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# From a Static to a Dynamic Perspective in Handball Match Analysis: a Systematic Review

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**Abstract:** The aim of this study was to perform a systematic review of the scientific literature on handball match analysis and to identify potential research areas for future work. Data were collected from Web of Science, MEDLINE, SPORT-Discus, Scopus, EBSCO, and ProQuest databases. The initial search found 148 journal articles. Only the papers focused on handball match analysis regarding tactical and technical aspects were considered, for a final list of 25 publications. The complexity approach under which each considered publication was conducted was taken into account (*i.e.*, static vs. dynamic). Therein, authors, main analysis, number of performance indicators under study, considered situational variables, statistics and/or analysis methods, type of competition, number of matches, and sex of participants were distinguished for classification purposes. Research on handball match analysis has evolved over the years, mainly due to the great technological advances. Studies conducted under the classical static complexity approach are the most extended. Studies performed under the relatively new dynamic complexity approach are growing. The present review identified the following main guidelines for future work on handball match analysis: conducting more studies focused on the defensive profile; analyzing handball national leagues and international club competitions; performing more studies in female handball; including game situational variables into the analysis (*i.e.*, game type, match status, game location, quality of opposition, game period); incorporating critical events of the game into the analysis (*e.g.*, team timeouts, exclusions); and, conducting further research from the promising dynamic complexity perspective.

**Keywords:** Dynamic, handball, handball review, match analysis, performance analysis, static.

## INTRODUCTION

The analysis of sport competitions aims to provide objective and reliable performance indicators (both individual and collective) that can help coaching staff to better understand how their athletes and/or teams can improve performance and, thereby, adapt their intervention in the training sessions. A performance indicator is defined as the selection, or combination of action variables that aims to define some or all aspects of performance, which to be useful should relate to successful outcome [1]. The search for reliable performance indicators in sports game is known as performance analysis and is today “firmly positioned as an integral part of the coaching process” [2]. Published studies regarding sport performance analysis have increased greatly in recent years. A very comprehensive and updated handbook to this branch of sports sciences has recently been published [3].

Sport performance analysis can be oriented to study different aspects of performance. The most important are: tactics, strategy, mechanical aspects of technique, physical

aspects, coach behavior, and referee behavior [3]. When some (or all) of these aspects are studied during team sports competitions we are referring to match analysis. Match analysis is a specific area within sport performance analysis. It refers to the objective recording and subsequent analysis of behavioral events occurred during competition, either at an individual level (players) or at a collective level (teams), or both (players and teams) [4].

The great technological advances in the last two decades have contributed decisively to the scientific development in many research areas, including sports sciences [5]. In the specific case of team sports match analysis, the increasingly frequent use of computerized notation systems and video-based analysis systems has enabled coaches (and analysts) to obtain valuable performance indicators to assess teams' and players' performance. This, together with the easy access to these data (usually available on the websites of the sports federations), has enhanced the accessibility to reliable resources in order to objectively analyze team sports match activities [4].

Sport performance analysis in general and match analysis in particular can be accomplished from two main different complexity approaches: static and dynamic [6]. Under the static perspective, the players and teams actions and the

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critical events of the game are registered on the basis of notation systems (before manual and mostly automatic now) that address the final match statistics, making little or no reference to the context of the match at each moment (*i.e.*, structure-oriented model) [7]. Under the dynamic perspective, the actions and the critical events are registered in connection with the match process at each instant in a chronological and sequential order (*i.e.*, process-oriented model) [7].

Handball is one of the most played widely team sports in the world, especially in Europe. Handball interest is not only limited to sports entertainment context (either at the amateur or the professional level) but transcends to the field of scientific research. Since 1990, there has been a gradual increase in the number of scientific publications in handball, mainly journal articles. Articles related to sports medicine are the most extended. As with other team sports, studies regarding sport training theory, in particular those related to performance analysis, have grown enormously in recent years. To the best of our knowledge, the literature on handball performance analysis has been only briefly reviewed as part of one of the chapters of the handbook previously cited [8]. In that chapter, Volossovitch reviewed the existing studies focusing on four issues: throwing performance analysis; goal-keeper performance assessment; physical activity profiles of players and time-motion analysis; and match analysis and modelling of team's performance. With respect to match analysis (Volossovitch's fourth issue), despite being a very interesting starting point for analysts, the chapter did not considered some important contributions that can help to draw a broader picture of handball match analysis.

Within this context, the aim of this study was to perform a systematic review of the scientific literature on handball match analysis and to identify potential research areas for future work. The complexity approach under which each considered publication was conducted was taken into account (*i.e.*, static vs. dynamic).

