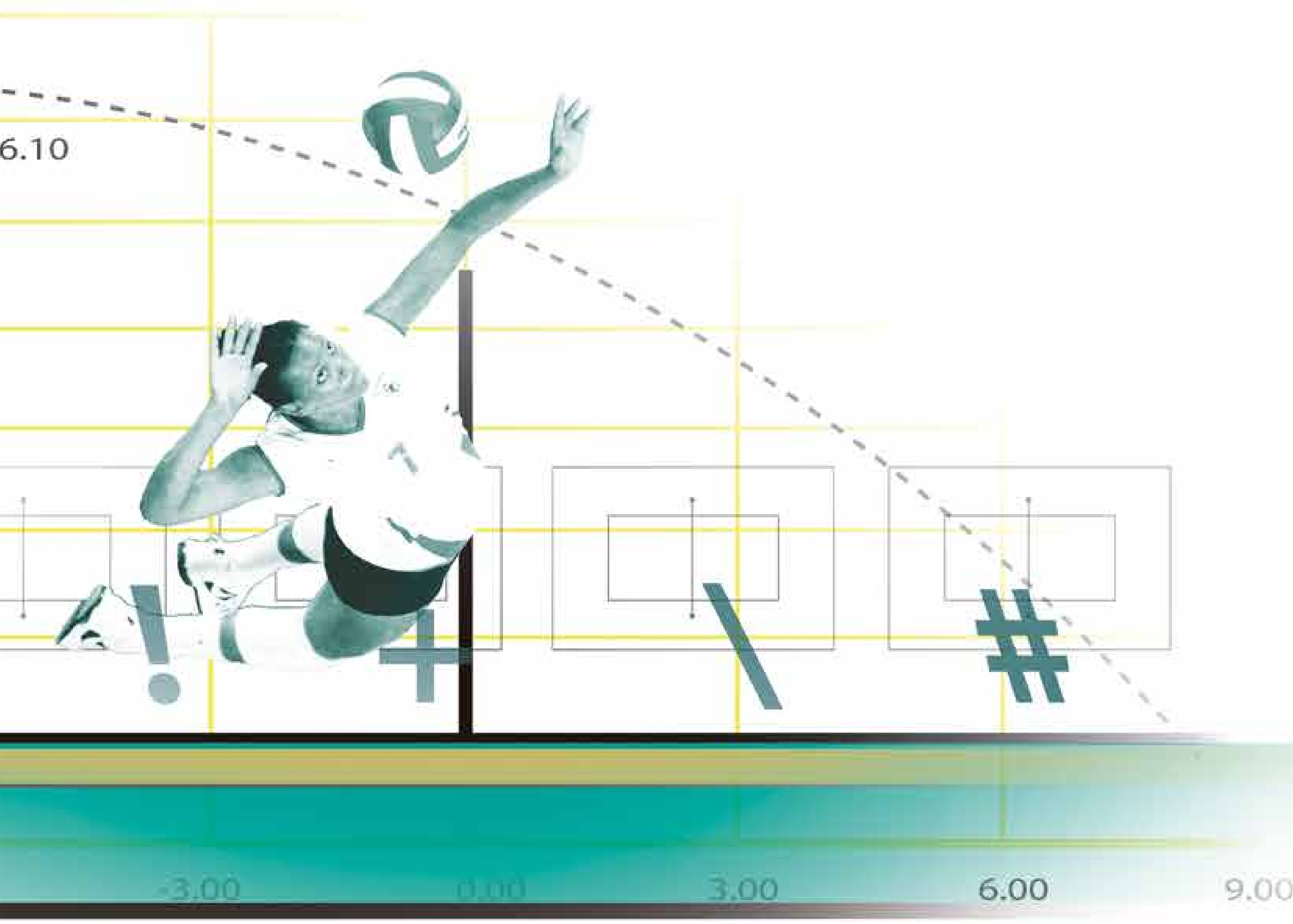
ANALYSIS OF THE SERVICE AS A PERFORMANCE FACTOR IN HIGH-LEVEL VOLLEYBALL AND BEACH VOLLEYBALL



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A THESIS SUBMITTED TO THE FACULTY OF EDUCATION, HUMANITIES AND TRANSLATION IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

PHD PROGRAM IN EDUCATIONAL INNOVATION AND INTERVENTION IN CONTEXTS OF DIVERSITY.

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UVIC UNIVERSITAT DE VIC

“If you’re trying to achieve, there will be roadblocks. I’ve had them; everybody has had them. But obstacles don’t have to stop you. If you run into a wall, don’t turn around and give up. Figure out how to climb it, go through it, or work around it.” ~ Vince Lombardi

“Coaching is about finding a system that works for your players. There are some underlying principles which are applied in any coaching situation but it’s about picking the lock to get this group of players to play the best volleyball they’re capable of playing for a long period of time.” ~ Hugh McCutcheon

“I’ve heard people say that maybe we’d be better served had we lost. I was kind of wondering what profession they were in. I wouldn’t want a lawyer representing me to think like that. I wouldn’t want a doctor operating on me to think like that.” ~ Russ Rose

UNIVERSITAT DE VIC

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ABSTRACT

The ultimate goal of this Dissertation was to identify some critical aspects of the use of service in high-level volleyball and beach volleyball. To address this purpose and to achieve a more contextualized approach, four studies on different aspects of service performance in both sports were conducted. The first study, carrying out an analysis between service mode, speed and effectiveness in high-level volleyball, highlighted the importance of the use of jump service abilities. Although no significant relationship was found between service velocity and a better direct outcome related to effectiveness, jump services were revealed as the perfect weapon to avoid first-tempo and quick outside attacks from the opponents.

Our second study was intended to verify the relationship between service speed and its effectiveness in a high-level beach volleyball tournament. In this new research, the sample included men and women's teams and incorporated two interesting additional performance factors: rally outcome and the ranking of the teams. The results showed that the proportion of jump float services used by men and women in beach volleyball is similar, while the differences are greater in the use of jump topspin service and standing float service. Despite finding no relationship between service speed and effectiveness in either gender, a relationship was found when service was categorized into three groups of speed. Greater percentages of perfect receptions were found when facing low speed services, with the opposite occurring at higher speed services. However, no correlation between service speeds, reception outcome, final rally outcome and service effectiveness was found for either gender in our final results.

Later, a third study aimed at clarifying if the peak velocity was an accurate value to understand how the service affects the reception in volleyball, was conducted. To register the speed of the ball while contacting with the receiver seemed a more contextualized and efficient value assessing service action, but a linear relationship between peak and final speed was found in the services registered during a

high-level volleyball tournament. Speed proved not to be the only factor affecting the quality of the reception, as we were unable to find any of the fastest services recorded among the ones from the winning team, and no significant differences were found between finalists and non-finalists in terms of average service speeds.

Our final research, framed within the field of analytics in sport, was an analysis to determine which of the skills and performance factors has the strongest effect on the result of a volleyball match, and used inferential statistics to obtain the results. Our main findings were that the result of a volleyball match could not be explained by just one performance factor. In our analysis the category of the team was the principal explanatory factor of performance, while the secondary factors identified as those increasing the possibility of winning were the transition phase production and the reduction of the number of reception errors and blocked attacks.

We can conclude that service is a very important element of performance in volleyball and beach volleyball. Although it cannot explain by itself the result of a match in high-level competitions, it is a key element in preventing an effective attack performance from the opponent. Service behavior and its ability to impair the opponent's game is not only based on speed, but is clearly influenced by the use of jump abilities. The successful execution of the service is a complex issue, and like the other skills in the game has a physical, technical, strategic and tactical component. Nevertheless, proper use of this technical skill is capital in making the result of a high-level match uneven. The contribution of the service skill to the production of the transition phase is clearly related to the achievement of a positive outcome. However, some other aspects have been identified as relevant to success in a volleyball or beach volleyball match.

ACKNOWLEDGMENTS

The process of achieving the academic degree of Doctor of Philosophy is long, and many people have contributed decisively to it. Over the next lines, I would like to pay tribute in the form of acknowledgment to all of them.

My first recognition is for our sport, volleyball. Without it, I would not have met so many interesting people, would not have developed my professional career, nor have experienced some personal success stories. Explicit thanks here for the players, coaches and organizations that kindly opened their doors for our research purposes.

I cannot but thank my director, Dr. Bernat Buscà, for his ongoing supervision and support throughout this process. This dissertation would not have come to a successful end without his decisive intervention. A special mention to Dr. Antoni Tort, for his understanding and guidance in the more than complex world of the doctoral programs, and Dr. Gerard Moras, for his vast influence, and for considering me part of his workgroup in my early research experiences. Also thanks to all the co-authors of the articles, colleagues, peers and former students without whom this work would not have been possible. I would like to underline the contributions of Mr. Sergio Rodríguez-Jiménez.

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Finally, I would like to thank my family for their continued support and love. An academic career is full of ups and downs. Without someone who understands them by your side, they are really difficult to overcome. Thanks Mum for teaching me the value of empathy with others. Thanks Dad for make me understand that working hard and putting in a great deal of effort is the only way to find a place in life. You are true role models! Iván, my “little bro”, thank you for showing me the different views on life and that barriers are there to be broken. Grandpa and Grandma, do you see? It was true… There is no elevator to success; you have to take the stairs.

To Carolina, the one I love. There will never be enough words to explain what you mean to me. Thank you for your continued love, support and unconditional devotion. I will be there for you, whenever you need it!

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LIST OF ABBREVIATIONS

F.I.V.B.: International volleyball federation	1, 3, 6, 20, 29, 56, 111
L.O.C.O.G.: London organizing committee for the olympic games	3
C.E.V.: European volleyball confederation	3, 20
U.S.A: United states of america	4, 32, 39, 48, 57, 72, 86
I.N.E.F.C.: National institute of physical education of catalonia	56
E.C.S.S.: European college of sport science	71, 109
N.S.C.A.: National strength and conditioning association	108
A.E.C.D: Spanish association of sport sciences	109, 114

CHAPTER 1

INTRODUCTION

According to the official F.I.V.B. rules, the service is "the act of putting the ball into play, by the right-back player, placed in the service zone". To execute the service adapting to the standards, the service should be performed within 8 seconds after the 1st referee authorizes it, hitting the ball with just one hand (or any part of the arm) after being released from the hands, and not touching the court at the moment of the service or during the takeoff for a jump service technique.

That performance may seem simple to someone not really expert in our sport. In fact, service is one of the original volleyball skills that William G. Morgan introduced in the first written rules back in 1897. Nevertheless, is better not to make the mistake of considering the service a minor skill of the game. Even as one of the few techniques in volleyball in which there is no interaction with the partner or the opponent in its execution, most authors agree about the importance of volleyball service as one of the capital skills in the game. Not surprisingly, during the evolution of our sport we have seen many variations and executions for this technical skill, simply in search of excellence. Standing, jump, float, spin, hook, underhand and overhand services are fairly common today in different competition levels and contexts.

Over the next lines, we will try to find some relevant issues and insights concerning the use of service in volleyball and beach volleyball, trying to develop a deeper knowledge of this relevant skill and understanding it as a main factor of success in volleyball and beach volleyball competitions.

Our perspective was within the latest trends of performance analysis in sport and will use notational analysis and statistical procedures, taking into account technical, tactical and kinematic approaches for its study.

The main goal is to provide a more ecological knowledge, analyzing the game from a more complex point of view, implying the need for a better fit of volleyball skills to the characteristics of the player and the team. Thus, the time spent in practices and the tactical approaches that result from the performance of every player may be more realistic and evidence-based.

SERVICE IN VOLLEYBALL

Volleyball service is a skill commonly described as the first element of the defense, essential in preventing a team from siding out (Wise, 2002). Since the introduction of the rally point system by the F.I.V.B. in 1998, the service has become an even more important skill in the game. Basically, a good service in combination with an efficient defensive strategy neutralizes the opponent's opportunity of creating a point. On the other hand, a mistake while serving leads to an error and consequently to a point, not just to a side-out as it used to be with the traditional scoring system.

In high-level volleyball, the chance of obtaining a direct point using the service is low. Nevertheless, the benefits from serving are not only based on the possibility of scoring, but also on influencing the next attack play of the opponent (Quiroga, García-Manso, Rodríguez-Ruiz, Sarmiento, De Saa, & Moreno, 2010). A team struggling to defend a good service efficiently will drastically reduce its possibilities of winning the match (Patsiaouras, Moustakidis, Charitonidis, & Kokaridas, 2011).

According to data from the L.O.C.O.G., during the 2012 men's Olympic competition 5,903 services were executed with a result of 346 aces (5.86%) and 980 errors (16.60%). The data from the women's competition is similar in terms of number of executed services (6,904) and obtained aces, 278 (4.56%) but clearly differs in the number of errors with 474 (7.77%). This difference probably lies in the specific serving skills used in men and women's high-level volleyball. While in men's volleyball the jump topspin service is the technique predominantly used, with percentages over 75% of the executed services in competition (Katsikadelli, 1996; Katsikadelli, 1998; Agelonidis, 2004) greater variability can be found in the women's game. Forty-eight point six percent of the services executed in two consecutive C.E.V. women's Final Four were standing float services, 23.9% jump topspin services and only 17% jump float services (Quiroga, García-Manso, Rodríguez-Ruiz, Sarmiento, De Saa, & Moreno, 2010). This difference in the performance of the service is more than likely due to the physical differences between men and women and the requirements for carrying out an effective jump topspin service: fast arm speed, fast approach, high and consistent toss, overall ball control and greater height of the performer (U.S.A. Volleyball, 2009).

The jump topspin service is very appealing for use in competition for a variety of reasons. The server can create greater forces, owing to an increased range of motion, and this enables the ball to travel at higher velocities than the other services. Strohmeyer (1988) in a classical study conducted regarding the jump servers of the men's and women's U.S.A. national teams found an average velocity of 19 $m \cdot s^{-1}$ for the jump services, while the "conventional servers" served at an average velocity of 14 $m \cdot s^{-1}$. The advantage of faster services compared with less aggresive services is that they give less reaction time to the flight path. Katsikadelli (1998) observed the flight times of the jump services of the two finalists of the 1994 World Championship, Italy and Netherlands, and noticed they were significantly lower than those of the rest of the teams.

Some other relevant factors of the jump service performance are that the jump action allows service at lower trajectory angles of about six degrees above horizontal for the jump topspin service, compared to 13 degrees above horizontal for the standing float service (Strohmeyer, 1988) and that when executed correctly, jump service carries the server onto the court, ready to play.

The principal disadvantages of the jump topspin services are a larger margin of error than traditional services, due to a lack of accuracy of this powerful skill, and a more than likely decrease in performance during the match due to accumulated fatigue. However, to our knowledge, the fatigue effects of executing this type of service have not been determined objectively.

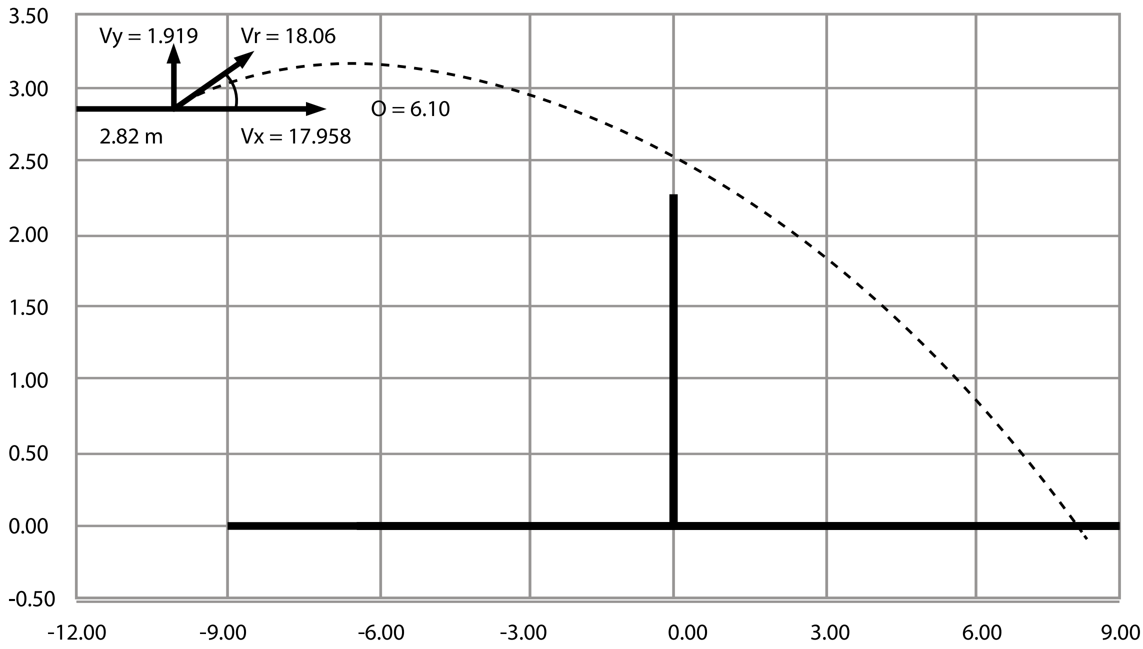

Figure 1: Projectile analysis of a jump service using equations by Northtrip, Logan and McKinney (1983) and values by Strohmeyer (1988).

The acceptance of the high risk of error related to the execution of the service (1 out of 5 jump services goes to the net or out of bounds according to Agelonidis, 2004) is part of the defensive strategy of the high-level volleyball teams. It has been proven that attack is one of the better predictors of team success (Eom & Schutz, 1992a; Yiannis & Panagiotis, 2005; Zetou, Tsigilis, Moustakidis, & Komninakidou, 2006; Zetou, Moustakidis, Tsigilis, & Komninakidou, 2007; Monteiro, Mesquita, & Marcelino, 2009; Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, De Saá, & García-Manso, 2011) and that blocking efficiency is closely related to the quality of the service (Drikos, Kountouris, Laios, & Laios, 2009). In fact, in international volleyball, there are already signs that the serving strategy is now based upon the team's blocking and defensive strategy, and that one of the goals of the serving strategy is to enable the formation of a double block, thus increasing the chances for the defense to play the ball (Papageorgiou & Spitzley, 2003). It seems then, that the serving team has no other choice to obtain an advantage but to take the opposing team out of the attack system, and particularly, preventing the first-tempo attacks (Zetou, Moustakidis, Tsigilis, & Komninakidou, 2007) and quick outside attacks

(Fellingham, Hinkle, & Hunter, 2013) by risking the service. Nevertheless, there is some evidence that the higher the level of the team is, the less the probability of unforced errors during the game (Palao, Santos, & Ureña, 2004) and that statement includes the service as well.

