unequal sets, setter performed a higher number of point executions in *Winner* groups than in *Loser* groups. In unpredictable sets this trend was reversed.

Middle blockers in the set winning group finished more points in *Walkover* and *Balanced* sets, with a difference of about 10% in contrast to *Tough* sets, where the middle blockers from the *Loser* group won slightly more points than those from the *Winner* group.

Discussion

As this study is one of the first of this type, no comparable models are available. In all the studies consulted, the matches used as samples were played by the official rules currently in force. Walkover, balanced and tough distribution of the final parts of sets in relation to a winning or losing outcome with observation of in-game role provides detailed insight into all final actions and trends related to the new rules tested. This study went into greater depth by analyzing elements such as the type of attack and unforced errors to obtain a clearer overview of the final points structure during 21 point sets (excluding the fifth set, to 15 points). Considering that a set can be won or lost due to one of two reasons (Rodríguez-Ruiz et al., 2011), this study focused on how the points were scored specifically in the last scoring interval (from point 16 to the end of the set) and by which in-game role.

The *Walkover* (Chi-Square$_{10}$ = 75.476; p = .000; Cramer's V = 0.410) and *Balanced* (Chi-Square$_{10}$ = 23,154; p = .010; Cramer's V = 0.230) group of sets showed that block and attack were critical factors in winning sets, concurring with the findings of other studies (Eom & Schutz, 1992a; Yiannis & Panagiotis, 2005). Monteiro, Mesquita, and Marcelino (2009) found a significant relation (Chi-square(3) = 9.034; p = .029; Phi = 0.099) between attack and set outcome, and Tsivika and Papadopoulou (2008) defined the attack as an element strongly correlated with match winning in volleyball. Many studies (Bellendier, 2002; Häyrinen et al., 2004; Marcelino & Mesquita, 2006; Marcelino, Mesquita, & Afonso, 2008; Oliveira,

Mesquita, & Oliveira, 2005; Palao et al., 2004) have placed vital importance on the spike as the principal winning factor in volleyball matches. The significant difference regarding unforced errors in attack between *Winner* and *Loser* groups of teams in *Walkover* and *Balanced* sets is not in correlation with the results of Monteiro et al. (2009). In *Tough* sets there is no significant difference, concurring with these authors.

In relation to the new rules tested, winning teams in the *Walkover* group showed a slightly lower significant difference in the serve than in blocking in winning the sets, whereas Patsiaouras, Moustakidis, Charitonidis, and Kokaridas (2011) found that the serve had similar significance to blocking in winning or losing a match. An earlier study (Marcelino et al., 2008) reported that high effectiveness of the block is closely related (Marelić, Rešetar, Zadražnik, & Đurković, 2005) to increasing the risk in the serve. Marcelino et al. (2008) reported that teams winning more points with serves also win more block points (r = .70) and have more block faults (r=-.44). Regarding *Level of Set Win*, our study obtained higher values for block in *Winner* than in *Loser* groups in all sets, in particular *Walkover* (Cramer's V = 0.410) and *Balanced* (Cramer's V = 0.230) sets, where a significant difference was found. This is in agreement with findings by Marcelino et al. (2008), Patsiaouras et al. (2011) and Palao et al. (2004).

In the *Walkover* and *Balanced* groups, and to a lesser extent in the *Tough* group, it is obvious that the set *Losers* made more unforced errors, concurring with findings by Patsiaouras et al. (2011). As an unforced error means a lost point entirely because of a player's own blunder ("Unforced error", n.d.), it is closely connected to the technical quality of each player, indicating that better results during competitions will be achieved by players with better technical skills, as reported by Grgantov, Katić, and Janković (2006).

Walkover sets in relation to new rules tested. In *Walkover* sets, elements such as block, attack, serve, opponent's unforced errors in attack and technical unforced errors were identified as significant factors for defining the set *Winner*, as reported by Rodríguez-Ruiz et al. (2011) for whole sets and in a different order of importance. The block was clearly the most significant factor, with 9.9% more for *Winner* than for *Loser* groups. Counter attack-spike and counter attack-block out were both significantly higher, with a 7.2% better result than that obtained by the set *Losers*. The *Winner* group achieved better results in performing aces during the serve, with a difference of 6.6%, although other authors (Asterios et al., 2009; Drikos, Kountouris, Laios, & Laios, 2009) defined the serve as a decisive action in team performance. Marcelino et al. (2008) placed the serve after the spike as a decisive element. The attack-spike and attack-tipping difference between set *Winners* and set *Losers* was 6.1%.

Balanced sets in relation to new rules tested. In the *Balanced* group of compared sets, the *Winner* group gained 8.5% more blocks. Marcelino, Mesquita, and Sampaio (2010) ($t = -4{,}564$; $p = .000$) and Häyrinen et al. (2004) ($p < .05$) also found that the *Winner* group executed significantly more blocks. Set *Winners* performed better than the *Loser* group in both counter attack-spike and tipping (by 4.7%). In contrast, the *Loser* group had higher values in all unforced types of errors during attack (by 9.4%) and in technical faults (by 3.9%).

Tough sets in relation to new rules tested. Rodríguez-Ruiz et al. (2011) found the block to be a decisive factor ($p < .05$) in even sets and matches (sets with more than 25 points or tie break sets). In this study the highest percentage difference in the block for set *Winners* was found in relation to the *Tough* group of sets, although no significant differences were observed. However, this is important from the point of view of the final outcome of the teams

observed. Marcelino et al. (2008) confirmed that the number of block points (r = .68) is a good predictor of the final match outcome. According to Häyrinen et al. (2004), international volleyball matches at the highest level are often very even because of equal skills level, tactics and physical abilities.

Because of the lack of quantitative research about point wins by in-game role in men's high level volleyball, a detailed explanation is given about each role and its scoring characteristics. Attacking, as expected, was found to be the highest scoring game action, concurring with other authors (Häyrinen et al., 2004; Marelić et al., 2004; Palao et al., 2004; Rodríguez-Ruiz et al., 2011; Yiannis & Panagiotis, 2005).

In the combined *Walkover* and *Balanced* sets, the percentage of points scored by setters in the set winning teams is 4.4% higher than in the set losing teams. In contrast, in *Tough* sets, setters from the losing teams scored 3.1% more points than setters from the winning teams, which can be explained by setters forcibly trying to score points when the set or the whole match is almost lost. The higher scoring percentage for *Loser* groups by the opposite player by more than 5% in *Walkover* sets and nearly 10% in *Balanced* sets can be explained by inequality in the level of players; in other words, the set *Losers* relied on the opposite players much more than the set *Winners* did. However, in *Tough* sets the players' level was similar, as shown by the very similar results obtained.

In *Walkover* and *Balanced* sets, the *Winner*'s middle blocker finished points almost 10% more often than the same position on the *Loser* teams. The explanation for this difference could be the obviously higher result of finished points from the serve of winning teams and much higher number of unforced errors in the attack by players from set-losing teams; when the receiving team has difficulty to receive the serve, this results in a weak attack and therefore the opposing block has more chances of scoring.

Conclusions

Potential limitations of the study: in this study 36 of the 38 matches played were observed. It would have been preferable to include all 38 games, although the results would not differ because of those two matches, as they were played by average level teams. We believe that this study, the first of its kind, can be a very good source for future analyses of U23 matches, whether they are played under the current rules or new rules, and for studies comparing women's and men's volleyball in similar circumstances.

This study on the relation of experimental rules (21 point sets and 15 seconds between rallies) and point-scoring plays in the final parts of the sets has identified the block as a decisive element in volleyball element. As attack efficacy becomes similar between the teams, the development of blocking and serving may have a much stronger influence in the future on the result of the final set and the match.

Attack-spike is still the main point-scoring play in volleyball and coaches should continue working on it with slightly more focus on developing attack-block out and attack-tipping, as set *Losers* showed the high possibility of winning points by these actions. The outside-hitter, as dominant position in the team for finishing points, must be well prepared physically, including precise technical training with adequate development of physical skills conducted from an early age. The analysis by *Level of set win* distribution showed that individual players forcibly try to score points because of the imbalance in the quality of players in the team.

Further study is required in relation to the setter and the actions of this player to trick the block, as well as the block and weak aspects of this position. The results can be very useful for coaches to design appropriate physical preparation, determine adequate defense strategies and the best types of attack, avoid common mistakes, and increase the general effectiveness of a team at all levels of volleyball. If the rules are changed, more attention should be placed on

technical elements, quality of early selection and daring tactical innovation in future development of volleyball.

References

Anguera, M. T., & Hernández-Mendo, A. (2013). Observational methodology in sport sciences. *E-Balonmano.com: Revista de Ciencias del Deporte, 9*(3), 135-160.

Araújo, R. M., Castro, J., Marcelino, R., & Mesquita, I. R. (2010). Relationship between the opponent block and the hitter in elite male volleyball. *Journal of Quantitative Analysis in Sports, 6*(4), 1–10.

Asterios, P., Kostantinos, C., Athanasios, M., & Dimitrios, K. (2009). Comparison of technical skills effectiveness of men's national volleyball teams. *International Journal of Performance Analysis in Sport, 9*(1), 1–7.

Bellendier, J. (2002). Ataque de rotación en el voleibol, un enfoque actualizado [Rotation's attack in volleyball, an updated approach]. *Lecturas de Educación Física y Deportes, Digital Journal,* (51), 1-2. Retrieved from http://www.efdeportes.com/efd51

Claver, F., Jiménez, R., Gil, A., Moreno, A., & Moreno, M. P. (2013). Relationship between performance in game actions and the match result. A study in volleyball training stages. *Journal of Human Sport and Exercise, 8*(Proc3), S651–S659.

Dávila-Romero, C., & García-Hermoso, A. (2012). Acciones finales discriminantes de voleibol en categorías de formación masculina: importancia del saque en los partidos igualados [Discriminatory volleyball final actions in male formative stages: importance of serve in equal matches]. *RICYDE. Revista Internacional de Ciencias del Deporte, 8*(8), 151–160.

Drikos, S., Kountouris, P., Laios, A., & Laios, Y. (2009). Correlates of team performance in volleyball. *International Journal of Performance Analysis in Sport, 9*(2), 149–

156.

Eom, H. J., & Schutz, R. W. (1992a). Statistical analyses of volleyball team performance. *Research Quarterly for Exercise and Sport, 63*(1), 11–18.

Eom, H. J., & Schutz, R. W. (1992b). Transition play in team performance of volleyball: A log linear analysis. *Research Quarterly for Exercise and Sport*, *63*(3), 261-269.

Escalante, Y., Saavedra, J. M., Mansilla, M., & Tella, V. (2011). Discriminatory power of water polo game-related statistics at the 2008 Olympic Games. *Journal of Sports Sciences, 29*(3), 291–298.

FIVB. (n.d.-a). *FIVB history*. Retrieved from http://www.fivb.org/EN/FIVB/FIVB_History.asp

FIVB. (n.d.-b). *The Federation*. Retrieved from http://www.fivb.org/EN/FIVB/FIVB_Structure.asp

FIVB. (n.d.-c). *The Game - Volleyball Rules; Major changes in volleyball rules*. Retrieved from http://www.fivb.org/TheGame/TheGame_VolleyballRules.htm

FIVB. (2013a). *Competition formula*. Retrieved from www.fivb.org/EN/volleyball/competitions/U23/Men/2013/Formula.asp

FIVB. (2013b). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2014). *Official volleyball rules 2015-2016.* In *34th FIVB Congress*. Sardinia, Italy: FIVB. Retrieved from http://www.fivb.org/en/Refereeing-Rules/documents/FIVB-Volleyball_Rules2013-EN_v2_20130422.pdf

Fleiss, J. L., Levin, B. A., & Paik, M. C. (2003). *Statistical methods for rates and proportions* (3rd ed.). Hoboken, NJ: John Wiley & Sons.

Gravetter, F. J., & Wallnau, L. B. (2004). *Statistics for the behavioral sciences* (6th

ed.). Belmont, CA: Wadsworth.

Grgantov, Z., Dizdar, D., & Janković, V. (1998). Structural analysis of the volleyball game elements based on certain anthropological features. *Kinesiology*, *30*(1), 44-51.

Grgantov, Z., Katić, R., & Janković, V. (2006). Morphological characteristics, technical and situation efficacy of young female volleyball players. *Collegium Antropologicum, 30*(1), 87–96.

Gruić, I., Vuleta, D., & Milanović, D. (2006). Performance indicators of teams at the 2003 Men's World Handball Championship in Portugal. *Kinesiology, 38*(2), 164–175.

Häyrinen, M., Hoivala, T., & Blomqvist, M. (2004). Differences between winning and losing teams in men's European top-level volleyball. In P. O'Donoghue, & M. Hughes (Eds.), *Proceedings of VI Conference Performance Analysis of Sport* (pp. 491–496). Belfast, Northern Ireland: University of Wales Institute Cardiff.

Hughes, M., & Franks, I. M. (2004). *Notational analysis of sport: Systems for better coaching and performance in sport* (2nd ed.). London, England: Routledge.

Hughes, M., & James, N. (2008). Notational analysis of soccer. In F. Prot (Ed.), *Kinesiology Research Trends and Applications – Research Methodology: Proceedings of the 5th International Scientific Conference on Kinesiology* (pp. 644-660). Zagreb, Croatia: University of Zagreb

Joao, P. V, Silva, M., Lacerda, D., & Vaz, L. (2012). The scoring skills which discriminate result, according set number in World Championship volleyball 2010. In R. Meeusen, J. Duchateau, B. Roelands, M. Klass, B. De Geus, S. Baudry, & E. Tsolakidis (Eds.), *Proceedings of the 17th annual Congress of the European College of Sport Science* (pp. 149–150). Bruges, Belgium: European College of Sport Science.

Lago, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences,*

27(13), 1463-1469.

Marcelino, R., & Mesquita, I. (2006). Characterizing the efficacy of skills in high performance competitive volleyball. In H. Dancs, M. Hughes, & P. O'Donoghue (Eds.), *Proceedings of the World Congress of Performance Analysis of Sport VII* (pp. 491–496). Szombathely, Hungary: Berzsenyi College.

Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1–7.

Marcelino, R., Mesquita, I., & Sampaio, J. (2010). Estudo dos indicadores de rendimento em voleibol em função do resultado do set [Study of performance indicators in male volleyball according to the set results]. *Revista Brasileira de Educação Física e Esporte, 24*(1), 69-78.

Marcelino, R., Mesquita, I., & Sampaio, J. (2011). Effects of quality of opposition and match status on technical and tactical performances in elite volleyball. *Journal of Sports Sciences, 29*(7), 733–741.

Marelić, N., Rešetar, T., & Janković, V. (2004). Discriminant analysis of the sets won and the sets lost by one team in A1 Italian volleyball league - A case study. *Kinesiology, 36*(1), 75–82.

Marelić, N., Rešetar, T., Zadražnik, M., & Durković, T. (2005). Modeling of situation parameters in top level volleyball. In D. Milanović & F. Prot (Eds.), *Science and Profession – Challenge for the Future: Proceedings of the 4th International Scientific Conference on Kinesiology* (pp. 459–462). Opatija, Croatia: Faculty of Kinesiology, University of Zagreb.

Marelić, N., Žufar, G., & Omrčen, D. (1998). Influence of some situation-related parameters on the score in volleyball. *Kinesiology, 30*(2), 55-65.

Mesquita, I., Manso, F., & Palao, J. M. (2007). Defensive participation and efficacy of

the libero in volleyball. *Journal of Human Movement Studies, 52*(2), 95–107.

Monteiro, R., Mesquita, I., & Marcelino, R. (2009). Relationship between the set outcome and the dig and attack efficacy in elite male volleyball game. *International Journal of Performance Analysis in Sport, 9*(3), 294–305.

Moras, G., Buscà, B., Peña, J., Rodríguez, S., Vallejo, L., Tous-Fajardo, J., & Mujika, I. (2008). A comparative study between serve mode and speed and its effectiveness in a high-level volleyball tournament. *Journal of Sports Medicine and Physical Fitness, 48*(1), 31–36.

Moreno, A., Moreno, M. P., Julián, J. A., & Del Villar, F. (2005). Estudio de la relación entre la eficacia de las acciones de primer contacto y la eficacia del ataque en voleibol masculino de alto nivel [Study of the relation between the efficiency of first contact plays and the efficiency of the attack in elite men's volleyball]. *KRONOS, IIII*, 57–61.

O'Donoghue, P., & Ingram, B. (2001). A notational analysis of elite tennis strategy. *Journal of Sports Sciences, 19*(2)*,* 107-115.

Oliveira, R., Mesquita, I., & Oliveira, M. (2005). Caracterização da eficácia do bloco no voleibol de elevado rendimento competitivo [Characterization of the efficiency of the block in high level volleyball competition]. *Lecturas de Educación Física y Deportes, Digital Journal,* (84). Retrieved from http://www.efdeportes.com/efd84/voleibol.htm

Palao, J. A., Santos, J. A., & Ureña, A. (2004). Effect of team level on skill performance in volleyball. *International Journal of Performance Analysis in Sport, 4*(2), 50–60.

Palao, J. M., Manzanares, P., & Ortega, E. (2015). Design, validation, and reliability of an observation instrument for technical and tactical actions in indoor volleyball. *European Journal of Human Movements, 34*, 75–95.

Patsiaouras, A., Moustakidis, A., Charitonidis, K., & Kokaridas, D. (2011). Technical skills leading in winning or losing volleyball matches during Beijing Olympic Games.

Journal of Physical Education and Sport, 11(2), 149–152.

Rodríguez-Ruiz, D., Quiroga, M. E., Miralles, J. A., Sarmiento, S., De Saá, Y., & García-Manso, J. M. (2011). Study of the technical and tactical variables determining set win or loss in top-level European men's volleyball. *Journal of Quantitative Analysis in Sports, 7*(1), 1–13.f

Sampaio, J., Godoy, S. I., & Feu, S. (2004). Discriminative power of basketball game-related statistics by level of competition and sex. *Perceptual and Motor Skills, 99*(3 suppl), 1231–1238.

Sánchez-Moreno, J., Marcelino, R., Mesquita, I., & Ureña, A. (2015). Analysis of the rally length as a critical incident of the game in elite male volleyball. *International Journal of Performance Analysis in Sport, 15*(2), 620-631.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Allyn & Bacon/Pearson Education.

Tsimpiris, A., Tsamourtzis, E., Sfingos, N., Zaggelidis, G., & Zaggelidis, S. (2006). A multimedia application for tactic analysis of basketball games. *Revista Stiinta Sportului, 52*, 17–39.

Tsivika, M., & Papadopoulou, S. D. (2008). Evaluation of the technical and tactical offensive elements of the men's European Volleyball Championship. *Physical Training*. Retrieved from http://ejmas.com/pt/2008pt/ptart_tsivika_0812.html

Unforced error. (n.d.). In *Oxford Dictionaries*. Retrieved from http://www.oxforddictionaries.com/definition/english/unforced-error

Ureña, A., Gallardo, C., Delgado, J., Hernández, E., & Calvo, R. (2000). Estudio sobre la evolución de las reglas de juego en voleibol [Study of the history of volleyball rules of the game]. *Habilidad Motriz: Revista de Ciencias de la Actividad Física y del Deporte, 16*, 32–39.

Yiannis, L., & Panagiotis, K. (2005). Evolution in men's volleyball skills and tactics as evidenced in the Athens 2004 Olympic Games. *International Journal of Performance Analysis in Sport, 5*(2), 1–8.

Zetou, E., Tsigilis, N., Moustakidis, A., Komninakidou, A. (2006). Playing characteristics of men's Olympic Volleyball teams in complex II. *International Journal of Performance Analysis in Sport, 6*(1), 172-177.

CHAPTER 4

STUDY 3

Chapter 4

Study 3. Effects of Tested Rules on Work-Rest Time in Volleyball

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Abstract

The aim of this study was to determine the influence of new rules tested at the inaugural Men's Under 23 (U23) World Championship (set to 21 points and 15 seconds between the end of a point and the new serve) on all aspects of time in volleyball matches. The study sample comprised 36 matches partially segmented into 123 sets and 4583 points played. Applying one-way ANOVA, it was shown that the active part of the set and the whole match last slightly more than one third of the total time. The most frequent rally duration was 5 to 10 seconds (43.5% of points). As sets became more unpredictable and approached the end, rest time between points was longer. Time analysis of volleyball matches is important as it helps with proper development of physical preparation for players, gives coaches insight into appropriate match flow and provides a clear time frame of each part of a volleyball match for organizers of competitive events, pools, championships and tournaments.