## SEARCH STRATEGY, DATA SOURCES AND INCLUSION/EXCLUSION CRITERIA

A systematic review was conducted. Data were collected from the following computerized databases for the period 1900-2012: Web of Science, MEDLINE, SPORTDiscus, Scopus, EBSCO, and ProQuest. Multiple searches were conducted. The search terms included: handball, match analysis, performance analysis, game analysis, static complexity, dynamic complexity, performance indicators. The obtained records were compiled for analysis into a single database using the web-based reference software package RefWorks (ProQuest LLC, MD, USA). The initial search found 148 journal articles. In a next step, only the papers focused on handball match analysis regarding tactical and technical aspects were considered. The articles focused on physical performance indicators were not considered (*e.g.*, [9]). Likewise, studies that may have some applications in handball but focused on other topics were not taken into account. For these purposes, the title and the abstract of each paper was read. In doubtful cases the full text was consulted. Lastly, relevant work published in conference proceedings extracted

from the reference lists of the retrieved studies were also incorporated into the analysis. This classification process identified a final list of 25 publications (21 journal articles; 4 conference papers). These studies were read slowly and cataloged within the static or the dynamic complexity approach. Therein, authors, main analysis, number of performance indicators under study, considered situational variables, statistics and/or analysis methods, type of competition, number of matches, and sex of participants were distinguished for classification purposes. In particular, to get insight into situational variables (*i.e.*, match location, match status, quality of opposition, match period, and type of competition) see Gómez, Lago-Peñas and Pollard [10].

## HANDBALL MATCH ANALYSIS: STATIC VS. DYNAMIC APPROACH

### Handball Match Analysis from a Static Complexity Approach

The static approach is the simplest form of complexity within team sports match analysis [6]. The actions of the players and teams during the match are recorded using notation systems that have evolved extraordinarily from the early simple hand notation systems, which only allowed registering some of the actions of the match, to the current semi-automatic or automatic computerized video-based notation systems, which allow an easy recording of the majority of significant actions that occur in a match. However, despite this substantial progress in the amount and ease of data collection, the outcome of these notation processes is a more or less thorough set of descriptive statistics, usually based on frequencies and percentages of different performance indicators, which only provides information about what has happened at the end of the match, without disclosing the process of how this has happened. That is, the data collection ignores what is the context of the match at each moment. Pfeiffer and Perl [7] refer to this static approach as a structure-oriented observation model that enable for registering the isolated elementary actions of a match, but do not allow for obtaining information about the process of how these actions occur (*i.e.*, no information is given about the match process). This static complexity approach has been the most extended in handball match analysis. Published studies have analyzed different performance indicators in relation to aspects of handball such as: scoring efficiency, collective tactics, discriminatory variables between winning and losing teams, situational efficiency predictor variables, technical success variables, team's success match statistics according to match location, *etc.* Table 1 presents the reviewed articles on handball match analysis from the static complexity approach.

With respect to the scoring efficiency, several articles have studied which are the players' actions and teams' collective tactics that most influence goal-scoring in handball matches. Srhoj *et al.* [11] analyzed the influence of 18 indicators of positional direction of the attack end conduction on the final match result. The sample comprised 80 matches from 1999 men's World Championship. The results of the study showed that the players on the position of

Table 1. Reviewed published studies in handball match analysis from the static complexity approach.