Recently, the F.I.V.B. has been evaluating some changes to the official volleyball rules referring to the characteristics of the hit to play the ball. One of the most controversial proposals is to put the use of overhead finger action during the reception actions, under close surveillance by the officials. The intention is to provoke poorer ball control during the first contact, and to decrease the attack levels to make the rallies longer. This new scenario would probably force a different development of the reception actions and would probably, change the profile of some of the players involved in reception systems. If the corresponding committee passes this new rule, we can anticipate an increase in the percentage of jump float services executed during the game. With a higher demand for the use of overhand techniques in reception, this service will be more dangerous in terms of mobility and accuracy from the players, forced to use the underhand pass technique more frequently. It will be interesting to study the changes that the introduction of this new rule may lead to the service strategies of high-level teams.

SERVICE IN BEACH VOLLEYBALL

Beach volleyball is a sport originating from volleyball, with a huge impact on the current athletic scene. Beach volleyball rules are fairly different from those of volleyball. The official format is played between two teams, each with two players, and the goal of the game described in the F.I.V.B. rules from 2001 is to win two sets of 21 points, using the rally point system (and adding a third set to 15 points, if necessary).

Figure 2: Beach volleyball official game playing surface and game structure.

The major skills characterizing beach volleyball are similar to the ones in volleyball, and like the indoor sport, it is divided into two phases: side-out and counterattack.

The use of the service is similar to volleyball, with an explicit intention to limit the offensive possibilities of the opposing team. However, the different court dimensions (8x8 m), the limited number of players, the particular characteristics of the playing surface and the changing climatic conditions make the service circumstances differ clearly from those in volleyball. As a result, the percentage of jump services used decreases to 54.7% regarding volleyball in male players, while remaining at similar percentages to the indoor game (45.3%) for female players (López-Martínez & Palao, 2009).

The game role is really influential in decreasing the number of jump services in beach volleyball. While in indoor volleyball the player performing the service is a back row player and its subsequent action (following the service) is a defensive action, in beach volleyball the usual structure of teams (with one specialized blocker) requires one of the players to go right to the block after the execution of the service. This leads most blockers to use the standing float service or the jump float service as their main services, and to use the jump topspin service only occasionally to preserve energy and to be able to fulfill all the duties arising from their role during the whole match. Considering that the average match duration in beach volleyball is quite stable, ranging from 30 to 60 minutes, that a beach volleyball match has a significant number of rallies to play (ranging from 78 to 96) and that in a tournament several matches are played, this strategy appears to be, at least, interesting (Palao, Valades, & Ortega, 2012).

The behavior of players performing jump services in beach volleyball is similar to those executing this type of services in indoor volleyball. The number of errors for these executions is significantly higher than for the standing float services (12% vs. 4.2% for males and 18.4% vs. 6.1% for females in López-Martínez & Palao, 2009) meaning that players show a clear preference for power services as a strategy to impair the set, expecting a direct effect on lowering the attack efficacy of the opposing team (Giatsis & Zahariadis, 2008).

The more interesting service strategies to reduce the attack potential of the opposing team in beach volleyball are, in general terms, similar to the ones used in indoor volleyball: serve to the seams and interference zones between receivers (López-Martínez & Palao, 2009), serve to the deep corners and serve short to have a greater opportunity to be passed back over the net, or into it (McGown, Fronske, & Moser, 2001). But there is a particular strategy in beach volleyball: serving to the players with a lower attack potential level. The main objective of this strategy is to force the worst attacker to perform a higher percentage of the attack actions. For this reason, in beach volleyball, the "over on two attack" technique (intended to partially reduce the effects of this serving strategy) is more common than in indoor volleyball (Giatsis & Zahariadis, 2008).

Some authors have studied the risk/reward ratio of using an aggresive serving strategy in beach volleyball. They have concluded that the use of the jump topspin service only proves efficient when the point-to-error ratio is less than 1:2. Effective services appear to be a less important factor since the reduction of the court to 8x8 m in favor of some of the skills in defense like block and dig (Giatsis & Tzetzis, 2003; López-Martínez & Palao, 2009). It seems then, that making too many mistakes by risking the service can lead to losing a match easily and that analysing correctly the strengths and weaknesses of the players is a key to enhancing the service performances in beach volleyball, as well.

PERFORMANCE ANALYSIS IN SPORT

Performance analysis in sport is "the investigation of actual sports performance or performance in training" (O'Donoghue, 2010).

Performance analysis is an interdisciplinary subject in nature, its main goal is twofold: on one hand it seeks to advance scientific understanding and on the other, pursues assisting sports practice by providing the coaching processes with augmented information (McGarry, O'Donoghue, & Sampaio, 2013). Glazier (2010) considers performance analysis as an independent sub-discipline of sport science, emerging during the first decade of 2000, and provoking some controversy among researchers from traditional and more established sub-disciplines like sport physiology, sport psychology or biomechanics.

According to O'Donoghue (2010) the main reason for carrying out performance analysis in sport is to develop an understanding of the game that can help decision-making processes. The complexity and dynamic nature of many sport disciplines, lead us to carry out observation and measurement to improve our knowledge of performance, applying this new knowledge to enhance it.

The rationale for the adoption of performance analysis is to overcome the limitations of using subjective observation alone, and to provide objective information to obtain a greater understanding of the performance.

If the essence of the coaching process is to produce changes in behavior and the coaching and teaching of a skill depends on analysis to make an improvement in athletic performance, informed and accurate measures are necessary for effective feedback, and hence, improvement of performance (Franks I. M., 2005). Feedback is defined as “information relating how a skill was performed and its effectiveness” (Hendry & Hodges in 2013) and the way it is presented can have important implications on the learning processes, the attitude of the learner and the proficiency of the skills developed

In most sports, the analysis of performance is based on a series of qualitative assessments and judgements made by the coach or the members of the staff, Franks, Goodman, & Miller (1983a) defined a simple flowchart of the coaching process that outlines it in all the phases:

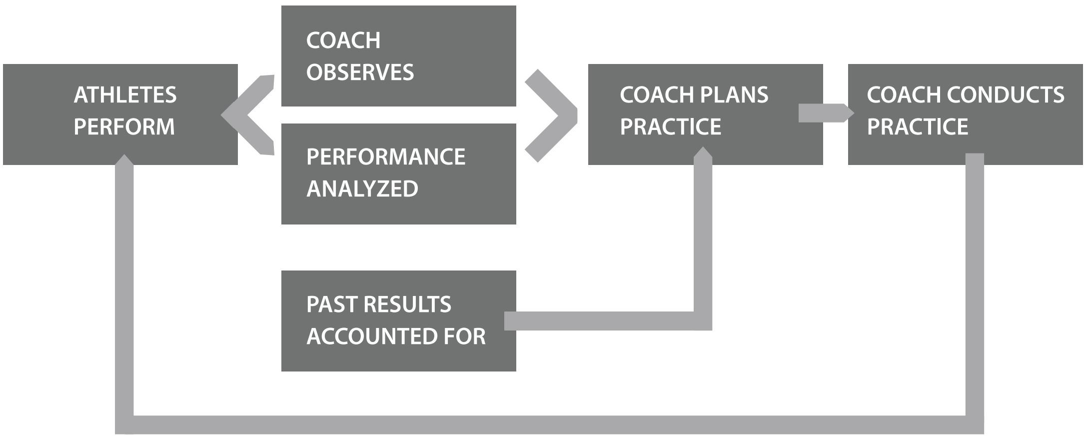

Figure 3: Diagram representing the coaching process.

After the match, the coach and the staff members will get an idea of positive and negative aspects of the performance, and these will be considered before planning and preparing for the next match. One of the main functions of performance analysis in sport is to provide the coaches with a standard, predefined system of monitoring performance that can be used for objectifying the events.

Those systems of monitoring performance can be used in two different moments of the coaching process (Hughes, 2008):

1. In real time: performance analysis can be used during the activity, to provide immediate feedback to the athletes and perform simple analyses.
2. With time lapsed: performance analysis is used in post-activity analysis, examining carefully and in detail all the relevant aspects of the performance.

The application of performance analysis is really extensive. O'Donoghue (2010) identified a revised set of research areas of performance analysis, indicating how they were applied to different groups of interest in sport activities:

Table 1-1: Different areas and groups of interest under research in sport performance analysis.

Area being analyzed	*Players*	*Coaches*	*Referees*
Technique	YES		
Technical effectiveness	YES		
Tactical evaluation	YES	YES	YES
Movement	YES		YES
Behavior/psychological aspects	YES	YES	YES

Nevertheless, in all sports the analysis and performance evaluation is beset with problems due to the number and diversity of playing actions and the complexity of the performance itself. To solve that problem partially, researchers in the field of study have developed systematic approaches to performance analysis, helping the coach to establish accurate and reliable specific systems of analysis in every sport. Many times, some of the performance analysis purposes and techniques have been tested first in research, just to be included later in the real sport situation. There is a long tradition and vast production in performance analysis research. O'Donoghue (2010) provides us with a list of research topics that have been used on a recurring basis in the field of performance analysis:

1. Coaches' behavior
2. Performance indicators
3. Work-rate analysis and evaluation of risk injury
4. Reliability of methods
5. Analysis of technique
6. Technical effectiveness
7. Tactical patterns of play
8. Performance profiling

This number of possibilities, and the great differences of each discipline, have generated a great variation in the assessment methods that can be used in every sport. Despite this variation in the methods, the purpose of the analysis and the type of information desired, a quantitative analysis with the use of an objective and reliable procedure appears to provide the most useful record of performance (Eom & Schutz, 1992a).

The main methods used in objectifying the process in team sports are through the use of notational analysis. We have evidence of the use of notational analysis to assess performance of team sports like American and Australian football, basketball, cricket, field hockey, handball, netball, rugby, soccer, beach volleyball and volleyball.

Notational analysis also has many connection points with other performance analysis sub-disciplines. Thus, researchers can achieve a deeper understanding of the study object. Glazier (2010), suggests a general accepted conceptualization of performance analysis that brings together notational analysis and biomechanics. For the author, the common factor linking both disciplines is that both “can be used to describe the same phenomenon”. To our knowledge, some other combinations between performance analysis sub-disciplines and notational analysis appear to make sense.

Hughes M. (2004) explains the process of performing a complete notational analysis:

1. Defining performance indicators.
2. Determining which of these indicators are important.
3. Establishing the reliability of gathered data.
4. Ensuring that enough data have been collected to define the stability of performance profiles.
5. Comparing different sets of data.
6. Modelling performances.

The correct definition of performance indicators (also called performance parameters) and their selection based on relevance criteria, is one of the key aspects to use this performance analysis technique. A performance indicator is a “selection or combination of action variables that aims to define some or all aspects of a performance” (Hughes & Bartlett, 2005) and it should be related to successful performance or outcome. Notational analysis has focused traditionally on team and match play sports, studying the interactions between players and the movements and behavior of individual team members.

Some of the performance indicators used by different analysts are very similar. Hughes & Bartlett (2005) summarized the performance indicators that have been used traditionally by net sports researchers in the following table:

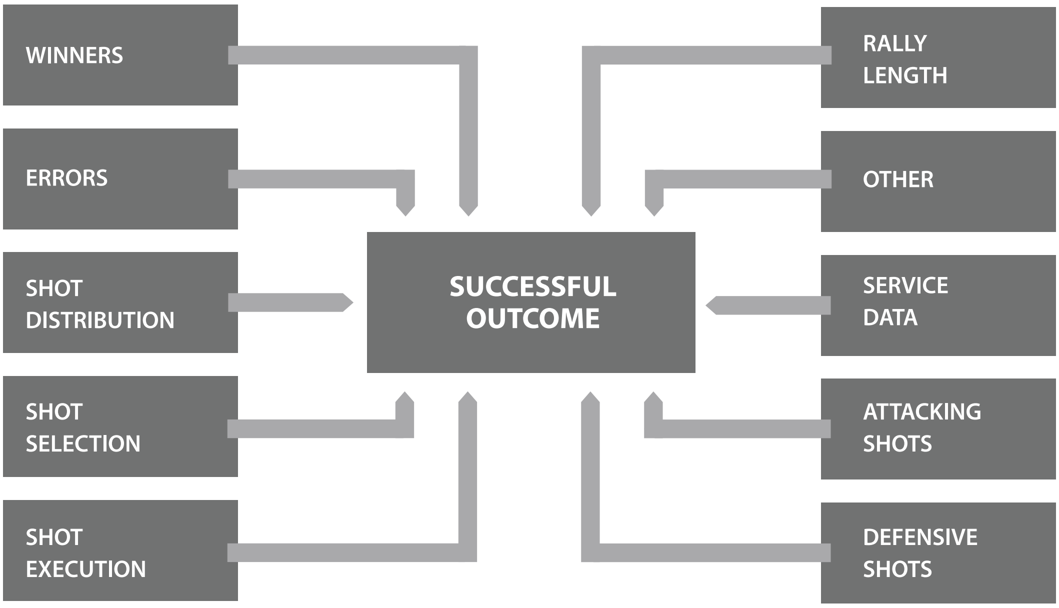

Figure 4: Performance indicators contributing to success or improved performance in net games such as volleyball.

In the following paragraphs we will discuss more extensively about notational analysis as one of the most important trends in sports performance analysis.

NOTATIONAL ANALYSIS IN SPORT

Hughes & Franks (1997) define notational analysis in sport as "an objective way of recording performance so that key elements of that performance can be quantified in a valid and consistent manner".

This data collection technique spread in sport as a result of some studies proving that coaching observations are not only unreliable, but also inaccurate. Franks & Miller (1986), using methodology from psychology (applied memory research) showed that international level soccer coaches could retain in their memory only 30% of the key factors that determined success during one match, and that information was less than 45% correct in the assessment of what occurred during a game (Franks & Miller, 1991). A third study by Franks (1993) with experienced gymnastic coaches, found that experts were not significantly better than novice coaches in detecting differences in sequentially presented handspring performances.

These and subsequent studies can be used to set an example of how the accuracy of human information processing system is questionable, if an objective accounting of past events is required.

Some of the inaccuracies in coaches' observation of sports performance can be explained by (O'Donoghue, 2010):

1. Memory overload: trying to retain too many items of information
2. Subjective bias: despite efforts at objectivity, coaches decisions will be always influenced by subjectivity.
3. Halo effect: performances will be rated higher or lower, if performer starts the activity well or badly.
4. Leniency error: a performance appraisal error which occurs when coaches over-rate a very poor performance and viceversa.
5. Highlighting: coaches will remember key elements of performance but not the essential sustaining elements ("bread and butter").
6. Increased arousal level: dysregulation of consciousness, attention, and information processing as a consequence of high stress and anxiety.
7. Errors in attentional focus: directing the attention to non-relevant information.

If one requires an objective, unbiased accounting of past events, the solution is to collect relevant details of performance during a live event and then recall these details at the termination of that event. Notational analysis proves to be an interesting technique for this purpose in all its forms: hand and computerized notation systems.

HAND NOTATION AND COMPUTERIZED NOTATION SYSTEMS.

Both hand notation systems and computerized notation systems have been applied to virtually all sporting situations, providing a substantial amount of quality data. In fact, rudimentary and unsophisticated forms of notation analysis have existed for some time. Initially soccer and squash were the disciplines with a superior quantity of research papers and work, but this has now changed significantly and a substantial number of publications can be found in almost every sport (Hughes & Franks, 1997).

Although some sports have little notational research published, this does not mean that systems do not exist or are not actually used in these disciplines.

The article considered as the earliest publication in notation of sport was "The inside game: the science of baseball" published by H.S. Fullerton at "The American Magazine" (1912). The paper explored the combinations of baseball players batting, pitching and fielding and the probabilities of success. However, the first attempt to devise a specific notation system for sport analysis known by the experts was the research from Messersmith and Bucher "The Distance Traversed by Big Ten Basketball Players" (1939), who provided the reader with insights to the distances covered by basketball players during a college match.

Notation systems were commercialized for American football play-analysis around 1966 (Purdy, 1977) and the Washington Redskins were one of the first teams to use them in 1968 (Witzel, cited by Purdy, 1977). Paradoxically, American football is the only sport that has a ban on the use of computerized notation systems in the stadium as part of its rules.

Today, the distinction between hand notation systems and computerized notation systems is blurring as the hand-gathered data is often processed using spreadsheet database softwares, and the traditional sheets of paper are being replaced by tablet computers.

Hand notation systems are very accurate in general terms, but they do have some disadvantages (Hughes & Franks, 2005):

1. The more sophisticated systems involve considerable learning time.
2. The amount of data that these systems produce can involve many man-hours of work in processing them into forms of output that are meaningful to the coach.

The use of computerized notation systems solves these disadvantages of using hand notation systems and tackles satisfactorily the data processing issues, in particular.

Used in real-time or post-event analysis in conjunction with video recordings, computerized notation systems enable immediate access to data. They also allow the sports scientist to present the data in graphical forms quickly understood by the coach and athlete. The sophistication and reduced cost of video systems have greatly enhanced the whole area of post-event feedback, and they can be used from playback with subjective analysis by a coach to detailed objective analysis by using notation systems.

The computerized notation systems have been used historically for four major purposes:

1. Analysis of movement.
2. Tactical evaluation.
3. Technical evaluation.
4. Statistical compilation.

The information derived from this type of computerized notation systems can be used for several purposes, as suggested by Franks, Goodman, & Miller (1983b):

1. Immediate feedback.
2. Development of a database.
3. Indication of areas requiring improvement.
4. Evaluation.
5. As a mechanism for selective searching through a video recording of the game.

Therefore, notational analysis, and particularly the use of video, gives coaches a chance to record, observe, reflect and check performances accurately through the use of a tool that fascinates both themselves and athletes (Hughes M. , 2008).

USE OF COMPUTERIZED NOTATION SYSTEMS IN VOLLEYBALL DISCIPLINES.

Team sports have the potential to benefit immensely from the development of notational analysis and computerized notation, and volleyball disciplines are not an exception (Eom & Schutz, 1992a; Eom & Schutz, 1992b; Giatsis & Zahariadis, 2008; López-Martínez & Palao, 2009; Castro, Souza, & Mesquita, 2011; Marcelino, Mesquita, & Sampaio, 2011). The sophistication of data manipulation procedures available would aid the coach in his efforts to enhance performance as to "increases in speed, accuracy, the efficiency of data recording and data reduction, providing a better understanding of the game patterns and more precise assessments of the team and the players involved" (Eom & Schutz, 1992a).