Introduction

The sport of volleyball has no time limits on the length of official matches. The first team to win 3 sets is the match winner (Fédération Internationale de Volleyball [FIVB], 2012). The duration of a volleyball match has changed over time. The length of a match obviously depends on its parts: scoring system, rally length (work time of the game), rest time (time between rallies, substitutions, sanctions, technical and team time-outs, time between sets, injuries, and other technical aspects) and level of the players (Häyrinen et al., 2011). The rally is the basic unit of one point, the time when a team can score a point. It is differentiated from the other parts of the game, which are considered rest time (Fellingham, Collings, & McGown, 1994).

Changes to the scoring system in beach volleyball introduced by Fédération

Internationale de Volleyball (FIVB) and Association of Volleyball Professionals (AVP) to satisfy TV broadcasting needs was a major factor in the growth of this sport (Giatsis, 2003). At the inaugural FIVB U23 Men's World Championship, held in Brazil in October 2013, new rules were tested with the idea of modernizing volleyball and making it more appealing for fans both at matches and watching television (FIVB, 2013c, Twenty-one point rule to be tested at U23 World Championships). Obviously the main way to change match duration is to modify the scoring system, and this has been done several times (Ureña, Gallardo, Delgado, Hernández, & Calvo, 2000) during the history of volleyball. Studies of beach volleyball and volleyball (Giatsis, 2003; Kountouris & Laios, 2000) found that match duration changed significantly after changes to the scoring system.

The changes tested (set to 21 points, excluding the fifth set to 15 points, with two points minimum difference at the end of sets; server has 15 seconds after the finished point to perform serve - 10 seconds to prepare and 5 seconds to execute the serve) were the first officially tested modifications of the Rally Point System (FIVB, 2013c, Twenty-one point rule to be tested at U23 World Championships; FIVB, 2015, Technical Survey (Summary of Men's U23 World Championship)).

The results can provide an understanding of the effect of the rule changes and help to identify the best way to prepare volleyball teams physically, mentally and tactically, not only at the highest level, but also in the various stages of youth development. At the same time, this study can help the FIVB to make volleyball more attractive for audiences and television companies, and contribute to the development of volleyball in general.

The purpose of this study was to determine the detailed effects of the tested rules (set to 21 points and 15 seconds maximum to next serve after finished point) on time in volleyball matches.

Methods

Participants. The analysis comprised 36 hours from 36 matches of the 38 games played at the U23 Men's World Championships in Uberlandia (Brazil). For the first time, a world championship was organized for under 23 male players, and competition took place in October 2013, with 12 national teams (144 players) participating. The FIVB organized the tournament following the competition system, testing two new rules: set to 21 points (excluding the fifth set, to 15 points) with a two point minimum difference at the end of sets, and 15 seconds for the server to execute the serve after the finished point (FIVB, 2013b, New rules test to be held in Brazil only).

FIVB officially authorized the use of all videos of matches and data from the Volleyball Information System (VIS) and the FIVB website. This study was performed in accordance with the Helsinki Declaration of 1975.

Measures

Competition structure. Competition had two rounds: group phase (Pool A and B), and semi finals and finals. In the group phase 30 matches were played and in the semi finals and finals 8 matches were played. The 12 teams, divided into 2 groups of 6, played according to the round-robin system to determine the ranking and were classified from 1st to 6th. The team ranked 3rd in Pool A played the team ranked 4th in Pool B. The team ranked 3rd in Pool B played the team ranked 4th in Pool A. The losers of these semi-final matches played for 7th and 8th final places and the winners played for 5th and 6th places. The team ranked 1st in Pool A played the team ranked 2nd in Pool B. The team ranked 1st in Pool B played the team ranked 2nd in Pool A. The losers of the semi-final matches played for 3rd and 4th place and the winners played for 1st and 2nd place (FIVB, 2013a, Competition formula).

Variables. Palao, Valadés, and Ortega (2012) studied the variables of match duration, total rallies per set and match, number of sets, team that won the set and the match, and type of match, established through the point difference between teams and gender. Häyrinen et al. (2011) analyzed the duration of rallies, sets (no 5th sets), and breaks between rallies (no time-outs or breaks between sets). Vilamitjana et al. (2008) studied the time variables of work time during the set: total set time minus rest time (time-outs, player substitution time and time for the ball to reach the serve). They also analyzed total jumps and total work time per subject.

In this study, all parts of the match duration were used as variables:

1. Work time (time between the referee's whistle for serve and the end of the point).
2. Rest time:
    A. Time after the whistle for finished point until the whistle for serve.
    B. Team time-out:
        a) Time before the whistle for the beginning of team time-out.
        b) Time between two whistles (time-out).
        c) Time after the whistle for the end of team time-out.
    C. Technical time-out:
        a) Time before the whistle for the beginning of technical time-out.
        b) Time between whistles.
        c) Time after the whistle for the end of technical time-out.
    D. Player substitutions:
        a) Time before the whistle for substitution.
        b) Time between whistles.
        c) Time after the whistle for the end of substitution.
    E. Player sanctions:

a) Time before the whistle for sanction.

b) Time between whistles.

c) Time after the whistle for the end of sanction.

F. Time between sets (time after the whistle for the end of last point until whistle for new set).

G. Player injury time.

H. Time of other technical aspects (fixing fallen antenna, problem with referee's chair):

a) Time before the whistle for fixing the technical problem.

b) Time between whistles.

c) Time after the whistle for the end of the technical problem.

FIVB technicians specially trained to use the VIS, who were approved, supervised and appointed by the FIVB Technical Commission, collected the data. VIS software processes all data collected and is one of the two methods most commonly used by coaches and observers to assess individual and collective performance of volleyball players in each phase of the match. The variables were assessed by methodical observation of every second of the games. To ensure reliability of the observation, a single observer with experience in volleyball scouting and good knowledge of volleyball observed all matches. The intraobserver Cohen's Kappa values obtained in observation of all the variables were higher than .81, the minimum value to be considered almost perfect agreement (Landis & Koch, 1977). To ensure the time reliability of the measurement, the same procedure was performed twice, in an interval of 10 days, and Cohen's Kappa values higher than .81 were obtained.

Procedures. Part of the data was collected by watching all matches and the remaining data were taken from the VIS, on the FIVB website. All data were recorded on an analysis scheme form, used to define and examine the variables (Tsimpiris, Tsamourtzis, Sfingos, Zaggelidis, & Zaggelidis, 2006). The FIVB authorised official collection of match videos and data from the VIS and the FIVB website. All matches were filmed using a PANASONIC HC-V720HD digital camcorder in AVCHD format. The camera was always located behind the court at a height of 5 m above the floor (Claver, Jiménez, Gil, Moreno, & Moreno, 2013) to give the best angle to follow everything happening on and beside the court.

VIS software has been used in various studies (Marcelino & Mesquita, 2008; Marcelino, Mesquita, & Afonso, 2008; Marcelino, Mesquita, Palao, & Sampaio, 2009). Its purpose is to quantify individual skills and it is accepted as a valid instrument in volleyball research.

Statistical analysis. IBM SPSS Statistics V19 software was used for the statistical analysis. All data were primarily processed by descriptive statistic procedures for each variable. One-way ANOVA was applied to test the significance of differences between the arithmetical means at different phases of the set and in sets with different levels of win. For more in-depth analysis and because of a small number of unbalanced observations in different categories of "time between sets", the Kruskal-Wallis nonparametric test was used. All tests were performed at the level of significance of .05 ($p < .05$).

Results

After measuring each part of total match duration, it was determined that total work time (time when the ball is in play) is a significantly smaller part than rest time, which has many components. Work time of the match and the set last slightly more than one third of the

total time (Figures 6 and 7).

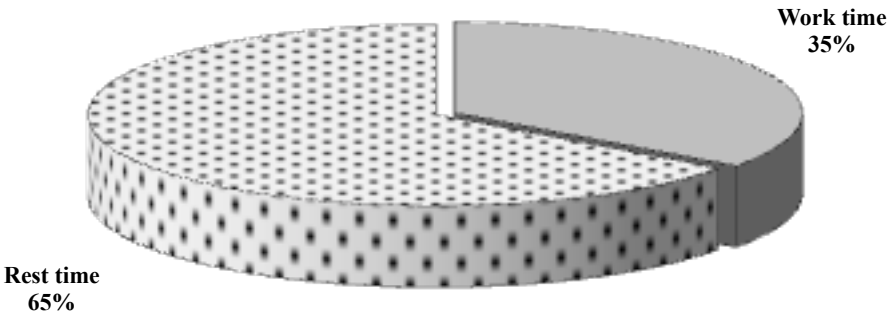

*Figure 6***.** Relation of total work and rest time during a volleyball match.

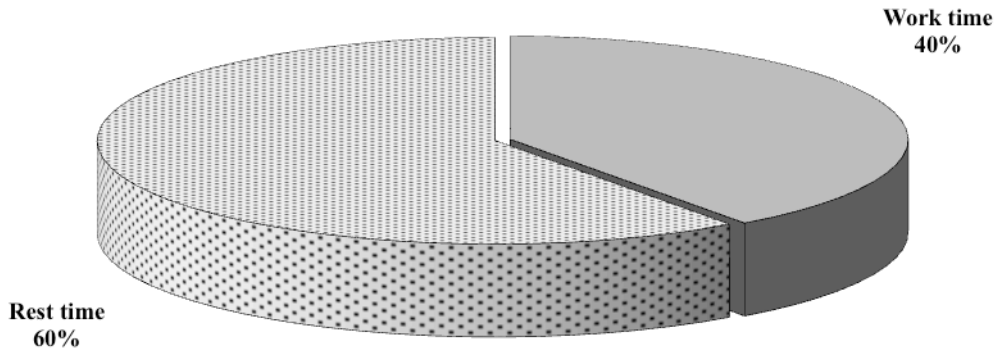

Figure 7. Relation of total work and rest time during an average set.

The longest element of rest time during a volleyball match corresponds to periods between rallies (27.37% of total match duration) and both time-outs (19.12%), followed by pauses between sets (12.04%) and substitutions (6.05%) (Table 6).

Table 6

Mean duration of each part of the match

Variable	N	Mean	Std. Dev.	Std. Error	Min.	Max.	Share of Set	Share of Match
		s	s	s	s	s	%	%
Point duration	4588	11.50	4.38	.065	2.84	41.50	39.78	34.99
Time after point	3568	11.57	2.08	.035	3.17	47.17	31.12	27.37
Time-out							14.82	13.03
Before the whistle	313	8.04	3.77	.213	.17	35.50	1.90	1.67
Between whistles	326	35.68	5.45	.302	24.33	64.33	8.77	7.71
Time after the whistle	325	16.92	5.46	.303	1.84	53.00	4.15	3.65
Technical time-out							6.92	6.09
Before the whistle	119	3.75	2.08	.190	.84	13.50	.34	.30
Between whistles	119	59.73	4.02	.368	53.33	76.17	5.36	4.71
Time after the whistle	119	13.63	4.89	.449	.00	26.17	1.22	1.08
Substitution							6.88	6.05
Before the whistle	413	6.61	3.09	.152	1.00	24.17	2.06	1.81
Between whistles	473	10.27	4.72	.217	2.67	60.17	3.66	3.22
Time after the whistle	409	3.77	3.01	.149	.84	21.00	1.16	1.02
Time between sets	87	208.81	27.66	2.966	143.84	399.33	/	12.04
Sanction							.31	.27
Before the whistle	10	14.47	4.69	1.484	8.33	21.00	.11	.10
Between whistles	10	21.49	8.43	2.664	9.00	38.33	.16	.14
Time after the whistle	10	4.92	3.93	1.242	2.17	12.33	.04	.03
Side change in 5th set	4	54.45	2.56	1.281	52.23	56.67	.16	.14
Other technical aspects							.03	.02
Before the whistle	1	8.50	/	/	8.50	8.50	.01	.01
Between whistles	1	20.00	/	/	20.00	20.00	.02	.01
Time after the whistle	1	2.50	/	/	2.50	2.50	.00	.00
Set duration	123	1226.38	312.85	8.861	1132.76	1420.83	100	/
Match duration	36	4190.08	1135.74	37.443	3398.27	6820.50	/	100

Note. S = seconds. In the following tables all descriptive parameters (Mean, Std. Deviation, Std. Error, Min, and Max) are shown in seconds (s).

Mean set duration was 1226.38±312.85 seconds (20.44±5.21 minutes), with the longest set lasting 1420.83 seconds (23.68 minutes) and the shortest lasting 1132.76 seconds (18.89 minutes). Mean match duration was 4190.08±1135.74 seconds (69.83±18.93 minutes), with the longest and shortest matches lasting 6820.50 seconds (113.68 minutes) and 3398.27 seconds (56.64 minutes), respectively.

It is significant that the highest number of pauses between finished points and the referee's whistle for serve lasted more than 10 seconds in most cases (about 12 seconds) (Figure 8). The rules tested at the Championship attempted to control this aspect. Even though some pause periods lasted more than 20 seconds, the number of long pauses was kept to a reasonable level.

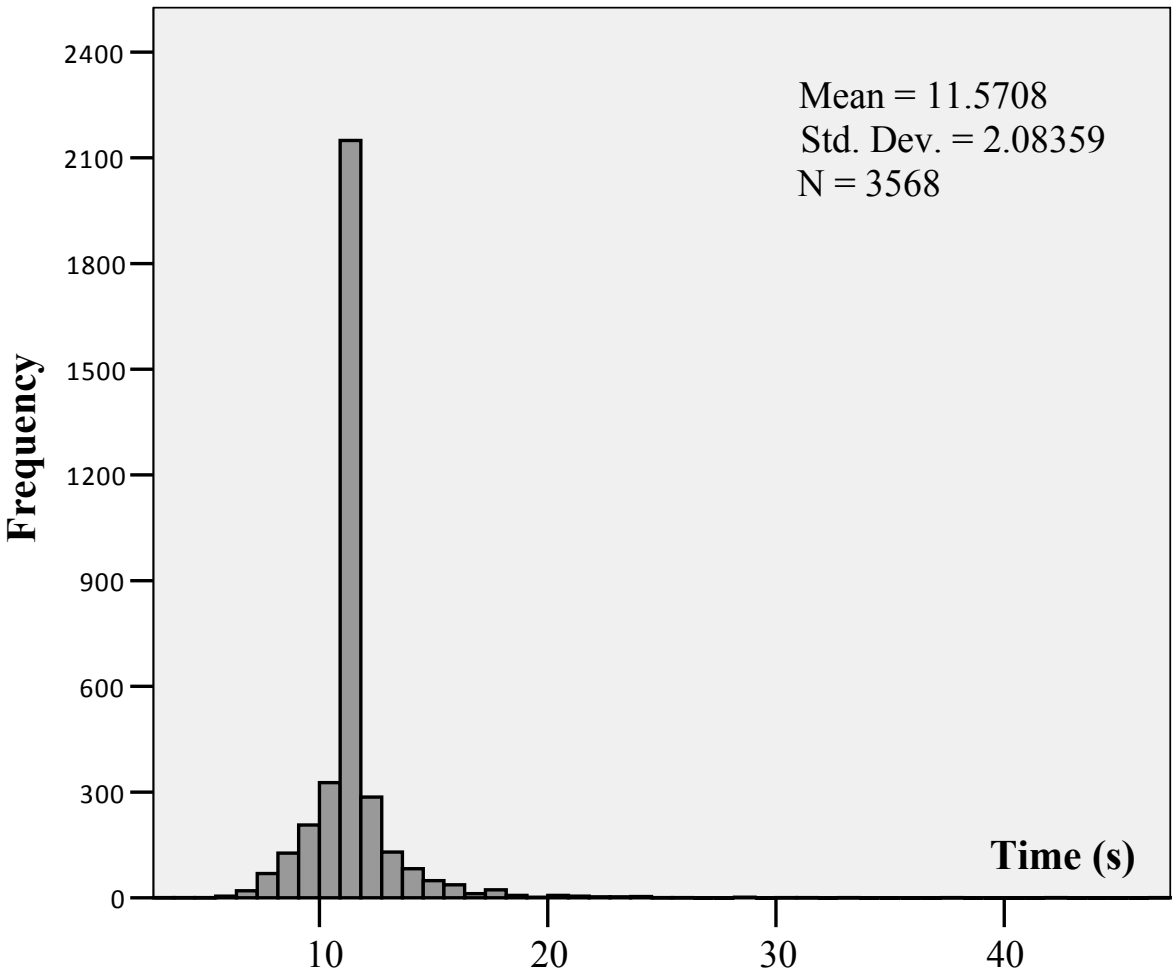

Figure 8. Distribution of pauses after rallies by duration.

The duration of the points finished during the matches analyzed is worth noting. The most frequent point duration was 5 to 10 seconds (43.5%) (Figure 9), followed by 41% of points lasting 10-15 seconds. About 11% of the points finished during the match lasted 15-20 seconds and 3.7% lasted 20-25 seconds.

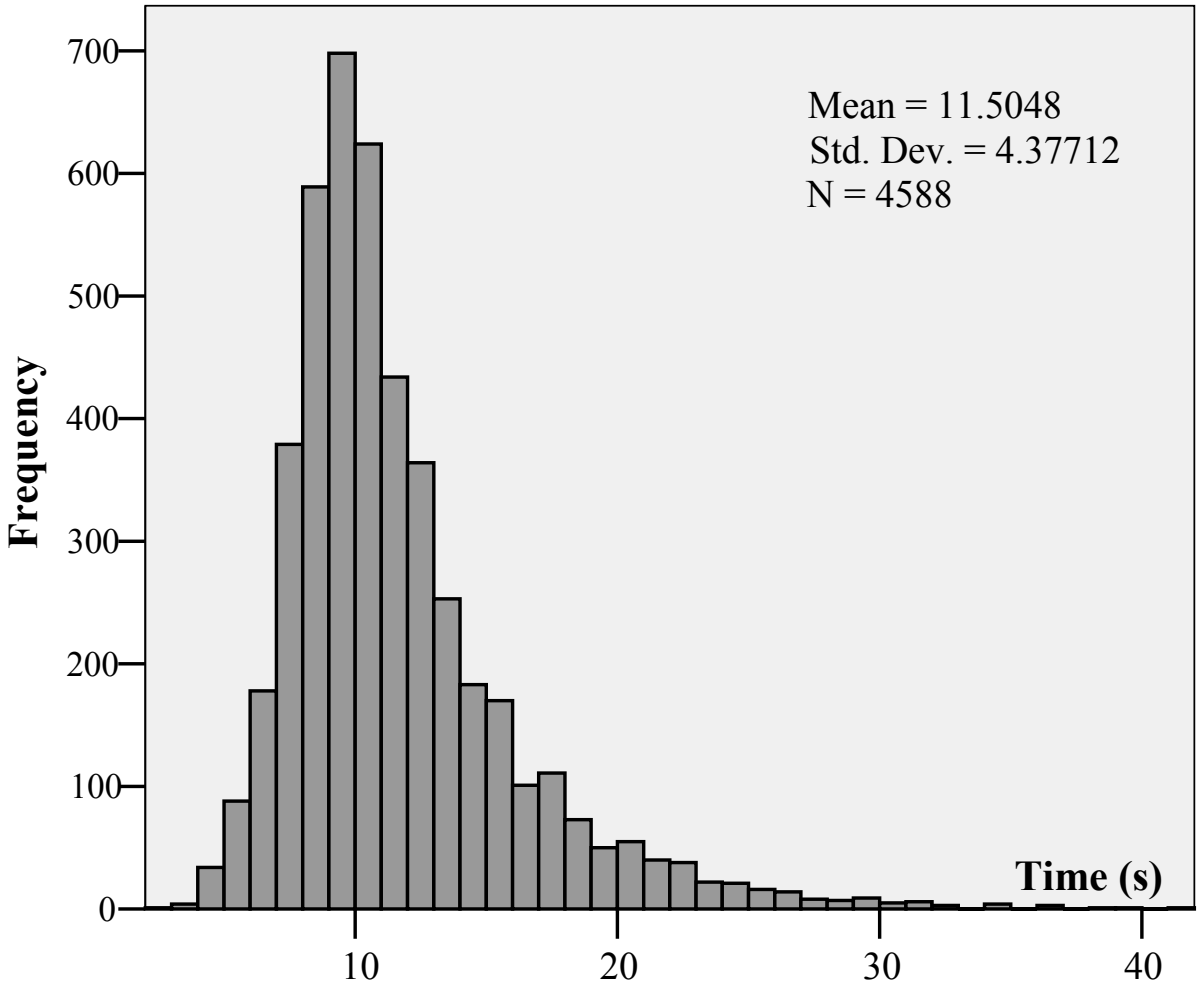

Figure 9. Distribution of finished points by duration.