| Study                                | Main Analysis                                                           | N° PI | Situational Variables | Statistics / Analysis Methods                             | Competition  | N° Matches | Sex          |
|--------------------------------------|-------------------------------------------------------------------------|-------|-----------------------|-----------------------------------------------------------|--------------|------------|--------------|
| Bilge 2012 [21]                      | Technical success variables                                             | 14    | TC                    | Descriptive statistics                                    | Ol, WCh, ECh | 72         | Men          |
| Gruic <i>et al.</i> 2005 [17]        | Backcourt attackers situation-related efficiency parameters             | 9     | —                     | Regression analysis                                       | WCh          | 15         | Women        |
| Gruic <i>et al.</i> 2006 [18]        | Situational efficiency predictor variables                              | 10    | —                     | Regression analysis                                       | WCh          | 60         | Men          |
| Gutiérrez and Ruiz 2013 [22]         | Game performance variables                                              | 8     | —                     | Data Envelopment Analysis and cross-efficiency evaluation | WCh          | 98         | Men          |
| Meletakos and Bayios 2010 [24]       | Goals scored and close games                                            | 1     | GL                    | Two-way ANOVA                                             | 7 European L | 10,358     | Men          |
| Meletakos <i>et al.</i> 2011 [20]    | Team statistics and performance indicators                              | 18    | —                     | MANOVA                                                    | WCh          | 288        | Men          |
| Ohnjec <i>et al.</i> 2008 [19]       | Situational efficiency performance indicators                           | 10    | —                     | Regression analysis                                       | WCh          | 60         | Women        |
| Pollard and Gómez 2012 [27]          | Home advantage according to sex, level of competition, and team ability | 1     | GL, QO, TC            | Three-way ANOVA                                           | Spanish L    | 480        | Men<br>Women |
| Rogulj 2000 [13]                     | Differences in the situational-related parameters of the game           | 27    | —                     | MANOVA and canonical discrimination analysis              | WCh          | 80         | Men          |
| Rogulj <i>et al.</i> 2004 [14]       | Collective attack tactics in relation to teams' score efficiency        | 19    | —                     | MANOVA and canonical discrimination analysis              | Croatian L   | 90         | Men          |
| Rogulj <i>et al.</i> 2011 [15]       | Performance efficiency of the elements of the collective attack tactics | 19    | —                     | MANOVA and canonical discrimination analysis              | Croatian L   | 90         | Men          |
| Srhoj <i>et al.</i> 2001 [11]        | Influence of the attack end conduction on final match result            | 18    | —                     | Regression analysis                                       | WCh          | 80         | Men          |
| Volossovitch and Gonçalves 2003 [16] | Relevant game indicators that discriminate winning/losing teams         | 77    | —                     | Binomial logistic regression                              | WCh          | 77         | Men          |
| Vuleta <i>et al.</i> 2003 [12]       | Relationship between variables of shooting for a goal and final outcome | 12    | —                     | Regression analysis                                       | ECh          | 38         | Men          |

PI Performance indicators. Situational variables: GL Game location; MS Match status; QO Quality of opposition; GP Game Period; TC Type of competition  
Competition: Ol Olympic Games; WCh World Championship; ECh European Championship; L League

central back attacker were those who performed more frequently the attack end conduction. The highest effectiveness of the shots was presented in clean situations (the attacker did not have an opposing defender) and in short distance shots (fast break, 7-meter, breakthrough, and pivot attacker). The lowest realization effectiveness was presented in long distance shots and low angle shots (usually from wing attackers), as well as in back attackers defender situations. Vuleta *et al.* [12] aimed to determine the relationship be-

tween 12 indicators of scoring efficiency and the final outcome of the matches when differentiating between winning and losing teams. The sample included 38 matches of 2000 men's European Championship. A regression analysis was performed. The main results showed higher efficiency for the winning teams in field shots, 7-meter throws, 6-meter center shots and wing shots.

In the same line of work, Rogulj headed throughout the years several interesting researches with the aim of determin-

ing which are the collective attack and defensive tactics related to the duration, continuity, systems, structure, and spatial direction that most differentiate between score efficient teams (*i.e.*, winning teams) and score inefficient teams (*i.e.*, losing teams). Rogulj [13] studied 27 situation- related performance indicators of the competitive successfulness of the teams participating in 1999 men's World Championship. The sample comprised a total of 80 matches. The main results revealed that winning teams were more efficient when conducting collective fast breaks and in individual actions of the breakthrough on attack. In the defensive profile, winning teams were more efficient in executing the non-contact elements of the defense, whereas losing teams committed many turnovers and executed largely ineffective shots from the back positions.

On the same subject, but focusing only on the offensive aspect of the game, Rogulj *et al.* [14] studied 19 elements of the collective attack tactics, also differentiating between winning and losing teams. The analysis covered 90 matches of 1998-1999 men's First Croatian Handball League. Winning teams were found to make short continuous attacks against unorganized defenses (usually fast breaks after a turnover by the opposing team) and short positional attacks (shorter than 25 seconds). Losing teams were found to conduct long-interrupted positional attacks, attacks with one pivot, low tactical complexity attacks, attacks based on players' individual attempts, and attacks based on group cooperation and group maneuvering of only a few players of the team. More recently, Rogulj *et al.* [15] studied the same 19 elements of the collective attack tactics in the same 90 matches sample, but this time classifying the actions into two groups depending on a realization efficiency criterion: actions that resulted in a scored goal or a forced 7-meter penalty shot were considered as efficient actions; actions that resulted in a missed goal and the loss of the ball were considered as inefficient actions. The authors concluded that to be efficient, collective attack tactics should be based on the performance of fast attacks against unprepared defenses, on short positional attacks (mainly oriented towards the line players, especially the pivot), on simple attacks founded on the basic attack principles (width and depth of the attack), and on individual-action-based attacks.

With regards to the variables that best discriminate between winning and losing teams in handball, Volossovitch and Gonçalves [16] analyzed which offensive and defensive game indicators (among more than 70) were associated to winning or losing outcome. A binominal logistic regression was performed in a sample of 77 matches from 2003 men's World Championship. The model identified five variables that had a high predictive value in determining the match result (a win or a loss, draws were not considered): number of shots, number of shots saved by the goalkeepers, number of blocks, side shot throwing efficiency, and number of failed passes.

