UNIVERSIDAD DE EXTREMADURA

TESIS DOCTORAL

ANÁLISIS DEL JUEGO EN BALONMANO FEMENINO: ORIENTACIONES PARA LOS TÉCNICOS DE ALTO NIVEL

ALEJANDRO TREJO SILVA

PROGRAMA DE DOCTORADO EN INVESTIGACIÓN EN LA ENSEÑANZA Y EL APRENDIZAJE DE LAS CIENCIAS EXPERIMENTALES, SOCIALES, MATEMÁTICAS Y LA ACTIVIDAD FÍSICA Y DEPORTIVA

Esta tesis cuenta con la autorización del Dr. Francisco Javier Brazo Sayavera, en calidad de director, y de la Comisión Académica del programa. Dichas autorizaciones constan en el Servicio de la Escuela Internacional de Doctorado de la Universidad de Extremadura.

2023

DOCTORAL THESIS

MATCH ANALYSIS IN FEMALE HANDBALL: GUIDELINES FOR HIGH PERFORMANCE COACHES

ALEJANDRO TREJO SILVA

DOCTORAL PROGRAM IN RESEARCH OF TEACHING AND LEARNING IN EXPERIMENTAL, SOCIAL SCIENCES, MATHEMATICS, AND PHYSICAL ACTIVITY AND SPORTS

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“NO PUEDO CAMBIAR LA DIRECCIÓN DEL VIENTO, PERO SÍ AJUSTAR MIS VELAS PARA LLEGAR A MI DESTINO”

“I CAN´T CHANGE THE DIRECTION OF THE WIND, BUT I CAN ADJUST MY SAILS TO ALWAYS REACH MY DESTINATION”

JAMES DEAN

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INDEX

INDEX OF TABLES

INDEX OF FIGURES

RESULTS DIVULGATION

Papers derived of this thesis

Notational analysis of Female Handball Panamerican Games 2015

Trejo-Silva, A., *Camacho, A., Camacho, M., González-Ramirez, A., & Brazo-Sayavera, J. (2020). Offensive performance under numerical inequality during exclusions in female handball. Revista internacional de ciencias del deporte, 16(62), 396-409. Doi: 10.5232/ricyde2020.06205*

Notational analysis of Female Handball Panamerican Championship 2017

Trejo-Silva, A., *Feu, S., Camacho-Cardenosa, A., Camacho-Cardenosa, M., & Brazo-Sayavera, J. (2022). Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball. Applied Sciences, 12(21). Doi: 10.3390/app122110774*

Notational analysis of Fermale Handball Euro 2018

Trejo-Silva, A., *Gómez-Ruano, M.; Feu, S. & Brazo-Sayavera, J. (2023). Analysis of offensive performance during exclusions in female senior handball.* International Journal of Performance Analysis of Sports*, XX(XX). Doi: 10.1080/24748668.2023.2180881*

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Year: 2019

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Year: 2020

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Author/s: Trejo-Silva, A.; Gómez-Ruano, M. & Brazo-Sayavera, J.

Title: ***MULTIVARIATE ANALYSIS OF FEMALE HANDBALL OFFENSIVE PERFORMANCE DURING EXCLUSIONS AT THE EURO 2018***

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Author/s: Trejo-Silva, A.; Gómez-Ruano, M. & Brazo-Sayavera, J.

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LIST OF ABBREVIATIONS

AE – Attack Efficacy

EN – Empty Net

GK - Goalkeeper

IHF – International Handball Federation

ISEF – Higher Institute of Physical Education

IUACJ – University Institute at Youth Christian Association

KPI – Key Performance Indicator

OG – Olympic Games

Min - Minute

PI – Performance Indicator

PPGG – Panamerican Games

PCh – Panamerican Championship

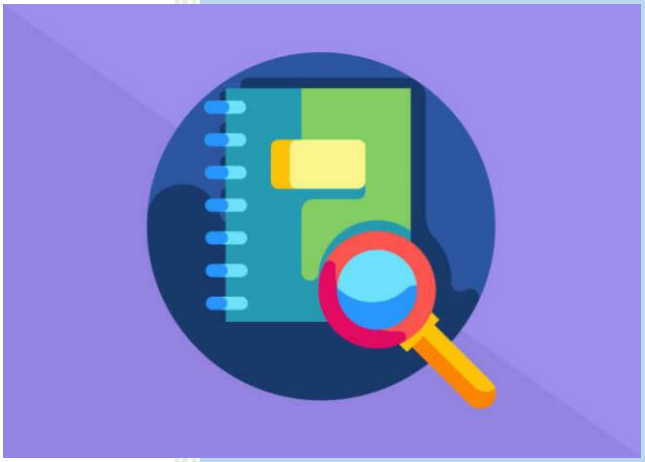
TE – Throwing Efficacy

TS – Team Sports

UdelaR – Univertisty of the Republic

WCh – World Championship

ABSTRACT/RESUMEN



ABSTRACT

In collective invasion sports, generating offensive numerical superiorities is one of the means the attack must be able to fulfill, being the main objective when in possession of the ball to score a goal. In handball, these numerical inequalities can additionally take place as a consequence of referee sanctions, as in 2-minute suspensions (also known as *exclusions*).

In this sense, and acknowledging a proven inequity in the abundance of studies dealing about performance of elite women's and men's in handball, the aim of this study is to analyze the offensive technical-tactical behaviors and actions in high-performance women's handball during exclusions. An observational methodological design was developed in order to address this approach.

Therefore, two linked features were taken into consideration: the first one is related to a change in rule 4.3 within the Rules of the Game, which directly affects the numerical ratio of team players in the field during a handball match. The second observes the notorious lack of researched information regarding Pan-American elite handball, afflicted by a very meager generation of knowledge. Hence, the production of studies on team sports in general and about the methodologies used for game analysis, either at competition or during training, can be key contributions.

As a consequence, this current Doctoral Thesis presents four studies that, within a time-line basis, can, on one hand, be regarded as a research carried out prior and post the implementation of a change in the rules. Therefore, the studies are arranged chronologically, in order to present the reader with a synthesis of the evolution of the game regarding the numerical inequalities that come about during the exclusions; this at Pan-American, European and Olympic Games level, and along the time period between 2015 and 2018. This period includes tournaments both before and after the rule change that came into effect on August 1st 2016.

In order to achieve the development and accomplishment of the objectives of this research, four articles, product of four studies aimed at recording, analyzing and discussing data on the offensive performance of elite female handball teams within the contexts of four different tournaments, were coherently designed and produced for publishing. Accordingly, the first chosen context was the last official tournament still played in Pan-America with 2010 IHF Rules of the Game.

Furthermore, the study was intended (i) to describe the situations of numerical inequality resulting from exclusions during the women's handball tournament at the 2015 Pan-American Games, and (ii) to analyze attack and throwing efficacy, in order to relate it to the final result of the matches.