Total team time-out lasted 13.03% of the match duration, more than twice the value for technical time-out (6.09% of match duration).

Total team time-out, comprising time before the whistle for the beginning of time-out, time between whistles (time-out) and time after the whistle for the end of time-out until the next referee's signal (e.g., for serve or substitution), had a mean duration of 60.64 seconds.

Total technical time-out had a mean duration of 77.11 seconds. Approximately 17 seconds lapsed from the end of team time-out until the new signal from the referee (e.g., for serve). The mean time spent during the period before the signal for the beginning of time-out was 8 seconds for team time-out and approximately 4 seconds for technical time-out.

For this study it was interesting to compare rally duration and rest time between rallies at different phases of the sets. The starting assumption was that the trend of the results would influence tactical acceleration or prolonging of the game. Variance analysis (Table 7) showed no significant difference between the mean duration of an active game in relation to *Early, Middle* and *Final* phase of the sets, although a significant difference was found between the mean duration of pauses or rest time after rallies and *Early, Middle* and *Final* phase of the sets (Table 8). Post hoc analysis showed that the source of variability was prolonging the pause in the *Final* phase of the sets. Rest time between points was almost the same in *Early* and *Middle* phase of the sets, with a value of 11.47 seconds.

Table 7

Rally duration in different phases of the set

Phase of the set	N	Mean	Std. Dev.	Std. Error	Min.	Max.
		s	s	s	s	s
Early phase	1723	11.69	4.55	.109	3.67	38.00
Middle phase	1563	11.33	4.21	.106	2.84	41.50
Final phase	1302	11.46	4.33	.120	3.84	36.84
Total	4588	11.50	4.38	.065	2.84	41.50

Note. F = 2.855 (p = .058).

Table 8

Duration of rest time after the rally in different phases of the set

Phase of the set	N	Mean	Std. Dev.	Std. Error	Min.	Max.
		s	s	s	s	s
Early phase	1721	11.46	1.28	.03088	3.17	31.00
Middle phase	1561	11.47	1.87	.04745	5.17	41.84
Final phase	1299	11.81	2.34	.06493	6.17	47.17
Total	4581	11.57	1.84	.02717	3.17	47.17

Note. F = 10.661* (p = .000)

*Asterisk indicates a statistically significant difference.

One-way ANOVA was used to compare the mean point duration and mean pause duration in sets of different *Win Level* (*Walkover, Balanced,* and *Tough* set). Once again, a significant difference was found only for rest time after points (Tables 9 and 10). As sets became more unpredictable, rest time between points was longer.

Table 9

Rally duration in sets of varying win level

Phase of the set	N	Mean	Std. Dev.	Std. Error	Min.	Max.
		s	s	s	s	s
Walkover	1889	11.48	4.22	.097	3.84	36.84
Balanced	1414	11.43	4.43	.118	2.84	41.50
Tough	1285	11.63	4.54	.127	3.33	38.00
Total	4588	11.50	4.38	.065	2.84	41.50

Note. F = .791 (p = .453).

Table 10

Duration of rest time after the point in sets of varying win level

Phase of the set	N	Mean	Std. Dev.	Std. Error	Min.	Max.
		s	s	s	s	s
Walkover	1882	11.31	1.41	.033	3.67	30.17
Balanced	1414	11.43	1.87	.050	3.17	41.84
Tough	1285	12.05	2.25	.063	6.67	47.17
Total	4581	11.57	1.84	.027	3.17	47.17

Note. F = 43.585* (p = .000).

*Asterisk indicates a statistically significant difference.

Total substitution time accounted for 6.05% of match duration and 6.88% of set time. The mean duration of substitutions was 10.27±4.72 seconds and the maximum value for a single substitution was 60.17 seconds. The mean time for calling substitutions was 6.61±3.09 seconds.

Time between sets accounted for 12.04% of match duration and the mean value was 208.81±27.66 seconds (3.48±0.46 minutes). The longest period between sets was 399.33 seconds (6.66 minutes) and the shortest period between sets was 143.84 seconds (2.40 minutes). A more in-depth analysis of time between sets revealed no significant differences (Table 11).

Table 11

Duration of pauses after each set in numerical order

Time between sets	N	Mean	Std. Dev.	Std. Error	Min.	Max.
		s	s	s	s	s
After 1st set	36	204.83	16.42	2.737	153.67	235.67
After 2nd set	36	210.77	38.02	6.337	143.84	399.33
After 3rd set	11	207.12	14.36	4.328	171.50	225.17
After 4th set	4	231.63	17.32	8.658	210.84	247.50
Total	87	208.81	27.66	2.966	143.84	399.33

Note. Kruskal-Wallis Chi Square = 6.933 (p = .074).

The shortest parts of sets and matches were sanctions, accounting for 0.31% of time in sets and 0.27% in matches, followed by the side change in the fifth set and other technical aspects (fixing a fallen antenna, fixing a problem with the referee's chair…). No time was spent on injuries.

Discussion

Few studies have addressed time in volleyball and none have examined all time segments. In this study a work to rest ratio of approximately 1:1.86 was found for the match and 1:1.5 for the set. On comparing only points and pauses between points, the work to rest ratio is 1:1. Häyrinen et al. (2011) reported a work to rest ratio of 1:4.3 for men's elite matches and 1:3.5 for Under 19 (U19), but did not include time-outs or breaks between sets. According to Palao, Valadés, Manzanares, and Ortega (2014), the mean work to rest ratio in men's beach volleyball is 1:4.42±5.73. Kovacs (2004) reported a work to rest ratio in men's

professional tennis of 1:2.67 within games and 1:4.73 within matches.

Häyrinen et al. (2011) found mean values for set duration of 26.3±2.2 minutes for elite teams and 23.5±2.3 minutes for U19 players, indicating a shorter set time by almost 6 minutes between U23 players and elite teams and about 3 minutes between U23 and U19 players. García-Alcaraz, Palao, and Valadés (2012) reported a duration of 24 minutes for elite Spanish teams and 19.7 to 21.3 minutes for Under 14 (U14), Under 16 (U16) and U19 youth categories, although this study of U23 male players found that sets were 4 minutes shorter than in elite teams, with a small difference of 1 minute compared to U16 and U19. Only U14 had shorter sets, but the main reason could be the large difference in quality of play.

Compared to the results found by Häyrinen et al. (2011), a noticeable shortening of time breaks between rallies is observed, leading to more dynamic games and shorter matches. These authors reported a mean duration of the break between rallies of 23.54±5.55 seconds for elite teams and 19.99±5.70 seconds for U19 European top teams. Sheppard et al. (2007) found 44% of periods between rallies last 12 seconds or less, with a mean value of 14 seconds, compared to the value of 11.57±2.08 seconds found in this study. The period between rallies in relation to *Level of Set Win* increased: between *Walkover* and *Balanced* sets it increased by 0.12 seconds and between *Balanced* and *Tough* sets the increase was 0.62 seconds.

The same tendency appeared in the different phases of the set. Between *Early* and *Middle* phases there was a small difference of 0.01 seconds, but between *Middle* and *Final* phases the increase was 0.34 seconds. The maximum rally duration in this study was 41.50 seconds, whereas in the study by Häyrinen et al. (2011) it was 39.9 seconds for the best 4 teams at the 2008 Olympic Games and 32.2 seconds for the best 4 teams at the U19 European Championship. Sheppard et al. (2007) found that 76.6% of rallies lasted 12 seconds or less, with an approximate mean rally of 11 seconds, although some lasted 3 seconds and others

lasted up to 40 seconds. In this study the most frequent point duration was 5-10 seconds (43.5%), followed by points lasting 10-15 seconds (41%) and 15-20 seconds (about 11%), whereas only 3.7% lasted 20-25 seconds. However, in the study by Häyrinen et al. (2011), rallies lasting less than 10 seconds were 84% for elite teams and 86% for U19 best teams, with 14% and 13%, respectively, lasting 10-20 seconds, and 2% of rallies lasting more than 20 seconds for both men and youth players. Sánchez-Moreno, Marcelino, Mesquita, and Ureña (2015) reported a mean length of 5.0±4.3 seconds for elite teams in world championships matches, compared to 11.50±4.38 seconds in this study. Point duration in the active part of the game was approximately the same as the mean time from the end of the point until the whistle for new serve. A comparison of the results with rally duration in other net and wall sports shows that volleyball is somewhere in the middle. In tennis the rally lasts 5-7 seconds (Kovacs, 2004; Smekal et al., 2001), in badminton 6.2 seconds (Férnandez-Férnandez, de la Aleja-Téllez, Moya-Ramón, Cabello-Manrique, & Méndez-Villanueva, 2013), in beach volleyball 7.25 seconds (Palao et al., 2014) and in squash 18.6 seconds (Girard et al., 2007).

McCutcheon (2013) discussed eliminating technical time-outs in sets to 21 points, replacing them with two 1-minute team time-outs each team can use any time, and if neither team calls a time-out before the 11th point, TV time-out starts automatically. The results for team time-out duration show a large gap between the maximum value (64.33 seconds) and the minimum value (24.33 seconds), and between the maximum and minimum values of time after the whistle for the end of time-out (53 seconds and 1.84 seconds, respectively). The maximum value for before the whistle for time-out was 35.50 seconds and the minimum was 3.77 seconds. With the new rule tested, of 10 seconds until the server starts the serve, the coach has a limit of about 5 seconds to call the substitution, which appears to be a reasonable dynamic for the game and time fluctuation. Before the Brazil Championship there was debate

about whether to incorporate free substitution to speed up and simplify the process and allow coaches more freedom for tactical subbing (McCutcheon, 2013). Häyrinen et al. (2011) reported values for time between sets of 217±17 seconds (3.6±0.3 minutes) for elite players and 213±20 seconds (3.6±0.3 minutes) for U19 players. Compared to the results found in this study, the difference is minimal and can be explained by referees strictly adhering to the rules. The shortest parts of sets and matches (sanctions, side change in 5th set and other technical aspects) have little effect on duration. This study found only 4 matches that had 5th set. The main characteristic of the 5th set is side changing what belongs to resting time for all players. Average duration of the side change was 54.45 seconds, with minimum value of 52.23 seconds, and maximum value of 56.67 seconds. Only 0.16% of set time and 0.14% of match time was spent on side change, what belongs to negligible influential periods. However, every coach can count on those values as a chance to give several advises.

Conclusions

Game analysis shows there is scope for limiting pauses between rallies to 10 seconds, giving players adequate time to reach the serving position and 5 seconds to perform the serve. On-the-fly substitutions of libero and middle blockers would need to be more synchronized.

Team and technical time-outs are two parts of rest time that can be adapted to make volleyball a more dynamic sport. The technology for technical time-outs should be applied to team time-outs to establish a clearer, automated time limit. The time after the whistle for the end of technical or team time-outs should be limited to 10-12 seconds so that after this time, all players must be ready on court with the server in position. The whole process will mean that calling for a team time-out will be indirectly limited to about 5 seconds, the time that coaches theoretically had at the the U23 Championship in Brazil. These time limits will increase the dynamics of the game and decrease rest time.

The periods between rallies in the *Early* and *Middle* phases were almost identical, but shorter than in the *Final* periods. The difference was about 0.3 seconds, but it would be much longer without the experimental rule of 15 seconds between rallies. This shows that in the *Final* phase, when uncertainty is higher, most teams try to take advantage of longer pauses between rallies. This study can also have an influence on developing the structure of the volleyball game.

References

Claver, F., Jiménez, R., Gil, A., Moreno, A., & Moreno, M. P. (2013). Relationship between performance in game actions and the match result. A study in volleyball training stages. *Journal of Human Sport and Exercise, 8*(Proc3), S651-S659.

Fellingham, G. W., Collings, B. J., & McGown, C. M. (1994). Developing an optimal scoring system with a special emphasis on volleyball. *Research Quarterly for Exercise and Sport, 65*(3), 237-243.

Fernández-Fernández, J., de la Aleja-Téllez, J. G., Moya-Ramón, M., Cabello-Manrique, D., & Méndez-Villanueva, A. (2013). Gender differences in game responses during badminton match play. *Journal of Strength and Conditioning Research, 29*(9), 2396-2404.

FIVB. (2012). Official volleyball rules 2013-2016. In *33rd FIVB Congress.* Anaheim, CA: FIVB. Retrieved from http://www.fivb.org/EN/Refereeing-Rules/documents/FIVB-Volleyball_Rules2013-EN_20121214.pdf

FIVB. (2013a). *Competition formula*. Retrieved from www.fivb.org/EN/volleyball/competitions/U23/Men/2013/Formula.asp

FIVB. (2013b). *New rules test to be held in Brazil only*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=43147&Language=en#.VMOwz8aI9YE

FIVB. (2013c). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2015). *Technical Survey (Summary of Men's U23 World Championship)*. Retrieved from http://www.fivb.org/EN/Technical-Coach/Document/FIVB_TE_U23_M_Summary.pdf

García-Alcaraz, A., Palao, J. M., & Valadés, D. (2012). Análisis de la duración de juego y la competitividad en diferentes categorías de competición en voleibol masculino [Analysis of the match duration and competitivity on different age groups in male volleyball]. In *Análisis del Rendimiento Deportivo: VII Congreso Internacional de la Asociación Española de Ciencias del Deporte* (p. 416). Granada, Spain: Faculty of Sports Science, University of Granada.

Giatsis, G. (2003). The effect of changing the rules on score fluctuation and match duration in the FIVB women's beach volleyball. *International Journal of Performance Analysis in Sport, 3*(1), 57–64.

Girard, O., Chevalier, R., Habrard, M., Sciberras, P., Hot, P., & Millet, G. P. (2007). Game analysis and energy requirements of elite squash. *Journal of Strength and Conditioning Research, 21*(3), 909–914.

Häyrinen, M., Lehto, H., Mikkola, T., Honkanen, P., Lahtinen, P., Paananen, A., & Blomqvist, M. (2011). Time analysis of men's and youth boy's top-level volleyball. *British Journal of Sports Medicine, 45*(6), 542.

Kountouris, P., & Laios, Y. (2000). Changes affecting on the game of volleyball by the enforcement of the new regulations. *Coaching Volleyball, 17*(1), 26–30.

Kovacs, M. (2004). A comparison of work/rest intervals in men's professional tennis.

Medicine and Science in Tennis, 9(3), 10–11.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159-174.

Marcelino, R., & Mesquita, I. (2008). Associations between performance indicators and set's result on male volleyball. In D. Milanović, & F. Prot (Eds.), *Kinesiology research trends and applications: Proceedings of the 5th International Scientific Conference on Kinesiology* (pp. 955–957). Zagreb, Croatia: Faculty of Kinesiology, University of Zagreb.

Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1–7.

Marcelino, R., Mesquita, I., Palao, J. M., & Sampaio, J. (2009). Home advantage in high-level volleyball varies according to set number. *Journal of Sports Science and Medicine, 8*(3), 352–356.

McCutcheon, H. (2013, September 16). Re: Game changer [Web log message]. Retrieved from http://www.teamusa.org/usa-volleyball/features/2014/september/16/game-changers

Palao, J. M., Valadés, D., Manzanares, P., & Ortega, E. (2014). Physical actions and work-rest time in men's beach volleyball. *Motriz: Revista de Educação Física, 20*(3), 257–261.

Palao, J. M., Valadés, D., & Ortega, E. (2012). Match duration and number of rallies in men's and women's 2000-2010 FIVB world tour beach volleyball. *Journal of Human Kinetics, 34*(1). 99-104.

Sánchez-Moreno, J., Marcelino, R., Mesquita, I., & Ureña, A. (2015). Analysis of the rally length as a critical incident of the game in elite male volleyball. *International Journal of Performance Analysis in Sport, 15*(2), 620–631.

Sheppard, J. M., Gabbett, T., Taylor, K. L., Dorman, J., Lebedew, A. J., & Borgeaud, R. (2007). Development of a repeated-effort test for elite men's volleyball. *International Journal of Sports Physiology and Performance, 2*(3), 292-304.

Smekal, G., Von Duvillard, S. P., Rihacek, C., Pokan, R., Hofmann, P., Baron, R., … Bachl, N. (2001). A physiological profile of tennis match play. *Medicine and Science in Sports and Exercise, 33*(6), 999–1005.

Tsimpiris, A., Tsamourtzis, E., Sfingos, N., Zaggelidis, G., & Zaggelidis, S. (2006). A multimedia application for tactic analysis of basketball games. *Revista Stiinta Sportului, 52*, 17–39.

Ureña, A., Gallardo, C., Delgado, J., Hernández, E., & Calvo, R. (2000). Estudio sobre la evolución de las reglas de juego en voleibol [Study of the history of volleyball rules of the game]. *Habilidad Motriz: Revista de Ciencias de la Actividad Física y del Deporte, 16*, 32–39.

Vilamitjana, J. J., Soler, D., Barrial, J. M., Del Grecco, P., Montes de Oca, M., & Rodríguez, F. (2008). Jumping profile of elite volleyball male players by field positions during a competitive season. *Medicine & Science in Sports & Exercise, 40*(5), S383.

CHAPTER 5

STUDY 4

Chapter 5

Study 4. Effects of Experimental Volleyball Rules Quantified by Type and Number of Jumps, Hits and Contacts

Abstract

The purpose of this study was to determine the influence of the two new rules tested at the inaugural U23 Men's Volleyball World Championship (21-point set excluding the fifth set, and 15 seconds between rallies – 10 seconds from the finished point until the referee's whistle for serve and five seconds for performing the serve) on number and types of jumps and number of contacts and hits. The analysis comprised 25930 jumps (an essential physical activity for volleyball), 15706 contacts and 10224 hits during 36 matches played by 144 males aged under 23 at the first Under 23 Men's World Championships organized in Uberlandia, Brazil, in 2013. Two investigations were conducted: 1) Analysis of jumps by Jump type, In-game role and Level of set win; 2) Analysis of contacts (reception, setting, block, defense) and hits (serve and attack) by Type, In-game role and Set outcome. Significant differences ($p = .00$) were found between in-game role and jump type, as middle blocker performed the most (34.7%), followed by outside hitter (24.9%), setter (24.6%) and opposite (15.8%). Significant differences were found for number and types of Hits between set *Winner* and *Loser* teams only for serves by setter ($p < .001$) and middle blocker ($p < .05$). The results showed major differences in jumps, hits and contacts between in-game roles: middle blocker was the most frequent jumping position, followed by outside hitter and setter. The libero showed a new tendency of being setter with a jump after the initial setter defense.

Introduction

Volleyball has become a very popular sport played in many countries worldwide (Aouadi et al., 2012; Sheppard et al., 2008; Sheppard et al., 2011). Throughout the history of volleyball the rules have been modified to make it a more exciting spectator sport (Ureña, Gallardo, Delgado, Hernández, & Calvo, 2000). The changes tested by Fédération Internationale de Volleyball (FIVB) during the first Under 23 (U23) Men's World Championship, in 2013, were intended to modernize volleyball and make it more appealing for fans attending matches or watching games on television (FIVB, 2013c, Twenty-one point rule to be tested at U23 World Championships). Two of the main characteristics of volleyball are the jump and the specific types of contact with the ball.

Investigations into players' ability to reach upwards, attack frequently from height and achieve a high blocking position showed that jumping is an important athletic skill for high performance in volleyball (Aouadi et al., 2012; Borràs, Balius, Drobnic, & Galilea, 2011; Marcelino & Mesquita, 2008; Sheppard et al., 2007; Sheppard et al., 2008; Vilamitjana et al., 2008). The attack and block, as important actions of a volleyball game, were identified as the best predictors in matches (Afonso, Esteves, Araújo, Thomas, & Mesquita, 2012; Castro & Mesquita, 2008; Marcelino & Mesquita, 2006; Marcelino, Mesquita, & Afonso, 2008; Rodríguez-Ruiz et al., 2011). Volleyball includes several types of jump techniques (jump for Jump Float Serve, spike and spin serve, setting and block) and new studies can focus on identifying optimum physical preparation for performing these kinds of jumps during competition.