One important group of researchers (Gruić, Vuleta, Milanović, and Ohnjec) published various studies exploring the potential influence of several situation-related efficiency performance indicators on the final outcome of the matches

in terms of the final goal differences. These indicators were considered as predictor variables of the team's successful performance. The studies differentiated between successful teams (*i.e.*, winning teams) and unsuccessful teams (*i.e.*, losing teams). Gruić *et al.* [17] studied the actions of 34 backcourt attackers to test the possible influence of different performance indicators on the final outcome of 15 matches played in the preliminary round of 2003 women's World Championship. The authors established 9 predictor variables relative to the shooting efficiency across the different playing positions (goals scored and shots missed by backcourt players, wingers and pivots), assists, extorted penalties, and technical errors committed in the attacks. A regression analysis was conducted. The main results identified line and side shots as the most effective for backcourt attackers of the winning teams, especially when the backcourt players penetrated into the pivot position as the second ones on the line. Individual breakthroughs and team tactic solutions, such as crossings and screenings (blocking an opponent with the body), were also effective for backcourt players throwing from good positions.

Published one year later, Gruić *et al.* [18] studied the elements that most determine the attack situational efficiency in a sample of 60 matches from 2003 men's World Championship. The authors considered the same predictor variables with a few changes. They incorporated the goals scored and shots missed from fast breaks and removed the extorted penalties. Regression models were performed to test the contribution of each variable to the team's success. The main results confirmed the key role of the backcourt attackers in the attack end conduction and the great efficiency of fast breaks. Published two years later, Ohnjec *et al.* [19] studied these 10 attack performance indicators in 60 matches of the preliminary round of 2003 women's World Championship. Simple regression analysis led to a general conclusion: effective offensive performance involved the simultaneous and coordinated activity of all the players in attack together with rational and economy-based shots (both from backcourt and from pivots and wings line positions).

Also focused on the offensive profile, Meletakos *et al.* [20] assessed the possible potential changes, trends, and differences between winning and losing teams across 2005, 2007, and 2009 men's World Championships in terms of throws attempted and goals scored, for a total of 288 matches under study. Each of the 29,439 executed throws was grouped according to six different throwing categories: three positional (6-meter, wing, and 9-meter, which define the position from where the throw was executed) and three situational (penalty, fast break, and breakthrough, which define the circumstances of the shot). Throw attempts, goals scored and subsequent scoring efficacy were calculated for the six categories, for a total of 18 variables under study. A multivariate analysis of variance (MANOVA) was performed to test the possible evolution of these offensive indicators throughout the three studied championships. The main findings showed that 6-meter and 9-meter throws had a great relevance in the offensive teams' profile. In particular, the 6-meter efficacy remained in constant figures across the three championships, whereas 9-meter efficacy experienced

a significant increase from 2005 to 2009. Very interestingly, the authors argued that this was due to the increasing quality of the pivots and their higher scoring efficiency, which had led the opposing teams to adopt special defensive tactics near the 6-meter line to prevent the pivots from getting the ball.

Delving also in the analysis of attack performance indicators, Bilge [21] studied several technical variables related to the efficiency of the attacks in terms of fast break efficiency, goalkeeper efficiency and throw efficiency depending on the players position (wing, pivot, backcourt) and on the situation of the play (breakthrough, fast break, and 7-meter). The study covered the statistics of the final top eight ranked teams of the European Championships, World Championships and Olympic Games in men's category within the period 2000-2010. The authors performed a comparative analysis considering two groups of tournaments: the European Championships as one group, and the World Championships and Olympic Games as another group. This comparison was conducted due to the great level that European teams demonstrate in World Championships and Olympic Games (in the period under study, 92.5% of the top eight teams in the World Championships and Olympic Games were from Europe). The analysis did not show statistically significant differences in the variables related to the number of attacks, shot efficiency, goalkeeper efficiency, ratio of wing positions goals and 7-meter position goals. Among the significant differences found, the results confirmed the great importance of fast breaks goals in modern top handball. In this sense, European teams had a higher effectiveness in fast breaks actions when playing against non-European teams (*i.e.*, in World Championships and Olympic Games), but fewer chances to conduct fast breaks when playing against European teams (*i.e.*, in European Championships). This study enhances the higher level of European national teams, and therefore European players, which despite being experts in conducting successful fast breaks, when playing against other European teams, the strong defenses they have to face makes it difficult to have chances to fast break. The same differences in favour of the European teams were found in terms of pivot position goals and breakthrough goals, which likewise shows the higher preparation of European teams, both in attack and defense.