Volleyball and beach volleyball matches are characterized by the integrated playing action of six main skills: service, reception, set, spike, block, defense and ball control (Shondell & Reynaud, 2002) developed in a sequence of events. That sequential nature of volleyball puts a lot of pressure on the human memory system, because only after a critical moment in the game does a previous event become significant (Hughes & Franks, 2005). As a result, processing all the events occurring throughout a match is really difficult without the use of some form of computer resource. To solve that problem partially, most classical hand notation systems in volleyball selected certain skills as key factors of performance, ignoring the rest of them, and using simple numerical scales to assess the quality of skill execution. It was an effective, but certainly incomplete, way of assessing performance. Thus, until the introduction of performance analysis computerized systems, by logical limitations, it was difficult to improve the quantity and quality of information to be analyzed.

Some classical research in notational analysis in volleyball has been done in the past by using basic computerized systems (Eom H. J., 1988; Eom & Schutz, 1992a) and some computerized quantitative systems have been developed to assess performance analysis in volleyball (Handford & Smith, 1996). However, the tendency in the use of these systems appears to have increased in recent scientific production, due to the emergence of some universalized advanced systems.

Today, the most widely used software for notational analysis in volleyball and beach volleyball is Data Volley from the Italian company Data Project. The program is used all over the world by many professional and national teams, statisticians and researchers to monitor volleyball games and to perform game-analysis (Marelic, Resetar, & Jankovic, 2004; Drikos, Kountouris, Laios, & Laios, 2009; Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, De Saá, & García-Manso, 2011). Virtually all the national teams participating in the top international competitions use Data Volley for performance analysis, becoming the gold-standard among the volleyball disciplines statistical softwares.

Data Project was founded in Salerno in 1992 and the company holds agreements for the use of its products with the most important federations and associations like the F.I.V.B. or the C.E.V. Today, all the official statistics from the competitions coordinated by these organizations are created using Data Project software.

The software architecture is based on notational analysis principles and its use is not really complex once it is completely understood. As volleyball is divided in two phases (offense and defense) and each of these phases has some sequential actions, with skills occurring in a hierarchical order, each one of these skills is typed with a code by the operator. At the same time, every code is associated with a numerical score (using a scale from four to six numbers, depending on the evaluated skill) which ranks the skill execution.

Data volley can be set up according to the operator requirements and abilities. People lacking experience will be able to analyze only a few basic technical skills, while experts will carry out a deep analysis in order to obtain a more in-depth and accurate understanding. Such deeper analyses require the use of a large number of codes, known as advanced or extended codes.

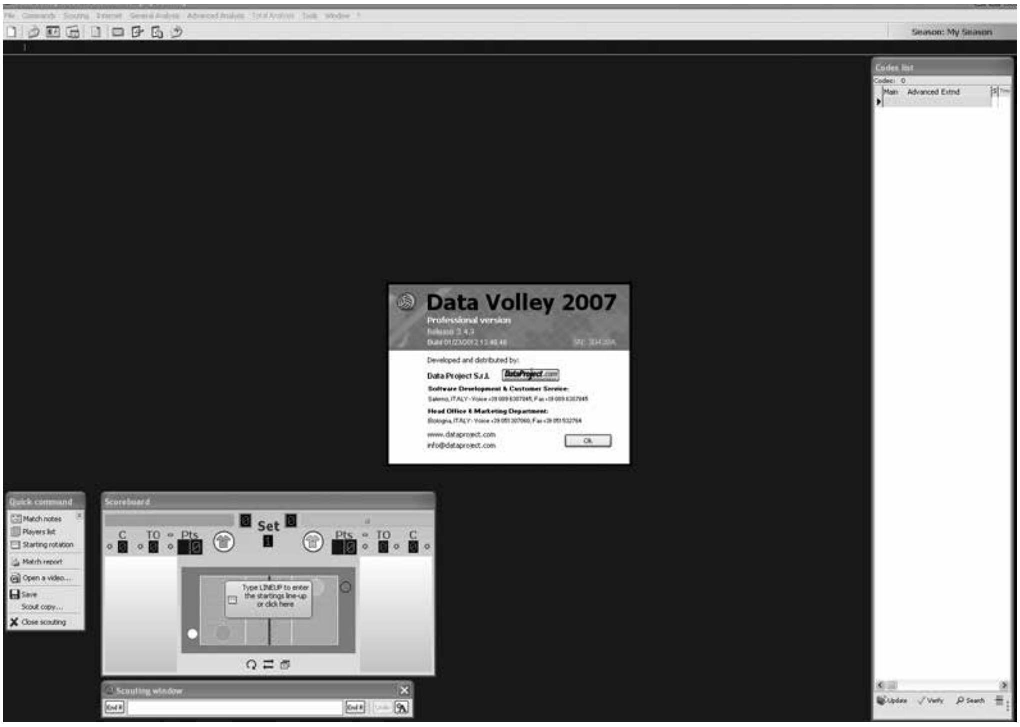

Figure 5: Data Volley software interface.

A perfect command of the software enables the possibility to perform the following advanced analyses:

1. Skill statistics: Detailed analysis of the skills of a player, or a team, of one or more rotations.
2. Zone analysis: Allows the evaluation of skills according to the zone where they were performed.
3. Service and attack directions: It is possible to study the attack directions using starting and landing zones or cones.
4. Attack distribution: It is possible to check the efficiency and distribution of the different type of attacks according to the starting zone, rotation or previous type of reception.
5. Detail of last hit: The software enables the viewing of the effects of the players' last hits divided by skill.
6. Play-by-play analysis: Trend analysis of the set or the match point by point with a graph to follow the score.
7. Total analysis: Deep analyses can be created using all the archive matches of the same team. This feature allows the creation of charts and graphs.

One additional software characteristic is the worksheet exportation, giving the user the possibility of using specific formulas and working with raw data in research statistical packages such as SPSS or SigmaPlot.

Data Project promotes the use of software bundles, as the company also offers a video analysis software called Data Video. This second program works with files and codes created in Data Volley, synchronyzing them with captured video from the matches. Once the synchronization is finished, the user will be able to highlight the relevant rallies of the game and create custom montages. The frames referring to a specific action or situation can be recalled easily, as well as edited with simple plots to outline the important aspects of the game. The professional version of the video software enables the use of multi-sequence viewing and montage customization. The montages can be exported to a wide variety of video formats that can be played on most media player software.

It is not difficult to find in the literature numerous research papers on volleyball performance analysis, carried out using the aforementioned software package (Marelic, Resetar, & Jankovic, 2004; Zetou, Tsigilis, Moustakidis, & Komninakidou, 2006; Zetou, Moustakidis, Tsigilis, & Komninakidou, 2007; Drikos, Kountouris, Laios, & Laios, 2009; Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, De Saá, & García-Manso, 2011) and some research based on beach volleyball (Yiannis & Panagiotis, 2005; Yiannis L. , 2008). All these studies were complemented with the use of statistical techniques to obtain the results, therefore computerized notational analysis was the basis for classifying and studying different performance factors.

Mesquita, Palao, Marcelino, & Afonso (2013) divide performance analysis research studies (using notational analysis and statistical techniques) into two groups: descriptive and correlation-based research. Among the latter group emerges the most innovative research trend called predictive analysis. The most particular feature of predictive studies is the use of the more sophisticated statistical techniques such as discriminant, log-linear and logistics analysis to establish non-linear relationships between performance factors. Their additional value is related to the predictive potential to regulate training and match performance while modelling player's performance subject to the principles of more complex systems (Bar-Yam, 1997).

However, most of this research is based only on notational analysis and statistical procedures, disregarding the possibilities of the integrated use of some other performance analysis sub-disciplines such as biomechanics or kinematics. It will be interesting to evaluate the impact that research with a multidisciplinary approach may have on the study field. This new approach may enable better understanding of the study object, or at least an interesting and new perspective that can contextualize our sport knowledge more satisfactorily.

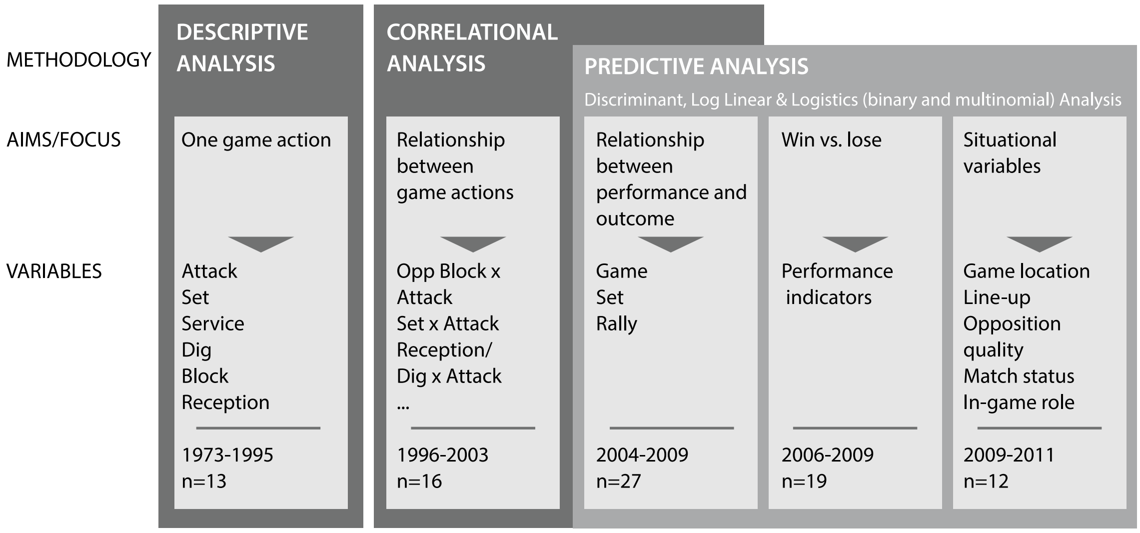

Figure 6: Research focused on performance analysis in volleyball defined by Mesquita, Palao, Marcelino, & Afonso (2013).

OVERVIEW OF DISSERTATION

The ultimate goal of this Dissertation was to identify some critical aspects of the use of service in volleyball and beach volleyball according to the new perspectives in performance analysis and using notational analysis, inferential statistics and kinematics to achieve a more ecological approach to the field of study.

The obtained knowledge has the purpose of helping players and coaches to understand how to improve their tactical systems, while enhancing technical and tactical behavior in competition and simulated situations in training. In our humble opinion, if scientific knowledge does not generate new attitudes and questions in practice, due to a lack of connection between research and applied training, all the sports scientific research loses its meaning.

Performance analysis has made huge progress and a large increase in sports scientific production since the 1990s. But current performance analysis methods have been questioned regarding a lack of harmony with the theoretical frameworks that provide the fundamental principles regulating performance achievement (Travassos, Davids, Araújo, & Esteves, 2013). To adapt better to those frameworks, Mesquita, Palao, Marcelino, & Afonso's proposal (2013) is to identify non-linear interactions in notational analysis research, instead of establishing simple cause-and-effect relationships between performance factors. This leads to a more ecological approach, considering volleyball matches and competitions as a complex dynamical system. The use of more complex multi-variate analysis techniques prevents sport performance prediction from a lower ecological validity. Thus, studies under these new perspective escape from classical approaches in which linear relationship between variables (and therefore, reductionist connections) were considered valid (Mesquita, Palao, Marcelino, & Afonso, 2013). A combined study of different performance factors also looks like a good option to better understanding of this new performance analysis paradigm.

Volleyball service has been traditionally considered one of the most important skills in the sport, relating its production in the game to the achievement of an optimal competitive outcome. Incidentally, this importance has been evaluated considering players and coaches' perceptions or research based on statistical analysis uniquely. But what would happen if we combined the study of several performance factors in our analysis simultaneously? Would we get the same results?

As far as we know, the advantage of jump service is related to its speed and the reduced possibility of reading and anticipating the trajectory that provides an increased ball speed. But although there are several studies that analyze the statistical impact on the game produced by the service action, and some others analyzing the biomechanical and kinematic characteristics of the performance of the service, to our knowledge there are no studies evaluating both issues at once.

This new perspective would be more valid, from a scientific point of view, as it would help to understand the behavior of service-receive systems and servers in a much more contextualized situation. The integrated use of kinematics and technical evaluation will allow us to confirm whether an excellent performance of the service actually has the impact that has been attributed to it in previous scientific experiences.

To assess the relationship between service speed and its direct effect on the opponent's action is capital in providing coaches and practitioners with a more realistic approach to service strategies. This analysis can reveal if the generalized use of jump topspin services in high-level competitions, is rational from an empirical standpoint.

Our search will not only be based on the understanding of the service performance and its influence on the game in volleyball, but will also do so in beach volleyball. Although this is a discipline with many similarities to indoor volleyball, it also presents important differences. The particular playing surface, wind influence, different court dimensions and especially, the reduced number of players are factors that lead us to attempt to find out more about the effect of the service in this discipline, discriminating the results from those obtained in volleyball research. Adding the rally outcome as a factor to better understand the effect of the service in the opponents' actions can be crucial to our knowledge of the extent of the use of this technical skill.

A lower level of homogeneity in the participating teams in the top-level beach volleyball competitions regarding volleyball competitions, and observed differences in the competitive level between the best female players and the rest of the participants, lead us to think that further investigation on the service in this sport should include competitive ranking and gender as performance factors to be taken in consideration, in order to be more explanatory and evidence-based.

Additional information about the characteristics of service behavior throughout the ball's trajectory to the opposite court would contribute to a complete understanding of the service performance. Typically, the study of the service in volleyball has been carried out putting greater emphasis on biomechanical parameters, but to our knowledge, the kinematic study of the ball speed (ignoring the causes of motion) is a new approach and could have a greater impact on the real sport conditions. In a common volleyball situation, the technical and tactical behavior are anticipated or conditioned reactions to the trajectory of the ball. The system that generates the trajectory often becomes a secondary element of analysis. As a result, finding out some additional data related to the ball speed (such as the mechanical behavior of the different trajectories or the effect of the aerodynamic resistance on the ball) will provide more efficient measures for assessing the effect of the service in play. To understand more closely the conditions in which the technical action of the reception takes place is an element of high interest and can improve deeply our understanding of the key factors in the success of this action.

Once evaluated in context all the above elements, it will be the subject of our study the management of analytics, to understand which technical skills are critical performance factors in high-level competitions. The use of analytics in sport is relatively new, but they have experienced a boom over the past few years. The role of these techniques is therefore to inform decision makers and help the coaches, managers and organizations to gain a competitive advantage on the field of play. Analytics use historical data, predictive models and information systems.

Rigurous review with large volume of data, consistent samples and enough practical knowledge may allow us to evaluate the real impact of the use of service in high-level volleyball. Considering that most studies of this type do not use statistical inference techniques, or they evaluate shorter competitions (with a low volume of registered services), a detailed study including advanced statistical inference techniques and employing large aggregates of data, would contribute to ou knowledge of the effect of this technical skill throughout a complete competition. Techniques like binary or multinomial logistic regressions have been used recently in volleyball research for predictive analysis, but not many of these studies have quantified and numerically solved the real impact on the result that these factors have in the game. Currently, some of these techniques make it possible and carrying out some research about it could be of great interest for top-level volleyball coaches and players.

Knowing the particular significance that each of the elements of the game has will optimize the coaching and training processes, helping to minimize errors in the main skills and emphasizing the factors producing a greater effect on the outcome.

On many occasions, the interpretation of how the game has to be played lacks scientific evidence. Only with the proper use of analytics and performance analysis can we get clear and objective information to enable a better understanding of the game.

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CHAPTER 2

A COMPARATIVE STUDY BETWEEN SERVE MODE AND SPEED AND ITS EFFECTIVENESS IN A HIGH-LEVEL VOLLEYBALL TOURNAMENT

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KEY WORDS: Muscle, skeletal, volleyball, physical fitness

ABSTRACT

Aim. This study carries out a comparative analysis between service mode and speed and its effectiveness at the 2004 Men's Olympic Qualification Tournament.

Methods. A total of 377 services were analyzed, 124 of which belonged to Cuba vs. Holland, 63 to Spain vs. Cameroon, 100 to Spain vs. Cuba, and 91 to Holland vs. Cameroon. Speed services were recorded using a tripod mounted radar gun.

Results. The analysis has shown the predominance of jump service (JUMP, 84.9%) compared with float service with jump (FLOAT JUMP, 9.5%) and float service (FLOAT, 5.6%). Only 25.3% of the total jump services analyzed was successfully stricken back making the first tempo attack possible. The respective percentages for FLOAT JUMP and FLOAT were 42.9% and 55.6%. Ball speed in JUMP (23.03 ± 3.94 $m \cdot s^{-1}$) was markedly higher compared with FLOAT JUMP and FLOAT (12.05 ± 3.44 $m \cdot s^{-1}$ and 11.47 ± 4.22 $m \cdot s^{-1}$). While negative outcomes (66.7%) in FLOAT stand out, a better balance between negative and positive outcomes were found in both JUMP (50%) and FLOAT JUMP (42.9%). However, no relationship was found between service speed and its effectiveness outcome (R^2=0 in the overall sample and R^2=0.005, when pooling the 5 service effectiveness categories into negative and positive outcomes. In fact, JUMP is mainly performed in the span of velocities between 23.06 and 28.06 $m \cdot s^{-1}$ in both error and direct point categories.

Conclusion. We found no significant relationship between service velocity and a better outcome related to effectiveness. In addition, JUMP and FLOAT JUMP present a better balance between negative and positive outcomes compared with FLOAT.

INTRODUCTION

Volleyball is a sport with complex technical, tactical and athletic demands on the players. Serving is one of the most important attack actions. Three different styles could be differentiated: float service, float service with jump and jump service. During the 90's and up to the present day, jump service has become increasingly relevant in high-level volleyball. From 1992 to 2002 the execution of jump service in high-level volleyball tournaments rose from 20.8% to 99.2% (Agelonidis, 2004). Katsikadelli (1996) observed that in the 1992 European Championship the overall percentage of the attack services executed with jump was 75%. Two years later, in the 1994 World Championship this percentage increased to 85.3%. The same author later undertook a tactical analysis on reception and service using data from the 1994 World Championship final and the 1995 European Championship final (1998) and was observed that attack service with a jump represented 84.2% and 90.3% of all services, respectively.