Very few studies of volleyball and beach volleyball have defined or accurately categorized types of ball touches. In a beach volleyball study (Palao, Valadés, Manzanares, & Ortega 2014), the authors did not specifically define which touches corresponded to hits and contacts. Almujahed, Ongor, Tigmo, and Sagoo (2013) equated all touches of the ball as

follows: serve and attack with hits, and reception, set, block and dig-defense with contacts. Others associated them individually: serve with hit (Lidor & Mayan, 2005; López, 2013); reception, set, block and dig-defense with contact (Afonso et al., 2012; Palao et al., 2014); and attack with hit (Palao et al., 2014). In this study, every touch of the ball during the point is divided into one of two basic groups: hits and contacts. Serve and attack belong to the group of hits and all other touches (reception, pass by setter, block and defense (dig)) belong to the group of contacts.

Vilamitjana et al. (2008) assessed jump profile in elite male volleyball players with particular reference to playing position. Part of the study by Sheppard, Gabbett, & Stanganelli (2009) addressed the jumping ability of various playing positions in elite male volleyball players. Using different terminology from our study, Marcelino and Mesquita (2008) examined the number of contacts and performance in volleyball by set result.

The purpose of this study was to determine the influence of the two new rules tested at the first U23 Men's Volleyball World Championship (21-point set excluding the fifth set, and 15 seconds between rallies – 10 seconds from the finished point until the referee's whistle for serve and five seconds for performing the serve) on the number and types of jumps related to In-game role and Level of set win, and number of contacts and hits related to each In-game role and Set outcome.

Methods

A total of 36 of the 38 matches played at the U23 Men's World Championships in Uberlandia (Brazil) were analyzed. At this unique tournament in the history of volleyball, changes to the Rally Point System were tested for the first time. The U23 World Championships took place in October 2013, with 12 national teams participating. The tournament followed the FIVB competition system with the addition of two new rules tested:

set to 21 points per set (excluding the fifth set, to 15 points) with a minimum two-point difference at the end of sets, and 15 seconds before the referee's whistle for serve (FIVB, 2013b, New rules test to be held in Brazil only).

Official authorization from FIVB was granted for this study to use all the videos of matches and data from the Volleyball Information System (VIS) and the FIVB website.

The competition had two rounds: a group phase (Pool A and B), and semifinals and finals. In the group phase, 30 matches were played, and in the semifinals and finals, eight were played. All 12 teams, divided into two groups of six, played according to the round-robin system to determine the ranking and were classified from 1st to 6th. The team ranked 3rd in Pool A played the team ranked 4th in Pool B. The team ranked 3rd in Pool B played the team ranked 4th in Pool A. The losers of the semi-final matches played for 7th and 8th final places, and the winners of the semi-final matches played for 5th and 6th places. The team ranked 1st in Pool A played the team ranked 2nd in Pool B. The team ranked 1st in Pool B played the team ranked 2nd in Pool A. The losers of the semi-final matches played for 3rd and 4th place and the winners of the semi-final matches played for 1st and 2nd place (FIVB, 2013a, Competition formula).

The study was conducted in two parts.

Investigation 1 - Number and types of jumps. The first investigation analyzed jumps in relation to the new rules tested. Data were collected by watching 36 matches using a previously prepared data form containing all variables.

In total, 25930 jumps during 36 matches of the inaugural U23 Men's World Championships in Uberlandia were analyzed.

Investigation 2 - Number and types of contacts and hits. The second investigation analyzed the contacts and hits in relation to the new rules tested. Data were collected from 36 matches from the VIS posted on the FIVB website and recorded on an analysis scheme form, as recommended by Tsimpiris, Tsamourtzis, Sfingos, Zaggelidis, and Zaggelidis (2006) for defining and examining variables.

Participants. The analysis comprised 15706 contacts and 10224 hits during 36 matches played by 144 male players under 23 years of age at the first U23 Men's World Championships, in Uberlandia. The average age of players was 21.1±1.4 years. This age group competes successfully in the highest men's volleyball leagues internationally and therefore the games are of a similar level to elite men's volleyball. FIVB officially authorized this study and the use of all match videos and data from the VIS statistical recording program and the FIVB website. The study was performed in accordance with the Helsinki Declaration of 1975 and approved by the Ethics Committee of the University of Las Palmas de Gran Canaria. For both investigations, players were classified as setters, outside hitters, middle blockers, opposites and liberos.

Measuring equipment. The data were collected from 36 pre-recorded videos. All matches were recorded using a PANASONIC HC-V720 HD digital camcorder in AVCHD format. To obtain the best angle to capture everything happening on and beside the court, the camera was always located behind the court at a height of 5 meters above the floor (Claver, Jiménez, Gil, Moreno, & Moreno, 2013). FIVB's VIS software quantifies individual skills and is accepted as a valid instrument in volleyball research, as it has been used in various studies (Marcelino & Mesquita, 2008; Marcelino et al., 2008; Marcelino et al., 2009).

Value categories (measures). Vilamitjana et al. (2008) used the following variables: 1) frequency of jumps per player, grouped by four field positions, 2) percentage of jumps in volleyball skills (spiking, spiking approach, jump serve, blocking and setting) by player, 3) work time during the set: total set time minus resting. Total number of jumps and total work time were calculated per player. Work-rate profile (WRP) during competition was determined by the ratio between total number of jumps and work time.

Several authors (Marcelino & Mesquita, 2008; Marcelino, Mesquita, Sampaio, & Moraes, 2010) used similar variables for contacts: number of spike points, spike errors, spike continuity, block points, block errors, block continuity, serve points, serve errors, serve continuity, dig excellent, dig errors, dig continuity, set excellent, set errors, set continuity, reception excellent, reception errors and reception continuity, set win and set loss.

In Investigation 1, the variables analyzed were the jumps performed during actions A-E below, related to in-game role (setter, outside hitter, middle blocker, opposite, and libero), and Level of set win (*Walkover*, *Balanced*, and *Tough* set), where *Walkover* sets were the group of sets finished by 21:15 (and less than 15 points), *Balanced* sets were finished with 21:16, 21:17, and 21:18, and *Tough* sets finished with a two-point difference (21:19, 22:20… or 15:13, 16:14… in the fifth set).

A. Jump for Jump Float Serve (JFS).
B. Jump for Jump Spin Serve (JSS).
C. Jump for attack.
D. Jump for setting.
E. Jump during block.

In Investigation 2, the following variables were analyzed by in-game role (setter, outside hitter, middle blocker, opposite and libero) and Set outcome (set *Winner* and set *Loser*):

A. Hit
    a. Serve.
    b. Attack.
B. Contacts
    a. Reception.
    b. Setting.
    c. Block.
    d. Defense.

Procedures (observing data protocol). The FIVB technicians specially trained for VIS, who were approved, supervised and appointed by the FIVB Technical Commission, collected data about contacts and hits. VIS software is the method most commonly used by coaches and observers to assess individual and collective performance of volleyball players in each phase of the game. It has become the most frequently used software for FIVB data collection because of its efficiency, simplicity and accuracy (FIVB, 2000).

To ensure consistency in the criteria and quality in coding the data, the observer was trained beforehand. Training comprised a briefing on the definition of the variables and a data recording period of two weeks until he obtained a Cohen's Kappa value higher than .90. The observer had at least three years' experience in data logging in earlier volleyball research and extensive experience as a scout and coach in this sport.

Reliability. To ensure reliability, 12% of the rallies were re-analyzed, exceeding the reference value of 10% (Tabachnick & Fidell, 2013). Cohen's Kappa ranged from .84 to .91 for inter-observer reliability and .82 to .92 for intra-observer reliability. All values met the criterion of .75 suggested in the literature (Fleiss, Levin, & Paik, 2003).

Statistical analysis. All numerical data are shown by frequency, separated into each volleyball element analyzed. Pearson's Chi-Square test was used to test significant differences between frequencies registered in individual subsamples. Significance between means established for specific elements in specific subsamples was tested using the T-test and One-Way ANOVA. Statistical analysis was conducted using IBM SPSS Statistics V19 software. Statistical inference was performed at the level of significance of .05 ($p < .05$).

Results

Investigation 1. Match and set analysis of absolute and relative frequency of jump types showed that the highest number of jumps made by all teams was during the elements attack (M_{match} = 103±27 jumps; M_{set} = 30±7 jumps) and block (M_{match} = 102±26 jumps; M_{set} = 30±7 jumps). Half as many jumps were performed during setting (M_{match} = 51±15 jumps; M_{set} = 15±5 jumps) and fewest jumps were registered during JFS (M_{match} = 38±15 jumps; M_{set} = 11±4 jumps) and JSS (M_{match} = 22±8 jumps; M_{set} = 7±3 jumps). In percentages, 33% of jumps were performed during attack, 32% during block, 16% during setting, 12% during JFS and only 7% during JSS. No significant differences were found for the distribution of jump types by Level of set win.

Analysis of number of jumps by in-game role showed that middle blocker performed the most jumps during the match, followed by outside hitter, setter and opposite in-game roles (Table 12). Although libero registered a low number of jumps, it was interesting to analyze

the type of jumps this in-game role performed.

Table 12

Average distribution of jumps by in-game role

Jumps	Setter	Outside hitter	Middle blocker	Opposite	Libero	Total
	%	%	%	%	%	%
JFS	26.2	30.2	36.5	7.1	/	100
JSS	12.7	44.1	11.9	31.3	0	100
Attack	1.6	28.5	46.3	23.7	.0	100
Setting	95.6	1.0	1.6	1.1	.6	100
Block	14.4	26.9	43.7	15.0	/	100
Total	24.6	24.9	34.7	15.8	.1	100

Note. Chi-Square = 13794.922* (p = .000).

*Asterisk indicates a statistically significant difference.

Analysis of individual positions in the game showed that setter, as expected, performed the highest number of jumps during setting (M = 98±88 jumps), block (M = 29±26 jumps) and Jump Float Serve (M = 20±17 jumps), and the lowest number of jumps in Jump Spin Serve (M = 6±3 jumps) and attack (M = 3±2 jumps).

Outside hitter performed almost the same number of jumps in attack (M = 59±54 jumps) and block (M = 55±49 jumps). Mean values for this in-game role were 23±19 jumps during serve by Jump Float and 20±17 jumps during Jump Spin Serve. As expected, the minimum number of jumps was in setting (M = 1±1 jump).

Middle blocker in-game role, the leading jump position, had a mean value of 96±87 jumps in attack per match and a slightly lower value in block (89±80 jumps). During Jump Float Serve the average was 28±24 jumps, with more than five times fewer during Jump Spin

Serve (M = 5±4 jumps). In setting, as expected, this in-game role performed minimum jumps (M = 2±1 jumps).

Opposite in-game role had a mean value of 49±45 jumps per match in attack, with a maximum value of 87 jumps and a minimum of 30 (Figure 10). In block, this in-game role performed an average of 30±9 jumps, followed by jumps in Jump Spin Serve (M = 14±12 jumps) and Jump Float Serve (M = 6±4 jumps). Opposite in-game role performed minimum jumps during setting (M = 1±1 jump).

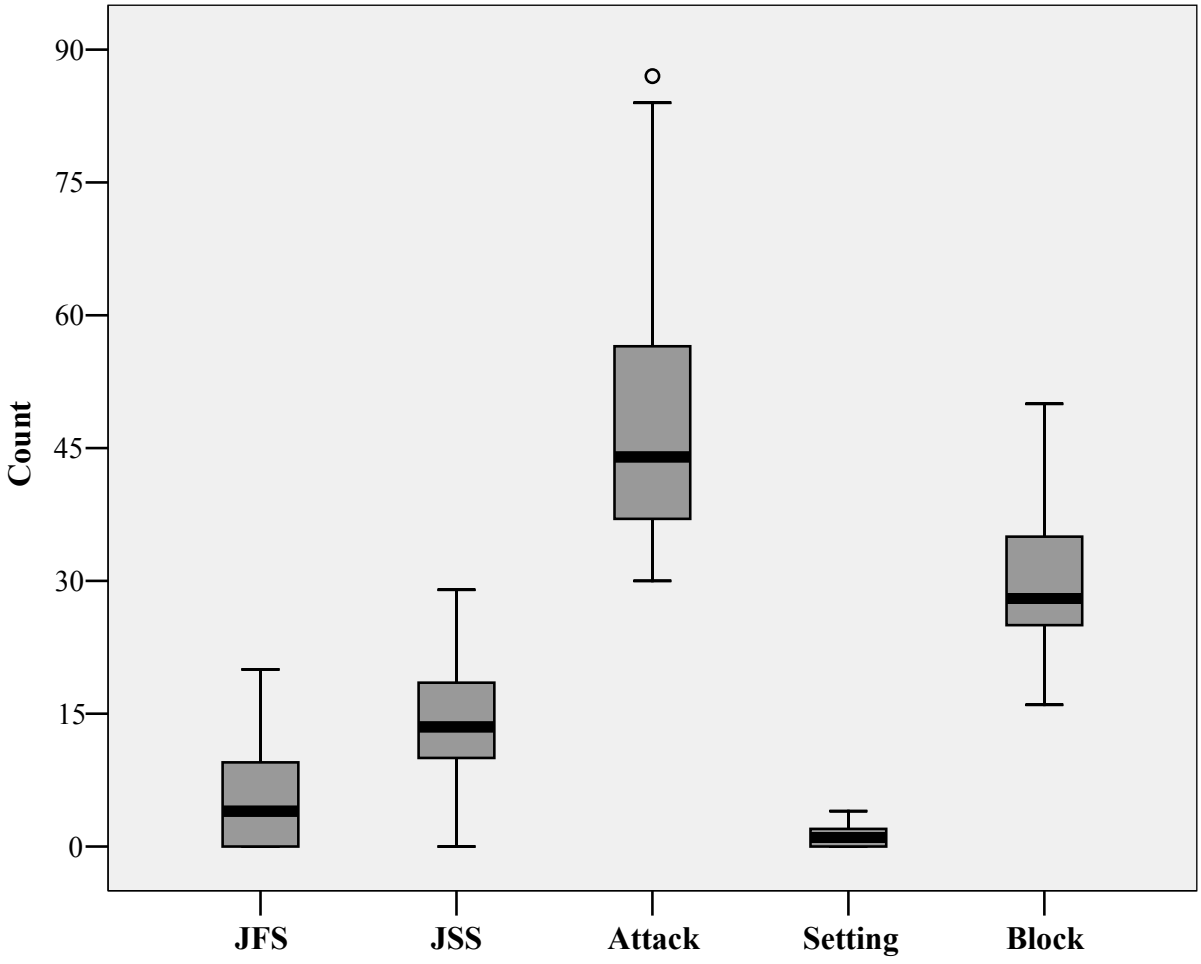

Figure 10. Average descriptive indicators for jumps by opposite in-game role per match.

Note. Circle (°) above the bar represents an individual extreme value that exceeded 3 standard deviations and is excluded from the analysis as parasitic data.

Jumps by libero were registered in only 14 of the 36 matches analyzed. From a total of 20 jumps libero performed during the whole tournament, 19 were during setting. In eight matches libero performed one jump per match during setting, in three matches two jumps per match and in one match five jumps. Analysis of the 13 matches in which libero jumped during setting showed a low average value of 1.62±1.12 jumps (minimum 1, maximum 5). Calculating the values for 36 matches, the values registered for libero were M = 0.58±1.025 jumps, Min = 0 jumps, Max = 5 jumps.

The 2nd investigation. T-test analysis of number and types of Hits showed a significant difference between set *Winner* and set *Loser* teams only for serves by setter ($p < .001$) and middle blocker ($p < .05$), while no statistical differences were found for other Hit performers (Table 13). Setter and middle blocker from set *Winners* hit the ball significantly more (by 4-5 hits) during serve than the same in-game roles from set *Losers*.

Table 13

Statistical descriptive for hit elements (per match)

Hits	Team	N	Mean	Std. Deviation	Std. Error Mean	T-test	*p*
Serve.S	Winner	36	15.61	5.738	.956	4.157*	.000
	Loser	36	10.75	4.038	.673		
Serve.OH	Winner	36	23.08	5.949	.992	1.433	.156
	Loser	36	20.61	8.473	1.412		
Serve.OP	Winner	36	9.97	3.707	.618	1.289	.202
	Loser	35	8.80	3.954	.668		
Serve.MB	Winner	36	21.81	5.651	.942	2.844*	.006
	Loser	36	17.75	6.425	1.071		
Attack.S	Winner	33	2.48	1.326	.231	-.969	.336
	Loser	32	2.84	1.648	.291		
Attack.OH	Winner	36	34.03	11.000	1.833	-1.462	.148
	Loser	36	38.36	13.970	2.328		
Attack.OP	Winner	36	24.86	9.372	1.562	-.453	.652
	Loser	36	26.00	11.835	1.972		
Attack.MB	Winner	36	14.03	5.945	.991	.291	.772
	Loser	35	13.63	5.610	.948		
Attack.L	Winner	1	1.00	/	/	/	/
	Loser	2	8.50	2.121	1.500		
Total hits	Winner	36	145.69	33.126	5.521	.883	.380
	Loser	36	138.28	37.996	6.333		

Note. ^{S} = Setter, ^{OH} = Outside Hitter, ^{MB} = Middle blocker, ^{OP} = Opposite, ^{L} = Libero.

*Asterisk indicates a statistically significant difference.

In the *Hits* group, outside hitter performed 22±7 hits during serve, followed by middle blocker (M = 20±6 hits), setter (M = 13±6 hits) and opposite (M = 9±4 hits) (Figure 11).

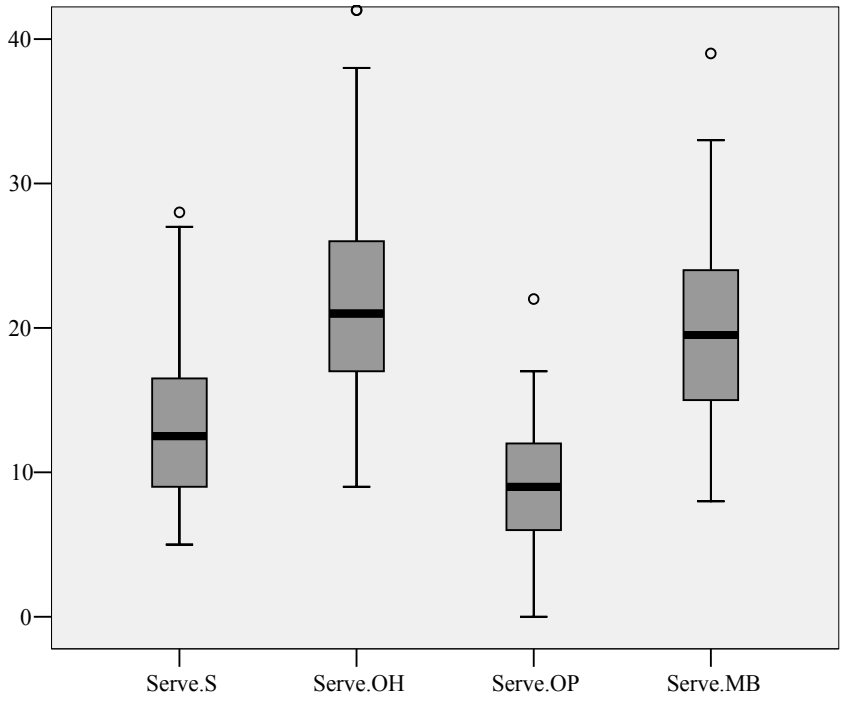

Figure 11. Descriptive for hits performed by servers (per match).

Note. ^{S} = Setter, ^{OH} = Outside hitter, ^{MB} = Middle blocker, ^{OP} = Opposite.

^{o}Circles above the bars represent individual extreme values that exceeded 3 standard deviations and are excluded from the analysis as parasitic data.

In attack, outside hitter executed the most hits (M = 25±11 hits), followed by opposite (M = 25±11 hits), middle blocker (M = 14±6 hits) and setter (M = 2±2 hits).

T-test comparison between set *Winner* and set *Loser* data for contacts showed significant differences in block by opposite players ($p < .05$) and middle blocker players ($p < .05$), and in reception by libero ($p < .05$). The in-game role that touched the ball most per match was setter from set *Loser* teams in setting (M = 66±18 contacts), followed by the same position from set *Winner* teams in setting (M = 60±22 contacts). The second in-game role by number of contacts was outside hitter from set *Loser* teams during reception (M = 41±13 contacts), followed by the same position from set *Winners* during reception (M = 36±13 contacts) (Table 14).