Recently published, Gutiérrez and Ruiz [22] studied 8 variables regarding goals and shots from different distances (6-meter, 7-meter, 9-meter), situations (fast break and breakthrough), and positions. The study analyzed the 24 teams that participated in 2011 men's World Championship. The authors used the Data Envelopment Analysis (DEA) [23] and the cross-efficiency evaluation for measuring each team's performance, obtaining a performance ranking of the teams that can be compared with the final classification of the tournament and, therefore, be able to establish a comparison between the game performance and the competitive performance of each team according to its level. The results identified 9 efficient teams and 15 inefficient teams. In particular, France, Denmark and Spain won gold, silver and bronze medals, respectively. Very interestingly, these teams also finished in the first, second, and third positions in the team's

performance ranking provided by the DEA and the cross-efficiency evaluation. That is, these teams obtained an outcome in the championship in accordance with their performance. However, in many other cases the performance ranking of the teams did not coincide with their competitive ranking, both negatively (teams do not benefit from their good game in terms of results) and positively (teams obtain better outcomes than those expected for their game). The authors highlighted the case of Sweden, which was the host country and ended in fourth place despite finishing in the 17<sup>th</sup> position in the cross-efficiency evaluation ranking. That is, Sweden was a great competitor, achieving much better results than those expected for their game, probably due to some of the factors concerning the home advantage phenomenon (crowd effects, familiarity, referee bias, territoriality, and psychological aspects).

As seen, all the reviewed studies regarding handball match analysis from a static complexity perspective considered somehow the goals scored. Scored goals are the final indicator of the match outcome and are influenced by multiple factors (as seen above). In addition, scored goals can provide useful information about the level of equality within the teams (*i.e.*, competitive balance, close matches), the match periods in which the teams score more goals, and the effect of match location (home or away) in determining the result of the matches (*i.e.*, home advantage). Meletakos and Bayios [24] performed a longitudinal study of the pattern of goals scored per match in seven major men's European national leagues (*i.e.*, Denmark, France, Germany, Greece, Poland, Spain, and Sweden). The study covered seven consecutive seasons, from 2002-2003 to 2008-2009, for a total number of 10,358 matches under study. The main results showed an important overall increase in the total number of goals scored across the seasons. Rule changes (introduced to raise the pace of the game) and more complete tactical, technical, physical and psychological preparation contributed to this increase in scoring. With respect to the number of close matches (those ending with a final score difference of two or less goals), significant differences were found across the countries. France and Spain had 34% of close matches, followed by the other countries under study (31% of close matches) and an overall figure of 30.9%. With respect to the match location, the study showed the existence of a home advantage effect in all the leagues, with statistically significant differences between the countries, varying from almost 60% of home wins in Germany and Poland, to 53.6% in Denmark. Home advantage is a firmly rooted phenomenon in multiple team sports, including handball [25, 26].

Also regarding the effect of the match location, Pollard and Gómez [27], in a reassessment due to methodological and statistical problems in a previous study by Gutiérrez *et al.* [28], analyzed the home advantage effect in Spanish handball. Sex of participants (men's vs. women's), level of competition (First Division vs. Second Division) and team ability were considered. The sample covered 11 seasons from 1997-1998 to 2007-2008, for a total number of 10,536 matches under study. The results confirmed the existence of home advantage in all the leagues, greater for men than for women, and higher at Second Division than at First Division.

**Table 2. Reviewed published studies in handball match analysis from the dynamic complexity approach.**

| Study                                | Main Analysis                                                        | N° PI | Situational Variables | Statistics / Analysis Methods             | Competition | N° Matches | Sex   |
|--------------------------------------|----------------------------------------------------------------------|-------|-----------------------|-------------------------------------------|-------------|------------|-------|
| Dumangane <i>et al.</i> 2009 [35]    | Probability of scoring based on past performance of the two teams    | 1     | GP                    | Linear probability model                  | WCh         | 224        | Men   |
| Lames 2006 [30]                      | Relationship between the two team scoring processes                  | 1     | –                     | Relative phase and random walks           | WCh         | 30         | Men   |
| Lames and McGarry 2007 [31]          | Scoring process and momentary scoring probability                    | 1     | –                     | Relative phase and random walks           | WCh         | 40         | Men   |
| Lozano and Camerino 2012 [39]        | Offensive tactical systems                                           | 6     | –                     | Temporal sequential analysis (T-patterns) | WCh         | 6          | Men   |
| Moescha <i>et al.</i> 2013 [37]      | Momentum in handball from a team perspective                         | –     | GP                    | Serial dependence and non-stationary      | Sweden L    | 43         | Women |
| Oliveira <i>et al.</i> 2012* [38]    | Team's success game statistics according to game location            | 1     | GL, QO, GP            | Repeated-measures ANOVA                   | Spanish L   | 10,536     | Men   |
| Pfeiffer and Perl 2006 [7]           | Tactical structures in the offensive attempts                        | –     | –                     | Artificial neural networks models         | Junior WCh  | 15         | Women |
| Prudente <i>et al.</i> 2008 [32]     | Type, area, and path of first attacking action after a ball recovery | 3     | –                     | Sequential analysis                       | WCh, ECh    | 25         | Men   |
| Volossovitch <i>et al.</i> 2009 [34] | Past performance dependency on the probability of scoring            | 1     | GP                    | Linear probability model                  | WCh         | 224        | Men   |
| Volossovitch <i>et al.</i> 2010 [36] | Influence of the pace of the match on the dynamic of the game        | 1     | GP                    | Linear probability model                  | WCh         | 224        | Men   |
| Vuleta <i>et al.</i> 2005* [33]      | Influence of the score progress across the match                     | 1     | GP                    | Beta distribution                         | WCh         | 60         | Men   |