The main results highlighted that the winning teams scored a higher percentage of the total goals and also showed a lower percentage of throws out. The winners exhibited a better performance in their attack efficacy (by number of goals in relation to the number of attacks/possessions) while playing in an inferiority context. In the context of offensive numerical inferiority, in 100% of the ball possessions the teams played keeping their goalkeeper in goal.

After that, the very first tournament where the 2016 IHF Rules of the Game were applied was at Rio 2016 Olympic Games. The study aimed to analyze the offensive performance under different scenarios of numerical inequalities during exclusions in women's handball, at Rio 2016. The main results observed were that during superiority context playing fast transitions, along with displaying the 3:3 offensive system (with a pivot) was linked to a high attacking efficacy (58%), being these elements predictors of the offensive game play in that context of inequality. On the other hand, during the inferiority context, playing with an empty goal (i.e. using the change of goalkeeper for an outfield player) was used in 35.0% of the possessions recorded, resulting this tactical option a predictor of the teams ending placed in the last 4 positions of the tournament (9 to 12) as well as for the 4 semi-finalists.

Following-up the analysis of the Pan-American continent, the study aimed to determine the indicators of offensive performance during exclusions in relation to the final ranking eventually obtained

in the 2017 Pan-American women's handball tournament. The results achieved show a tendency for teams ranked 1 to 6 (out of 10 participating teams) to play in numerical superiority over numerical inferiority. Teams ranked 7 to 10 tended to finish without throwing during their attacks. On the other hand, playing with an empty goal was a predictor of finishing in places 1 to 3 in the tournament.

The last study was performed at EURO 2018. It can be concluded that during the female Euro 2018 handball championship, teams tended to keep on increasing the option of playing with EN during the inferiority context. However, teams ranked 1st to 4th displayed a tendency to play with GK at goal. In addition, this new strategy was associated with ending in turnovers and receiving a fast transition from the opponent as a consequence. Moreover, fast transitions (direct counterattack and extended fast break) were performed mostly during superiority, and when playing positional build-up phase the 2:4 offensive system was the most used one.

The results in the studies showed that although teams performed better in contexts of superiority than in inferiority, this difference was not as distinct as expected. Along the time-line (2015-2018), teams registered a tactical adaption to play with an empty net (changing the goalkeeper for an in-court player) during inferiority context. However, during the period studied, some top European teams were more reluctant to this change. Moreover, and in spite of what some indicators displayed seemingly leading to the conclusion that Pan-American handball is played in a similar manner to European or World level (regarding average of exclusions per game, game time when they are sanctioned and relation of exclusions sanctioned with final ranking), important differences were found in the playing styles among Pan-American, European and rest of the world teams level.

Data from this thesis generates a valuable contribution of information for elite and national level coaches, providing an objective outlook of female elite level teams´ performance in offensive situations during numerical inequality circumstances, once a 2-minute suspension is sanctioned. In addition, results from this research can enable practical applications for teaching, training and the development of the sport, emphasising the main characteristics and profiles revealed by the analysed teams in their different geographical regions, especially in regards to a strategic interpretation of regulatory aspects affecting the way in which the teams do play. It contributes to the development of theoretical material, which may well be positively useful, both at the formation of bachelor´s in Physical Education as well as of Coaches.

Keywords: numerical inequalities; game outcome; final ranking; empty net; exclusions; 2-minute suspensions; team sports.

RESUMEN

Generar superioridades numéricas ofensivas es uno de los medios tácticos ofensivos que debe cumplir el ataque en los deportes colectivos de invasión, siendo el objetivo principal para marcar un gol cuando se está en posesión del balón. En balonmano, estas desigualdades numéricas también se producen como consecuencia de las sanciones arbitrales (como en las suspensiones de 2 minutos, también conocidas como exclusiones). Por otra parte, y en el contexto de una demostrada disparidad de estudios sobre el rendimiento del balonmano de élite femenino y masculino, el objetivo de este estudio fue analizar los comportamientos y acciones técnico-tácticas ofensivas en el balonmano femenino de alto rendimiento durante las exclusiones. En el abordaje de este tema se desarrolló un diseño metodológico observacional.

No obstante, se tienen en cuenta dos aspectos, uno relacionado con la modificación de la regla 4.3 de las Reglas de Juego que afecta directamente a la relación numérica de las jugadoras de campo de los equipos que disputan un partido de balonmano, y el otro es la demostrada falta de producción de conocimiento sobre el balonmano de élite panamericano. En relación a estos dos elementos, puede ser un aporte la producción de estudios sobre los deportes de equipo en general y sobre las metodologías utilizadas en el análisis del juego en competición y entrenamiento. En consecuencia, la presente Tesis Doctoral presenta 4 estudios que, con una base cronológica, pueden considerarse anteriores y posteriores a la implementación de un cambio en las reglas. Por lo tanto, están ordenados cronológicamente con el fin de presentar al lector una síntesis de la evolución del juego durante las desigualdades numéricas que se producen en las exclusiones, tanto a nivel panamericano, europeo y de los Juegos Olímpicos en el período comprendido entre 2015 y 2018. Este periodo incluye torneos anteriores y posteriores al cambio de reglas que entró en vigor el 1 de agosto de 2016.

El desarrollo y consecución de los objetivos de esta investigación se alcanzaron a través del diseño y publicación de cuatro artículos que incluyeron cuatro estudios destinados a registrar, analizar y discutir

el rendimiento ofensivo del balonmano femenino de élite durante cuatro contextos de torneo diferentes, así como bajo dos contextos de reglas de juego diferentes.

En primer lugar, el contexto elegido fue el último torneo oficial disputado en Panamérica con reglas de juego IHF 2010. El estudio tuvo como objetivo (i) describir las situaciones de desigualdad numérica como consecuencia de las exclusiones durante el torneo de balonmano femenino de los Juegos Panamericanos 2015 y (ii) analizar la eficacia de ataque y lanzamiento, para relacionarla con el resultado final de los partidos. Los principales resultados mostraron que los equipos ganadores anotaron un mayor porcentaje del total de goles y mostraron un menor porcentaje de lanzamientos fuera. Los ganadores mostraron un mejor rendimiento en su eficacia ofensiva (número de goles en relación al número de ataques/posesiones) cuando jugaron en un contexto de inferioridad. En el contexto de inferioridad numérica ofensiva, en el 100% de las posesiones de balón los equipos jugaron manteniendo a su portera en la portería.