Table 14

Statistical descriptive for contact elements (per match)

Contacts	Team	N	Mean	Std. Deviation	Std. Error Mean	T-test	*p*
Block.S	Winner	36	5.33	3.295	.549	.837	.405
	Loser	35	4.71	2.916	.493		
Block.OH	Winner	36	10.36	3.322	.554	.884	.380
	Loser	36	9.44	5.261	.877		
Block.OP	Winner	36	6.89	3.740	.623	2.111*	.038
	Loser	35	5.17	3.073	.519		
Block.MB	Winner	36	16.67	7.282	1.214	2.270*	.026
	Loser	36	13.08	6.054	1.009		
Defense.S	Winner	36	8.39	3.705	.618	-1.294	.200
	Loser	36	9.50	3.582	.597		
Defense.L	Winner	36	13.53	5.406	.901	-.195	.846
	Loser	36	13.78	5.452	.909		
Defense.OH	Winner	36	15.83	6.153	1.025	-1.326	.189
	Loser	36	18.31	9.344	1.557		
Defense.OP	Winner	36	6.58	3.324	.554	-.795	.429
	Loser	35	7.26	3.807	.643		
Defense.MB	Winner	36	4.89	2.638	.440	-1.360	.178
	Winner	35	5.91	3.649	.617		
Setting.S	Winner	36	60.36	22.049	3.675	-1.120	.267
	Loser	36	65.72	18.415	3.069		
Setting.L	Winner	33	4.09	2.185	.380	-1.291	.201
	Loser	35	4.80	2.336	.395		
Setting.OH	Winner	33	4.03	2.114	.368	-1.714	.091
	Loser	35	4.97	2.395	.405		
Setting.OP	Winner	21	2.33	1.017	.222	.541	.591
	Loser	27	2.19	.879	.169		
Setting.MB	Winner	29	3.00	1.626	.302	.799	.428
	Loser	33	2.67	1.652	.288		
Reception.L	Winner	36	13.06	6.568	1.095	-2.056*	.044
	Loser	36	16.64	8.139	1.356		
Reception.OH	Winner	36	35.61	13.122	2.187	-1.692	.095
	Loser	36	40.81	12.928	2.155		
Reception.MB	Winner	11	1.45	.934	.282	-.994	.329
	Loser	19	2.00	1.667	.382		
Reception.S	Winner	8	1.00	.000	.000	/	/
	Loser	13	1.00	.000	.000	/	/
Reception.OP	Winner	0	/	/	/	/	/
	Loser	9	7.11	6.353	2.118	/	/
Total	Winner	36	209.42	64.748	10.791	-1.194	.236
Contacts	Loser	36	226.47	56.129	9.355		

Note. ^{S} = Setter, ^{OH} = Outside hitter, ^{MB} = Middle blocker, ^{OP} = Opposite, ^{L} = Libero.

*Asterisk indicates a statistically significant difference.

For contacts with the ball during block per match, middle blockers performed the highest number (M = 15±7 contacts), followed by outside hitter (M = 10±4 contacts), whereas opposite (M = 6±4 contacts), and setter (M = 5±3 contacts) touched the ball considerably less (Figure 12).

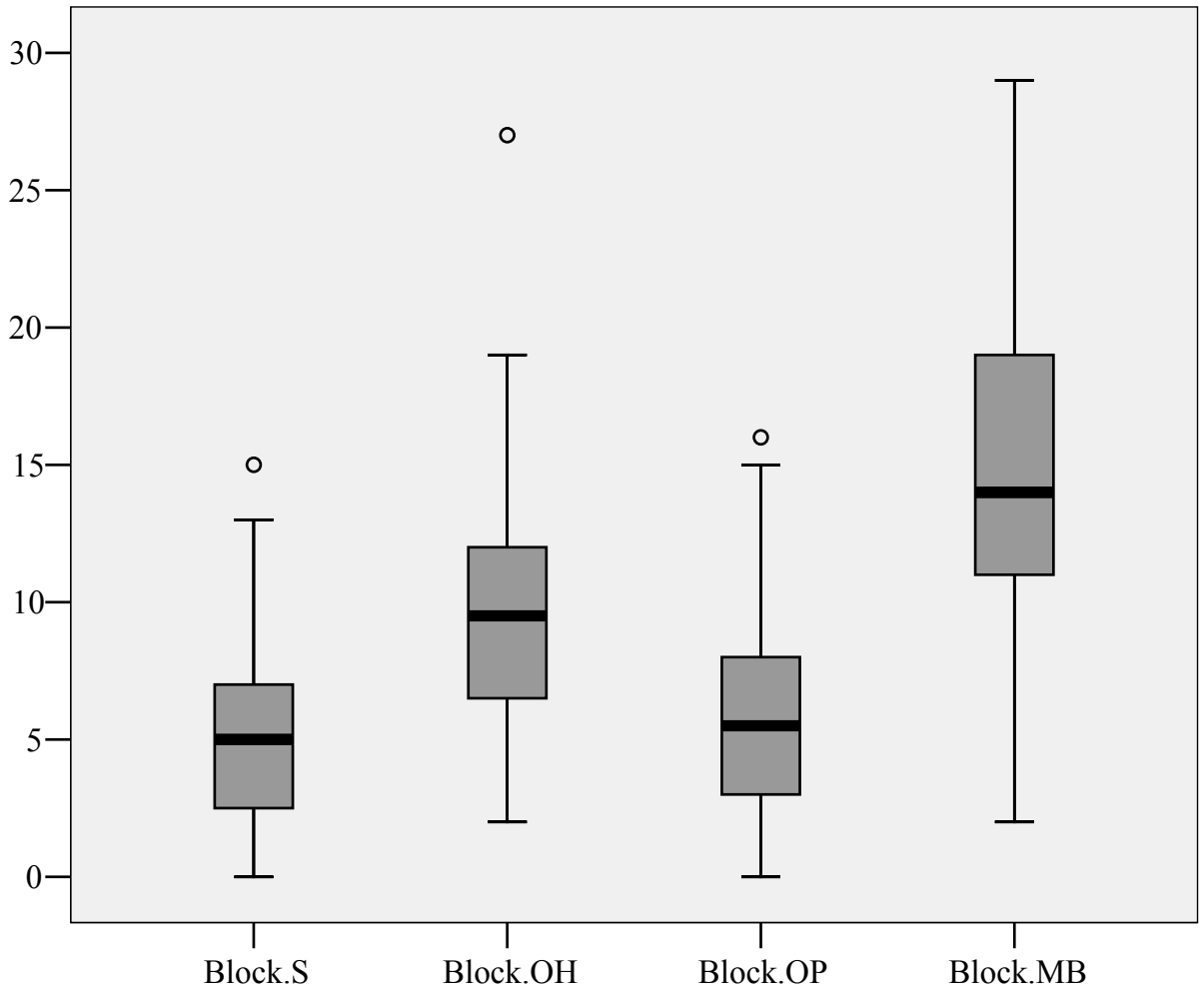

Figure 12. Descriptive for contacts made by blockers (per match).

Note. ^{S} = Setter, ^{OH} = Outside hitter, ^{MB} = Middle blocker, ^{OP} = Opposite, ^{L} = Libero.

^{o}Circles above the bars represent individual extreme values that exceeded 3 standard deviations and are excluded from the analysis as parasitic data.

For contacts with the ball in defense, outside hitter had a mean value of 17±8 contacts per match, followed by libero (M = 14±5 contacts), with considerably lower values achieved by setter (M = 9±4 contacts), opposite (M = 7±4 contacts) and middle blocker (M = 5±3 contacts).

For contacts with the ball during setting, setter is the absolute leader for number of touches, with a mean value of 63±20 contacts per match, followed by outside hitter (M = 4±3 contacts), libero (M = 4±3 contacts), middle blocker (M = 2±2 contacts) and opposite (M = 2±1 contacts).

Outside hitter led in the number of contacts during reception, with a mean value of 38±13 contacts, followed by libero with a mean of 15±8 contacts, and minimum values were obtained by opposite (M = 1±3 contacts), middle blocker (M = 1±1 contact) and setter.

Discussion

Few studies have addressed the number and type of jumps by in-game role and Level of set win or hits and contacts by in-game role and Set outcome in volleyball. In beach volleyball, Palao et al. (2014) found no statistical difference between in-game roles for average jumps, contacts and hits per play. Marcelino et al. (2010) reported significant differences for contacts. Serve point, serve continuity and spike point are the performance indicators most correlated with win in volleyball (Marcelino & Mesquita, 2008), which is closely related to the parts of this study concerning Hits.

Jumps. Information about the number and type of jumps gives coaches appropriate insight into the physical exertion and technical requirements by each in-game role. Sheppard et al. (2007) and Sheppard et al. (2009) identified middle blocker as the most frequent performer of jumps during block in comparison to setters and outsides hitters, while middle

blockers performed more jumps during attack than outside hitter and setter, concurring with our study. Vilamitjana et al. (2008) reported that the most frequent performer of jumps is middle blocker, followed by outside hitter, setter and opposite, also concurring with our study. The same authors found that most jumps are performed during block (37.9%) and attack (21.7%), in agreement with our study, although the values in our study were similar (about 33% each, of total jumps). In the same study, 17.6% of jumps were performed during *Jump Serve* and 14.5% during setting, compared to 7% during JSS, 12% during JFS and 16% during setting in our study.

To be able to compare our results to the study by Vilamitjana et al. (2008), a simple conversion process into percentages was necessary. Vilamitjana et al. (2008) identified setter with about 67.5% of jumps during setting, recording a similar percentage (15%) of both jumps in block and serve, whereas in our study setter performed 62.6% during setting, 18.8% during block and 16.5% in serve, including both JFS and JSS. The same authors found that outside hitter performed most jumps during block (45%), followed by jumps during spiking (about 32%) and serve (about 21%), whereas in our study the same in-game role performed most jumps during attack (37.4%), followed by block (34.8%) and jump serve using both JFS and JSS (27.2%). According to Vilamitjana et al. (2008), middle blocker performed about 47% of jumps during block, about 17% during serving and 14% during spiking, whereas in our study the same position jumped less in block (30.5%), considerably more in attack (43.6%) and slightly less in Jump Serve, including JFS and JSS (15.2%). Opposite is the absolute leader in jumps during attack, in which this in-game role performed about 46% of total jumps in the study by Vilamitjana et al. (2008) and around 17% during Jump Serves, whereas in our study the value for jumps during attack was slightly higher (49.0%), 19.4% during both JFS and JSS, and 30.5% during block.

Given the lack of references to jumps by libero in the literature, this study will be

among the first to draw attention to the new tendency of libero to jump during setting. In our study, 95% of jumps performed by libero were during setting. Libero can also attack according to official volleyball rules (FIVB, 2012), but in official matches it has been seen that coaches often become frustrated because of a limited understanding of the rules of the game.

Hits and contacts. For hits, the significant difference for setter and middle blocker by set outcome and in-game role agree with the findings of Marcelino and Mesquita (2010), who found significant differences in attack and serve by set outcome. According to Marcelino and Mesquita (2006), the average attack attempt (corresponding to the term "attack hit" in this study) per match is 97.09±20.25 and the average serve attempt (corresponding to "serve hits") is 88.15±16.17.

Marcelino et al. (2010) found significant differences in reception block, defense, setting and reception between set *Winners* and *Losers*, whereas in our study significant differences were found for Set outcome for three in-game roles: libero for reception and opposite and middle blocker for block. In the study by Marcelino and Mesquita (2006), the term "average block attempts" (48.30±14.93) corresponds to contacts in block, "dig attempts" (M = 55.63±16.48 attempts) corresponds to contacts in defense and "reception attempts" (70.82±14.59) corresponds to contacts in reception. Analysis of setting shows that setter must be technically and physically well prepared to perform about 63±20 passes, whereas outside hitter and libero perform only 4±3 passes per match. Middle blocker and opposite appear to set extremely rarely.

Conclusions

For hits, the significant difference for setter and middle blocker by set outcome and in-game role agree with the findings of Marcelino and Mesquita (2010), who found significant differences in attack and serve by set outcome. According to Marcelino and Mesquita (2006), the average attack attempt (corresponding to the term "attack hit" in this study) per match is 97.09±20.25 and the average serve attempt (corresponding to "serve hits") is 88.15±16.17.

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References

Afonso, J., Esteves, F., Araújo, R., Thomas, L., & Mesquita, I. (2012). Tactical determinants of setting zone in elite men's volleyball. *Journal of Sports Science & Medicine, 11*(1), 64–70.

Almujahed, S., Ongor, N., Tigmo, J., & Sagoo, N. (2013). *Sports analytics*. Fairfax, VA: George Mason University.

Aouadi, R., Jlid, M., Khalifa, R., Hermassi, S., Chelly, M. S., Van Den Tillaar, R., & Gabbett, T. (2012). Association of anthropometric qualities with vertical jump performance in elite male volleyball players. *Journal of Sports Medicine and Physical Fitness, 52*(1), 11–17.

Borràs, X., Balius, X., Drobnic, F., & Galilea, P. (2011). Vertical Jump Assessment on Volleyball: A Follow-Up of Three Seasons of a High-Level Volleyball Team. *Journal of Strength and Conditioning Research, 25*(6), 1686–1694.

Castro, J. M., & Mesquita, I. (2008). Estudo das implicações do espaço ofensivo nas características do ataque no Voleibol masculino de elite. *Revista Portuguesa de Ciências Do Desporto, 8*(1), 114–125.

Claver, F., Jiménez, R., Gil, A., Moreno, A., & Moreno, M. P. (2013). Relationship between performance in game actions and the match result. A study in volleyball training stages. *Journal of Human Sport and Exercise, 8*(Proc3), S651–S659.

FIVB. (2000). *VIS (Volleyball Information System) STAFF Guidelines - Evaluation Criteria 2000*. Lausanne, Switzerland: FIVB.

FIVB. (2012). FIVB, official volleyball rules 2013-2016. *In 33rd FIVB Congress*. Anaheim, CA: FIVB. Retrieved from http://www.fivb.org/EN/Refereeing-

Rules/documents/FIVB-Volleyball_Rules2013-EN_20121214.pdf

FIVB. (2013a). *Competition formula*. FIVB. Retrieved from www.fivb.org/EN/volleyball/competitions/U23/Men/2013/Formula.asp

FIVB. (2013b). *New rules test to be held in Brazil only*. FIVB. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=43147&Language=en#.VMOwz8aI9YE

FIVB. (2013c). *Twenty-one point rule to be tested at U23 World Championships*. FIVB. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

Fleiss, J. L., Levin, B. A., & Paik, M. C. (2003). *Statistical Methods for Rates and Proportions* (3rd ed.). Hoboken, NJ: John Wiley & Sons.

Lidor, R., & Mayan, Z. (2005). Can beginning learners benefit from preperformance routines when serving in volleyball? *The Sport Psychologist, 19*(4), 343–363.

Liu, G. C., Huang, G. C., & Huang, C. (2001). Effects of different approach lengths of the last stride on volleyballer run up vertical jump. In J. R. Blackwell, & R. H. Sanders, *Proceedings of XIX International Symposium on Biomechanics in Sports* (pp. 120–123). San Francisco, CA: University of San Francisco.

López, J. P. (2013). *Analysis of the service as a performance factor in high-level volleyball and beach volleyball* (doctoral dissertation). University of VIC – Central University of Catalonia, Barcelona, Spain.

Marcelino, R., & Mesquita, I. (2006). Characterizing the efficacy of skills in high performance competitive volleyball. In H. Dancs, M. Hughes, & P. O'Donoghue (Eds.), *Proceedings of the World Congress of Performance Analysis of Sport VII* (pp. 491–496). Szombathely, Hungary: Berzsenyi College.

Marcelino, R., & Mesquita, I. (2008). Associations between performance indicators and set's result on male volleyball. In D. Milanović (Ed.), *Kinesiology Research Trends and*

Applications - Top-level Sport: Proceedings of the 5th International Scientific Conference on Kinesiology (pp. 955–957). Zagreb, Croatia: Faculty of Kinesiology, University of Zagreb.

Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in Volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1–7.

Marcelino, R., Mesquita, I., Palao, J. M., & Sampaio, J. (2009). Home advantage in high-level volleyball varies according to set number. *Journal of Sports Science and Medicine, 8*(3), 352–356.

Marcelino, R., Mesquita, I., Sampaio, J., & Moraes, J. C. (2010). Estudo dos indicadores de rendimento em voleibol em função do resultado do set. *Revista Brasileira de Educação Física e Esporte, 24*(1), 69–78.

Palao, J. M., Valadés, D., Manzanares, P., & Ortega, E. (2014). Physical actions and work-rest time in men's beach volleyball. *Motriz: Revista de Educação Física, 20*(3), 257–261.

Rodriguez-Ruiz, D., Quiroga, M. E., Miralles, J. A., Sarmiento, S., De Saá, Y., & García-Manso, J. M. (2011). Study of the technical and tactical variables determining set win or loss in top-level European men's volleyball. *Journal of Quantitative Analysis in Sports, 7*(1), 1–13.

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. *Journal of Strength and Conditioning Research, 22*(3), 758–765.

Sheppard, J. M., Dingley, A. A., Janssen, I., Spratford, W., Chapman, D. W., & Newton, R. U. (2011). The effect of assisted jumping on vertical jump height in high-performance volleyball players. *Journal of Science and Medicine in Sport, 14*(1), 85–89.

Sheppard, J. M., Gabbett, T. J., & Stanganelli, L. C. (2009). An analysis of playing positions in elite men's volleyball: considerations for competition demands and physiologic characteristics. *Journal of Strength and Conditioning Research, 23*(6), 1858–1866.

Sheppard, J. M., Gabbett, T., Taylor, K. L., Dorman, J., Lebedew, A. J., & Borgeaud, R. (2007). Development of a repeated-effort test for elite men's volleyball. *International Journal of Sports Physiology and Performance, 2*(3), 292–304.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson Education.

Tsimpiris, A., Tsamourtzis, E., Sfingos, N., Zaggelidis, G., & Zaggelidis, S. (2006). A multimedia application for tactic analysis of basketball games. *Revista Stiinta Sportului, 15*(52), 17–39.

Ureña, A., Gallardo, C., Delgado, J., Hernández, E., & Calvo, R. (2000). Estudio sobre la evolución de las reglas de juego en voleibol. *Habilidad Motriz: Revista de Ciencias de la Actividad Física y del Deporte, 16*, 32–39.

Vilamitjana, J. J., Soler, D., Barrial, J. M., Del Grecco, P., Montes De Oca, M., & Rodriguez, F. (2008). Jumping profile of elite volleyball male players by field positions during a competitive season. *Medicine & Science in Sports and Exercise, 40*(5), S383.

CHAPTER 6

Chapter 6

General Discussion

As previously indicated, this Dissertation consists of four totally different studies designed to determine explanations and trends in relation to how the new rules tested (21-point set and 15 seconds between points) influence the dynamic of the volleyball game regarding serves, point-scoring plays, work and rest time, and jumps, hits and contacts. During research, performance analysis and notational analysis were used. Ad-hoc analysis shows that volleyball is among the group of sports undergoing most development in the world in the last two decades. It is obvious that one of the reasons for this is the constant improvement of the rules and the structural and technical details of the volleyball game. As each change in rules for any sport has an effect on the dynamic of the game, it was an attractive prospect to be among the first investigators to analyze how the changes discussed could influence the game of volleyball in general. Why were these particular elements chosen for analysis? The decrease in the total number of set points led to the opinion that this change must somehow influence point-scoring plays in the final part of the set and therefore a model of scoring actions should be developed. As a result, the idea for this dissertation was born. At the same time, the shorter set means there are fewer points to play and less margin for errors, so all teams can reduce their errors through the element of the serve. The choice to analyze the serve was strengthened by the rule for 15 seconds between points, which reduces the time for serve preparation and execution. In addition, both rules tested were intended to cut the duration of the volleyball set and match, which led to the spontaneous decision to analyze work and rest time. The fourth research component, the most demanding in terms of data compilation and support through existing literature, came from the desire to do something

completely new, different and unexpected to define the volleyball game by its fundamental subelements, such as jumps, hits and contacts. By quantifying such subelements, it is possible to obtain important trends and compile a database for future investigation. Lastly, the most important part of this study is to provide relevant information for athletes to prepare physically and learn appropriate techniques.