PI Performance indicators. Situational variables: GL Game location; MS Match status; QO Quality of opposition; GP Game Period; TC Type of competition  
Competition: OI Olympic Games; WCh World Championship; ECh European Championship; L League

\* Static/dynamic complexity approach

No interaction effects were found between sex and level of competition.

### Handball Match Analysis from a Dynamic Complexity Approach

The dynamic complexity perspective establishes a direct relationship between the events that occur in the match and the moment in which these events happen (*i.e.*, the match context). That is, time is set as a variable of study that allows the actions and critical events of the match to be recorded in a chronological and sequential order (*i.e.*, the match process at every moment is considered, contrary to the static perspective). Pfeiffer and Pearl [7] refer to the dynamic approach as a process-oriented model where a match is “characterized by a sequence of events and event-based temporal changes of the system's state”. The dynamic complexity perspective is a relative young branch of knowledge in sports performance analysis that has grown progressively in recent years mainly

due to the great technological advances in video-based match analysis software, motion tracking systems and user-friendly statistical packages [29]. In the particular case of handball, existing dynamic studies are fewer in number in comparison with those published under the static perspective, but show growing interest among researchers. Published papers have studied how to address the dynamic complexity of handball using a variety of methods, such as neural networks, mathematical modelling, sequential analysis, and probabilistic analysis. Table 2 presents the reviewed articles on handball match analysis from the dynamic complexity approach.

Pfeiffer and Pearl [7] propose the use of artificial neural networks to easily deal with the large volumes of data that can be obtained from the analysis process of the play structure and, therefore, get valuable insight into sports complex match and tactical structures, in particular in handball. The authors developed a process-oriented observation model based on a prepared neural network, which was trained with nearly 3,000 offensive attempts of the teams participating in

2001 women's Junior World Championship, with the aim of identifying the most frequent offensive tactics used by the teams. The network identified several tactical attack formations, as well as different offensive type-patterns. In the discussion section, the authors emphasize the possibilities that artificial neural networks provide to investigate the run of handball matches and extract very valuable information about the match process, which cannot be obtained through the static complexity perspective.

Based on the approach of mathematical models, Lames [30] tested two different methods for modelling game sports as dynamic processes by considering the time evolution of the game. The first method analyzed the positional interaction of single tennis players during 30 rallies recorded from Roland Garros and Australian Open in both men's and women's category. The lateral displacements of the opposing players obtained by image detection methods were subjected to relative-phase analysis using the Hilbert transform. The second method analyzed the scoring process during 30 matches of 2001 men's handball World Championship, which was seen as a random walk and described by moving averages of the scoring probability. The results showed the dynamic nature of the scoring process, with periods of the matches in which almost every ball possession ended in goal and other phases in which any goals were scored. In addition, the analysis revealed phases with an apparent strong dependence in the scoring rate between the two opposing teams, but other phases in which this scoring rate was independent from the opposing team rate. This study served as the starting point for a pioneering paper in which Lames and McGarry [31] questioned the search for reliable and stable indicators in game sports when following the classical static complexity approach. The authors argued that it is the unstable nature of the game what makes performance traits inherently unstable and, therefore, performance indicators unreliable by nature. In the first section of the article, the authors highlight some conceptual and empirical problems that can arise when searching for reliable performance indicators within the classical-theoretical performance analysis perspective. They used the same tennis and handball data of Lames' research [30] to illustrate how such problems may appear. In the second section of the paper, the authors propose a number of alternatives on the basis of considering game sports as complex dynamical systems (*e.g.*, probabilistic processes, finite Markov chain analysis) and reinforce the idea that dynamical systems theory opens up a new and promising path for increasing the understanding of the structure of game sports, in particular of handball. The article concludes by giving some practical implications for sport performance analysts.