Posteriormente, el primer torneo en el que se aplicaron las Reglas de Juego IHF 2016 fue en los Juegos Olímpicos de Río 2016. El estudio tuvo como objetivo analizar el rendimiento ofensivo durante diferentes escenarios de desigualdad numérica en las exclusiones en el balonmano femenino en los Juegos Olímpicos de Río 2016. Los principales resultados a destacar fueron que jugar transiciones rápidas, así como el uso del sistema ofensivo 3:3 (con un pivote) estuvo vinculado a una alta eficacia ofensiva (58%), siendo estos elementos predictores del juego ofensivo en ese contexto de desigualdad. Por otro lado, en el contexto de inferioridad, jugar con portería vacía (utilizando el cambio de portera por una jugadora de campo) fue utilizado en el 35,0% de las posesiones registradas, resultando esta opción táctica un predictor de los equipos situados en las 4 últimas posiciones del torneo (9 a 12) así como para los 4 semifinalistas.

Siguiendo con el análisis del continente panamericano, el siguiente estudio tuvo como objetivo determinar los indicadores de rendimiento ofensivo durante las exclusiones en relación con la clasificación final obtenida en el torneo Panamericano de balonmano femenino 2017. Los resultados obtenidos

muestran una tendencia de los equipos clasificados del 1 al 6 (de un total de 10 equipos participantes) a jugar en superioridad sobre inferioridad. Los equipos clasificados del 7 al 10 tendieron a terminar sin lanzamiento sus ataques. Por otra parte, jugar con la portería vacía fue un factor predictivo de acabar en los puestos 1 a 3 del torneo.

El último estudio se centró en la Eurocopa 2018. Se puede concluir que durante la Eurocopa femenina de balonmano 2018, los equipos tendieron a seguir aumentando el uso del juego con portería vacía durante el contexto de inferioridad. Sin embargo, los equipos clasificados del 1º al 4º mostraron una tendencia a jugar con su portera en la portería. Además, esta nueva estrategia se asoció con finalizar en pérdidas de balón y recibir como consecuencia una transición rápida del adversario. Por otra parte, las transiciones rápidas (contraataque directo y contraataque ampliado) se realizaron sobre todo durante la superioridad, y cuando se jugaba la fase de juego posicional, el sistema ofensivo 2:4 era el más utilizado.

Los resultados de los estudios mostraron que los equipos rindieron mejor en superioridad que en inferioridad, aunque no tanto como se esperaba. Durante el contexto de inferioridad, los equipos registraron una adaptación táctica para jugar con portería vacía (cambiando la portera por una jugadora de campo) a lo largo de la línea de tiempo. Sin embargo, algunos de los mejores equipos europeos se mostraron más reacios a este cambio durante el periodo estudiado. A pesar de lo que muestran algunos indicadores que llevan a concluir que el balonmano panamericano se juega de manera similar al europeo o mundial (en cuanto a promedio de exclusiones por partido, tiempo de juego en que son sancionadas y relación de exclusiones sancionadas con la clasificación final), se encontraron importantes diferencias en el estilo de juego entre los equipos panamericanos, europeos y del resto del mundo.

Los datos de esta tesis aportan información valiosa para los entrenadores de élite y de nivel nacional, proporcionando una visión objetiva del rendimiento de los equipos femeninos de élite en situación ofensiva durante las situaciones de desigualdad numérica una vez que se sancionan 2 minutos de suspensión. Además, los resultados de esta investigación pueden permitir aplicaciones prácticas en la

enseñanza, entrenamiento y desarrollo de este deporte, destacando las principales características y perfiles que los equipos analizados presentaron en sus diferentes regiones geográficas, especialmente en lo que se refiere a una interpretación estratégica de los aspectos reglamentarios (jugar o no con portería vacía) que afectan a la forma de jugar de los equipos. Contribuye para el desarrollo de material teórico útil tanto en la formación de licenciados en Educación Física como de entrenadores.

Palabras clave: desigualdades numéricas; condición final; clasificación final; portería vacía; exclusiones; suspensiones de 2 minutos; deportes colectivos.

Chapter 1. INTRODUCTION

1 INTRODUCTION

My professional profile in relation to handball encompasses two main fields.

In one of them (and perhaps to my own surprise/quite a surprise in a beginning) I thrive close to academy, were as time went by I became a specialist lecturer in the matter of Handball, at the Higher Institute of Physical Education of the University of the Republic (ISEF-UdelaR) and at the University Institute of Youth Christian Association (IUACJ). I even accomplished to publish my first articles about handball studies. I am also lecturer of "Handball at School" at the South-Center Handball Confederation (COSCABAL) and at different workshops and seminars organized by the Uruguayan Handball Federation (FUH).

The other field, of course, is the practical one: I have been working as a handball coach for 25 years, being involved in many different levels of development, including physical education lessons, initiation, formation, school competition, club´s competition; both for male and female teams. I had the chance of being the coach of the Female Beach Handball National Team for 10 years (taking part in several continental tournaments and three World Championships); for 2 years, I coached the Female Handball National Team (participating in continental championships); since November 2021 I am the coach of the Male Handball National Team (attending continental championships and the recently finished XXIII World Championship Poland/Sweden 2023).

Consequently, all these above-mentioned links with handball were the drives and motivation of my subject choice for this doctoral thesis. In addition, the daily contact with handball and the constant concern to deepen its study, has led me over time to ask myself many questions, both about the analysis of this sport and regarding possible theoretical and practical approaches that may arise from all this to improve the training processes and their application in real competition conditions.

Also, the daily contact with handball and the constant concern to deepen in its study, has led me over time to ask myself many questions, both in the analysis of this sport and in the possible theoretical and practical proposals that may arise from it to improve the training processes and their application in real competition conditions.

This doctoral thesis also stems from an initial study conducted as a final master's degree research work, at the Official University Master's Degree in Sports Performance: Technification and High Level (RETAN) organized by the University of Barcelona (UB) and the INEFC (2013-2015), which focused on the female offensive performance during exclusions at Serbia 2013 Female Handball World Championship, event I got the opportunity to attend to and follow very closely, since I was an International Olympic Committee´s coach-grantee holder (sharing the preparation process and the competition participation of Spain National Team, and following Brazil from the knock-stages onwards). The Master Degree resulted in an article named "Offensive Efficacy in Numerical Inequality Situations in Female Handball" (Trejo-Silva & Planas, 2018).

Moreover, the very first time the *academic-bug* entered my bloodstream was back in 2012 when along with colleagues of handball at IUACJ we were granted a fund to develop our first research on performance analysis of handball (I believe the first ever of this kind in team sports (TS) at Uruguayan academic level), accomplishing two publications about critical moments (Botejara et al., 2012; González-Ramírez et al., 2013). That *contagion* should have made a perfect melt with my passion with maths and all related with numbers and statistics.