Although jump service has a higher failure percentage than other service styles (Katsikadelli, 1997) all high-level teams seem to accept the high risk of error related to this style. One out of 5 jump services goes to the net or out of play, while the ratio for the other modest services is about 1 out of 12 (Agelonidis, 2004). Therefore, the success of the jump service cannot be exclusively considered in light of the number of won aces or even the number of services at which the opponents cannot respond with an attack. Thus, the key point is not the direct benefit likely to be obtained, but what can be avoided through it (Agelonidis, 2004). It has been statistically proven in high-level volleyball that attack is a better predictor of team success than defense (Eom & Schutz, 1992). On the other hand, there seems to be no improving tendency of the blocking strategies (Katsikadelli, 1997). Hence, it seems that the team on the service has no other choice than trying to complicate as much as possible the opponent's reception (Mose, 1982).

Agelonidis (2004) analyzed 23 matches and 4,338 services during high-level tournaments between 1992 and 2002. Only 28% of jump services executed were stricken back by attacks programmed in the first tempo. In other type of services the same response was 49.3%. Katsikadelli (1996) also emphasizes that a relative decrease in first tempo attacks might be due to the high proportion of jump services.

Another studied aspect has been the mean flight time of the ball. When comparing service tactics of the competing teams at the 1992 European Championship and 1994 World Championship, big differences were observed in mean flight time between jump and no jump services. Jump services took less mean flight time. Consequently, it was stated that mean flight time can be used as a measure for classification and assessment (Katsikadelli, 1996). In this respect, Selinger (1992) stated that the important factor that gives the jump service the edge over all other kinds of services is the minimization of the opponent's reaction time in reception. According to Strohmeyer (1996) the jump service gives a team an advantage because the higher velocities of the ball give defense less time to react to the ball's flight path.

Both authors underline the increasing use of jump service in present-day high-level volleyball. Related to this, Katsikadelli (1998) observed that the flight times of the jump services of the two finalists in the 1994 World Championship (Italy and Holland), were significantly lower ($P<0.05$) than the ones of all the other teams.

Radar guns have been used in several studies related to sports like tennis, baseball or soccer in order to calculate the speed of the ball (Lachowetz, Evon, & Pastiglione, 1998; Elliot, Nicholls, Fleisig, & Escamilia, 2003; Pugh, Kovaleski, Heitman, & Gilley, 2003; Broglio, Guskiewicz, Sell, & Lephart, 2004; Bower & Cross, 2005; Jegede, Watts, Stitt, & Hore, 2005; Markovic, Dizdar, & Jaric, 2006). In volleyball some studies have used a radar gun to analyze the relationship between spiking velocity and physical or physiological parameters (Ferris, Signorile, & Caruso, 1995; Forthomme, Croisier, Ciccarone, Crielaard, & Cloes, 2005) or to measure velocity of the spike service of young players (Zahalka & Suss, 2002). However, to our knowledge no study has been performed to relate initial service velocity to its effectiveness. Therefore, the purpose of this study is to analyze relationships between service velocity and effectiveness in a high-level volleyball tournament played in 2004.

METHODS

VOLLEYBALL TOURNAMENT

We chose for this purpose the 2004 Men's Olympic Qualification Tournament, held in Madrid (Spain) on 28th-30th May, at the Rocódromo de la Casa de Campo, between the national teams of Cuba, Spain, Holland and Cameroon. The total number of services analyzed were 377, 124 of which belonged to Cuba vs. Holland, 63 to Spain vs. Cameroon, 100 to Spain vs. Cuba, and 91 to Holland vs. Cameroon.

DATA RECORDING

Service velocities were recorded using a tripod mounted radar gun (Stalker Pro, Radar Sales Incorporated, Minneapolis, U.S.A.), with an accuracy $\pm$0.1 MPH, speed range 1-300 MPH, 1-480 KPH, and Target Acquisition Time: 0.01 Sec. The radar gun was connected to the portable computer. The Stalker ATS software program records the speed data, assigns time information, and then calculates distance and acceleration values for each data sample. The radar gun was positioned behind the court, 6 m behind the rear line and at 3 m of height to achieve an accurate recording (fig. 7)

Figure 7: Positioning of radar.

With the frantic pace of the match it was only possible to record and save one out of two alternative services. At the same time lost services in net were not taken into consideration in this article because only those services which allowed interaction with the defense where considered.

TYPES OF SERVICES

The services were coded as: FLOAT= Float service, FLOAT JUMP= Float service with jump, JUMP=Jump service.

Specifically, in JUMP the player starts from some distance behind the line and throws the ball up and forward and at the same time runs forward, jumps at the end line, meets the ball in the air and executes a spike. In FLOAT the player hits the ball standing on the floor from some distance behind the line or at the end line. He throws the ball up and drives his hand into the ball. In FLOAT JUMP, player starts from some distance behind the line and throws the ball up and forward and at the same time runs forward. Jumps at the end line, meets the ball in the air and drives his hand hard into the ball and abruptly stops it. The ball should not spin. This creates a float effect by keeping the ball from spinning.

VALUE CATEGORIES

Service effectiveness was divided in 5 categories, following Data Volley System valuation (DataProject, Bologna, Italy): 1) (=) error, outside; 2) (−) poor, the opponent receives perfectly; 3) (/) neuter, the opponent sends a free-ball to the server's court; 4) (+) positive, the opponent receives (is not able to attack the first time); 5) (#) point, the opponent does not receive, or it receives losing the ball in the following intervention.

STATISTICAL ANALYSIS

Statistical data processing was performed using the statistical pack SPSS vs. 13.0. Statistical analysis was performed using an analysis of variance (ANOVA) and regression. The programmed significance level was $P \leq 0.05$. Outcome is presented by the mean and standard deviation.

RESULTS

Figure 8 shows the quantitative distribution of each mode of service. The proportion of JUMP was 84.9%, FLOAT 9.5%, and FLOAT JUMP 5.6%. Table 2-1 shows the overall distribution of services related to service effectiveness.

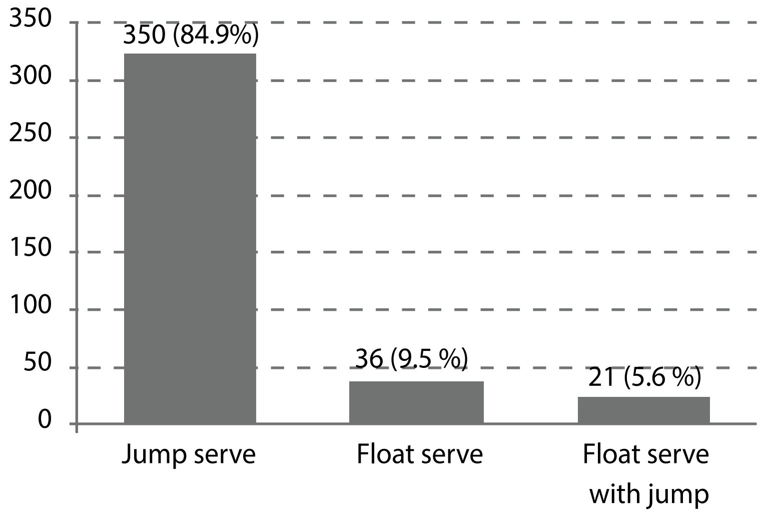

Figure 8: Frequency and percentage of each kind of service.

Table 2-1: Service types vs. value categories.

Kind of serve		1 Error (=)	2 Perfect reception (–)	3 Neuter (/)	4 Does not allow first-tempo attack (+)	5 Direct Point (#)	Total
A Float serve	Total serves	4	20	2	9	1	36
	% of kind of serve	11.1%	55.6%	5.6%	25%	2.8%	100%
	% of effectiveness	4.8%	18.2%	11.1%	6.6%	3.4%	9.5%
	% of the total	1.1%	5.3%	5%	2.4%	3%	9.5%
B Float serve with jump	Total serves	0	9	0	12	0	21
	% of kind of serve	0.0%	42.9%	0.0%	57.1%	0.0%	100%
	% of effectiveness	0.0%	8.2%	0.0%	8.8%	0.0%	5.6%
	% of the total	0.0%	2.4%	0.0%	3.2%	0.0%	5.6%
C Jump serve	Total serves	79	81	16	116	28	320
	% of kind of serve	24.7%	25.3%	5%	36.3%	8.8%	100%
	% of effectiveness	95.2%	73.6%	88.9%	84.7%	96.6%	84.9%
	% of the total	21.0%	21.5%	4.2%	30.8%	7.4%	84.9%
Total	Total serves	83	110	18	137	29	377
	% of kind of serve	22%	29.2%	4.8%	36.3%	7.7%	100%
	% of effectiveness	100%	100%	100%	100%	100%	100%
	% of the total	22%	29.2%	4.8%	36.3%	7.7%	100%

Serve types and value categories relationship. Total serves; numbers of serves performed for each value category. % of kind of serve; effectiveness percentage related to total serves of each type. % of effectiveness; percentage of serves for each value category. % of the total; percentage of serves related to the total of performed serves.

Mean velocities were significantly higher for JUMP (23.03±3.94 $m \cdot s^{-1}$) compared with FLOAT (12.05±3.44 $m \cdot s^{-1}$), and FLOAT JUMP (11.47±4.22 $m \cdot s^{-1}$).

No significant relationship was found between service velocity and a better outcome related to effectiveness ($R^2=0$ in the overall sample and $R^2=0.005$, when pooling the 5 service effectiveness categories into two groups: negative outcome (= and –) and positive outcome (/ , +, #)).

Concerning distribution of JUMP services with '=' and '#' in rank velocity values, the highest service percentage is found, in both cases, in the span of velocities between 23.06 and 28.06 $m \cdot s^{-1}$ (Table 2-2).

Table 2-2: Jump service distribution with a value '=' (error) and '#' (direct point) in velocity ranks.

	Maximum velocity ($m \cdot s^{-1}$)	n (=)	% total
Value '='	8.06 – 13.06	0	0%
	13.06 – 18.06	1	1.3%
	18.06 – 23.06	16	20.3%
	23.06 – 28.06	54	68.4%
	28.06 +	8	10.1%
	Total	79	100%
Value '#'	8.06 – 13.06	0	0%
	13.06 – 18.06	3	10.7%
	18.06 – 23.06	5	17.9%
	23.06 – 28.06	17	60.7%
	28.06 +	3	10.7%
	Total	28	100%

DISCUSSION

The volleyball service is a complex skill that may vary due to individual needs, capabilities, and match situation. Effectiveness of this action appears to be a determinant factor in the outcome of a given game. Thus, at a high-level, the player may choose to produce a high ball velocity to restrain the attacking capabilities of the opponents. However, no research has evaluated the potential relationship between service speed and effectiveness. The major finding of this study is that no significant relationship was found between service velocity and a better outcome related to effectiveness. In addition, from the three service styles JUMP and FLOAT JUMP has resulted as the best options compared with FLOAT. As expected, we have found a greater predominance of jump service in high-level volleyball. These results are in agreement with those found in other studies during the last decade (Katsikadelli, 1996; Katsikadelli, 1997; Katsikadelli, 1998; Agelonidis, 2004). To the best of our knowledge, this is the first study to analyze service mode and speed in a real elite-level competition.

From the results in table 2-1 it may be argued that jump service benefits should not be analyzed only from the point of view of winning points because only 8.8% of JUMP obtained an ace, compared with a 24.7% of direct errors. Therefore, performing a jump service can be considered as a high risk of error action. Specifically, 1 out of 4 jump services was an error, while as for the other kinds of services the failure ratio was about 1 out of 14.

On the other hand, jump service seems to be the perfect weapon to avoid first time chances of attack from the opponents. Only 25.3% of the total JUMP services were received in perfect conditions, i.e. allowing first time attack, while for the other types of services, the proportion was 42.9% (FLOAT JUMP) and 55.6% (FLOAT) which is similar to values found by Agelonidis (2004). These results could be explained by either the high ball speed attained in JUMP that may give the receivers <0.5 s to react (Katsikadelli, 1996) or to the often use of a heavy topspin which also makes it more difficult for the opponents to control the ball.

We must also underline the high percentage of FLOAT JUMP which did not allow for a first time attack (57.1%) which, *a priori*, does not correspond with the theoretical difficulty of reception, knowing that its mean velocity is practically the same as in FLOAT. Clearly, the faking factor inherent in FLOAT JUMP explains these results and justifies its use due to its high positive outcome and small number of errors. However, we must also take into account that the number of this type of services analyzed in this study is small.

Higher velocity services do not mean, *a priori*, better effectiveness. In fact, from the missed 79 jump services, 68.4% corresponded to high velocities between 23.06 and 28.06 $m\cdot s^{-1}$. Thus, it appears that the higher the velocity of the ball the higher the risk of error (Lehnert, Janura, & Stromsik, 2003). In contrast, we also observed the highest percentage of direct points (60.7%) in the same velocity interval. These velocities are closer to those reported during the spiking action in high-level players (approximately 27-28 m·s^{-1}) (Coleman, 1993; Forthomme, Croisier, Ciccarone, Crielaard, & Cloes, 2005). This was unsurprising, given the similarities between the two actions. Therefore, if service velocity alone is not in itself a determinant of effectiveness, delivering the ball to problematic or high complex court zones for the receptors could be the clue. In this sense Gambardella (1982) pointed out that an offensive service must contain three important features: velocity, movement, and placement. The results obtained in our study allows us to justify the wide use of JUMP compared to FLOAT if we pool the five effectiveness categories in two effectiveness groups: positive outcome (/, + and #) and negative outcome (− and =). In doing so, JUMP shows a balance between negative and positive outcomes, but in FLOAT the proportion is 66.7% and 33.4% respectively. Specifically, this higher percentage of positive outcome found in JUMP makes it the best option despite the high percentage of possible errors. As for FLOAT JUMP, its outcome comes near the JUMP. In this case, though, effectiveness registers of '=' and '#', and in the category '/' were not obtained. Specifically, it was found a 42.9% for '–' effectiveness category and a 57.1% in '+' effectiveness category.

A potential limitation of the study is the inability to register all the services in the analyzed matches due to the frantic pace of the matches. However, the obtained results are similar to those found in earlier studies and seem to be representative of elite-level competition.

Although failed in net services '=' effectiveness value were not registered, we consider that bias in the obtained results is of a minor importance because of the small frequency of this kind of services. However, percentages obtained in the different categories are again similar to those obtained by other authors.

Further studies are needed to analyze the relationship between type and velocity services and ground zones where the services are sent. In addition, an analysis of the influence of being ahead or behind in the score is needed. Likewise, further investigation into the real outcome of float service with jump is needed.

CONCLUSIONS

No significant relationship was found between service velocity and a better outcome related to effectiveness. In addition, both jump services (with or without float effect) present a better balance between negative and positive outcomes compared with float service.

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CHAPTER 3

THE INFLUENCE OF SERVE CHARACTERISTICS ON PERFORMANCE IN MEN'S AND WOMEN'S HIGH-STANDARD BEACH VOLLEYBALL

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ABSTRACT

The precise influence of service type and service ball speed on beach volleyball performance is unclear. We examined the relationship between service type and speed and their effectiveness during the 2008 Men and Women's Open World Tour Tournament.

Three hundred and seventy-eight and 375 services performed by men and women respectively from the main draw tournament were analyzed. Service speed was recorded using a radar gun. Two expert observers recorded service speed, service mode, service effectiveness and rally outcome. There was no relationship between service speed and its effectiveness for men ($r= -0.047$, $P> 0.05$) and for women ($r=-0.048$, $P> 0.05$).

However, there was a relationship between service ball speed and its effectiveness both for men and women, when speed was categorized into three groups. There was a better balance between negative and positive outcomes at medium speeds for men and at low and high speeds for women. There was a relationship between ranking and service ball speed only for women and between ranking and type of service for both genders. There was no relationship between rally outcome and service effectiveness. The combination of high ball speed and jump service are characteristic of high-ranking women but not of men.

INTRODUCTION

In recent years, a rising number of participants and tournaments have led to a proliferation of several studies on beach volleyball. In most instances, these studies have analyzed energy expenditure (Zetou, Giatsis, Mountaki, & Komninakidou, 2008), injury epidemiology and rehabilitation (Pfirrmann, Jost, Pirkl, Aitzetmuller, & Lajtai, 2008; Lajtai, Pfirrmann, Aitzetmuller, Pirkl, Gerber & Jost, 2009), kinematic analyses of movement patterns (Tilp, Wagner, & Muller, 2008), physical performance (Sheppard, Cronin, Gabbet, McGuigan, Etxebarria & Newton, 2008; Riggs & Sheppard, 2009; Lidor & Ziv, 2010), body composition (Palao, Gutierrez, & Frideres, 2008) and technical-tactical playing characteristics (Koch & Tilp, 2009; López-Martínez & Palao, 2009).

To be successful at both beach and indoor volleyball, a strong service is required so as to limit the opponent's attacking options. The service often used to perform a strong service is called a jump service, where the player throws the ball up and then jumps while airborne strikes the ball. Between 1992 and 2002, the proportion of jump services in high-level men's indoor volleyball rose from 20.8% to 99.2% (Agelonidis, 2004) and this high percentage has been maintained (Katsikadelli, 1997; Agelonidis, 2004; Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008). By contrast, women players have a marked preference for the standing service with an increase in the jump service being recorded from 8.4% (1996 Olympic Games) to just 18.1% (2000 Olympic Games) (López-Martínez & Palao, 2009). Yet, the jump service is well suited to avoid first-time actions of attack from the opponent (Agelonidis, 2004; Moras, Buscà, Peña, Rodríguez, Vallejo, Tous-Fajardo & Mújika, 2008). The higher velocities achieved in the ball's flight path give players less time to react. In this regard, the jump service has the edge over all other kinds of service because it reduces the receiver's time for the reception (Katsikadelli, 1997; Selinger & Ackermann-Blount, 1992). While ball speed is the key factor in a jump service, the key to the floating service is the uncertainly experienced by the receiver in determining the trajectory of the ball and the exact point at which it will fall.

Recent research has focused on the impact of both the technical and tactical characteristics of beach volleyball (Koch & Tilp, 2009), especially after the rule changes introduced in 2001 (reduction of court size and the adoption of a rally score system). As anticipated, scores for service reception have been higher in games played according to these new rules (Grgantov, Katic, & Marelic, 2005). As in indoor volleyball, the three motor skills used for serving in high-level beach volleyball tournaments are float, jump float and jump service. In the 2003 Beach Volleyball World Championship and the 2004 Olympic Games the service used in the women's game did not undergo any notable changes for indoor play, but this was not the case in the men's game where the standing float was used for 42.9% of actions and the jump service for the other 57.1% (López-Martínez & Palao, 2009).