The **first study** was an analysis of 4588 serves by in-game role, serve type, serve quality, serve zone, placement zone, set phase and set outcome for all serves performed at the tournament. The study revealed several significant differences between the variables analyzed:

1. Serve type and set phase
2. Set outcome and serve quality
3. Set outcome and serve zones
4. Serve placement zone and serve quality
5. Set type and in-game role
6. Serve zone and in-game role
7. Serve placement zone and serve zone

However, no significant differences were found between the following variables:

1. Set outcome and set phase by serve placement zone
2. Serve quality and set phase
3. Serve zone and set phase

These differences reveal a clear model and trend in the volleyball games in which the new rules were tested. Jump Float Serve (JFS) was found to be the most frequently used serve in all phases of the set at a total of 60.6%, and was especially used in the *Final* phase of the

set, unlike the frequency of Jump Spin Serve (JSS), which decreased with the approach to the *Final* phase.

As expected, set *Winners* performed better quality serves than set *Losers*, providing fewer chances for the opponents to organize any type of attacks and forcing the opponent to play third tempo attacks. Set *Winners* made fewer serve errors, scored more aces and provoked more free balls from the opponent.

Both set *Winners* and *Losers* performed more than 50% of serves from BZ1, about 25% from BZ5, and considerably fewer from BZ6. Parsing the results shows that considerably more serves were performed from BZ6 by set *Winners* than *Losers*. Set *Losers* executed more serves from BZ1 than the *Winners*, while both groups have almost the same frequency of performing serves from BZ5.

From BZ1, players served mostly to zone 6, then to zone 5. From BZ5 and BZ6, players served mostly to zones 5 and 6 at almost the same percentage (about 32%) and directed about 20% of serves to zone 1. Most serves with good quality were performed from BZ1 (54.6%), followed by BZ5 (26.3%) then BZ6 (19.1%). Almost 60% of aces were served from BZ1. Serve errors were predominant in serves from BZ1 (58.6%), although serves resulting in a *Free ball* had the lowest percentage (51.7%) among all serves from BZ1.

As expected, zones 1, 5 and 6 were the most frequent placement zones. The highest number of *Serve Errors* were made in serves to zone 6. The easiest serves were performed to zone 6. The highest number of free balls and aces resulted from serves to zone 5.

Setters and middle blockers mainly used the Jump Float Serve, whereas opposite players performed Jump Spin Serve more often. Outside hitters also frequently used Jump Float Serve, closely followed by Jump Spin Serve. Opposite is the in-game role with the lowest number of serves at the tournament, although these players accounted for the highest number of aces and the highest number of serve errors, undoubtedly causing the greatest

trouble for receivers. Serves by the setter resulted in the highest number of opponent third-tempo attacks and free balls. The middle blocker position had the highest relative frequency of serves that allowed a first-tempo attack.

From behind zone 1, the opposite in-game role performed almost 70% of serves, while the setter and outside hitter performed around 64%; the middle blocker in-game role had the lowest percentage of serves from this zone (around 31%). The middle blocker was unique in performing the highest percentage of serves from behind zone 5 (47%) and the lowest percentage from behind zone 1.

During the study, the extensive experience of the investigators in observing volleyball matches and compiling data from the highest level men's volleyball allowed them to identify obvious differences in approaches to serving positions in matches with and without the 15 seconds rule. In matches with the 15 seconds rule, players immediately run to their serving positions after scoring the point and perform the serve without waiting, right after the referee whistles for serve.

The choice to perform mostly JFS, especially in the *Final* phase, indicates that teams need an effective, safe serve without great risk. It is also likely that running to the serving position influenced the choice of JFS, which requires less physical and mental preparation than the JSS. The JFS has proven to be a high quality serve type and is difficult to receive. Set *Winners* consistently had better serves which were performed more frequently from BZ6 than serves by set *Losers* and were evenly distributed among all serving zones. The most common serve placement zones were zones 5 and 6, which can be explained by the tactical ideas of the coach and players. The best quality serves and aces were performed from BZ1, consistent with the fact that the greatest number of serves were performed from that zone, as well as the better technical possibilities for right-handed players, who are in the majority. The outside hitter in-game role was found to be the position that combined different types of serves the

most, choosing between JFS and JSS, while in 25-point sets, the same in-game role mostly serves with JSS. The middle blocker in-game role is characterized as a safe serving in-game role with the least quality serves, who serves most frequently from BZ5. Opposite is the in-game role that serves most from BZ1, achieves most aces and leads in serve errors. Above all, the new rules tested influence the approach to the serving location, choice of serve type and serve quality.

The aim of the **second study** was to determine how both experimental rules influenced point-scoring plays in the final parts of the sets, defined as points 16 to 21 in the first four sets and points 10 to 15 in the fifth set. The study processed the following variables: in-game role, score fluctuation, serve-ace, attack, counter attack, block, opponent/unforced error, set outcome (*Winner vs. Loser*) and level of set win (*Walkover-Balanced-Tough*).

Regarding *Level of set win*, significant differences were found between set *Losers* and *Winners* mainly in *Walkover* and *Balanced* sets, while no differences were found in *Tough* sets. Analyzing the in-game role by *Level of set win* and *Set outcome* revealed no significance differences in any of the three models of *Walkover*, *Balanced* and *Tough* sets.

The differences between the set *Winners* and *Losers* in the structure of point-scoring plays decrease as the set becomes tougher. Analysis by *Set outcome* showed that both *Winner* and *Loser* groups performed similar point-scoring play structures. Attack-spikes and blocks were the most predominant point-scoring plays, followed by errors in serve and attack.

Further examination of the *Walkover* sets shows that the *Winners* won more points than *Losers* by block, first attack, counter attack and serve (ace), while, as expected, the *Losers* made more unforced errors in attack and unforced technical mistakes. In *Balanced* sets, *Losers* also made more unforced errors in attack, while *Winners* successfully blocked more. In *Tough* sets, the attack-spike was the predominant method of scoring points for both *Winners* and *Losers*, and both groups made similar numbers of unforced errors. The *Winners*

performed slightly better in blocks.

While no significant differences were found among in-game roles, comments can be made on descriptive frequencies. Outside hitter scored the most points, followed by middle blocker and opposite. However, for *Walkover* and *Balanced* sets, this was not the case for the *Losers* team in-game roles, as the highest number of points were scored by opposite players. This does not hold for unpredictable sets, where the outside hitter and opposite from both the *Winners* and *Losers* group executed almost the same number of points and the other roles showed the usual prevalence. Setter performed a higher number of point executions in *Winner* groups than in *Loser* groups. In unpredictable sets, this trend was reversed. The middle blocker from set *Losers* finished fewer actions than set *Winners* during *Walkover* and *Balanced* sets, while the converse held for *Tough* sets.

The attack-spike action once again proved to be the leading point-scoring action. However, the study can also justify the development of attack-block and attack-tipping as wise final actions. The block is another decisive factor between *Winners* and *Losers* in volleyball sets according to the experimental rules. The inequality with respect to in-game roles in *Loser* teams shows weaknesses against evenly built teams with almost equal role qualities. In line with the experimental structure of the volleyball game during the U23 Men's Championship in Brazil, the outside hitter must be physically, technically and tactically well-prepared.

The **third study** aimed to determine the detailed effects of the two rules tested on all aspects involving time in volleyball matches.

This study finds that work time is significantly shorter than rest time. The durations of the set and match account for similar proportions of the total time: the average set lasts 40% of the total time and the average match lasts 35%. Rest time consists of several subcategories, with the longest corresponding to breaks between rallies (27.37%), followed by both types of

time-outs (19.12%), pauses between sets (12.04%) and substitutions (6.05%).

Significant differences were found in the duration of rest time after the rally in different phases of the set (*Early, Middle,* and *Final* phase), while no significant differences were found in rally duration between set phases. The duration of rest time after the point in relation to *Level of set win* resulted in significant differences, while rally duration in relation to *Level of set win* showed no significant differences. No significant differences were found between the duration of pauses after each set.

Under the 21-point set and 15-second break between points, average set duration was 20.44±5.21 minutes. The longest set lasted only 3.24 minutes more than the average set and the shortest was only 1.55 minutes shorter than the average. Matches lasted an average of 69.83±18.93 minutes, with the longest match at 113.68 minutes and the shortest at 56.64 minutes.

Despite the 10 seconds planned between a finished point and the referee's whistle for serve, the average duration for this period was about 12 seconds, while some periods lasted up to 20 seconds.

About 84.5% of rallies lasted 5-15 seconds (43.5% of points lasted 5-10 seconds and 41% of rallies lasted 10-15 seconds). Compared to several studies of men's world-level volleyball with sets to 25 points, the average duration (11.50±4.38 seconds) for rallies in this study is greater by 2-6 seconds. About 11% of the points finished during the match lasted 15-20 seconds and 3.7% lasted 20-25 seconds.

Although the official rules state that team time-outs last 30 seconds and technical time-outs last 60 seconds, the duration of team time-out was more than twice the total duration of technical time-out (13.03% compared to 6.09%). The first reason for this difference is that there are almost three times as many team time-outs than technical time-outs recorded. If we take into consideration all three subcategories from both team and technical time-outs, the

average difference between their durations is only 16.47 seconds. In addition, technical time-outs were under electronic device control, whereas team time-outs were controlled by the referee, explaining why time limits were not observed more frequently for team time-outs.

Rest time between points was almost the same in the *Early* and *Middle phases* of the sets (11.46 seconds *Early*, 11.47 seconds *Middle*). While there were significant differences between pauses in different phases of the sets, post-hoc analysis showed that the source of variability was in prolonging pauses in the *Final* phase of the sets.

Substitution time took 6.05% of the match and 6.88% of the set. Substitution times varied considerably, with an average value of 10.27±4.72 seconds. Some substitutions lasted up to 60.17 seconds, the maximum value recorded.

Time between sets accounted for 12.04% of the match duration, with a mean value of 3.48±0.46 minutes. Given the wide range of values, from 2.40 minutes to 6.66 minutes, stricter systems should be defined to control the duration of time between sets.

The shortest parts of sets and matches did not significantly influence any aspect, although all values can help future research. Sanctions accounted for 0.31% of time in sets and 0.27% of time in matches, followed by the side change in the fifth set and other technical aspects (e.g. fixing a fallen antenna or fixing a problem with the referee's chair). No time was spent on injuries.

To make the game more attractive for spectators, an optimum relation should be established between work and rest time. All sports have a structure governing these variables. Based on the games in this study and in volleyball in general, the structure of work and rest time should be reversed to make matches more entertaining, exciting and unpredictable. This study shows that there is a basis for limiting pauses between rallies to 10 seconds, giving the player an optimum amount of time to reach the serving position and 5 seconds to execute the serve. On-the-fly substitutions of libero and middle blockers would need to be more

synchronized. The duration of team time-outs ranges considerably at present. They could be controlled electronically, in the same way as technical time-outs, to ensure a more stable time flow. Game analysis indicates that after the whistle for the end of time-out, there should be 10-12 seconds for all players to be ready on the court with the server in position. In this case, coaches will have 5 seconds to call a time-out, 30 or 60 seconds for the time-out and 10-12 seconds for preparing at the court. These time limits will increase the dynamics of the game and decrease rest time. Without the 15-second rule between rallies, there is enormous potential for calculating or taking advantage of moments of uncertainty, as shown by our study on different phases of the set. As sets to 21 points yield an average match duration of 70 minutes, it will be of great importance to conduct the same study on highest-level matches, above 23 years of age, to compare set and match durations.

The objective of the **fourth study** was to determine how the experimental rules influenced jumps by *In-game role* and *Level of set win*, and relate the number of hits and contacts to *In-game role* and *Set outcome.* A total of 25930 jumps, 10224 hits and 15706 contacts in 36 matches were analyzed, divided into two investigations: 1) investigation about jumps, and 2) investigation about hits and contacts.

Significant differences were found between jump type and *In-game role*, but none were found between jump type and *Level of set win*. In the second investigation, significant differences were noted between set *Winners* and *Losers* only for serves by setter and middle blocker; no statistical differences were found for the other *Hitting* performers. In contacts, significant differences were found for blocks by opposite and middle blocker in-game roles and for reception by libero in-game role.

The greatest number of jumps per match were performed during attacking (M = 103±27 jumps) and blocking (102±26 jumps), half as many during setting (M = 51±15 jumps), even fewer during Jump Float Serve (M = 38±15 jumps) and the least during Jump Spin Serve (M

= 22±8 jumps). Middle blocker was the most frequent jumper of all in-game roles, jumping the most during JFS, attack and block. Setter and outside hitter performed about 25% each of total jumps, with the setter jumping more only during setting, as expected. Outside hitter performed the most jumps during Jump Spin Serve (44% of total JSS). It was noted that the libero also jumped, but as expected, rarely and only during setting.

Setter and middle blocker are two in-game roles that make a difference in serves between *Winners* and *Losers*. Outside hitter hit the ball the most times in a match for serves (M = 22±7 hits) and attacks (M = 25±11 hits).

As the block is one of the most crucial elements for winning the match, our analysis aimed to determine which in-game role causes that difference. Opposite and middle blocker in-game roles accounted for the highest number of contacts in block performed by set *Winners*.

Reception is directly connected to and depends on the serve. However, the significant differences found for two in-game roles in serves (setter and middle blocker) affected contacts with the ball in reception by the libero from the set *Winners*. Because the *Winners* had more chances to serve, the *Losers* had more opportunities to receive.

Better teams had better servers in setter and middle blocker roles, better blockers in opposite and middle blocker roles, and better libero in-game roles. The libero followed a new trend of setting the ball with a jump after the initial setter defense action. Middle blocker was found to be the greatest performer of jumps and the most decisive in-game role both in serves and contacts in block.

The following characteristics are typical in volleyball games with the new rules tested for sets to 21 points and 15 seconds between points: Teams won an average match of 70 minutes with adequate rest time between points of 15 seconds, mostly performing Jump Float Serve with an optimum combination of other serving techniques without taking notable risks.

The team adequately distributed serves among the three serve zones but placed most serves in zones 6 and 5, then finished points mostly by attack using a well-prepared outside hitter. Decisive blocks were mostly performed by the middle blocker, the most frequent jumper, and the team libero performed setting with jumps.

Conclusions

This dissertation determines and explains the effects of the new rules tested (21-point sets and 15 seconds between points) on several selected components of the volleyball game. The investigation focused on serves, point-scoring plays in the final parts of the sets, work and rest time, and jumps, hits and contacts, examined according to the set as the basic unit of the match. The study gives detailed insight into the areas examined and presents trends and a basis for all researchers, coaches, practitioners and volleyball developers for use in future investigations into the development of volleyball or in applying the knowledge in practice. There is certainly more scope for studying the effects of the rules we have investigated and this study is simply a small step in that direction.

This thesis provides answers to four major areas of analysis.

- It was shown that the Jump Float Serve is the predominant serve type under the new rules. The setter, middle blocker and outside hitter in-game roles mostly used Jump Float Serve, whereas the opposite in-game role mostly performed Jump Spin Serve. Jump Float Serve appears to be a safe but complex weapon that becomes more frequent towards the end of the set, while the use of Jump Spin Serve decreased closer to the *Final* phase. The highest quality serves were performed from behind zone 1, with the greatest number of aces and free balls. Outside hitter and middle blocker were

found to be safe servers, while the setter was constantly an offensive server and the opposite was a highly offensive serving position, achieving the most aces and making the most errors. To win the set, the team must not only perform controlled serves, but also attack with minimum errors, ensuring that their serves result in as few first tempo attacks as possible. It was observed that most servers performed the Jump Float Serve after both types of of time-outs, indicating that most teams wanted to ensure a safe serve inside the court. Set *Winner* teams had clearly better results in all serve aspects than set *Loser* teams. Middle blocker was identified as the in-game role that combined serving zones the most, followed by both setter and outside hitter, while opposite served mostly from behind zone 1. Set *Winners* served more frequently from behind zone 6 and slightly less from behinds zones 1 and 5 compared to set *Losers.* Set *Winners* often deployed servers among all three serving zones. Most serves were executed from behind zone 1 to zone 6 (medium diagonal) and zone 5 (parallel).

- The block is identified as a decisive element in point-scoring plays in volleyball. As attack efficacy is similar between teams, the development of blocking and serving may have a much stronger influence in future on the results of the final set and the match. This study showed that the attack-spike is still the main point-scoring play in volleyball, with set *Losers* showing the high potential for winning points by attack-block out and attack-tipping. The outside-hitter, a dominant position in the team for finishing points, must be well-prepared physically through precise technical training and adequate development of physical skills from an early age. The analysis by *Level of Set Win* distribution showed that individual players are obliged to score points due to an imbalance in the quality of players in the team. Further study is required, particularly into the block and weaknesses in this action and the setter's action to trick the block.

- Game analysis related to work-rest time shows that there is a basis for limiting pauses between rallies to 10 seconds, giving players adequate time to reach the serving position, followed by 5 seconds to perform the serve. On-the-fly substitutions of libero and middle blockers need to be more synchronized. In an average 70-minute match with average sets of about 20 minutes, team and technical time-outs are two components of rest time that could be adapted to make volleyball a more dynamic sport. The technology for technical time-outs should be applied to team time-outs to establish a clearer, automated time limit. The time after the whistle for the end of technical or team time-outs should be limited to 10-12 seconds so that, after this time, all players must be ready on the court with the server in position. The whole process will change so that calling for a team time-out will be indirectly limited to about 5 seconds, the time that coaches theoretically had at the U23 Championship in Brazil. These time limits will increase the dynamics of the game, decreasing rest time, which takes up 65% of the whole match, and bringing into focus volleyball actions lasting mostly 5-10 seconds. The periods between rallies in the *Early* and *Middle* phases were almost identical, but shorter than in the *Final* periods. The difference was about 0.3 seconds, but it would be much longer without the experimental rule of 15 seconds between rallies. This shows that in the *Final* phase, when uncertainty is higher, most teams try to take advantage of longer pauses between rallies. This study can therefore also influence the development of the structure of the volleyball game.
- With respect to the type and number of jumps, hits and contacts, this investigation revealed major differences in jumps, hits and contacts between in-game roles. Middle blocker was identified as the most frequent jumping position, followed by outside hitter and setter. Middle blocker was found to be the most decisive in-game role in the serve and in contacts during block, followed by opposite, who makes a difference

between set *Winners* and *Losers.* Libero showed a new tendency of being setter with a jump after the initial setter defense action. This can provide a basis for future research, such as comparing the present rules (25-point set, no time limit between rallies) in all men's categories. The study does not examine the relation between jumps and set outcome, which could provide interesting information, including whether players from set *Winners* or *Losers* jump more frequently and which types of jumps they use. The complex study of each jump, contact and hit during every volleyball set provides an in-depth definition of the game.

- If these rules become part of the official volleyball rules, similar research could be conducted in all men's and women's categories. This study could then be a helpful guide in building team tactics and strategy. More attention should be focused on technical elements, quality of early selection and daring tactical innovations in future developments in volleyball. The study also provides insight for FIVB into the effect of the rules tested for further developments in the game. To bring the volleyball game to perfection, scientific analysis of all volleyball elements is vital in addressing the evolution of this sport.

Knowledge Dissemination

The major "culprit" for the rapid development of civilization throughout history is a process known as knowledge dissemination. One of the goals of researchers, educators, and tutors is to spread knowledge. While it is true that there is a lack of connection between the theory and practice of sports, the gap becomes narrower every year. Advances in information technology, the involvement of more and more people in professional and recreational sports, and the dependence of salaries on sport results have encouraged people to investigate, research and study structures, correlations, influences, effects and trends in all sports. There is

currently a great need for a close relation between coaches and those involved in the sport and in sports science. Experience has shown that no good theory exists without practice, and no good practice exists without good theory. Today sports scientists have an opportunity to disseminate their findings through scientific journals, magazines, conferences, congresses, workshops and, of course, in universities.

The first successful dissemination of the knowledge gained through this dissertation was the presentation of the abstract "Effects of experimental volleyball rules quantified by jumps, number of hits and contacts" at the 14th International Scientific Conference on Transformation Processes in Sport "Sport Performance" (Stankovic, Peric, Ruiz-Llamas, Quiroga-Escudero, 2017). Two articles are also in-press. The first of these is "Analysis of serve characteristics under rules tested at Volleyball Men's Under 23 World Championship", in-press at *Retos – Nuevas Tendencias en Educación Física, Deportes y Recreación*, and the second is "Effects of Tested Rules on Work-Rest Time in Volleyball", in-press at *Revista Motricidade.*

Currently, the plan is to publish all four articles in scientific journals, where anyone from the academic community and volleyball practice can access the information and apply it to their work. We will also search for an opportunity to present our studies at volleyball congresses and coaches' conferences, and to share the findings with FIVB, which is directly responsible for the development of volleyball.