Ever since then, I started to keep on getting involved in performance analysis in sports in general, and after getting a position at ISEF-UdelaR in 2015 I received a fund from CSIC to develop research about performance analysis in female handball. By then we were a group of colleagues interested in researching on sports performance (especially in TS) and we eventually settled as a Formal Research Group registered at CSIC (# 883101) in 2018. The group has nowadays several lines of research, with a network established

with research groups along South America (Brazil and Argentine), North America (USA and Canada), Europe (Spain, Portugal, Island) and Asia (Japan). One of these lines is "Technical and tactical performance analysis", based on notational studies (focusing on basketball, football and handball).

Gómez-Ruano (2017) mentioned that since its inception (Messersmith & Corey, 1931), studies based on notational basis have gone through a process that has contributed to a deeper analysis of sports. Those studies have improved sports knowledge, having an impact in the sports performance itself (Gómez-Ruano, 2017). In particular, the high complexity and unpredictability of invasion TS (Hernández Mendo & Anguera Argilaga, 2001) asked for fulfill the need for observational and measurement methods for knowledge production (Gómez-Ruano, 2017).

Handball is a collective sport game (played by two teams) that presents a group of individuals interacting with each other, with agreed aims and defined roles and objectives. Certainly sharing some common elements with other TS: the playing field (where individual and collective behavior is developed), individual and/or group and collective behavior developed towards goals; two roles (depending on the possession of the balls) that act simultaneously and opposed (attack and defense); a game object (a ball) that is moved by hand with the intention to score goals; all of these within a framework established by the rules of the game (Bayer, 1986; Garganta, 1998).

Some rules that have a direct impact in the numerical relationship of the players. According to the International Handball Federation (IHF) Rules of the Game (IHF, 2018) some actions or behaviors are plausible to be sanctioned with a *2-minute suspension* (exclusion), meaning that the excluded player must leave the court two minutes, and not being possible to be substituted for a team mate, which causes a *temporal numerical inequality* in the relationships of players. Other TS also have this scenario, and research has been developed for futsal (Gómez et al., 2019), water polo (Escalante et al., 2011; Lupo et al., 2014) and ice hockey (Widmeyer & McGuire, 1997). Likewise, temporal dismissals have also been studied in handball (Gutierrez et al., 2010; Prieto, Gómez, et al., 2015; Srhoj et al., 2001).

However, some specific require to be approached: a study about teams´ performance during those temporal numerical asymmetries; the impact of the 2016 change in the rules, that allows goalkeepers to be substituted for an in-court player (wearing field players' uniform); the gender issue, reflected in less studies dedicated to female handball and the need for south American academic studies about the regional reality.

As far as coaches can recall less than 59% of the events that taking place during a TS match (Laird & Waters, 2008) registering players´ actions during a match can be seen as a need. Performance analysis enables coaches and team officials to collect objective measurements of performance from the game to understand and develop effective offensive and defensive strategies and tactics. By collecting data from multiple games, it is possible to identify patterns that can be used to prepare the strategy for the next game based on the expected game strategy of opponent (Lord et al., 2020). Coaches declared that performance analysis´ data has an impact in their short, medium and large- term plans, and in fact 80% of them said they use performance analysis to modify their strategy for the next game (Wright et al., 2013).

Expert coaches had emphasized the importance of initial and continuous formation focusing on technical-tactical and methodological aspects, preferring reading online magazines, books and articles published in journals related to TS (Abad et al., 2013). Handball coaches apply academic training and former players´ experience at the beginning of their professional career; those at the highest level (those with the best academic training) use the knowledge acquired at different levels or sources for (training and updating) (Feu et al., 2012). Coaches themselves emphasize the importance of continuous training in the physical, technical and tactical aspects of the sports they coach, some of them having gone through a postgraduate process after getting their Physical Education and Sports bachelor´s degree (Pérez, 2012).

All the above-mentioned lead to the decision of developing the present doctoral thesis called "Match analysis in women's handball: guidelines for high performance coaches", which emphasizes in the analysis of the offensive performance in elite female handball during exclusions, in particular at Pan-

American level (Panamerican Games 2015, Panamerican Championship 2017), European level (Euro 2018) and world level (Rio 2016 Olympic Games). Tournaments were selected based on observation of Pan-American and top-ranked world level teams, and prior-post new rules of the game were applied (August 1st., 2016).

The purpose was to provide a description of those moments of the game when the numerical equality is interfered by an infraction in the rules, taking into consideration several contextual variables and using different statistical approaches. The results obtained should be relevant for coaches to be used as an input both at training and competition levels. In order to carry out this study, it was necessary to follow a coherent research process as well as a series of actions chronologically ordered during the different academic years (Table 1).

Table 1.

Chrono of the Doctoral Thesis

Academic Year	Actions
2017/2018	• Preparation of the Research Plan and Thesis Project.
2018/2019	• Collect of video images from 4 tournaments • Design and validation of 3 instruments (based on (Trejo-Silva & Planas, 2018) • Data collection of 1 tournament • Data analysis of 1 tournamet
2019/2020	• Data collection of 2 tournaments • Writing the first article
2020/2021	• Design and validation of 1 instrument (based on (Trejo-Silva & Planas, 2018) • Data collection of the 4th. tournament • 1st. Article published • Data analysis of 3 tournaments
2021/2022	• Writing and publication of articles • Start of the process of final document
2022/2023	• Writting and publication of articles • Final document elaboration • Doctoral Thesis deposit

This current Doctoral Thesis is presented as a compendium of articles, and it meets all the academic quality requirements (publications in JCR indexed journals) for this type of work.

The document is divided into 10 chapters with the aim of making it easier for the reader to tackle and comprehend this work. The different chapters are structured step-by-step and provide information about diverse actions, procedures, and tools employed along the research that supply answers to the objectives of the research. Below there is a brief description of the 10 chapters.

In the current chapter (Chapter 1), an introduction is given to explain the general puorpose of the study, as well as the different procedures and actions that have been carried out in order to prepare this Doctoral Thesis.

Chapter 2 displays the theoretical framework on which this study is based. This chapter presents the current state of performance analysis in sports, specifically regarding the notational analysis and the unbalanced production on female TS studies in general (handball in particular); an approach to the dynamic-ecological perspective of TS and handball; an explanation about the impact of the 2-minute suspensions on the numerical equality of players; the 2016 change of the rule, representing a new framework in the strategies to be used by coaches; the perspective of the constraints in TS and its relation with contextual variables; the use of the studies on performance analyses by coaches in both: training and competition; and finally, a theoretical approach of the observational methodology, in which this research based its design.

Next, in Chapter 3, the objectives of the study are further detailed in a progressive and coherent manner so that they can be clearly understood by the reader. These objectives are the foundation on which this Doctoral Thesis is based.