Several authors have confirmed the importance of the service in high-level beach volleyball. Michalopoulou, Papadimitriou, Lignos, Taxildaris & Antoniou (2005) found that among leading Greek players service effectiveness was greater for the winning team. Koch & Tilp (2009) found that service reception skills were affected by the type of service. Accordingly, López-Martínez & Palao (2009) concluded that the jump service has more errors, points and actions that limit the opponents attack options than is the case with the standing service.

Few studies have reported the relationship between ball speed and its impact on performance in different sports, including golf, baseball, tennis and volleyball. For instance, ball speed, ball control and sensitivity to string tension were assessed using a radar gun in tennis (Bower & Cross, 2005). Similarly, throwing speed was used to explain the relationship between body elevation and lower limbs performance in water polo (McCluskey, Lynskey, Leung, Woodhouse, Briffa & Hopper, 2010) and club head speed was directly correlated with golf handicap as an indicator of a player's performance (Fradkin, Sherman, & Finch, 2004). Also in the sport of golf, ball speed together with upper torso and pelvis rotation were identified as acceptable predictors of swing performance (Myers, Lephart, Tsai, Sell, Smoliga & Jolly, 2008). In indoor volleyball, there was no relationship between service ball speed measured with a radar gun and effectiveness of outcome (Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008). Ball speed in jump services was markedly higher than that achieved with a float jump or float (23.03 $m \cdot s^{-1}$, 12.05 $m \cdot s^{-1}$ and 11.47 $m \cdot s\text{-}^{1}$, respectively). However, to the best of our knowledge, no studies have investigated service characteristics and performance indicators in beach volleyball.

The main aim of the present study was to determine the relationship between service speed and its effectiveness in a high-level beach volleyball tournament in men and women. Moreover, we analyzed the types of service and its effectiveness, the relation between service speed and type of service with final tournament ranking and the influence of service effectiveness on the rally outcome.

METHODS

SAMPLE

Services were recorded during the 2008 Open World Tour tournament, held in Barcelona (Spain). The total number of services analyzed was 378 and 375 in men and women, respectively. The sample included 11 matches (22 sets) from the women's and 11 matches (23 sets) from the men's main draw tournament randomly selected. The number of matches per round was: 3 (Round 1), 3 (Round 2), 3 (Round 3) and 2 (Round 4) for women, and 3 (Round 1), 2 (Round 2), 3 (Round 3) and 3 (Round 4) for men. We analyzed a total of 17 men's (mean ranking=9.2, range 1-25) and 17 women's teams (mean ranking=8.4, range 1-20) from 13 and 11 countries, respectively. Permission to record data was provided by the F.I.V.B. The study was reviewed and approved by an institutional review board of the I.N.E.F.C of Barcelona for research with human participants.

DESIGN AND VARIABLES

The services were coded as: float (float service), float jump (float service with jump), jump (jump service). Specifically, in the case of jump the player throws the ball up and forward and then runs forward, jumps at the end line and while airborne strikes the ball (Strohmeyer, 1996). In float the player hits the ball from a standing position on the sand. He or she throws the ball up and drives his hand into the ball bringing their hand to an abrupt stop. The ball should not spin. In the float jump, the player throws the ball up and forward and at the same time runs forward. The player jumps and hits the ball as described above for the float.

We divided service effectiveness in four categories according to the Data Volley System 2 (Data Project, Bologna, Italy, release 2.4.0): 0) Error, outside (=); 1) Poor (−), the opponents' reception does not limit the set action; 2) Positive (+), opponent reception leads to one of the following outcomes: A) the opponent receiver sends a free ball to the server's court; B) the reception forces the setter to set further than a 3-meter distance from the net; C) the ball flies towards the external side of the receiver, beyond the perpendicular line between the receiver's position and the net at the time of making contact with the ball; D) the ball flies behind the setter's position, forcing the player to change direction abruptly; E) reception is so low that the setter is forced to bend down and set with a forearm pass; F) reception just clears the net or makes contact with it, restricting the setter's options; 3) Direct point (#), the opponent fails to receive, or the ball is not returned to the server's court after reception.

The categorical variables were: service speed (Men: Low = ≤ 12.39 $m \cdot s^{-1}$, Medium = 12.40 $m \cdot s^{-1}$ - 16.11 $m \cdot s^{-1}$, High = >16.12 $m \cdot s^{-1}$; Women: Low = ≤ 13.33 $m \cdot s^{-1}$, Medium = 13.34 $m \cdot s^{-1}$ - 15.00 $m \cdot s^{-1}$, High = >15.01 $m \cdot s^{-1}$;); service effectiveness (0–3); type of service (float, float jump and jump); final tournament ranking (high: 1-6; medium: 7-13; low: 14-25) and rally outcome (lose: the serving team lose the rally; continue: the serving team defend and return the ball to the opposite court; win: the serving team win the rally). For the high ranking (1^{st}-6^{th}), all teams were one match away from the semi-finals. For the medium ranking (7^{th}-13^{th}), all teams reached, but did not pass, round 4. Finally, for the low ranking (14^{th}-25^{th}), no teams passed round 3.

PROCEDURES AND MATERIALS

Two expert observers recorded data. Observer 1 recorded ball speed using a radar gun (Stalker Pro, Radar Sales Incorporated, Minneapolis, U.S.A.) with a precision of ±0.04 $m \cdot s^{-1}$, speed range 0.44-134.11 $m \cdot s^{-1}$, and target acquisition time: 0.01 s. The radar gun was connected to a portable computer. Observer 2 was located in one of the lateral side courts, aligned with the net, noting type of service, service effectiveness and rally outcome. We assessed data reliability using James, Taylor & Stanley (2007) intra- and inter-observer testing procedures. Two expert observers analyzed the effectiveness data of four matches corresponding to the qualifying tournament while they were recording the matches with a video camera. Two weeks after the event, they re-analyzed the matches. The data from the two observers was used to determine inter-observer agreement while the data from the tournament analysis and video re-analysis were used to determine intra-observer agreement. Both were determined using the percentage error method (Hughes, Cooper & Nevill, 2004). The percentage of error was <5% and considered acceptable in both cases. The pace at which the matches were played made it impossible to record and save all points in every set.

We recorded ball speeds using a tripod-mounted radar gun. The Stalker ATS software program records speed data, assigns time information, and calculates distance and acceleration values for each data sample. We placed the radar gun 8 m behind the end court line and at a height of 3 m to ensure the accuracy of the recording. The radar gun was aligned to the server position and in the direction of the center end line of the opposite court, to guarantee a maximal error less than 10 degrees (1.5% error) (Figure 9). The error resulting from assessment of the speed of an object that is not in line with the radar beam is termed cosine error. Thus, at the volleyball speeds recorded, a 10° error in projectile path would amount to a cosine error of less than 0.33 $m \cdot s^{-1}$, typically less than 4.7% of recorded values.

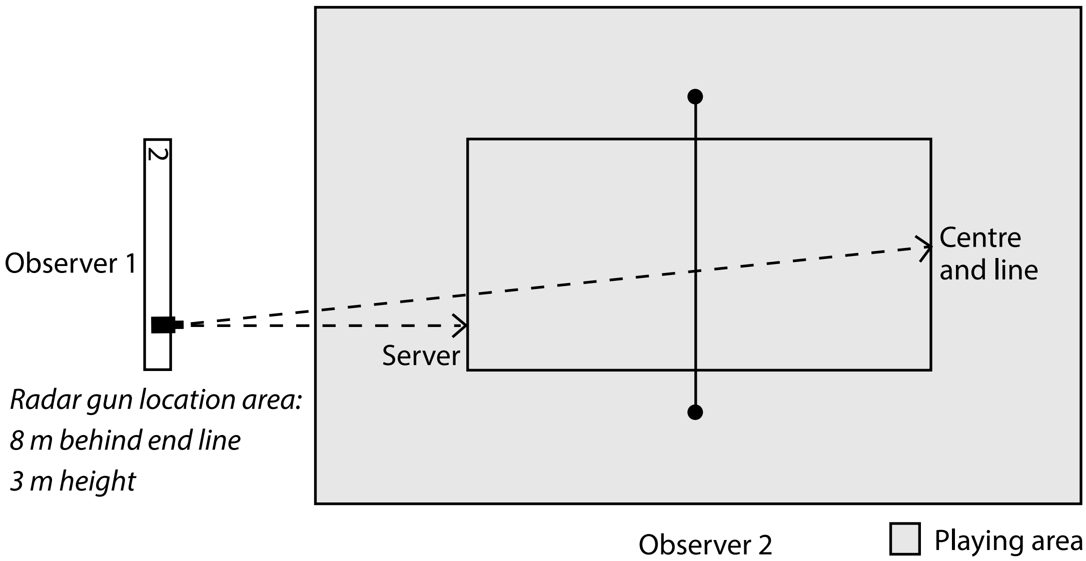

Figure 9: Assessment of service ball speed. [1]Radar gun, [2]Radar gun location area.

STATISTICAL ANALYSIS

Categorical variables were reported as the percentage distribution and continuous variables as means (s). Service ball-speed distribution was examined with the Shapiro-Wilk normality tests. Comparisons of men and women player service ball-speeds according to service type were made using the nonparametric two-sided Mann-Whitney U test for independent samples. To adjust for multiple comparisons, we applied a Bonferroni correction; therefore, a two-tailed $P < 0.017$ was considered statistically significant. We calculated Cohen's *d* effect sizes (ES) to assess the meaningfulness of observed differences between service speeds. Effects sizes of 0.20–0.49, 0.50–0.79, and ≥ 0.8 were considered to be small, moderate, and large respectively.

The relationship of service ball speed and effectiveness was assessed using Spearman's correlation coefficient for non-parametric data. For other variables that were categorical, chi-square tests for independence were used. Statistical significance was set at $P < 0.05$. If the overall chi-square was significant, we examined the adjusted residuals (non-parametric equivalent of z-scores) for the cell percentage of each subgroup. An adjusted residual score greater than 1.96 or less than -1.96 for a given subgroup percentage indicated that the subgroup differed from the overall group percentage. We calculated the standard error (SE %) using the following equation:

$$\sqrt{\frac{p(1-p)}{n}}$$

Where *p* is the cell percentage and *n* the cell count.

Statistical analysis was performed using a statistical software package SPSS (Version 18.0 for Windows, SPSS Incorporated, Chicago, Illinois).

RESULTS

The proportion of *float* was 17.2% (n=65) and 32.5% (n=122), *float jump* 37.8% (n=143) and 32.0% (n=120), and *jump* 45.0% (n=170) and 35.5% (n=133) for men and women, respectively. Table 3-1 shows the overall distribution of service type according to the value (effectiveness) categories. Service ball speed differed across service modes both in men and women ($p < 0.017$) and displayed small SE between *float jump* and *float* (men SE = 0.36; women SE = 0.38) and large SE between *jump* and *float jump* (men SE = 2.59; women SE = 2.05) and *jump* and *float* (men SE = 2.90; women SE = 2.43) (see Figure 10).

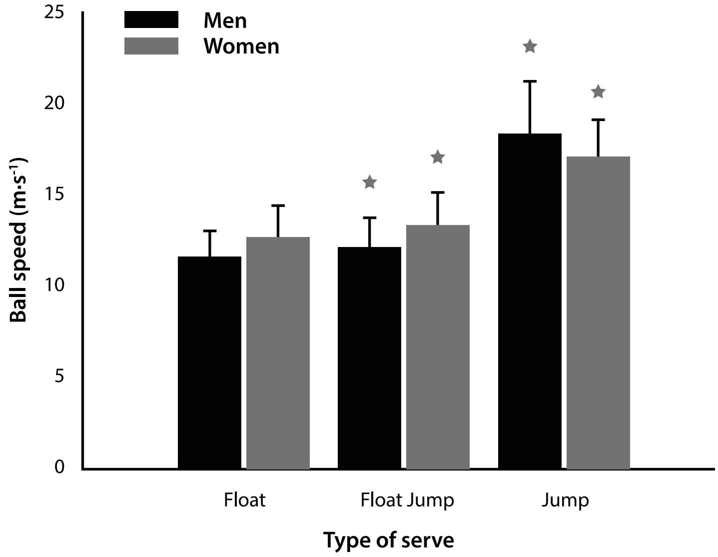

Figure 10: Ball speed for each type of service (men n=378; women n=375). *Different ($P < 0.05$) from the other types.

Table 3-1: Service types according to value categories (effectiveness).

Serve types	Serve value categories: 1 Error (=)		2 Poor Perfect reception (−)		3 Positive Poor reception (+)		4 Direct Point (#)	
	M	W	M	W	M	W	M	W
FLOAT								
Total serves	3	18	43	69	14	23	5	12
% of type of serve	4.6	14.8	62.2	56.6	21.5	18.9	7.7	9.8
FLOAT JUMP								
Total serves	15	16	98	66	24	27	6	11
% of type of serve	10.5	13.3	68.5	55	16.8	22.5	4.2	9.2
JUMP								
Total serves	35	33	95	58	27	29	13	13
% of type of serve	20.6	24.8	55.9	43.6	15.9	21.8	7.6	9.8
TOTAL								
Total serves	53	67	236	193	65	79	24	36
% of the total	14	17.9	62.4	51.5	17.2	21.1	6.3	9.6

Total serves: number of serves performed in each value category. % of type of serve: percentage of serves in each value category. % of the total: percentage of the total serves performed in each value category related to the total of serves performed. M: men; W: women.

There was no correlation between service speed and outcome in terms of effectiveness in men (r = -0.047, P > 0.05) and women (r = -0.048, P> 0.05). For both sexes, we categorized service speed into three groups (*low, medium and high*) with equal percentiles based on cases scanned. A 3 × 4 contingency table tested whether service speed differed from service effectiveness (Table 3-2). There was a relationship between service speed and service effectiveness (and $\chi 2$ = 17.79, p<0.05, for men and women, respectively). In both sexes, the prevalence of '=' increased with service speed, whereas the prevalence of '–' decreased. There were fewer errors at *low* speed (7.1%; adjusted residual = -2.7 and 10.1%; adjusted residual = -3.0 for men and women, respectively) and more at *high speed* (24.6%; adjusted residual = 4.2 and 25.4%; adjusted residual = 2.6 for men and women, respectively). Greater prevalence of '–' occurred at *low speed* for men (73%; adjusted residual = 3.0) and for women (61.9%; adjusted residual = 3.1), while the prevalence was less at *high speed* (50.8%; adjusted residual = -3.3 and 41.0%; adjusted residual = -2.8 for men and women, respectively). Furthermore, the prevalence of '#' was lower only at *low speed* in men (2.4%; adjusted residual= -2.2).

There was a relationship between ranking and service speed in the case of women ($\chi 2$ =23.00, P < 0.001) but not in the men ($\chi 2$ =4.03, P > 0.05) (Table 3-3). In women players, *high ranking* had greater prevalence at *high speed* (59%; adjusted residual = 4.6 and less prevalence at *low speed* (33.1%; adjusted residual = -2.7). By contrast, medium ranking had less prevalence at *high speed* (18.9%; adjusted residual = -2.7) and greater prevalence at *low speed* (35.3%; adjusted residual = 2.5). Finally, the prevalence of *high speed* was less for *low ranking* (22.1%; adjusted residual = 2.5).

There was a relationship between ranking and service type in the case both of men ($\chi 2$ =16.84, P < 0.05) and women players ($\chi 2$ =57.74, P < 0.001) (Table 3-3). Men's *medium ranking* had lower prevalence (33.6%; adjusted residual

= -2.1) of *float jump*. *Float* was used mainly by the *medium ranking* group (61.5%; adjusted residual = 3.8) and was not a common technique in *low ranking* players (7.7%; adjusted residual = -2.6). Conversely, there was a greater prevalence of j*ump* for women among *high ranking* players (65.4%; adjusted residual = 6.8) with less prevalence of *float* (23.0%; adjusted residual = -5.2). In addition*, medium* and *low ranking* had less prevalence of *jump* (15.0%; adjusted residual = -4.1 and 19.5%; adjusted residual = -3.3, respectively) and greater prevalence of *float jump* (38.3%; adjusted residual = 3.1) for *medium* ranking and greater prevalence of *float* (45.9%; adjusted residual = 4.6) in *low ranking* players.

There was no relationship between final rally outcome and service effectiveness selecting '–' and '+' categories, for men ($\chi 2 = 1.09$, P> 0.05) and women ($\chi 2 = 3.23$, P > 0.05) (Table 3-4). When service was '–', men and women had a similar distribution between the three rally outcome categories, with approximately 45% of points being won by the receiving team. However, when service was '+' men maintained a similar distribution to '–', though not the women, who presented a similar balance of results across the three possible outcomes.

Table 3-2: Service speed according to value categories (effectiveness).

Serve speed group	Serve value categories							
	1 Error (=)		2 Poor Perfect reception (–)		3 Positive Poor reception (+)		4 Direct Point (#)	
	M	W	M	W	M	W	M	W
Low	7.1%	10.1%	73.0%	61.9%	17.5%	16.5%	2.4%	11.5%
Medium	10.3%	19.3%	63.5%	50.0%	18.3%	23.7%	7.9%	7.0%
High	24.6%	25.4%	50.8%	41.0%	15.9%	23.8%	8.7%	9.8%

M: men; W: women; Low M= ≤12.39 $m \cdot s^{-1}$, Medium M= 12.40 - 16.11 $m \cdot s^{-1}$, High M= > 16.12 $m \cdot s^{-1}$; Low W= ≤ 13.33 $m \cdot s^{-1}$, Medium W= 13.34 - 15.00 $m \cdot s^{-1}$, High W= > 15.01 $m \cdot s^{-1}$

Table 3-3: Service speed and type of service according to ranking.

Variables	Categories	Ranking: High (1-6) M	High (1-6) W	Medium (7-13) M	Medium (7-13) W	Low (14-25) M	Low (14-25) W
Serve speed	Low	34.1%	33.1%	45.2%	35.3%	20.6%	31.7%
	Medium	45.2%	35.1%	34.9%	28.1%	19.8%	36.8%
	High	41.3%	59.0%	41.3%	18.9%	17.5%	22.1%
Type of serve	Float	30.8%	23.0%	61.5%	31.1%	7.7%	45.9%
	Float Jump	42.7%	35.8%	33.6%	38.3%	23.8%	25.8%
	Jump	41.8%	65.4%	38.2%	15.0%	20.0%	19.5%

M= men; W= women. See Table 3-2 for serve speed groups values.

Table 3-4: Rally outcome according to service categories (effectiveness).