Based on sequential analysis methods, Prudente *et al.* [32] studied a number of questions related to ball recovery in top level handball, as it facilitates defense-attack transitions with numerical and/or spatial advantage. The authors examined the type and area of the ball recovery and the path of the first attacking action after it. The sample included 3,170 offensive sequences of 25 matches of the final top eight teams of men's 2002 European Championship and 2003 World

Championship. The main results revealed that was the goal-area the zone in which most ball recoveries took place, mainly due to goalkeeper's savings, defenders recovers after opponent disarming or ball interception, and defensive rebounds.

Probabilistic analysis has also been examined as a possible method for addressing the dynamic complexity of game sports, in particular in handball. Vuleta *et al.* [33] studied the influence of the teams scoring processes on the final outcome throughout the match, which was divided for analysis purposes into four quarters of 15 minutes each. The research was conducted on a sample of 60 matches played in the preliminary round of 2003 men's World Championship. A regression analysis was performed to determine which of the four established time periods (if any) had a greater influence on the final match score. The regression results showed that were the goals scored in the first and second quarter of the match (*i.e.*, the first half) those with the highest impact on the final score goal difference. The authors explained that the higher-quality teams imposed their level due to quality differences in the initial alignments and quality reactions to the positional play of the opponents. The second half of the matches were not intended to increase the goal difference, but to preserve the functional integrity of the teams in order to maintain the already existing goal difference. Volossovitch [8] points out that Vuleta's study can be inscribed within a static/dynamic complexity approach, due to the fact that the four analyzed 15-minutes time periods were considered independent, disregarding their possible interaction throughout the match.

Also using probabilistic analysis methods, Volossovitch *et al.* [34] and Dumangane *et al.* [35] examined whether the teams' past offensive and defensive performance influence the probability of scoring in the match. Research was conducted on the sample of 224 matches from 2001, 2003 and 2005 men's World Championships, for a total of 32,273 ball possessions under study. A linear probability model was developed to estimate the scoring probability as a function of the past team's performance. The main results showed that the scoring probability did not seem to be influenced by the past offensive performance of the attacking team (*i.e.*, the own team), but indirectly by the opposing team's past offensive actions (hence it is directly related to the own team defensive performance) and by the scoreboard difference in the last ball possession. In this sense, when the teams are winning (*i.e.*, positive score difference) the scoring probability decreases as the teams focus on maintaining the advantage rather than attacking for increasing it.

Published one year later, Volossovitch *et al.* [36] analyzed whether the factors examined in their previous studies (*i.e.*, influence of the opposing teams' past performance and point difference on the scoring probability) were affected by the pace of the match. Matches were divided into slow (49 to 57 ball possessions) and fast paced matches (58 to 66 ball possessions) according to the total number of ball possessions. The subsequent model estimation found interesting results. In slow paced matches, the effect of the opposing

team's past offensive actions was negative and non-stationary during the match, whilst the effect of the point difference in the last ball possession was positive and stationary. In fast paced matches, the effect of the past offensive performance of the opponent team was negative and stationary during the match, whereas the effect of the point difference was positive, but non-stationary across the match. These results refuted the existence of a collective hot hand effect in handball and showed the need to consider the pace of the match (e.g., slow paced matches vs. fast paced matches). More in detail, Moeschke *et al.* [37] investigated the prevalence of momentum in handball from a team perspective. The sample included 43 matches of the play-off round of women's Swedish handball league. Momentum was measured through serial dependence and non-stationarity. The main results revealed that even though autocorrelation analysis showed that only 11.6% of the matches (16.3% when using chi-squared test) exhibited signs for momentum, nearly 75% of all the matches showed specific 5-minutes periods in which momentum emerged. That is, momentum usually not lasts for complete matches but emerges in short-term periods.

Regarding the effect of match location, Oliveira *et al.* [38] studied the home advantage phenomenon in men's Spanish professional handball league and examined the 5-minutes match periods in which the teams score more goals. In particular, the effectiveness of 6-meter, 7-meter and 9-meter shots and fast breaks was analyzed. Quality of opposition (balanced vs. unbalanced matches) and final outcomes (winners vs. losers) were considered. The sample covered the seasons 2007-2008 and 2008-2009. The results confirmed the existence of home advantage (64%), which was higher in balanced matches (71%) and lower in unbalanced matches (55%), but did not show any specific 5-minutes match period wherein the home advantage emerges. The last 5-minutes periods of each half of the match were those in which more goals were scored, especially in the second half. Furthermore, when compared with the losing teams, the winners showed a greater effectiveness in 6-meter, 7-meter, and 9-meter shots, as well as in fast breaks. In particular, an interaction effect between match location and quality of opposition was found in 6-meter shots, with home teams having a higher effectiveness in these shots when playing unbalanced matches. In this study we find two differentiated complexity approaches. A static approach, in which the variables under study are quantified considering the final match results and statistics, so that the match process is not contemplated, and a dynamic approach, in which the variables are examined within different match periods, so that the match process is considered. This fact allows categorizing this study within a static/dynamic complexity perspective.