In Chapter 4, the methodology of this research is presented. Since all the studies followed the observational methodology procedures and design, in this chapter the following items for each study are presented for each study: characteristics of the samples and the instruments used; criterion and

categories are described; as well as a description of the different procedures followed in the development of each study; quality of data procedures; statistical analysis performed.

Chapter 5 presents results from all 4 studies. For a better understanding and aiming to display a time-line analysis of the performance at elite female handball level, the studies are presented in chronological order regarding the year in which each tournament was played. In that sense Study 1 presents results from Panamerican Games (PPGG) Toronto 2015 (played under *old rules*). Study 2 follows with results from Rio 2016 Olympic Games (OG), which was the first official tournament played under the 2016 Changes of the rule. Study 3 presents results from Panamerican Championship (PCh) 2017 and finally Study 4 shows the analysis of Euro 2018. Each study corresponds to an article published (or accepted for revision) in an indexed journal. Table 2 presents details of title, authors, and indexation indexes of each journal.

Table 2.

Academic production details related to the studies of the thesis

Tournament	Reference	Index	IF	Q
2015	**Trejo-Silva, A.**, Camacho, A., Camacho, M., González-Ramirez, A., & Brazo-Sayavera, J. (2020). Offensive performance under numerical inequality during exclusions in female handball. *Revista internacional de ciencias del deporte*, *16*(62), 396-409. doi:10.5232/ricyde2020.06205	ESCI	0.33	Q3
2016	**Trejo-Silva, A.**, Gómez-Ruano, M.; Parmar, N. & Brazo-Sayavera, J. (2023). Multivariate analysis of offensive performances during numerical asymmetries in female handball games at Rio 2016. *Healthcare (under review)*	JCR	3.160	Q2
2017	**Trejo-Silva, A.**, Feu, S., Camacho-Cardenosa, A., Camacho-Cardenosa, M., & Brazo-Sayavera, J. (2022). Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball. *Applied Sciences*, *12*(21). doi:10.3390/app122110774	JCR	2.838	Q2
2018	**Trejo-Silva, A.**, Gómez-Ruano, M.; Feu, S. & Brazo-Sayavera, J. (2023). Analysis of the offensive performance during exclusions in female senior handball. *International Journal of Performance Analysis in Sport (accepted Feb 13th)*. doi: 10.1080/24748668.2023.218088	JCR	2.488	Q2

Note: Index = Indexation; IF = Impact Factor, 2022; Q = Quartile; *ESCI* = *Emerging Sources Citation Index*; *JCR* = *Journal Citation Reports*.

Chapter 6 discusses the results obtained in the different studies based on the information extracted from the existing scientific literature. This chapter is structured according to the objectives set out in Chapter 3 and aims to show how the offensive performances varies remains stable in all 4 studies, and how the change of the rule did have an impact in the strategies used by teams.

Chapter 7 presents the conclusions obtained from the study after analyzing the results according to the objectives set. In addition, this chapter shows the practical applications that can help coaches both in their training sessions as well as in the competition context. It also provides suggestion on how the results of this research might be used in their practical lessons by lecturers at both Coaching Formation and universities.

Next, Chapter 8 focuses on the strengths of the study, showing the aspects that complement the existing scientific literature; details the limitations found during the elaboration and development of this work; as well as develops on the future prospects that have given rise due to this Doctoral Thesis.

In Chapter 9, the bibliographic references used for the elaboration of this Doctoral Thesis are presented, support and scientific basis for this study.

Chapter 10 presents the original articles that are part of this Doctoral Thesis in the format of a compendium of articles. Three of the articles have been accepted by scientific journals and have been published. The fourth one is under revision after passing the first revision round at journal indexed in JCR. This chapter also helps the reader to better understand the development of this scientific research. Also, it specifically shows the presentation of results in international congresses, conferences and workshops in chronological order.

Chapter 2. THEORETICAL FRAMEWORK

2 THEORETICAL FRAMEWORK

This Doctoral Thesis focuses on the elite women's handball game, taking into account the context of exclusions and offensive game play within numerical relationships of inequality. In this sense, a series of variables have been considered in order to identify indicators during real game situations, providing elements to improve coaches´ interventions. These variables can be grouped into changes in the rules of the game; type of competition; playing time; match status; game phase; and type of inequality. Therefore, it is necessary to search, within the existing scientific literature, all the aspects that are nowadays contemplated when analyzing offensive performance in handball, and especially during the context of numerical inequalities due to exclusions.

2.1 Performance indicators in sports

Studying and understanding the contextual variables that describe TS performance can be an important resource for coaches to plan training and prepare for competition (Gómez-Ruano et al., 2016; Marcelino et al., 2012). Performance indicators (PI) derived from the selection or combination of variables can be used by coaches to compare against opponents' or own past performance (Hughes & Bartlett, 2002). They also suggest the need to consider analyzing data without contextualization can lead to misinterpretation. Indeed, the behavior of an athlete/player in competition context can be seen as the "visible and tangible" of many processes that have occurred; then the aim of many sports science disciplines is to understand those process, having in match (performance) analysis the chance to integrate the separate contributions of various disciplines (McGarry & Franks, 2003).

PI are single or combined action variables that describe some of sports performance (Hughes & Bartlett, 2002) not being another description for "variable". They represent valid measures of performance backed by an objective and valid data collection procedure as well a valid means of interpretation (O´Donoghue, 2010). PI can be used to explain game outcome, advancing in the understanding thorough meaningful understanding of game behaviors; naturally they can also be only but

not necessary associated with outcomes (Sampaio & Leite, 2014). Performance in TS is complex to analyz, due to interactions between team mates and opponents that allow for emergent behavior to occur; being also dynamic (interactions are time dependent, especially in invasion TS (TS) and non-linear (since the output is almost never directly proportional to the correspondent input) (Sampaio & Leite, 2014).

Analysts and coaches now use the PI in evaluating the performance of teams and athletes to judge the quality of their performance (Bilge, 2012). Performance analysis consists of a process of abstraction that attempts to transform reality into a set of parameters or indicators that seek to represent it, taking as an example a combination of physical, technical, or tactical parameters during a competition (Rein & Memmert, 2016). Nonetheless, TS´ PI ought to be contextualized, as the performance environment, tournament characteristics, sports culture, or level of competition in different countries or regions can impose limits or constraints on player´s performance (Gomez et al., 2013).

Data collected during competition is suitable not only for statistical purposes but also for coaches when modeling and adjusting athlete performance (Franks & Goodman, 1986). In this sense, Prieto, Gomez, et al. (2015) suggested that coaches take into account the analytical data performed and then tailor their training and match interventions. In fact, performance analyst and coaches use them after describing or comparing positive or negative aspects of performance within or even between competitions (Sampaio & Leite, 2014). In this regard, verifying the effectiveness of PIs can allow coaches to correct technical-tactical errors during training (Trninić et al., 2010) by providing players with more skills to improve their performance in matches. Visual identification of an opponents' action is relevant for appropriate performance in TS elite players. This information (factors influencing in players' performance) is not easy to identify as a consequence that team sport is complex and multifactorial (Loffing & Cañal-Bruland, 2017; Wagner et al., 2014).