Serve value categories	Rally outcome: Lose M	Lose W	Continue M	Continue W	Win M	Win W
Poor (–)	46.2%	45.2%	28.8%	31.6%	25.0%	23.2%
Positive (+)	43.1%	31.5%	35.4%	37.0%	21.5%	31.5%

DISCUSSION

The frequency of use of alternative service types among high-level beach volleyball players differs from that of their indoor counterparts. This is especially so for the marked difference in the frequency of use of the *jump* service. While this technique is prevalent in men's indoor volleyball (Agelonidis, 2004; Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008) the results reported here are similar to those reported by Koch & Tilp (2009) from the Grand Slam in Klagenfurt 2005 and show that in men's beach volleyball, the use of *jump* and *float jump* services are similar although there is a slight predominance of the *jump* service. By contrast, in women, the distribution of beach volleyball service types is more even and closer to that in indoor volleyball (López-Martínez & Palao, 2009). Our results support findings of earlier studies that indicated a shift towards a greater prevalence of *jump* service techniques (Koch & Tilp, 2009). In 2001, women served 63% of *float* services (Papageorgiou & Hömberg, 2004), 48% in 2005 (Koch & Tilp, 2009) and just 17.2 % in 2008, as reported in the present study. Simultaneously, the percentage share of the float jump increased from 8% in 2001 to 32% in 2005 and 2008.

Service speeds differed for all types of service, both in men and women. These findings are similar to those of previous studies that compared ball speed of the *jump* service, *float* and *float jump* in men's indoor volleyball (Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008). Ball speeds in the *jump* service (23.03 $m \cdot s^{-1}$) for men's indoor volleyball were greater than those for beach volleyball (18.21 $m \cdot s^{-1}$). This might reflect the new beach volleyball rules, or could be the result of specific ball characteristics, the smaller court dimensions (8 x 16 m), wind influence or the game structure.

There were no relationships between service ball speed and its effectiveness in either sex group for men's indoor volleyball (Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008), although we have no data to contrast with women players. However, when ball speed was categorized into three groups of equal percentiles there was a relationship. There was a greater percentage of '−' (perfect reception) in the *low speed* group and a lower percentage in the *high speed* group, both for men and women. Moreover, the higher the service ball speed, the greater was the number of service errors. Furthermore, if we compare the percentage of '=' with the percentage of positive actions ('+' plus '#'), serving at top speed is not the best option. The percentage of '=' actions (24.6% and 25.4% for men and women, respectively) is similar to the percentage of positive actions for men (24.6%) but slightly lower for women (33.6%) at high though not at *low* or *medium* speeds.

The frequency distribution shows that serving at *medium speed* provides a better outcome for positive actions (26.2%) vs. '=' (10.3%) for men. However, *low* and *high speeds* seem to be the best options for women (28% vs. 10.1% and 33.6% vs. 25.4%, respectively). These results justify the use of high speed solely for women where it can guarantee a low percentage of errors. Thus, particular interest should be paid to monitoring the point-to-error ratio during training and in competition.

There was a relationship between tournament ranking and service speed for women but not for men. The greater percentage of *high speed* and the lower percentage of *low speed* for *high ranking* women might be explained by the greater heterogeneity in their force production abilities. For elite-standard women beach volleyball players the standard deviation in kinetic and kinematic variables for squat jumps and countermovement jumps is frequently greater than for men (Riggs & Sheppard, 2009). There was also a greater prevalence of *jump* services in *high ranking* women and less prevalence of *float* because the use of *jump* and *float service* are typically associated with high and low speeds, respectively. The allegedly better physical condition of high-ranking women gives them an advantage over other ranks of women, as improved physical condition corresponds to the improved performance of effective *jump* services. In addition, the greater prevalence of *float* services in *low-ranking* players reinforces the ranking group differences for service behavior. Thus, an improvement in the specific physical performance of women players seems to be a factor for increasing the efficacy of the *jump* service and, consequently, achieving a higher ranking. In contrast to women, the distribution of service type does not influence group membership of *high-ranking* male players. However, that *low ranking* players performed only 50 per cent of *jump* service as opposed to *medium* and *high ranking* (20% vs. 38.2% and 41.8%, respectively) could be because of their poorer technical and physical condition. Surprisingly, *medium-ranking* players performed 61.5% of *float* services in contrast to *high* (30.8%) and *low ranking* (7.7%). The *low ranking* players' tendency to use jump service techniques of services might be attributable to their need to compensate for their supposed defensive weaknesses, although we have no clear evidence of this.

The absence of a relationship between service effectiveness and final outcome of the rally in both sexes suggest that eventual performance cannot exclusively be explained by the quality of service and recognizes that in beach volleyball, the quality of setting is generally excellent regardless of reception efficacy (Koch & Tilp, 2009). Moreover, López-Martínez & Palao (2009) reported no relationship between service type and the outcome of the rally. However, while women presented an even balance of '+' services in rally outcomes (*lose, continue* and *win*), surprisingly the distribution of these outcomes for men players did not vary substantially between '−' and '+'. Here, it should be noted that women in particular enjoy a theoretical advantage when the service hinders the opponent's reception.

The findings reported in this study could help men's and women's coaches develop strategies for limiting their opponents' attacking options. However, further research is needed to determine the importance of assessing service speed during training sessions and to provide individual feedback on the most effective speed for increasing service effectiveness.

CONCLUSION

In men both *jump* and *float jump* services were common, with a predominance of *jump* whereas in women the three service types were equally distributed. There were no relationships between service ball speed and its effectiveness in either sex, although there was a relationship when service speed was categorized into three groups. There was a greater percentage of perfect reception at *low speed* and a lower percentage of perfect reception at *high speed*, both for men and women. Moreover, the higher the speed of the ball, the greater was the number of errors made on the service. Thus, serving at *medium speed* in the case of men, and at *low* and *high speed* in that of women, seems to constitute the best options. There was a relationship between ranking and service ball speed for women but not for men. *High ranking* women showed a greater prevalence at *high speed* and a lower prevalence at *low speed*. There was greater prevalence of *jump* among *high ranking* women and a lower prevalence of *float*. There was no relationship between final rally outcome and service effectiveness, although women seem to obtain an advantage when the service limits the opponent's reception.

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CHAPTER 4

THE EFFECT OF AERODYNAMIC DRAG IN THE SERVICE SPEED OF HIGH-LEVEL MEN'S VOLLEYBALL

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KEY WORDS: Sport performance, radar technology, kinematics, statistics, peak velocity.

INTRODUCTION

The service speed is an important factor for the game performance in volleyball (Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008; Quiroga, García-Manso, Rodríguez-Ruiz, Sarmiento, De Saa, & Moreno, 2010). However, even more relevant seems to be the ball speed at the reception contact. The aim of the present study was to analyze if due to drag effect, the speed at which the ball reaches the receiver has significant differences with the peak velocities registered during service execution and to determine if this parameter is relevant to assess the service outcome in high-level men's volleyball.

METHODS

The present study was carried out in January 2012. Seven-hundred seventy-four services from the Spanish Volleyball Cup held in Teruel were analyzed.

Service velocities were recorded and assessed using a Stalker ATS II radar-gun and the Stalker ATS software (Stalker Pro, Radar Sales Incorporated, Minneapolis, U.S.A.).

The services included in the sample were the jump topspin (J.T.) and the jump float (J.F.) services because of their preferential use in high-level men's volleyball (Agelonidis, 2004; Häyrinen, Mikkola, Honkanen, Lahtinen, Paananen & Blomqvist, 2011).

Two expert observers executed the recording and the encoding of the data in every game. The first observer started speed recording with the authorization of the service and stopped it when the ball contacted with the receiver. The second observer introduced additional data referred to the analyzed service in a worksheet (player, type and effect of the service).

An intraclass correlation analysis and descriptive statistical tests were performed to all records.

RESULTS

The average peak speed recorded for the J.T. was 25.69±3.58 $m·s^{-1}$ and for the J.F. was 14.97±1.61 $m·s^{-1}$. The average speed at which the ball reached the receiver was 20.79±3.46 $m·s^{-1}$ and 13.14±1.49 $m·s^{-1}$ respectively; the average loss rate due to aerodynamic drag effect was 4.89±1.39 $m·s^{-1}$ for the J.T. and 1.90±0.78 $m·s^{-1}$ for the J.F. Intraclass correlation coefficient of 0.964 indicates agreement between peak and reception velocities.

DISCUSSION

Significant differences can be found between the peak velocities and the speed at which the ball reaches the receiver in a volleyball service due to the effect of aerodynamic drag. Reception contact speed records provide a better value to assess the effect of the different services in game-like situations, with a higher adjustment to the conditions in which the reception is performed.

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CHAPTER 5

WHICH SKILLS AND FACTORS BETTER PREDICT WINNING AND LOSING IN HIGH-LEVEL MEN'S VOLLEYBALL?

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ABSTRACT

The aim of this study was to determine which skills and factors better predicted the outcomes of regular season volleyball matches in the Spanish "Superliga" and were significant for obtaining positive results in the game.

The study sample consisted of 125 matches played during the 2010-2011 Spanish men's first division volleyball championship. Matches were played by 12 teams composed of 148 players from 17 different nations from October 2010 to March 2011.

The variables analyzed were the result of the game, team category, home/away court factors, points obtained in the break point phase, number of service errors, number of service aces, number of reception errors, percentage of positive receptions, percentage of perfect receptions, reception efficiency, number of attack errors, number of blocked attacks, attack points, percentage of attack points, attack efficiency and number of blocks performed by both teams participating in the match.

The results showed that the variables of team category, points obtained in the break point phase, number of reception errors, and number of blocked attacks by the opponent were significant predictors of winning or losing the matches. Odds ratios indicated that the odds of winning a volleyball match were 6.7 times greater for the teams belonging to higher rankings and that every additional point in Complex II increased the odds of winning a match by 1.5 times. Every reception and blocked ball error decreased the possibility of winning by 0.6 and 0.7 times, respectively.

INTRODUCTION

The assessment of performance indicators in high-level volleyball is an important issue for coaches and players to understand the main factors affecting the game. By increasing the knowledge of the game, these indicators emphasize the amount of training necessary for improving the skills that provide a clear advantage through decision-making and error control.

The use of notational analysis (Castro, Souza & Mesquita, 2011; Marcelino, Mesquita & Sampaio, 2011) and computerized systems (Eom & Schutz, 1992a; Eom & Schutz, 1992b) is the most common methodology in sports performance studies. Evidence from these studies has resulted in increases in speed, accuracy, the efficiency of data recording and data reduction, providing a better understanding of the game patterns and more precise assessments of the team and the players involved. Computerized systems have created the possibility of employing standardized evaluation programs to generate and exchange information without the need for codification, reading or understanding major issues.

The Data Volley program is used all over the world by many national and professional teams (Marelic, Resetar & Jankovic, 2004), and volleyball research has been performed in the past using this software (Drikos, Kountouris, Laios & Laios, 2009; Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso, 2011). Statisticians and researchers use it to monitor volleyball games and to perform multi-variate analysis.

The literature has highlighted the importance of the different factors and skills that are considered relevant in volleyball performance. Eom and Schutz (1992a) analyzed 72 matches from the third Federation of International Volleyball Cup men's competition and determined that the principal differences between the high- and low-ranked teams and between winning and losing matches arose from the skills that were used in the counterattack process: blocking, digging, setting and attacking. The same authors stated that blocking and attacking were the most important skills in determining team success, taking into consideration all of the fundamentals and phases of the game. Later, Hughes and Daniel (2004) found that high-level teams were significantly better at serving and receiving than low-standard teams. Their study also showed that the quality of the attack was dependent on the quality of the set and that the quality of the set was dependent on the quality of the defense or the reception. Zetou, Moustakidis, Tsigilis and Komninakidou (2006, 2007) studied the effectiveness of different skills grouped in Complex I (K-1: reception, setting, attacking, and covering phases) or Complex II (K-2: serving, blocking, defense, setting, counterattacking and covering phases) in the 2004 men's Olympic volleyball matches. The results of their analysis identified some elements for explaining match outcomes. For Complex I, these elements included perfect reception, a first tempo attack or a high set to the outside hitter in zone 4 or 2 after a good reception. The most determinant predictor for teams to win in this complex was a direct point from the first attack after reception. In Complex II, the best predictors identified were direct point from a service (ace) and direct points coming from a counterattack. None of the categories of blocking or defense showed the ability to predict the final outcomes of matches. In contrast, Palao, Santos & Ureña (2004) found that blocking was the most important skill for high-ranked male and female teams in the 2000 Olympic Games. They also observed a reduction in blocking errors and significantly better reception, attacking, blocking and digging according to the teams' final rankings. Patsiaouras, Charitonidis, Moustakidis & Korakidas (2011) agreed with Palao, stating that blocking was a significant factor in the outcomes of the 2008 national men's teams who competed in the frames of the Olympic Games. They concluded that blocking provoked some situations that caused enormous difficulties for opposing teams to defend effectively and counterattack. Furthermore, their findings revealed that reception errors and service points had a similar significance to blocking for winning or losing a match. In agreement, Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso (2011) affirmed that attacking was the highest point-scoring game action, but as matches became more even (sets with more than 25 points or tie break sets), the points scored by blocking became decisive for attaining victory in the 2009 European Men's Volleyball Championship.

Miskin, Fellingham & Florence (2010) observed the relationships between passing, setting and digging and the final outcome of the NCAA Division I women's competition. The authors stated that significant differences existed in the importance of skills between men and women. While men hit the ball harder when attacking and serving and subsequently gained greater benefits from these skills, women can defend more often and prolong rallies. In accordance with Miskin et al., Monteiro, Mesquita & Marcelino (2009) found significant relationships among set outcomes, digging and attack efficacy in the 2007 men's World Cup. Their results showed a significant relationship between attack efficacy and set outcome because the winners made few errors and had greater efficacy in the counterattack phase. They also demonstrated that digging efficacy was not significantly associated with set outcome.

Similar results were found by Yiannis & Panagiotis (2005), who compared the effectiveness of the five principal skills in men's volleyball (serving, reception, attacking, blocking and digging) between the Sydney 2000 and the Athens 2004 Olympic Games. Their findings revealed a universal tendency of high-level men's volleyball teams to enhance their defense by reducing blocking and digging errors. In contrast, they found an increase in reception errors as a consequence of the improvement in service effectiveness. The authors stated that the Athens gold-medal winning team from Brazil showed high effectiveness in reception and outstanding attack ability, emphasizing attacking as the most important skill in volleyball.

Home advantage is another interesting topic to consider in evaluating success predictability in volleyball. Gómez, Pollard & Luis-Pascual (2011) found a significant home advantage for all disciplines in a comparative study of the home advantage factor in nine different professional team sports in Spain. Nevertheless, the advantage was greater for rugby and less for hockey, water polo and volleyball (seasons from 2005-2006 to 2009-2010). Marcelino, Mesquita, Palao & Sampaio (2009) found that home teams had greater advantages during the beginning of matches (first set) and in the last two sets of matches (fourth and fifth set) in a study of 275 sets from the 2005 men's volleyball World League. Their findings were likely the result of home teams' familiarity with their facilities and the crowd.

Hence, the aim of our study was to determine which skills and factors better predicted winning and losing during regular season volleyball matches in the 2010-2011 Spanish men's first division and which skills and factors were more relevant for obtaining positive outcomes in the games. That information can be appropriate to provide coaches and practitioners with a better understanding of the game needs and to streamline the training processes.

METHODS

EXPERIMENTAL APPROACH TO THE PROBLEM

The purpose of the study was to determine whether any skills or factors of the games played in the 2010-2011 Spanish men's first division competition were predictors of winning or losing games.

The study variables assessed were the team category, home/away court factors, points obtained in the break point phase, service errors, service aces, reception errors, the percentage of positive and perfect receptions, reception efficiency, attack errors, blocked attacks, attack points, attack percentage, attack efficiency and the blocking performances of both teams.

The data were recorded during the regular season of the 2010-2011 Spanish men's first division volleyball championship.

SUBJECTS

The study sample consisted of 125 matches played during the regular season of the 2010-2011 Spanish men's first division volleyball championship ("Superliga").

The games were played by 12 teams consisting of 148 players from 17 different nations from October 2010 to March 2011. Permission to use data and images was provided by the Real Federación Española de Voleibol (RFEVB).

The Ethics Committee of the University of Vic according to the revised Declaration of Helsinki approved the protocol of the study.

PROCEDURES

The data analysis was performed using recorded matches obtained from the RFEVB video server (VideoSharing 2009, from Data Project, Bologna, Italy, release 2009.0.9). All of the matches were recorded using the instructions of the RFEVB referring to the correct placement and focusing of the video camera (camera positioned approximately 15 m above the playing court and approximately 20 m back from the edge of the court, parallel to the baseline).

Two trained observers performed the data observation and registration using a data-entry program (Data Volley 2007 system from Data Project, Bologna, Italy, release 3.4.8) to perform a notational analysis.

The data reliability of the observations was guaranteed by assessing the intra- and inter-observer agreements using the percentage method (Hughes & Daniel, 2003; Hughes, Cooper & Nevill, 2004). Two weeks after every match, to prevent any learning effect, each observer reanalyzed one random match. For inter-observer reliability testing, each observer analyzed one match previously analyzed by the other observer. The reliability values obtained were <5% error and considered acceptable in all cases. All skills were categorized according to the Data Volley 2007 System criteria (Data Project, Bologna, Italy, release 3.4.8), using six categories for service, reception and attack skills and five for blocking, as shown in Table 5-1.

The following variables were analyzed: (a) results of games using a binary variable (1, won match; 0, lost match); (b) team category according to the final ranking of the teams at the end of the regular season (category 1 for the teams ranked 1-4, category 2 for the teams ranked 5-8 and category 3 for the teams ranked 9-12); (c) home/away court factor; (d) points obtained in the break point phase (points scored when the team was in possession of the service); (e) service errors; (f) service aces; (g) reception errors; (h) percentage of positive receptions ([+ #] / Total receptions performed by the team * 100); (i) percentage of perfect receptions ([#] / Total receptions performed by the team *100); (j) reception efficiency ([+ #] – [– /] / Total of receptions performed by the team *100); (k) attack errors; (l) blocked attacks; (m) attack points; (n) percentage of attack points ([#] / Total of attacks performed by the team *100); (o) attack efficiency ([#] – [= /] / Total of attacks performed by the team * 100); and (p) blocks performed.

STATISTICAL ANALYSES

Inferential analysis was performed using a one-step logistic regression with the result of the game as the dependent variable.