Limitations and Future Directions

In this doctoral dissertation, four studies related to newly tested rules in volleyball were conducted, combining variables such as in-game role, *Level of set win* and *Set outcome*. While all researchers try to satisfy all aspects of studying a specific field, there is almost always scope to further complicate the studies or correct an oversight. The effect of the new rules

tested on the dynamic of the volleyball game, the topic of our work, can be perceived from many angles and by different approaches. In conducting the study, we kept to our defined framework. Although we researched 36 matches, we did not include all 38 matches played. It is always better to analyze a complete sample rather than a partial one, even if the missing sample is not of great importance, as in this case. A researcher who uses the whole sample will never have cause to wonder how the study may have differed if missing data had been included. As this study is among the first to study this topic, we did not have any studies for comparison, which can be considered a limitation. In the future, it may be very interesting to ask players and coaches to complete a detailed questionnaire with the main goal of obtaining their opinions about the rules changes, particularly in relation to the variables studied.

Future studies on serves under the new rules could measure serve speeds compared to previous studies under current rules. Other studies could measure the time between points under the current rules for U23 Men's Championships and compare them with our findings.

It would also be interesting to analyze point-scoring plays for whole matches and test the difference by score trend (*Early-Middle-Final* phase). Further studies could include analysis of all secondary factors that influence final actions, such as reception, setting and defense.

Future studies of time analysis could provide more information about work and rest time by measuring these elements by in-game role. Variables could be divided by types of movements such as a) standing-walking during rest time and b) volleyball movements divided into subcategories. This idea would be an enormous investment in time and energy, but it could ultimately reveal the relationship between rest and work time with movement categories for each in-game role.

Despite analyzing jumps, hits and contacts, our study does not include any relation between jumps and *Set outcome,* which could provide interesting results such as whether the

players from set *Winners* or *Losers* jump more frequently and which types of jumps they prefer.

If FIVB brings in the rules analyzed in this study, it will be very interesting to conduct the same studies for different ages and categories for both male and female teams to compare all the results and draw conclusions about the differences.

REFERENCES

References

Afonso, J., Esteves, F., Araújo, R., Thomas, L., & Mesquita, I. (2012). Tactical determinants of setting zone in elite men's volleyball. *Journal of Sports Science & Medicine, 11*(1), 64–70.

Agelonidis, Y. (2004). The jump serve in volleyball: from oblivion to dominance. *Journal of Human Movement Studies, 47*(3), 205–214.

Alemany, T. (2000). Superliga masculina: voley a fondo [Men's Superleague: Deep Volleyball]. *Set Volleyball*, *5*, 26-33.

Almujahed, S., Ongor, N., Tigmo, J., & Sagoo, N. (2013). *Sports analytics: Designing a volleyball game analysis decision-support tool using big data*. Fairfax, VA: George Mason University.

Anguera, M. T., & Hernández-Mendo, A. (2013). Observational methodology in sport sciences. *E-Balonmano.com: Revista de Ciencias del Deporte, 9*(3), 135-160.

Aouadi, R., Jlid, M., Khalifa, R., Hermassi, S., Chelly, M. S., Van Den Tillaar, R., & Gabbett, T. (2012). Association of anthropometric qualities with vertical jump performance in elite male volleyball players. *Journal of Sports Medicine and Physical Fitness, 52*(1), 11–17.

Araújo, R. M., Castro, J., Marcelino, R., & Mesquita, I. R. (2010). Relationship between the opponent block and the hitter in elite male volleyball. *Journal of Quantitative Analysis in Sports, 6*(4), 1–10.

Asterios, P., Kostantinos, C., Athanasios, M., & Dimitrios, K. (2009). Comparison of technical skills effectiveness of men's National Volleyball teams. *International Journal of Performance Analysis in Sport, 9*(1), 1–7.

Bellendier, J. (2002). Ataque de rotación en el voleibol, un enfoque actualizado [Rotation's attack in volleyball, an updated approach]. *Lecturas de Educación Física y Deportes, Digital Journal,* (51), 1-2. Retrieved from http://www.efdeportes.com/efd51

Bergeles, N. (1993). *Volleyball training*. Athens: Author [in Greek.]

Borràs, X., Balius, X., Drobnic, F., & Galilea, P. (2011). Vertical Jump Assessment on Volleyball: A Follow-Up of Three Seasons of a High-Level Volleyball Team. *Journal of Strength and Conditioning Research, 25*(6), 1686–1694.

Callejón-Lirola, D. (2006). Estudio y análisis del saque en el voleibol masculino de alto rendimiento. [Research and analysis of the serve in the current high performance Men's Volleyball]. *RICYDE. Revista Internacional de Ciencias del Deporte, 2*(5), 12–28.

Castro, J. M., & Mesquita, I. (2008). Estudo das implicações do espaço ofensivo nas características do ataque no Voleibol masculino de elite. *Revista Portuguesa de Ciências Do Desporto, 8*(1), 114–125.

Castro, J., Souza, A., & Mesquita, I. (2011). Attack efficacy in volleyball: elite male teams. *Perceptual and motor skills, 113*(2), 395-408.

Charitonidis, K., Patsiaouras, A., & Charitonidi, M. (2007). Comparison terms of the effectiveness of technical skills between the Greek national volleyball team and other European national teams. *Inquiries in Sport & Physical Education, 5*(3), 431 – 436.

Ciuffarella, A., Russo, L., Masedu, F., Valenti, M., Izzo, R. E., & De Angelis, M. (2013). Notational Analysis of the Volleyball Serve. *Timisoara Physical Education and Rehabilitation Journal, 6*(11), 29–35.

Claver, F., Jiménez, R., Gil, A., Moreno, A., & Moreno, M. P. (2013). Relationship between performance in game actions and the match result: a study in volleyball training stages. *Journal of Human Sport and Exercise*, *8*(Proc3), S651–S659.

Conejero, M., Claver, F., Fernández-Echeverría, C., Gil-Arias, A., & Moreno, M. P. (2017). Toma de decisiones y rendimiento en las acciones de juego intermedias y finalistas en voleibol, en sets con diferente resultado [Decision-making and performance in intermediate

and terminal actions in volleyball, according to the set result]. *Retos - Nuevas Tendencias en Educación Física Deporte y Recreación, 31*, 28-33.

Cox, R. H. (1974). Relationship between selected volleyball skill components and team performance of men's northwest 'AA' volleyball teams. *Research Quarterly. American Alliance for Health, Physical Education and Recreation, 45*(4), 441- 445.

Dávila-Romero, C., & García-Hermoso, A. (2012). Acciones finales discriminantes de voleibol en categorías de formación masculina: importancia del saque en los partidos igualados [Discriminatory volleyball final actions in male formative stages: importance of serve in equal matches]. *RICYDE. Revista Internacional de Ciencias del Deporte, 8*(8), 151–160.

Dávila-Romero, C., García-Hermoso, A., & Saavedra, J. M. (2012). Poder discriminatorio de las acciones finales de voleibol en etapas de formación [Discriminatory power of final game actions volleyball in formative stages]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 12*(48), 745–755.

Díaz Mariño, J. (2001). Evolución de los sistemas de entrenamiento en la evolución del saque desde la perspectiva cubana [Evolution of training systems during service evolution from the Cuban perspective]. In *VIII Congreso internacional sobre Entrenamiento Deportivo*. León, Spain: Real Federación Española de Voleibol.

Drikos, S., Kountouris, P., Laios, A., & Laios, Y. (2009). Correlates of team performance in volleyball. *International Journal of Performance Analysis in Sport, 9*(2), 149–156.

Dyba, W. (1982). Physiological and activity characteristics of volleyball. *Volleyball Technical Journal, 6*(3), 33–51.

Eom, H. J., & Schutz, R. W. (1992a). Statistical analyses of volleyball team performance. *Research Quarterly for Exercise and Sport, 63*(1), 11–18.

Eom, H. J., & Schutz, R. W. (1992b). Transition play in team performance of volleyball: a log-linear analysis. *Research Quarterly for Exercise and Sport, 63*(3), 261-269.

Escalante, Y., Saavedra, J. M., Mansilla, M., & Tella, V. (2011). Discriminatory power of water polo game-related statistics at the 2008 Olympic Games. *Journal of Sports Sciences, 29*(3), 291–298.

Fellingham, G. W., Collings, B. J., & McGown, C. M. (1994). Developing an optimal scoring system with a special emphasis on volleyball. *Research Quarterly for Exercise and Sport, 65*(3), 237–243.

Fellingham, G. W., Hinkle, L. J., & Hunter, I. (2013). Importance of attack speed in volleyball. *Journal of Quantitative Analysis in Sports, 9*(1), 87–96.

Fernández-Fernández, J., de la Aleja-Téllez, J. G., Moya-Ramón, M., Cabello-Manrique, D., & Méndez-Villanueva, A. (2013). Gender differences in game responses during badminton match play. *Journal of Strength and Conditioning Research, 29*(9), 2396-2404.

Fernández-Echeverría, C., Gil, A., Moreno, A., Claver, F., & Moreno, M. P. (2015). Analysis of the variables that predict serve efficacy in young volleyball players. *International Journal of Performance Analysis in Sport, 15*(1), 172–186.

FIVB. (n.d.). *Volleyball Information System (VIS)*. Retrieved October 1, 2013, from http://www.fivb.org/en/volleyball/VIS.asp

FIVB. (n.d.-a). *FIVB history*. Retrieved from http://www.fivb.org/EN/FIVB/FIVB_History.asp

FIVB. (n.d.-a). *The Game - Volleyball - Service*. Retrieved October 2, 2013, from http://www.fivb.org/TheGame/TheGame_Volleyball.htm

FIVB. (n.d.-b). *The Federation*. Retrieved from http://www.fivb.org/EN/FIVB/FIVB_Structure.asp

FIVB. (n.d.-b). *Volleyball history – The origins*. Retrieved October 3, 2013, from http://www.fivb.org/en/volleyball/History.asp

FIVB. (n.d.-c). *The Game - Volleyball Rules; Major changes in volleyball rules*. Retrieved from http://www.fivb.org/TheGame/TheGame_VolleyballRules.htm

FIVB. (2000). *VIS (Volleyball Information System) STAFF Guidelines - Evaluation Criteria 2000*. Lausanne, Switzerland: FIVB.

FIVB. (2012). FIVB, official volleyball rules 2013-2016. *In 33rd FIVB Congress*. Anaheim, CA: FIVB. Retrieved from http://www.fivb.org/EN/Refereeing-Rules/documents/FIVB-Volleyball_Rules2013-EN_20121214.pdf

FIVB. (2013). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved October 1, 2013, from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2013a). *Competition formula*. FIVB. Retrieved from www.fivb.org/EN/volleyball/competitions/U23/Men/2013/Formula.asp

FIVB. (2013a). *New rules test to be held in Brazil only*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=43147&Language=en#.VMOwz8aI9YE

FIVB. (2013b). *New rules test to be held in Brazil only*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=43147&Language=en#.VMOwz8aI9YE

FIVB. (2013b). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2013c). *Twenty-one point rule to be tested at U23 World Championships*. Retrieved from http://www.fivb.org/viewPressRelease.asp?No=42863&Language=en#.VL5CBcaI9YE

FIVB. (2014). Official Volleyball Rules 2015-2016. In *34th FIVB Congress*. Sardinia,

Italy: FIVB. Retrieved from http://www.fivb.org/en/Refereeing-Rules/documents/FIVB-Volleyball_Rules2013-EN_v2_20130422.pdf

FIVB. (2015). *Technical Survey (Summary of Men's U23 World Championship)*. Retrieved from

http://www.fivb.org/EN/Technical-Coach/Document/FIVB_TE_U23_M_Summary.pdf

FIVB. (2015). *The Game - Volleyball Rules; Major changes in volleyball rules*. Retrieved January 1, 2015, from http://www.fivb.org/TheGame/TheGame_VolleyballRules.htm

Fleiss, J. L., Levin, B. A., & Paik, M. C. (2003). *Statistical Methods for Rates and Proportions (3rd ed.)*. Hoboken, NJ: John Wiley & Sons.

Fraile, F. (1999). *Anticipación de la jugada* [Anticipation of the game]. Cádiz, Spain: Federación Andaluza de Voleibol.

Fry, A. C., Kraemer, W. J., Weseman, C. A., Conroy, B. P., Gordon, S. E., Hoffman, J. R., & Maresh, C. M. (1991). The effects of an off-season strength and conditioning program on starters and non-starters in women's intercollegiate volleyball. *The Journal of Strength & Conditioning Research, 5*(4), 174–181.

Fröhner, B. (1995). 100 years of volleyball [100 años de voleibol]. *International Volley Teach (Spanish edition), 3*(95), 5-9.

García-Alcaraz, A., Palao, J. M., & Valadés, D. (2012). Análisis de la duración de juego y la competitividad en diferentes categorías de competición en voleibol masculino [Analysis of the match duration and competitivity on different age groups in male volleyball]. In *Análisis del Rendimiento Deportivo: VII Congreso Internacional de la Asociación Española de Ciencias del Deporte* (p. 416). Granada, Spain: Faculty of Sports Science, University of Granada.

García-Tormo, J. V, Redondo, J. C., Valladares, J. A., & Morante, J. C. (2006). Análisis del saque de voleibol en categoría juvenil femenina en función del nivel de riesgo asumido y su eficacia [Analysis of volleyball serve in junior female category by risk taken and efficiency]. *Motricidad. European Journal of Human Movement, 16*, 99–121.

George, C. (1992). Blocking and how to read the hitter. In *Coaching Volleyball, 6*, 8–10.

Giatsis, G. (2003). The effect of changing the rules on score fluctuation and match duration in the FIVB women's beach volleyball. *International Journal of Performance Analysis in Sport, 3*(1), 57–64.

Giatsis, G., & Zahariadis, P. (2008). Statistical Analysis of Men's FIVB Beach Volleyball Team Performance. *International Journal of Performance Analysis in Sport, 8*(1), 31–43.

Giddens, S., & Giddens, O. (2005). *Volleyball: Rules, Tips, Strategy, and Safety*. The Rosen Publishing Group.

Gil-Arias, A., Claver, F., Fernández-Echeverría, C., Moreno, A., & Moreno, M. P. (2016). Análisis comparativo del saque en voleibol entre los Campeonatos de España 2005-2010 [Comparative Analysis of the Serve in Volleyball between the Spanish Championships 2005-2010]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 16*(62), 439-456.

Girard, O., Chevalier, R., Habrard, M., Sciberras, P., Hot, P., & Millet, G. P. (2007). Game analysis and energy requirements of elite squash. *Journal of Strength and Conditioning Research, 21*(3), 909–914.

Gónzález-Silva, J., Moreno, A., Fernández-Echeverría, C., Conejero, M., & Moreno, M. P. (2016). Características de la colocación en voleibol, en etapas de formación, en sets ganados y perdidos [Characteristics of the set in volleyball, in formative stages, in set win and

lost]. *Retos - Nuevas Tendencias en Educación Física Deporte y Recreación, 30*, 43-47.

González, C., Ureña, A., Santos, J. A., Llop, F., & Navarro, F. (2001). Características del juego del voleibol tras los nuevos cambios en el reglamento [Volleyball game characteristics after the new rules changes]. *Lecturas de Educación Física y Deportes, Digital Journal, 7*(42), 1-2. Retrieved from http://www.efdeportes.com/efd42/voley.htm

Gravetter, F. J., & Wallnau, L. B. (2004). *Statistics for the behavioral sciences* (6th ed.). Belmont, CA: Wadsworth.

Grgantov, Z., Dizdar, D., & Janković, V. (1998). Structural analysis of the volleyball game elements based on certain anthropological features. *Kinesiology*, *30*(1), 44-51.

Grgantov, Z., Katić, R., & Janković, V. (2006). Morphological characteristics, technical and situation efficacy of young female volleyball players. *Collegium Antropologicum, 30*(1), 87–96.

Gruić, I., Vuleta, D., & Milanović, D. (2006). Performance indicators of teams at the 2003 Men's World Handball Championship in Portugal. *Kinesiology, 38*(2), 164–175.

Häyrinen, M., Hoivala, T., & Blomqvist, M. (2004). Differences between winning and losing teams in men's European top-level volleyball. In P. O'Donoghue, & M. Hughes (Eds.), *Proceedings of VI Conference Performance Analysis of Sport* (pp. 491–496). Belfast, Northern Ireland: University of Wales Institute Cardiff.

Häyrinen, M., Hoivala, T., & Luhtanen, P. (2000). Factors affecting winning in men's International level volleyball. In J. Avela, P. Komi, & J. Komulainen (Eds.), *5th Annual Congress of the European College of Sport Sciences* (p. 339). Jyväskylä, Finland: European College of Sport Sciences.

Häyrinen, M., Lahtinen, P., Mikkola, T., Honkanen, P., Paananen, A., & Blomqvist, M. (2007). Serve speed analysis in men's volleyball. *Science for Success II*, 10. Retrieved from http://www.kihu.fi/tuotostiedostot/julkinen/2007_hay_serve_spee_10000.pdf

Häyrinen, M., Lehto, H., Mikkola, T., Honkanen, P., Lahtinen, P., Paananen, A., & Blomqvist, M. (2011). Time analysis of men's and youth boy's top-level volleyball. *British Journal of Sports Medicine, 45*(6), 542.

Huang, C., & Hu, L. H. (2007). Kinematic analysis of volleyball jump top spin and float serve. In H. J. Menzel, & M. H. Chages (Eds.), *XXV International Symposium on Biomechanics in Sports* (pp. 333–336). Ouro Preto – Brazil.

Hughes, M., & Franks, I. M. (2004). *Notational analysis of sport: Systems for better coaching and performance in sport* (2nd ed.). London, England: Routledge.

Hughes, M., & James, N. (2008). Notational analysis of soccer. In F. Prot (Ed.), *Kinesiology Research Trends and Applications – Research Methodology: Proceedings of the 5th International Scientific Conference on Kinesiology* (pp. 644-660). Zagreb, Croatia: University of Zagreb

Hummel, L. (1997). *U.S. Patent No. 5,692,978*. Washington, DC: U.S Patent and Trademark Office. Volleyball block back device.

Humski, L., & Skocir, Z. (2011). Volleyball Information System. In *11th International Conference on Telecommunications - ConTel* (pp. 117–124). Graz - Austria: University of Zagreb Faculty of Electrical Engineering and Computing/Department of Electrical Engineering.

João, P., Leite, N., Mesquita, I., & Sampaio, J. (2010). Sex differences in discriminative power of volleyball game-related statistics. *Perceptual and Motor Skills, 111*(3), 893–900.

João, P., Silva, M., Lacerda, D., & Vaz, L. (2012). The scoring skills which discriminate result, according set number in World Championship volleyball 2010. In R. Meeusen, J. Duchateau, B. Roelands, M. Klass, B. De Geus, S. Baudry, & E. Tsolakidis (Eds.), *XVII annual Congress of the European College of sport science* (Vol. 30, pp. 149–

150). Bruges, Belgium: European College of Sport Science.

Katsikadelli, A. (1995). Tactical analysis of the attack serve in high-level volleyball. *Journal of Human Movement Studies, 29*(5), 219-228.

Katsikadelli, A. (1996). A comparative study of the attack serve in high-level volleyball tournaments. *Journal of Human Movement Studies, 30*(6), 259-268.

Katsikadelli, A. (1997). Tactical analysis of the serve in volleyball in relation to the execution distance. *Coaching and Sport Science Journal, 2*(2), 13–16.

Kenny, B., & Gregory, C. (2006). *Volleyball: Steps to success*. Campaign, IL: Human Kinetics.

Kountouris, P., & Laios, Y. (2000). Changes affecting on the game of volleyball by the enforcement of the new regulations. *Coaching Volleyball, 17*(1), 26–30.

Kovacs, M. (2004). A comparison of work/rest intervals in men's professional tennis. *Medicine and Science in Tennis, 9*(3), 10–11.

Lago, C. (2009). The influence of match location, quality of opposition, and match status on possession strategies in professional association football. *Journal of Sports Sciences, 27*(13), 1463-1469.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*(1), 159-174.

Lee, K. T., & Chin, S. T. (2004). Strategies to serve or receive the service in volleyball. *Mathematical Methods of Operations Research, 59*(1), 53–67.

Lidor, R., & Mayan, Z. (2005). Can beginning learners benefit from preperformance routines when serving in volleyball? *The Sport Psychologist, 19*(4), 343–363.

Liu, G. C., Huang, G. C., & Huang, C. (2001). Effects of different approach lengths of the last stride on volleyballer run up vertical jump. In J. R. Blackwell, & R. H. Sanders, *Proceedings of XIX International Symposium on Biomechanics in Sports* (pp. 120–123). San

Francisco, CA: University of San Francisco.