Examples of PI identified in handball can be found in the literature. In this sense, the scoring efficiency has been studied previously to determinate which player's actions are that most influence in

handball games. Thus, the highest effectiveness of the shots for the winner teams was obtained in short distance shots (7-meter throws and 6-meter centre) and wing shots (Srhoj et al., 2001; Vuleta et al., 2003). Moreover, the attack efficacy (AE) at the men Atenas 2004 OG differed in a significantly way from the 2006 European Championship and 2007 World Championship (WCh), while throwing efficiency (TE) was similar in those tournaments (Bilge, 2012). Manifestation of those performance indicators could be observed whether in training sessions (Andersen et al., 2018; Hartz et al., 2018; Mazurek et al., 2018) or official competitions (Cardinale et al., 2017; Hansen et al., 2017).

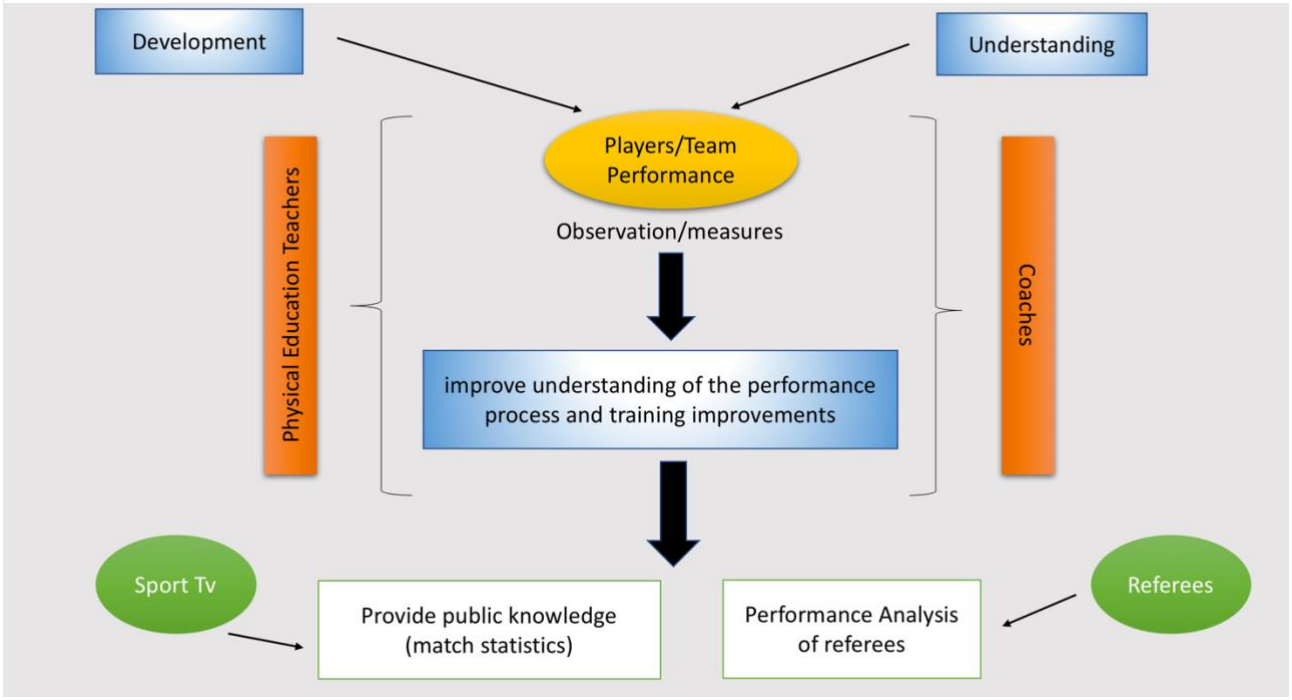
2.2 Notational studies

Notational studies have undergone a process of contributions to the analysis of sports since its inception (Messersmith & Corey, 1931), becoming as sports analysis studies (O'Donoghue, 2015). Notational analysis (Performance Analysis) is defined as the study of performance in competition and training without manipulating the game actions that occur there. It is used within a cycle of concurrence of events, reflection, decision making and preparation for future competitions (O´Donoghue, 2014) to provide objective feedback to players and/or coaches in a bid to generate a positive change in their performance (Fliess-Douer et al., 2016). It covers different contexts (high performance, training, coaches, referees, etc). Therefore, it uses competition and training, not being in laboratory situations. From this point of view, they can be defined as non-experimental designs (Hernández Sampieri et al., 2010). Applied research is sought and it is intended to improve the training processes and the control of the activity in competition. The biological - morphological aspects (heart rate, VO2 max, body mass index, weight) would complements the notational analysis and other main sources of the studies (O`Donoghue as cited in Gómez-Ruano (2017)). The application on performance analysis and its application improves and implements knowledge of the sport, helping to develop performance in it (Gómez-Ruano, 2017). In particular, the high complexity and unpredictability of collective cooperation and opposition sports (Hernández Mendo & Anguera Argilaga, 2001; Parlebas, 2001) requires observational and measurement

processes to be necessary, for the production of knowledge (Gómez-Ruano, 2017). Figure 1 shows the link between the aforementioned factors that are linked when training and playing a sport.

Figure 1.

Relationship of factors in the need for research in notational analysis



Note: Adapted from Gómez-Ruano (2017).

The analysis of the results of the actions is an input for coaches when having reliable information about the performance of their players or their rivals. Input that is also used by researchers to identify performance characteristics of certain players in certain roles (Sampaio et al., 2008), or the differences between starting players and reserves (Sampaio, Ibáñez, et al., 2006).