Previously, a multi-collinearity diagnostic to find inter-correlations between predictive variables was performed. Once the data included in the model were re-considered by avoiding the use of highly inter-correlated variables, the analysis of the different variables was performed using a logistic regression technique.

Logistic regressions allow for the testing of models to predict the outcomes of a binary dependent variable based on one or more predictor variables using the next formulation, where p is probability, and e is a mathematical constant equal to approximately 2.71828:

$p = e^{z}/1+e^{Z}$ or $p = 1/1+e^{-Z}$.

Z is the linear combination of:

$Z = B_0 + B_1X_1 + B_2X_2 + \ldots + B_PX_P$,

where B is the coefficient estimated by the model, and X is the independent variable y. The significance level for the variables in the equation was established as $p \leq 0.05$.

After the multi-collinearity diagnostic, the variables (j) reception efficiency and (o) attack efficiency were excluded from the model due to having tolerance values less than 0.1 (0.025 and 0.063, respectively). The rest of the variables were included in the model. After the analyses, only four variables were used in the final logistic regression tests because the model estimated them as significant; all the rest were excluded.

All of the statistical analyses were performed using the SPSS statistical software package (version 18.0 for Windows, SPSS, Incorporated, Chicago, Illinois, U.S.A.).

RESULTS

To assess the "goodness of fit" of the logistic regression, Cox & Snell R square, Nagelkerke R square and Hosmer-Lemeshow tests were performed. The values obtained were 0.630 for the Cox & Snell R square test and 0.840 for the Nagelkerke R square test (with a maximum value of 1).

Chi-square test with a value of 2.303 and a 0.970 significance level for the Hosmer-Lemeshow test (significant with $p > 0.05$) showed support for the model, too.

The -2 log likelihood function result of 98.001, with all of the significant variables in the model, demonstrated the fit of the variables, as the likelihood result of the function with only the constant introduced in the model had a value of 346.574, and the reference to maximum likelihood was a value of 0.

Only cases 10, 72, 128, 195 and 214 were considered as Z residual values, indicating the cases in the sample for which the model did not fit well, with values greater than 2.5 or less than -2.5.

All of the cases (250) were included in the analysis, with 0 missing cases. The variables (b) team category according to the final ranking of the teams, (d) points obtained in break point phase, (g) reception errors and (l) blocked attacks were found to be significant predictors of winning and losing matches in the Spanish men's professional league for the season 2010-2011.

Table 5-1: Skills categorization according to the Data Volley 2007 system.

	=	-	/	+	!	#
Service	Error (ball to the net, out of bounds, foot foul)	Negative (opponent receives perfectly)	Positive (ball sent directly to the server's court)	Positive (opponent receives separated from the net and has no chance of first tempo attack)	Positive (opponent receives separated from the net and has a chance for a risky first tempo attack)	Direct point (ace or opponent loses the ball)
Reception	Error (direct point for the opponent)	Negative (ball can be played, but only high trajectories can be set)	Negative (ball sent directly to the server's court)	Positive (ball can be played but no first tempo attack possible)	Positive (not perfect but all attack combinations can be set)	Perfect reception (all attack combinations can be set)
Attacking	Error (out, net ball, invasion)	Poor (easily dug by the opponent, who can try to play the ball again)	Blocked attack (point goes to the opponent)	Positive (opponent defended with difficulty)	Blocked (however, recovered by the team that performed the attack)	Winning (Direct point)
Blocking	Error (hands out, net ball, ball in own side or opposite side)	Poor (the opponent can play the ball again)	Invasion (point goes to the other team)	Positive (the ball is touched and can be played again by the home team)		Winning (Direct point)

Table 5-2: Model coefficients, significance value, odds ratios and lower and upper confidence interval values.

				Confidence interval for odds ratio (95.0%)	
	Model coefficients	Significance value	Odds ratio	Lower	Upper
Team category		0.014			
Team category 1	1.908	0.005	6.742	1.800	25.259
Team category 2	0.349	0.582	1.418	0.410	4.909
Break points	0.440	0.000	1.553	1.352	1.784
Reception errors	-0-449	0.000	0.607	0.503	0.732
Blocked balls	-0.338	0.000	0.713	0.612	0.830
Constant	-2.992	0.017	0.050		

All the other variables — (c) home/away court factor; (e) service errors; (f) service aces; (h) percentage of positive receptions; (i) percentage of perfect receptions; (j) reception efficiency; (k) attack errors; (m) attack points; (n) percentage of attack points; (o) attack efficiency; and (p) blocks performed — were considered not significant and were excluded from the final model.

Team category was only significant for category 1 teams (teams ranked at the end of the regular season in positions 1-4), as the model considered category 3 (teams ranked from positions 9-12) as the reference category.

The odds ratios indicated that the odds of winning a volleyball match in the Spanish professional league were 6.7 times higher for the teams belonging to category 1, as well as that every additional point in the break point phase increased the odds of winning by 1.5 times. Every reception error fewer and blocked ball fewer increased the possibility of winning by 0.6 and 0.7 times, respectively.

The confidence intervals for odds ratios at 95% were adjusted more for the variables (d) points obtained in the break point phase, (g) reception errors and (l) blocked attacks than for category 1 teams, indicating that the odds ratios of winning for teams in this category could be even higher.

With the data described above, logistic regression could estimate the probability (from 0 to 1) of winning a match in the Spanish men's volleyball professional league for the 2010-2011 season using the constants and the model coefficients in Table 5-2 with the following calculations:

Z = CONSTANT + 1.908

(1 if team belongs to category 1, 0 for the rest)

+0.440 (BREAK–POINTS)

-0,449 (RECEPTION ERRORS)

-0.338 (BLOCKED ATTACKS).

For instance, a team belonging to category 1, with 29 break points, 3 reception errors and 3 blocked balls by the opponent will have a Z value of 9.166:

Z = -2.992 +1.908 (1)

+ 0.440 (29) -0.499(3) -0.338 (3)

=9.166.

The probability of a team in the 2010-2011 Spanish men's first division competition winning a match with this Z value would be 0.9998955:

$p = 1/1+e^{-Z}$.

$e^{-Z} = e^{-9,166} = 0.0001045$.

p=1/1+0.0001045 = 0.9998955.

DISCUSSION

Points obtained in the break point phase, the number of reception errors and the number of blocked attacks were the skill predictors found to be significant for anticipating a positive or negative outcome in the Spanish men's volleyball "Superliga." Enhancing the performance of Complex II skills and minimizing errors in Complex I seemed to be relevant to succeeding in this competition.

Break points include one's own service aces, counterattack points, and number of winning blocks and the opponent's errors, although these factors did not explain the outcomes of matches by themselves in our model. In this competition, the number of points obtained in the break point phase was the factor that made the greatest contribution to final outcomes. This factor is completely related to the performance of the opponent's reception and the opponent's attack. Reducing the number of errors in these two skills would have a direct, negative impact on the number of points obtained in Complex II skills by the opposing team. These findings agree partially with those found on the literature (Eom & Schutz, 1992; Palao, Santos & Ureña, 2004; Zetou, Tsigilis, Moustakidis and Komninakidou, 2006; Patsiaouras, Charitonidis, Moustakidis & Korakidas, 2011; Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso, 2011) that highlighted the importance of some skills in the counterattack process in winning volleyball games. The most significant difference between our findings and the data in the literature is that earlier studies considered only some of the skills in the counterattack phase to be relevant, while we have estimated the importance of the points obtained in the entire phase. Similar results have been found in other studies (Durkovic, Marelic & Resetar, 2003), concluding that the differences between semi-finalists and the rest of the teams in the 2003 Youth European Volleyball Championship were located in Complex II performance. Furthermore, decreasing the number of reception errors and blocks performed by the opponent to improve one's own performance concurs with other studies, who stated that high-level teams make fewer mistakes and executed more perfect actions in the reception phase than low-standard teams (Hughes & Daniel, 2003). As we have found, reception errors are a primary factor regarding the degree of significance of winning or losing a match (Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso, 2011) and high-level teams make fewer negative actions in attacking and have greater efficacy in the counterattack phase (Monteiro, Mesquita & Marcelino, 2009).

The numbers of service aces, service errors, positive and perfect receptions, attack points, and attack errors, the percentage of attack points, and the number of blocks performed during a match were not considered relevant for inclusion in the model.

All high-level volleyball teams assume risks when serving, despite no significant relationship being found between service velocity and better outcomes in terms of effectiveness (Moras, Buscà, Peña, Rodríguez, Vallejo, Tous & Mújika, 2008). The use of aggressive and powerful service in men's volleyball (Miskin, Fellingham & Florence, 2010) is intended to limit the offensive possibilities of opposing teams. Many teams use such services as their main strategy for winning against high-ranking teams, increasing significantly the number of their direct points, as well as the number of errors, but the number of points achieved by serving tended to be similar among high-ranking European men's teams and makes no difference in between opponents of the same competitive level by itself (Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso, 2011).

A similar explanation can be used to interpret the lack of relevance of reception skills and the number of positive and perfect actions in our results. Thus, the addition of a third player in reception to counteract a large number of jump services and the use by all teams of specialized players for reception (the Libero) made the reception efficacy similar for both the winning and losing teams (Joao, Mesquita, Moutinho & Mota, 2005). Pass quality is better when the Libero participates.

Improvement in the management of high attacks, due to a greater frequency of such attacks in today's games, provides us the keys to understanding similarities in performance, considering the number of attack points, the number of attack errors and the percentage of attacks between teams. Similar or even better attack levels for the losing team, compared to the winning teams, have been found in high-level European men's volleyball (Rodríguez-Ruiz, Quiroga, Miralles, Sarmiento, de Sáa & García-Manso, 2011) and high-level teams show improved effectiveness in reception and attack (Yiannis & Panagiotis, 2004). Handling errors appears to be a more important factor for attacking in high-level volleyball than just attacking effectively.

With regard to blocking as an outcome predictor, several studies have agreed with our findings (Marelic, Resetar & Jankovic, 2004; Zetou, Tsigilis, Moustakidis & Komninakidou, 2006), attributing less importance to blocking in volleyball match outcomes.

Our model did not consider the home advantage in the Spanish men's volleyball competition as a predictor of match outcomes. The differences between high-ranking and low-ranking teams in these competitions can make it difficult to demonstrate the influence of this factor, as the top teams won more home and away matches compared to the rest of the teams taking part in the competition. When matches are won in straight sets, home-court advantage seems to be limited only to the first set of the match (Marcelino, Mesquita, Palao & Sampaio, 2009). Those findings agree partially with other studies that have found home advantage evidences in team sports in Spain (Gómez, Pollard & Luis-Pascual, 2011), but with volleyball among the sports with the lowest significant home advantage.

Belonging to the group of teams ranked from 1 to 4 (category 1) seemed to be a significant factor in increasing the probability of winning more matches in this competition. The number of categories was fixed at three due to historical and budgetary reasons, given the number of teams not in the playoffs (category 3) and the intermediate ranked teams (category 2). Volleyball is a sport with a high predictability of outcomes because of its structure, unlike other sports, in which random effects and opponent interference can be decisive factors. Nevertheless, the confidence intervals for the odds ratios obtained by the model related to team category demonstrated even greater differences among the teams in category 1, in comparison with the teams belonging to the other categories. Belonging to this category could be an even more crucial factor.

In conclusion, the points obtained in the break point phase, the number of reception errors and the number of direct blocks of the opponent, as well as team category, could be used as predictors of volleyball match outcomes in the Spanish men's "Superliga."

PRACTICAL APPLICATIONS

Volleyball coaches and players could use our principal findings to evaluate the relative importance of the different skills and factors involved in a volleyball match. Increasing the time, quality and objectives of the training of the Complex II skills and fundamentals has a decisive contribution to the final outcome. Therefore, re-considering the amount of practice necessary to improve the technical, tactical and physical fitness aspects of the Complex II could be an interesting strategy in training.

Decreasing the number of errors coming from the Complex I skills and fundamentals will help competitive men's teams to get a better outcome when facing opponents of the same competitive level, too.

Coaches should emphasize over the improvement of the attack efficiency, reduction of the number of unforced attack errors and increasing the number of balls recovered from the attack coverage.

Minimizing the number of reception errors while facing powerful services, even reducing the accuracy if it's necessary, is also a key to enhance volleyball performance.

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CHAPTER 6

GENERAL DISCUSSION AND CONCLUSIONS

The ultimate goal of this Dissertation was to identify some critical aspects of the use of service in high-level volleyball and beach volleyball. To address this purpose and to achieve a more contextualized approach, four studies about different aspects of service performance in both sports were conducted. In them, new perspectives in performance analysis, notational analysis, analytics and kinematics were used.

The first study, carrying out an analysis between service mode, speed and effectiveness in high-level volleyball, highlighted the importance of the use of service jump abilities, while encouraging players and coaches to explore the possibilities of using different jump techniques during the performance of this important skill. Despite no significant relationship having been found between service velocity and a better direct outcome related to effectiveness, jump services were revealed as the perfect weapon to avoid first-tempo and quick outside attacks from the opponents, compared to traditional float services. In our research, only 25.3% of the receptions performed in opposition to jump topspin services were perfect receptions (allowing all the attack combinations prepared in the attack system to be set), while for jump float services the proportion was 42.9% and 55.6% for traditional standing float services. The problem found with the use of jump topspin services was the high risk of error, rewarding the opponent with an easy side-out. While in jump float and standing float services the error ratio was 1 out of 14 services, using jump topspin services this ratio increased to 1 out of 4 attempts (25%), due to the lack of accuracy that a technique with such a powerful arm swing and such an offensive intention implies. The jump topspin services executed with a higher percentage of direct points result (60.7%) were performed at the same range of speeds at which a higher percentage of errors (68.4%) were also recorded (between 23.06 and 28.06 $m \cdot s^{-1}$). This strengthens the idea that speed is not the unique factor in the explanation of the success of a service in volleyball. To serve into the seams in between receivers (where space management is harder due to the assignment of responsibilities), to seek areas of the court that are covered with great difficulty and even sometimes neglected (like corners, side and end lines), or a performance of the service with strategic purpose, seemed to be the key elements combined with a high speed execution, that can help jump topspin service performers to achieve a better success in their result.

Float jump services were shown in our research to be the services with a better balance between positive outcome and error. A high percentage of receptions coming from this kind of service did not allow a first-tempo attack (57.1%), while the number of errors was really low. These facts contradict the idea that this type of service cannot be effective in high-level volleyball, demonstrating very little scientific backing for this general axiom. A performance of jump float services with a high reach and a downward trajectory, combined with the deceptive flotation effect that only this kind of service offers, can turn it into a crucial service in high-level volleyball. However, further research is needed in this subject.

Our second study was intended to verify whether the previous findings in indoor volleyball, regarding the use of different types of service, could be extrapolated to beach volleyball. In this new research, the sample included men and women's teams and incorporated two interesting additional performance factors: rally outcome and competitive level of the teams (or ranking). The evidence found in our first investigation led us to consider wether the competitive level, service execution speed, type of service, effectiveness of the service action and the result of the rallies were somehow related. Expanding the range of factors that could be studied made sense, following our previous findings. Although volleyball and beach volleyball are similar disciplines, several aspects lent interest to a new study of the receivers' behavior after different types of services in the outdoor discipline. While in indoor volleyball all the jump topspin services are always faced with service-receive systems using three players, in beach volleyball that solution is completely impossible, due to obvious limitations derived from the game rules application. In contrast, in beach volleyball the proportion of court to be covered by each player in reception is smaller, resulting in an advantage over the indoor discipline. On the other hand, not all techniques that could be used in volleyball for receiving the service are allowed by the regulations in beach volleyball (like the overhead finger action, with a restricted use in beach volleyball). This involved some additional elements worth considering in new research approaches to the sand discipline.

The results showed that the proportion of float jump services used by men and women in beach volleyball is similar (37.8% and 32.0% for men and women, respectively), while the differences are clear in the jump service (45.0% for men and 35.5% for women) and the standing float service use (17.2% in men's competition and 32.5% in women's). Despite finding a relationship between service speed and service effectiveness for both sexes (with a higher prevalence of '=' in increased speeds), no correlation between service speed and outcome in terms of effectiveness was found in either gender, similar to what happened in men's volleyball. An interesting finding is that female beach volleyball shows a relationship between service speed and ranking, but not the male's competition. The explanation for this phenomenon probably lies in the existing physical condition differences between the top ranking women's teams and the rest of the teams playing the top-level beach volleyball competitions, while in men's beach volleyball they are not so evident. Furthermore, a relationship was found between the type of service and the ranking of male and female teams. Float jump services had lower prevalence of use in medium ranking men's players, while standing float services were mainly used in the same competition level, being this classic skill an uncommon technique for players in the lower competitive level. Higher prevalence of jump topspin services was found for higher-ranking women's teams with less use of standing float services in the same level group. Again, the conditioning level of these high-ranking teams allows the players to serve using jump skills consistently during the whole tournament, while for the rest of the teams the continuous use of this technical skill will probably be impossible without incurring in errors too frequently. In these women's high-ranking teams, the alternation between the specialized roles of defense and blocking is more frequent than in the rest of competitive levels, and even in men's volleyball. This factor also enables frequent use of this type of service without an obvious physiological fatigue effect. As happened in volleyball, there is a relationship between jump service and competitive level since mid-level teams were most prevalent for the standing float and jump float services. However, this trend is not as significant in beach volleyball as in volleyball, referring to the total number of actions executed using jump skills. In beach volleyball, service actions are shared among fewer players and the nature and environment of the sport determine much of the physical and mental fatigue of the players throughout a match and a tournament. Female and male higher-ranking teams have a regular higher level of performance that favors the use of more aggressive jump services, but it is also true that they have fewer matches to play (participating directly in the main draw and avoiding qualification phases) and they always play in the best facilities (avoiding to a greater extent adverse weather conditions). No relationship was found between final rally outcome and service effectiveness for men and women. The absence of a relationship between service effectiveness and final outcome of the rally in both genders suggests that the quality of reception has only a partial effect on the quality of the set and the attack, and that skills can be more critical to the assessment of the rally outcome. However, while women presented an even balance in rally outcomes after positive services, for male players this distribution did not vary substantially after positive or negative services (with a general positive outcome for the receiving team). This suggests that women's teams have a certain advantage when the service hinders the opponent's reception.

Average ball speeds using jump topspin technique were greater in men's volleyball (23.03 $m \cdot s^{-1}$) than in beach volleyball (18.21 $m \cdot s^{-1}$), being in our opinion a result of the specific ball characteristics, smaller court dimensions, wind influence, game structure and specific physiological demands.