More recently, Lozano (Spanish World Champion handball player, still active) and Camerino [39] studied the effectiveness of different offensive systems in handball from a dynamic, complex and nonlinear perspective. Observational methodology was used to study the 6 matches that confronted the teams that finished in the top four final positions of 2011 men's World Championship (*i.e.*, France, Denmark, Spain and Sweden), for a total of 1,043 offensive actions

under analysis. An *ad hoc* observation instrument was built in order to conduct a detailed study of the offensive dynamics. The analysis assessed the type of defense, the symmetry or asymmetry between attackers and defenders, and the offensive sequence order. Offensive tactical systems in positional attack (both structured and unstructured) or in fast breaks were differentiated. The main results pointed out that the fast break was the most effective offensive system whatever the opposing defense or the symmetry (or asymmetry) between attackers and defenders. Structured offensive systems were the most widely used although they were not always the most effective. Offensive sequences with more than three attack configurations were less effective than those that ended with fewer configurations, both structured and unstructured. The results also showed that it was more effective to use the same offensive system during all the offensive sequence than to change the system during its development.

## CONCLUSION AND FUTURE PERSPECTIVES

Research in game sports performance analysis, in particular match analysis, has evolved over the years, mainly due to the great technological advances. In the particular case of handball match analysis, existing published studies have examined players' and teams' performance from two different complexity perspectives. On the one hand, a group of studies (the most extended) have considered the classical static complexity approach, wherein the actions of players and teams are registered (usually in terms of descriptive frequencies of events) to obtain a final data set that describes what has happened at the end of the match, without considering how it happened. That is, the match process is not taken into account. On the other hand, another group of studies (fewer in number) have considered the relatively new dynamic complexity approach, wherein the actions are recorded taking into account the chronological and sequential order in which they occur. That is, the performance context and the match process at every moment are considered.

It can be observed that most of the articles focused on studying the offensive actions. In particular, the shots constituted the main action under study, in relation to which different positions (wing, pivot, backcourt), distances (6-meter, 9-meter) and situations of the play (fast break, breakthrough, penalty) were considered. Likewise, an important number of studies analyzed the differences between efficient teams (*i.e.*, winning teams) and inefficient teams (*i.e.*, losing teams). With respect to the analysis methods, articles conducted under the static perspective were based on descriptive and comparative studies of the end-of-match accumulated statistics. In contrast, studies performed from the dynamic approach used a variety of advanced analysis techniques for assessing the time evolution of performance during the match (e.g., artificial neural networks, mathematical modeling, and probabilistic analysis). With regards to the type of competitions, most studies focused on national teams international Championships, mainly World Championships, with very few studies regarding neither national handball leagues nor international club competitions. According to the sex of participants, the vast majority of studies considered men's competitions.

The present systematic review can provide useful information on future potential work lines for performance analysts in the field of handball match analysis. General guidelines for future work on handball match analysis include, but are not limited to (i) conduct more studies focused on the defensive profile, (ii) to analyze handball national leagues and international club competitions, (iii) to perform more studies in female handball, (iv) to include game situational variables into the analysis (*i.e.*, game type, match status, game location, quality of opposition, game period), (v) to incorporate critical events of the game into the analysis (*e.g.*, team timeouts, exclusions) and, (vi) to conduct further research from the promising dynamic complexity perspective.

## LIMITATIONS OF THE STUDY

Two main limitations of the study should be acknowledged. First, and most important, although the intention of the present study was to perform a systematic review of the scientific literature on handball match analysis, the increasing globalization of scientific research makes it very difficult to consider all the published studies. Thereby, articles published in journals not indexed in the major scientific databases may have fallen out of our analysis. The same applies to the possible articles published during the writing of this review or during the journal peer review process prior to publication. However, we modestly believe that the present extensive systematic review covered the most important contributions to handball match analysis. Second and last, we decided not to consider several web periodical articles published by the European Handball Federation (accessible from their website: <http://activities.eurohandball.com/web-periodicals>), because despite being interesting readings for handball match analysts, coaches, players, and fans [40-46] (all under the static approach) they cannot be considered strictly as scientific articles.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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