Lobietti, R. (2009). A review of blocking in volleyball: from the notational analysis to biomechanics. *Journal of Human Sport & Exercise, 4*(2), 93–99.

López, J. P. (2013). *Analysis of the service as a performance factor in high-level volleyball and beach volleyball* (doctoral dissertation). University of VIC – Central University of Catalonia, Barcelona, Spain.

López-Martínez, A., & Palao, J. M. (2009). Effect of serve execution on serve efficacy in men's and women's beach volleyball. *International Journal of Applied Sports Sciences, 21*(1), 1–16.

Lucas, J. (1985) *Pass, set, crush: volleyball illustrated*. Wenachee, WA: Euclid Northwest Publications.

Mackenzie, S., Kortegaard, K., Levangie, M., & Barro, B. (2012). Evaluation of two methods of the Jump Float Serve in volleyball. *Journal of Applied Biomechanics, 28*(5), 579–586.

Maia, N., & Mesquita, I. (2006). Characterization of the serve in the female volleyball in high competitive outcome. In H. Dancs, M. Hughes, & P. O'Donoghue (Eds.), *Proceedings of the World Congress of Performance Analysis of Sport VII*. Szombathely, Hungary: Berzsenyi College.

Marcelino, R., Afonso, J., Moraes, J. C., & Mesquita, I. (2014). Determinants of attack players in high-level men's volleyball. *Kinesiology, 46*(2), 234-241.

Marcelino, R., & Mesquita, I. (2006). Characterizing the efficacy of skills in high performance competitive volleyball. In H. Dancs, M. Hughes, & P. O'Donoghue (Eds.), *Proceedings of the World Congress of Performance Analysis of Sport VII* (pp. 491–496). Szombathely, Hungary: Berzsenyi College.

Marcelino, R., & Mesquita, I. (2008). Associations between performance indicators

and set's result on male volleyball. In D. Milanović, & F. Prot (Eds.), *Kinesiology research trends and applications – Top-level Sports: Proceedings of the 5th International Scientific Conference on Kinesiology* (pp. 955–957). Zagreb, Croatia: Faculty of Kinesiology, University of Zagreb.

Marcelino, R., Mesquita, I., & Afonso, J. (2008). The weight of terminal actions in volleyball. Contributions of the spike, serve and block for the teams' rankings in the World League 2005. *International Journal of Performance Analysis in Sport, 8*(2), 1–7.

Marcelino, R., Mesquita, I., Castro, J., & Sampaio, J. (2008). Sequential analysis in volleyball attack performance: a log-linear analysis. *Journal of Sport Sciences, 26*(suppl. 2), S83-S84.

Marcelino, R., Mesquita, I., Palao, J. M., & Sampaio, J. (2009). Home advantage in high-level volleyball varies according to set number. *Journal of Sports Science and Medicine, 8*(3), 352–356.

Marcelino, R., Mesquita, I., & Sampaio, J. (2010). Estudo dos indicadores de rendimento em voleibol em função do resultado do set [Study of performance indicators in male volleyball according to the set results]. *Revista Brasileira de Educação Física e Esporte, 24*(1), 69-78.

Marcelino, R., Mesquita, I., & Sampaio, J. (2011). Effects of quality of opposition and match status on technical and tactical performances in elite volleyball. *Journal of Sports Sciences, 29*(7), 733–741.

Marcelino, R., Mesquita, I., Sampaio, J., & Anguera, M. T. (2009). Ventaja de jugar en casa en voleibol de alto rendimiento [Home advantage in high-level volleyball]. *Revista de Psicología del Deporte, 18*(2), 181–196.

Marcelino, R., Mesquita, I., Sampaio, J., & Moraes, J. C. (2010). Estudo dos indicadores de rendimento em voleibol em função do resultado do set [Study of the

performance indicators in Volleyball according to the set outcome]. *Revista Brasileira de Educação Física E Esporte, 24*(1), 69–78.

Marelić, N. (1994). Utjecaj situacijskih parametara u odbojci na rezultat u odbojkaškom setu [Influence of situational parameters on outcome of a volleyball set] *Hrvatski Športskomedicinski Vjesnik, 9*(2-3), 70-76.

Marelić, N. (1998). *Kineziološka analiza karakteristika ekipne igre odbojkaša juniora* [Kinesiological analysis of the junior volley-ball team play characteristic] (Unpublished doctoral dissertation, University of Zagreb). Zagreb, Croatia: Faculty of Kinesiology, University of Zagreb.

Marelić, N., Rešetar, T., & Janković, V. (2004). Discriminant analysis of the sets won and the sets lost by one team in A1 Italian volleyball league – A case study. *Kinesiology, 36*(1), 75-82.

Marelić, N., Rešetar, T., Zadražnik, M., & Đurković, T. (2005). Modeling of situation parameters in top level volleyball. In D. Milanović, & F. Prot, *Science and profession - challenge for the future: Proceedings of the 4th International Scientific Conference on Kinesiology* (pp. 459–462). Opatija, Croatia: Faculty of Kinesiology, University of Zagreb.

Marelić, N., Žufar, G., & Omrčen, D. (1998). Influence of some situation-related parametres on the score in volleyball. *Kinesiology, 30*(2), 55-65.

Masumura, M., Marquez, W. Q., Koyama, H., & Michiyoshi, A. (2007). A biomechanical analysis of serve motion for elite male volleyball players in official games. *Journal of Biomechanics, 40*(S2), S744.

Matias, C. J. A., & Greco, P. J. (2011). De Morgan ao voleibol moderno: o sucesso do Brasil e a relevância do levantador [From Morgan to modern volleyball: The success of Brazil and the relevance of the setter]. *Revista Mackenzie de Educação Física e Esporte, 10*(2), 49-63.

McCutcheon, H. (2013, September 16). Re: Game changer [Web log message]. Retrieved from http://www.teamusa.org/usa-volleyball/features/2014/september/16/game-changers

McGown, C. (1994). *Science of coaching volleyball*. Human Kinetics Publishers.

McLaughlin, J. (2006) Attacking. In K. LeNoerg (Ed.), *Volleyball skills and drills: Ameri- can Volleyball Coaches Association* (pp. 53-68). Champaign, IL: Human Kinetics.

Mesquita, I., Manso, F., & Palao, J. M. (2007). Defensive participation and efficacy of the libero in volleyball. *Journal of Human Movement Studies, 52*(2), 95–107.

Miller, B. (2005). *The Volleyball Handbook: Winning essentials for players and coaches.* Champaign. IL: Human Kinetics.

Molina, J. J., Santos del Campo, J. A., Barriopedro, M. I., & Delgado, M. A. (2004). Análisis de juego desde el modelo competitivo: un ejemplo aplicado al saque en voleibol [Game analysis from the competitive model: an example applied to serve in volleyball]. *KRONOS, III*(5), 37–45.

Monge, M. Á. (2007). *Construcción de un sistema observacional para el análisis de la acción de juego en voleibol* [Construction of an observational system for the analysis of volleyball game plays]. A. Coruña (Ed.). Coruña, Spain: University of Coruña, Publication Service.

Monteiro, R., Mesquita, I., & Marcelino, R. (2009). Relationship between the set outcome and the dig and attack efficacy in elite male volleyball games. *International Journal of Performance Analysis in Sport, 9*(3), 294–305.

Moras, G., Buscà, B., Peña, J., Rodriguez, S., Vallejo, L., Tous-Fajardo, J., & Mujika, I. (2008). A comparative study between serve mode and speed and its effectiveness in a high-level volleyball tournament. *Journal of Sports Medicine and Physical Fitness, 48*(1), 31–36.

Moreno, M. P., García de Alcaráz, A., Moreno, A., Molina, J. J., & Santos, J. A.

(2007). Estudio de la dirección del saque en la superliga masculina de voleibol [Study of serve direction in elite men's volleyball]. *Motricidad. European Journal of Human Movement, 18*, 111–134.

Moreno, A., Moreno, M. P., Julián, J. A., & Del Villar, F. (2005). Estudio de la relación entre la eficacia de las acciones de primer contacto y la eficacia del ataque en voleibol masculino de alto nivel [Study of the relation between the efficiency of first contact plays and the efficiency of the attack in elite men's volleyball]. *KRONOS, IIII*, 57–61.

Neville, W. (1994) *Serve it up: volleyball for life*. Mountain View, CA: Mayfield.

O'Donoghue, P., & Ingram, B. (2001). A notational analysis of elite tennis strategy. *Journal of Sports Sciences, 19*(2)*,* 107-115.

Oliveira, R., Mesquita, I., & Oliveira, M. (2005). Caracterização da eficácia do bloco no voleibol de elevado rendimento competitivo [Characterization of the efficiency of the block in high level volleyball competition]. *Lecturas de Educación Física y Deportes, Digital Journal,* (84). Retrieved from http://www.efdeportes.com/efd84/voleibol.htm

Palao, J. M., Manzanares, P., & Ortega, E. (2015). Design, validation, and reliability of an observation instrument for technical and tactical actions in indoor volleyball. *European Journal of Human Movement, 34*, 75-95.

Palao, J. M., Manzanares, P., & Valadés, D. (2015). Way of scoring of Spanish first division volleyball teams in relation to winning/losing, home/away, final classification, and type of confrontation. *Journal of Human Sport & Exercise, 10*(1), 36-46.

Palao, J. M., Santos, J. A., & Ureña, A. (2004). Effect of team level on skill performance in volleyball. *International Journal of Performance Analysis in Sport, 4*(2), 50–60.

Palao, J. M., Valadés, D., Manzanares, P., & Ortega, E. (2014). Physical actions and work-rest time in men's beach volleyball. *Motriz: Revista de Educação Física, 20*(3), 257–

261.

Palao, J. M., Valadés, D., & Ortega, E. (2012). Match duration and number of rallies in men's and women's 2000-2010 FIVB world tour beach volleyball. *Journal of Human Kinetics, 34*(1). 99-104.

Palou, N. (1992). Historia del voleibol [Volleyball history]. In COE (Ed.). *Voleibol* (pp.15-58). Madrid: COE.

Paolini, M. (2001) *Il Nuovo sistema pallavolo: tecnica, tattica e didattica con esercitazioni pratiche* [The new volleyball system: technique, tactic, and didactic with practical exercises]. Perugia, Italy: Calzetti & Mariucci.

Papageorgiou, A., & Spitzley, W. (2003). *Handbook for competitive volleyball*. Meyer & Meyer Verlag.

Parisi, F., & Raiola, G. (2014a). The serve in under 12-13 Italian volleyball team. *Journal of Human Sport & Exercise, 9*(Proc1), S588-S591.

Parisi, F., & Raiola, G. (2014b). Video analysis in youth volleyball team. *Journal of Human Sport & Exercise, 9*(Proc1), S584-S587.

Patsiaouras, A., Moustakidis, A., Charitonidis, K., & Kokaridas, D. (2011). Technical skills leading in winning or losing volleyball matches during Beijing Olympic Games. *Journal of Physical Education and Sport, 11*(2), 149–152.

Peña, J., Rodriquez-Guerra, J., Busca, B., & Serra, N. (2013). Which skills and factors better predict winning and losing in high-level men's volleyball? *Journal of Strength and Conditioning Research, 27*(9), 2487–2493.

Pfeifer, P. E., & Deutsch, S. J. (1981). A probabilistic model for evaluation of volleyball scoring systems. *Research Quarterly for Exercise and Sport, 52*(3), 330–338.

Polglaze, T., & Dawson, B. (1992). The physiological requirements of the positions in state league volleyball. *Sports Coach, 15*, 32–37

Quiroga, M. E., Garcia-Manso, J. M., Rodriguez-Ruiz, D., Sarmiento, S., De Saa, Y., & Moreno, M. P. (2010). Relation between in-game role and service characteristics in elite women's volleyball. *Journal of Strength and Conditioning Research, 24*(9), 2316–2321.

Quiroga, M. E., Rodriguez-Ruiz, D., Sarmiento, S., Muchaga, L., Grigoletto, M., & Garcia-Manso, J. (2012). Characterisation of the main playing variables affecting the service in high-level women's volleyball. *Journal of Quantitative Analysis in Sports, 8*(1), 1-11.

Raiola, G., Altavilla, G., De Luca, C., & Di Tore, P. A. (2016). Analysis on some aspects of the service in volleyball. *Sport Science 9*(1), 74-77.

Raiola, G., Parisi, F., Giugno, Y., & Di Tore, P. A. (2013). Video analysis applied to volleyball didactics to improve sport skills. *Journal of Human Sport & Exercise, 8*(Proc2), S307-S313.

Rentero, L., João, P. V., & Moreno, M. P. (2015). Análisis de la influencia del líbero en diferentes fases del juego en voleibol [Analysis of the influence of the líbero in different phases of game in volleyball]. *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 15*(60), 739-756.

Rodriguez-Ruiz, D., Quiroga, M. E., Miralles, J. A., Sarmiento, S., De Saá, Y., & García-Manso, J. M. (2011). Study of the technical and tactical variables determining set win or loss in top-level European men's volleyball. *Journal of Quantitative Analysis in Sports, 7*(1), 1–15.

Ruiz, N. M., & Hernandez, P. P. (2003). Algunas características del saque desde el voleibol tradicional hasta el rally point [Some characteristics of the serve from traditional volleyball to the rally point]. *EFDeportes Revista Digital, 9*(66), 1–4. Retrieved from http://www.efdeportes.com/efd66/voley.htm

Sampaio, J., Godoy, S. I., & Feu, S. (2004). Discriminative power of basketball game-related statistics by level of competition and sex. *Perceptual and Motor Skills, 99*(3 suppl),

1231–1238.

Santos, J. A., Viciana, J., & Delgado, M. A. (1996). *La actividad fisica extraescolar en los centros educativos. Voleibol*. [Extracurricular physical activity in schools. Volleyball]. Madrid. Consejo Superior de Deportes.

Sánchez-Moreno, J., Marcelino, R., Mesquita, I., & Ureña, A. (2015). Analysis of the rally length as a critical incident of the game in elite male volleyball. *International Journal of Performance Analysis in Sport, 15*(2), 620–631.

Selinger, A., & Ackermann-Blount, J. (1986). *Arie Selinger's power volleyball*. New York, NY: St. Martin Press.

Sheppard, J., Borgeaud, R., & Strugnell, A. (2008). Influence of stature on movement speed abilities in elite volleyball players. *Journal of Australian Strength and Conditioning, 16*, 12–14.

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. *Journal of Strength and Conditioning Research, 22*(3), 758–765.

Sheppard, J. M., Dingley, A. A., Janssen, I., Spratford, W., Chapman, D. W., & Newton, R. U. (2011). The effect of assisted jumping on vertical jump height in high-performance volleyball players. *Journal of Science and Medicine in Sport, 14*(1), 85–89.

Sheppard, J. M., Gabbett, T. J., & Stanganelli, L. C. (2009). An analysis of playing positions in elite men's volleyball: considerations for competition demands and physiologic characteristics. *Journal of Strength and Conditioning Research, 23*(6), 1858–1866.

Sheppard, J. M., Gabbett, T., Taylor, K. L., Dorman, J., Lebedew, A. J., & Borgeaud, R. (2007). Development of a repeated-effort test for elite men's volleyball. *International Journal of Sports Physiology and Performance, 2*(3), 292–304.

Smekal, G., Von Duvillard, S. P., Rihacek, C., Pokan, R., Hofmann, P., Baron, R., … Bachl, N. (2001). A physiological profile of tennis match play. *Medicine and Science in Sports and Exercise, 33*(6), 999–1005.

Smith, D. J., Roberts, D., & Watson, B. (1992). Physical, physiological and performance differences between Canadian national team and universiade volleyball players. *Journal of Sports Sciences, 10*(2), 131–138.

Stankovic, M., Peric, D., Ruiz-Llamas, G., & Quiroga-Escudero, M. E. (2017). Effects of experimental volleyball rules quantified by jumps, number of hits and contacts. In D. Bjelica, S. Popovic, & S. Akpinar (Eds.), *Proceedings of the 14th International Scientific Conference on Transformation Processes in Sport - Sport Performance* (pp. 39-40). Budva, Montenegro: Montenegrin Sports Academy.

Stork, J. (1992). Set it sweet. *Volleyball Monthly, 4*, 32-34

Strohmeyer, H. S. (1988). *An analysis of selected cinematographic and descriptive variables in the jump and conventional overhand serves of the United States Olympic athletes.* Laramie, WY: University of Wyoming.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston, MA: Allyn & Bacon/Pearson Education.

Tabachnick, B. G., & Fidell, L. S. (2013). *Using multivariate statistics* (6th ed.). Boston: Pearson Education.

Thissen-Milder, M., & Mayhew, J. L. (1991). Selection and classification of high school volleyball players from performance tests. *Journal of Sports Medicine and Physical Fitness, 31*(3), 380–384.

Tillman, M. D., Hass, C. J., Brunt, D., & Bennet, G. R. (2004). Jumping and landing techniques in elite women's volleyball. *Journal of Sports Science and Medicine, 3*(1), 30–36.

Tsimpiris, A., Tsamourtzis, E., Sfingos, N., Zaggelidis, G., & Zaggelidis, S. (2006). A

multimedia application for tactic analysis of basketball games. *Revista Stiinta Sportului, 52*, 17–39.

Tsivika, M., & Papadopoulou, S. D. (2008). Evaluation of the technical and tactical offensive elements of the Men's European Volleyball Championship. *Physical Training*. Retrieved from http://ejmas.com/pt/2008pt/ptart_tsivika_0812.html

Unforced error. (n.d.). In *Oxford Dictionaries*. Retrieved from http://www.oxforddictionaries.com/definition/english/unforced-error

Ureña, A., Gallardo, C., Delgado, J., Hernández, E., & Calvo, R. (2000). Estudio sobre la evolución de las reglas de juego en voleibol [Study on the evolution of game rules in volleyball]. *Habilidad Motriz: Revista de Ciencias de la Actividad Fisica y del Deporte, 16*, 32–39.

Ureña, A., Santos, J. A., Martínez, M., Calvo, R., Hernández, E., & Oña, A. (2001). El principio de variabilidad como factor determinante en la táctica individual del saque en voleibol masculino de nivel internacional [The principle of variability as determinate factor in the individual tactics of serve in men's international volleyball level]. *Revista Motricidad, 7*, 63–74.

USAV (2009). *Volleyball Systems & Strategies*. Champaign, IL: Human Kinetics.

Viitasalo, J. T., Rusco, H., Pajala, O., Rahkila, P., Ahila, M., & Montonen, H. (1987). Endurance requirements in volleyball. *Canadian Journal of Applied Sports Science, 12*(4), 194–201.

Vilamitjana, J. J., Soler, D., Barrial, J. M., Del Grecco, P., Montes De Oca, M., & Rodriguez, F. (2008). Jumping profile of elite volleyball male players by field positions during a competitive season. *Medicine & Science in Sports and Exercise, 40*(5), S383.

Vunić, M., Hraški, Z., & Marelić, N. (2005). Comparative kinematical analysis of novice and elite volleyball spike technique. In D. Milanović, & F. Prot, *Science and*

profession - challenge for the future: Proceedings of the 4th International Scientific Conference on Kinesiology (pp. 819-821). Opatija, Croatia: Faculty of Kinesiology, University of Zagreb.

Weishoff, P. (2002) Attacking. In D. Shondell and C. Reynaud (Eds.), *The volleyball coaching bible* (pp. 199-226). Boston, MA: Human Kinetics.

Wise, M. (2002). Serving in. In *The Volleyball coaching bible* (pp. 163–176). Champaign, IL: Human Kinetics.

Yiannis, L., & Panagiotis, K. (2005). Evolution in men's volleyball skills and tactics as evidenced in the Athens 2004 Olympic Games. *International Journal of Performance Analysis in Sport, 5*(2), 1–8.

Zetou, E., Moustakidis, A., Tsigilis, N., & Komninakidou, A. (2007). Does effectiveness of skill in Complex I predict win in men's Olympic volleyball games? *Journal of Quantitative Analysis in Sports, 3*(4), 1-9.

Zetou, E., Tsigilis, N., Moustakidis, A., & Komninakidou, A. (2006). Playing characteristics of men's Olympic volleyball teams in complex II. *International Journal of Performance Analysis in Sport, 6*(1), 172-177.

Zhang, R. (1996). Fundamental technical and tactical aspects of setter training. *International Volleytech, 3*, 20-25.