The third study aimed at clarifying an issue that originated some unexpected questions in our first research experiences using radar technology in volleyball. To our knowledge of kinematics, peak velocities during the execution of service actions are registered very near to the precise moment when the hitter contacts with the ball. Once the ball contacts the receiver, it is probably no longer travelling at the same speed as when it leaves the hand of the server. So is the peak velocity, registered with the radar during the service execution, an accurate value to understand how the service affects the reception in volleyball?

To register velocities in the different moments of the ball's trajectory is not a research yet performed in volleyball, probably as a result of the limitations of data collection instruments. Today, modern radar technology enables a more precise analysis of the ball's instantaneous speed at different points of its trajectory towards the opposite court. Thus, the objective of our research was to analyze if the speed at which the ball reaches the receiver is a more relevant parameter for assessing the service's effect and probability of success than the peak speed, usually recorded in the very early stages of the ball's trajectory towards its objective.

Our research analyzed 774 services, including in the sample only the jump float and the jump topspin services due to their preferential use in high-level men's volleyball. In fact, these two types of services constituted 95.11% of those performed in competition, demonstrating the residual use of the classic standing float service in top-level competitions today. Within the total number of services included in the sample, 485 were recorded in the quarterfinals round, 191 in the semifinals and 98 in the final. A significantly low percentage of the executed services was excluded from the sample (3.8%), because they did not fulfill the inclusion criteria (they contacted with the net, went directly out of bounds or resulted in a direct point without any receiver interaction).

An average loss rate and stable relation between peak and final speed was found for both jump float and jump topspin services. Although the peak speed for topspin services is typically higher, so is their average loss. This explains the reason why in many cases a well-executed jump float service can be the same or more effective than a jump topspin service. If we add a more deceptive and downward trajectory to a more stable speed, jump float services can be a perfect weapon for serving teams. As additional findings in our study, we found no significant differences between the average speeds recorded from the finalists and the rest of the teams not playing in the final match, indicating a similar conditioning and technical level between the teams participating in the tournament. The number of jump float services executed was higher than in our previous studies, with 44.31% of the total amount of services recorded, showing different trends in the serving style between domestic leagues and high-level national teams competitions. None of the maximum speed records were registered in the final, neither for the jump float service nor for the jump topspin services. From the 10 higher speed records registered, six were from one of the finalists and the rest from teams losing in the first round of the tournament. Within the 10 fastest jump topspin services none of them were performed by a team playing in the final. Surprisingly, members of the same team, which only reached the semifinals, performed all of them. The winning team did not have any of its players among those executing top speed services in any of the modalities discussed. All this leads us to think that in a tournament of this nature, the performance of an effective service takes into consideration strategic and tactical approaches more than service speed. The individual differences of the players and a proficient risk-error ratio, also seemed to be aspects that successful teams in the tournament valued in their approaches to service performances and styles.

Jump services are practically the only ones used in high-level volleyball, the average values of speed appear to be increased from our previous studies (25.69±3.58 $m \cdot s^{-1}$ for jump topspin services and 14.97±1.61 $m \cdot s^{-1}$ for jump float services). In contrast, the percentages of each type of jump service performed favored the jump topspin service less (50.8% vs. 84.9% in our 2008 study). These differences are likely due to particularities in the sample, as well as to the influence of the analyzed competitions. We have found significant differences between peak and final speeds in all the services due to aerodynamic drag effect, and these differences are greater among the jump topspin services (average loss rate of 4.89±1.39 $m \cdot s^{-1}$) than in jump float services (1.90±0.78 $m \cdot s^{-1}$). This lower loss rate occurs because aerodynamic drag in objects moving in the air at speeds lower than the speed of sound is proportional to the square of the speed. Thus, services with lower peak velocities benefit from a smaller impact of this force. Therefore, to register the speed of the ball while contacting with the receiver seems a more contextualized and efficient value, in order to assess the effect of the service action in the quality of the passing skills. Nevertheless, there is a linear relationship between peak and final speed. Again, it seems that speed is not the only factor affecting the quality of the reception, as we were unable to find the fastest services in the winning team, and no significant differences were found between finalists and no finalists in terms of average service speeds.

Our final research, framed within the field of analytics in sport, is a deep analysis to determine which of the skills and performance factors have the strongest effect on the result of a volleyball match. In our previous research emerges a need for a complex analysis of the game of volleyball, to try to understand more explicitly what the key elements affecting the achievement of an optimal game outcome are. Knowledge the real impact of the service skill, while analyzed with some other performance factors, should also enable a deeper understanding of our previous studies' conclusions.

If the use of the service is not clearly related to the game result, but is accepted by previous scientific research as one of the key elements of the game, it is probably because a multi-variate analysis is required to obtain a list of performance factors. To carry out this analysis we chose to use inferential statistics, using a one-step logistic regression with the result of the game as a dependent variable. Logistic regression is a technique that allows the testing of models to predict the outcomes of a binary dependent variable based on one or more predictor variables. In this case the result of the game was the binary dependent variable and the skills typically assessed in volleyball statistics, with the addition of team's category (with a three-group scale) and home court advantage, the potential predictor variables. A multi-collinearity diagnostic to avoid finding inter-correlations between predictive variables was performed. After the diagnostic, the variables reception efficiency and attack efficiency were excluded from the model due to high collinearity found with the variables attack efficacy and reception efficacy. Faced with the choice of deciding between these collinear variables, the prevalent selection criteria were to use the most common variables among volleyball coaches and researchers.

Unsurprisingly, according to our findings the result of a volleyball match cannot be explained by just one performance factor. In our analysis the category of the team was the most explanatory factor of performance; teams for category 1 had 6.7 times greater possibilities of winning a match than the teams from the remaining categories. To determine all the factors affecting the team category is extremely difficult but, in the field of professional sports, the quality of the players on the roster is the one that generates great agreement. Usually, the teams finishing at the top positions of a championship are those with a bigger budget, which can be well managed to hire better players. The second factor identified that increased the possibility of winning was the production of the transition phase, or also known as break point phase. According to our results, the odds of winning a match increase 1.5 times with every additional point scored in that phase. These results are rather interesting because in some way they explain the importance of factors such as service, block or counterattack skills in the outcome of a volleyball match. These skills have been identified as predictors of performance in volleyball by previous research, and all of them are part of the above-mentioned game phase. This shows us that even though the side-out phase is the one with a higher production in the game, in terms of scoring, the points obtained from transition phase can make the difference between the winning and losing team. We also found some other interesting predictors with less weight in the outcome of the game, but no less important for coaches and practitioners: reception errors and number of blocked attacks. Every reception error less increases the possibilities of winning 0.6 times, while every additional attack blocked less does it 0.7 times. In this case, the importance of the use of service is quite obvious, since it is responsible for causing the opponent's reception errors, decreasing the production of the side-out phase. Decreasing the opponent's blocking effectiveness, thanks to a better management of the attack, and consequently affecting the number of points obtained in transition, also proves to be a key factor in the enhancement of team performance.

Our findings may be helpful for coaches and practitioners to improve the management of their practices, as well as understanding the relevant aspects of the game more profoundly. Minimizing the number of forced and unforced errors coming from the side-out phase, and enhancing the production of the transition phase are capital when facing teams of the same competitive level. Decreasing the negative effect of the opponent's service is, according to our study, important in terms of unbalancing the competition.

Thus, we can conclude that the service is a very important element of performance in volleyball and beach volleyball, but cannot explain by itself the result of a match in high-level competitions. Correct time management of the practices and use of the proper amount of the schedule to develop all the skills, seem to be a key aspect according to the experts' opinion. Research like ours can provide help in that regard to novice coaches, while reinforcing the ideas of coaches who understand the game better. It may also prevent inappropriate behavior from grassroots and lower level team practices, which are mostly based only on skills with an immediate return (like the service), without thinking about the damage they can cause in their players' future performances. At these levels, an improvement in all the technical skills is necessary, emphasizing those important in the long run and not just practicing those like the service, which give an immediate return.

We may also agree that service behavior in volleyball and beach volleyball, and its ability to impair the opponent's game, is not only based on one of its characteristics, speed. A successful execution of the service in volleyball related disciplines is a complex issue, and like the rest of skills in the game has a physical, technical, strategic and tactical component.

KNOWLEDGE DISSEMINATION

Knowledge dissemination is one of the key aspects in actual scientific research. In our area, the gap between theory and practice has been, traditionally, wide. In the past, practitioners and researchers have had few connections, as the result of no shared language and interests. In our field of study it is the responsibility of researchers and research laboratories to evaluate the real needs of coaches and to design with them the study purposes aimed at solving the real problems of daily practice. Organizations like the N.S.C.A. are putting a lot of emphasis on the practical applications of articles published in their journals, with the clear objective of changing theory into practice. To design studies that can be applied to practice and then to communicate the results in the right circles and forums is almost an obligation in the duties of sport researchers.

Universities and research laboratories are responsible for transferring to society the achievements and findings that allow development. Promoting scientific activities with a remarkable educational value is a key to discover scientific vocations, reinforcing people's training and providing a more human relation with scientists. Lastly, knowledge dissemination improves universities' public image by becoming a benefit not only for citizens but also for researchers and the university itself.

If sport science researchers target the research needs of coaches, there would be a need in the future for disseminating their findings through forums more suitable to coaches and sport specific magazines as well as coaching conferences and workshops. To this end, research-funding bodies should condition that funding to research findings being presented in the right congresses and conferences.

In my role as an applied researcher myself, knowledge dissemination is an important part of my work. As such, I have made consistent efforts to disseminate the findings of our research within sport and academic environments. Knowledge dissemination to the academic community has occurred through presentations at the 12th and 18th Annual Congresses of the E.C.S.S. (Rodríguez, Moras, Buscà, Peña, Tous, Vallejo & Mújika, 2007; Peña, Buscà, Moreno-Galcerán & Bauzà, 2013) and the 7th Congress of the A.E.C.D. (Peña, Buscà, Moreno-Galcerán, Bauzà & Cladera, 2012) as well as at a Symposium about Sports Technology, satellite to the 18th Annual Congress of the E.C.S.S. with a presentation about the use of radar technology in sport (Padullés & Peña, 2013). Our research has also been explained to members of the academic community of several institutions visited for teaching and research exchange purposes during the last two years (Teesside University, 2012 and University of Alberta, 2013).

Our research findings have been presented in volleyball congresses, such as the 6th International Conference in Volleyball Training (Moras, Peña, Buscà, Rodríguez, Vallejo, Tous & Mújika, 2007) and coaches conferences such as the 2nd Conference on Health and Fitness: Athletic Performance Assessment (Peña, 2012). Currently, we are planning to carry our findings to more events with the involvement of coaches and practitioners. Unfortunately, the number of these is rather reduced in our country. For this target of population, basic training is more common than on-going training activities.

Finally, summaries of the results of our research have been shared with coaches and players that facilitated data gathering.

LIMITATIONS AND FUTURE DIRECTIONS

For this dissertation four studies regarding aspects related to the execution of the service in volleyball and beach volleyball were conducted. The complexity of team sports understanding and the limitations of any research and analysis perspective make these studies merely approximations to the study fact, without entirely conclusive results.

Each of these investigations has obvious limitations that may be addressed in future replication studies. The world of sports performance analysis is constantly evolving and therefore, it is impossible to know today the techniques and technologies that we will have available in the future, or to know the real extent of the main aspects concerning the field of study.

Below we will discuss the general limitations and improvable aspects of our studies, to be incorporated or taken in consideration in similar investigations carried out in the future. Later we will discuss several ideas for further research, which could be conducted within the performance analysis of the volleyball disciplines.

One of the limitations of our first study about speed and effectiveness in volleyball service was the sample size. Despite the interesting number of services analyzed, the percentage of jump float services registered was small, affecting our ability to be more conclusive about the effect of this type of service in the competition. Subsequent studies have analyzed interesting aspects about the service in women's high-level volleyball, but to our knowledge none of them used the same perspective. To use a women's competition in our study would have undoubtedly been interesting, and in all probability we would have been able to find similar differences to those detected later in beach volleyball. To assess the relationship between service speed and effectiveness in the final stages of the World Championships or the Olympic Games may also be useful in obtaining interesting results. However, the F.I.V.B. is extremely reluctant to allow access to the playing facilities for research staff members, thus hindering this analysis. Recent research using statistical inference has been conducted to study the use of volleyball technical skills in the different moments of the set, considering the evolution of the score. Which is an interesting approach for further research based on the use of service.

We did not have the chance to compare the results of our second study with previous research based on women's volleyball service. Although it was not strictly necessary to write our conclusions, it would have been appropriate, similar to what we did with men's volleyball results from our previous research. In this study it would also have been interesting to analyze a greater number of events of the F.I.V.B. beach volleyball World Tour, but most of the teams in the top positions of the ranking were in Barcelona. The tournament gave the last points for the Olympic qualification for Beijing 2008. Therefore the sample quality and size was representative enough to analyze the service and its use in high-level beach volleyball. Again, inclusion of the moment of the matches as an additional factor affecting performance, could be interesting while conducting a similar study in the future.

Despite proven efficacy of radar technology in numerous studies in sport, the use of this technology to observe instantaneous speeds of the volleyball in its trajectory towards its final destination, is completely new. Its reliability can be questioned when compared to classical technologies used in time motion analysis, like high-speed cameras, but its advantages are undeniable. It is much faster, enables a large number of analyzed events, takes less time to process the data and eventually, with some practice, demonstrates accurately enough (as our research has shown). Probably, using the methodology that we have implemented with a sample of men and women's national teams tournament, and the performance of a comparative analysis, would be of great interest in the complementation of our results.

The approach to our fourth study, due to its complexity, allows many suggestions and ideas that could improve the proposal. Starting from the use of samples from national teams, to the inclusion of play-off matches within the analyzed matches, through conducting similar studies in beach volleyball tournaments seem suggestions worth being considered. These methods enable a host of possibilities that can be explored in the future.

To carry out all these investigations has opened up numerous possibilities within the field of performance analysis in sport. From refining some of them, to exporting the methodologies to some other sports of similar characteristics, there are several aspects of team sports that are worth of studying. Future research to explore deeply other volleyball and beach volleyball performance factors, and the use of statistical models such as multinomial logistic regressions would be beneficial to fully explore factors involved in the enhancement of performance in our disciplines.

CONCLUSIONS

This dissertation provides insight into some of the different factors associated with the use of service in volleyball and beach volleyball, while underlining some of the keys to using this important technical skill properly in competition. During the reading of this text we have been able to understand how the use of the service in volleyball and beach volleyball takes into consideration different aspects ranging from individual abilities to team's strategic approaches, including the search for the benefit of its use in the longer term during a match or a competition. Interesting practical applications about the use of the service in the volleyball disciplines have been provided in our studies for coaches, practitioners and researchers. However, the difficulty of addressing completely this question, because of its complexity and the continuous advances made by the sport performance analysis disciplines, requires further investigation to complete our knowledge. Thus, new and contextualized research about performance factors in volleyball and beach volleyball is strictly necessary. To achieve a greater understanding and to back up our practical knowledge in new findings, supported by scientific evidence and not purely on intuition or habits, seems key in the future to face new challenges in the field of sport sciences.

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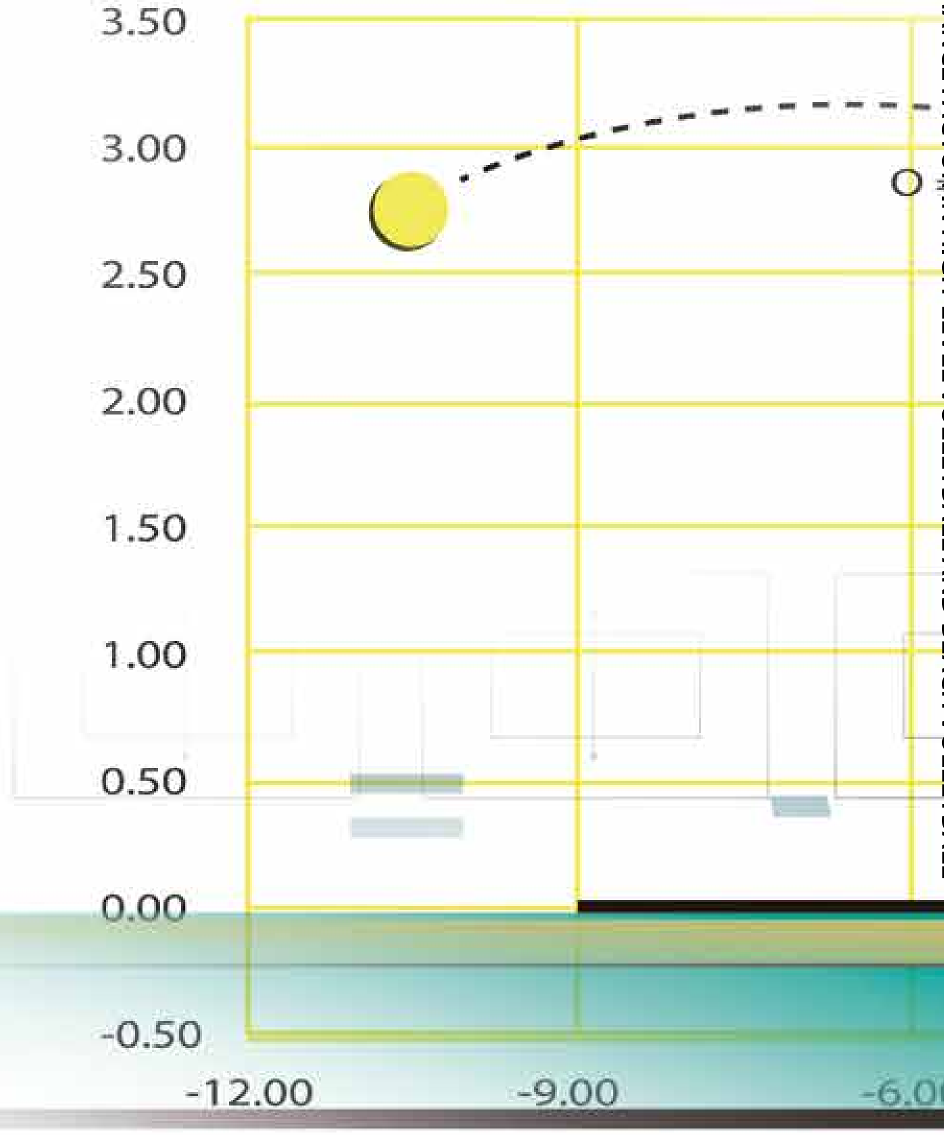
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