At present, as a consequence of the development of this type of study, a high level of specificity has been reached, therefore the following lines of research can be found (Gómez-Ruano, 2017): 1) Critical moments and disturbances; 2) The analysis of the behavior of the trainer; 3) Sport performance indicators; 4) The analysis of the incidence of injuries and the physical load; 5) Analysis of the type of displacement;

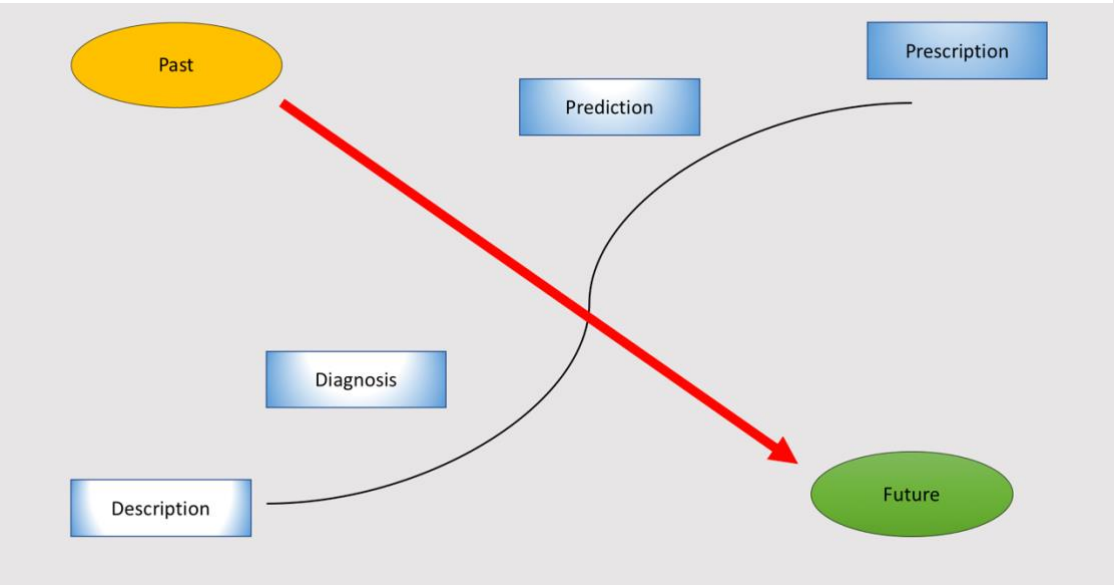
6) Reliability of the registration methods; 7) Analysis of the technique; 8) Analysis of the tactic; 9) Performance profiles; 10) The effectiveness in the use of notational analysis; and 11) Analysis of the referees.

These lines of research, with the passage of time, have become more precise and contextualized to aspects of performance both in training and in matches. The different approaches in statistical analysis have made a contribution that Sampaio et al. (2013) outline them in a descriptive analysis, dynamic analysis and non-linear descriptive processes. In static analyses, the temporal dimension and its relationship with performance is not taken into account and in dynamic ones they are linked. Nonlinear descriptive processes present a more powerful and specific statistical analysis due to the first steps with Big Data.

The path that performance analysis studies are following goes from a description of how the game is played, to a diagnosis and explanation of why certain behaviors are played or are presented, continuing with a moment of prediction of how it could be played to reach prescription (Figure 2).

Figure 2.

Evolution of research´s lines in notational studies



Note: adapted from Sampaio et al. (2013); Sampaio and Leite (2013).

2.3 The gender issue: studies about female elite handball

Over the last 70 years, the number of women participating in sports and exercise has grown exponentially. For example, at the elite level, women participating in the Olympics increased from her 10.5% of athletes (Helsinki 1952) reaching the forecast peak of 48.8% competitors in Tokyo 2020 (Elliott-Sale et al., 2021), being London 2012 the first ever OG with the same number of sports for males and females (Grappendorf, 2013). Indeed, every single country at that event had at least one female participant in its official delegation (Coche & Tuggle, 2016). This increase in participation can be attributed mainly to changing social and cultural attitudes and increased development in women´s sport (Forsyth & Roberts, 2018).

Although the proportion of women participating in sports and exercise has increased, research on women who exercise, and the response of women's bodies to exercise is still lower than that of studies based on men (Forsyth & Roberts, 2018). In spite of the fact that a decrease in the gender gap in sport and exercise participation can be detected, there remains a gender data gap within sport and exercise

science research (Cowley et al., 2021). In an effort to rebalance exercise and sport science, some research papers have recently been published highlighting gender disparities (Costello et al., 2014; Emmonds et al., 2019; Martínez-Rosales et al., 2021). In a systematic review of 5.261 JCR publications from six sport and exercise science journals between the years 2014 to 2020, 61% includes data from both sex, 31% exclusively from male and 6% exclusively from female (Cowley et al., 2021). The recent need, interest, and methodological support for high-quality exercise and sport science data specifically for women can all play an important role in bridging the sex data gap stated by the previously mentioned authors (Cowley et al., 2021).

It looks like imperative for the developing of women in sports, to advance in the future of studies in sport and exercise science including women, to better understand women's performance (in a holistic point of view) and its impact on sport and exercise outcomes. Ultimately, this will optimize the support given to women, allowing them to realize their full health and performance potential.

Handball it is not the exception of the rule. There are fewer studies on female handball compared to male handball, leading to less new knowledge in this area (Wagner et al., 2019). Indeed, López-Villar and Alvariñas (2011) in their study of 433 publications in sports science in Spain found that distribution according to gender was despair. From the total sample used in all the publications 10.7% corresponded to handball studies (9.8% only male sample, 0.9% only female samples, 0% both sex). Recent researches on female handball present results about anthropometric aspects (Haksever et al., 2021; Vuleta et al., 2020); injuries assessments (Martín-Guzón et al., 2022; Sanchez-Lastra et al., 2021); the effect of relative age (Camacho-Cardenosa et al., 2018); the position of the player's indicators (De Conti-Texeira et al., 2017; Hatzimanouil, 2019); throwing performance (Fragoula et al., 2021); effects of training tasks upon performance (Graja et al., 2022; Hammami et al., 2022; Jurišić et al., 2021) and match analysis (Karalić, 2020; Vinhas de Paula et al., 2020).

Despite some research studied female elite handball in European clubs or national teams, OG, WChs and even Asian clubs, no studies were found about female Pan-American handball tournaments so far. Therefore, the present research intends to produce knowledge also about the profile of the competition in the countries participating at official female Pan-American tournaments.

2.4 Handball as a team sport

2.4.1 Team sports as a dynamic system

TS can be presented as generic model with the presence of several systems (or subsystems), without which the phenomenon of collective invasion sports could not be fully explained. It is obviously a dual model, conceived as a duel, where players from two rival teams face each other in a competitive context (Lasierra, 2017). In this sense Lozano (2014) and Grehaigne et al. (1997) presented three models of analysing TS: the analytical model (associated to individualism); the structural model (holistic based) and the systemic model (associated to the systemic model).

The systematic perspective defines its characteristics from the interactions between its parts and is applied to sport using a variety of models drawn from the sciences of psychology, biology, learning and motor control, which try to consider the analysis of sports modalities based on the balance and systemic relationship between the three basic pillars related to those previously mentioned: player, sport and methodology of intervention (Bonnet cited in Lasierra (2017)). Various disciplines had in common the systematic approach.

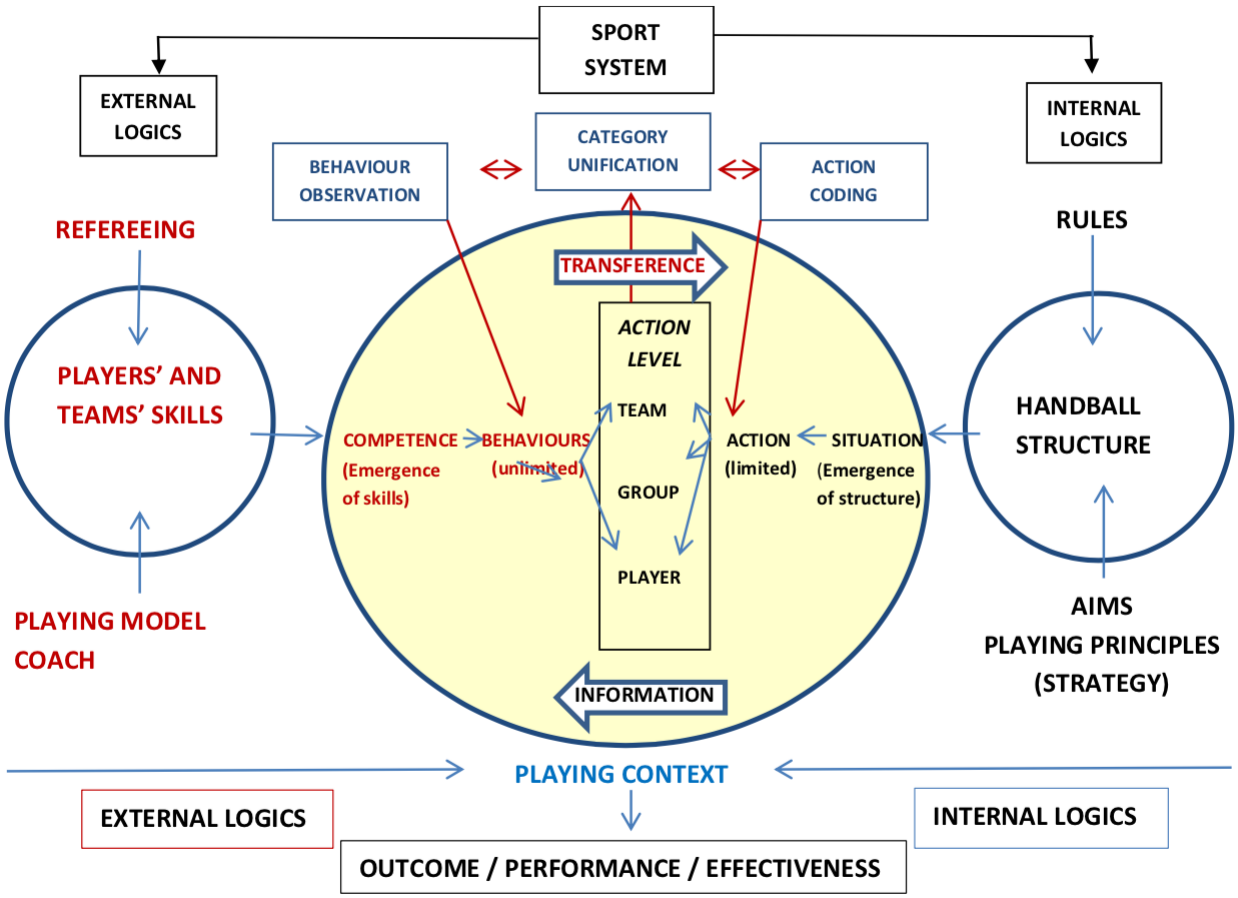
Praxeology (Parlebas, 2001) and the structural horizontal models (Bayer, 1986) are examples of it analysis TS as a structure in relation to a context. In both perspectives, the type of relation among players and within the context in general are taken into account, leading to identify aspects that can be defined as external and internal logic. Those aspects lead to characterize actions of players based on define roles (determined by the rules of the game) and goal-orientated. Other disciplines analyse the player and /or team as a system itself, which are based in the relationship “performer-environment”. Examples of this

perspective are the non-linear learning theories (Chow et al., 2015; Chow et al., 2021); the complex system (Kelso, 2014) and the ecological psychology (Araujo & Davids, 2009).

It is then possible to integrate in a unique perspective the previous mentioned approaches in the intention to have a model for interpretation TS. In this sense, Lasierra (2017) proposed to focus on context (figure 3). Taking the context as the focal point of observation would allow to corroborate systemic relationships among teams and/or players (as systems).

Figure 3.

Action and behavior observation in a playing context based on dynamic system theory



Note: adapted from Lasierra et al. (2020).

In such a view, the environment presents contextual issues of a specific game situation where the "knowledge" (perceived as behaviors) emerges constantly modified as situations change (Serra-Olivares

& García-López, 2016). Context factors derive from the concept of context as a scene and refer to the coexistence of structural elements and specific placements in handball, as well as different interpretations of models used by the team, and player skills (that alter the dynamics of the game). Figure 3 presents a graphic summary of how TS are considered dynamic system (Lasierra et al., 2020). It is important to remark that performance, score, or effectiveness are not considered as contextual factors, but as a result of the ability of players and teams to perform in any game situation (environment-context).

2.4.2 Handball: invasive team sport

Broad understanding of the sporting phenomenon starts by looking at the characteristics of the modality. Therefore, it is possible to identify individual sports, team, net, wall, aggression, specific space, attack, court, hall field, hall, etc. A collective sport game presents a set of individuals interacting with each other, with close relationships and consequences, as well as reciprocal relationships with agreed goals and defined functions and objectives.

Handball corresponds to these characteristics, with elements common to other TS: a playing field (where individual and collective actions are developed), individual and/or group and collective actions developed towards an objective, which must be attacked or defended by teammates; the object of the game (the ball), which is moved by hand by the team members who cooperate to achieve the goal of the game: score a goal, requested to beat their opponent, all of them regulate by the rules of the game (Bayer, 1986; Garganta, 1998).

Movement on the field occurs in a particular way, in what is called a phase or cycle of the game (the alternation of power of whoever has the ball attacking and trying to score) in search of victory. These stages of play, determined by possession of the ball or not, are linked and inseparable, as are the performances of the players/teams. Thus, when possession of the ball is passed from one team to another, the role immediately changes, passing from offensive player to defensive player and vice versa. During a handball match, the behavior of the players based on the principles of the game, possibly

depending on the stage of the attack, maintaining possession of the ball, moving towards the goal and finally finding the finish line; and when in defense: regain possession of the ball, stop the progression of the opponent's progress and avoid the opponent's finish (Hernández Moreno, 1984). Handball has other peculiarities, through its organizational structure known to the player through the rules of the game, which clearly state what is allowed and what is not. Content and actions (individually or collectively) take place in a highly volatile, unpredictable and anonymous context, making it difficult to predict events, and require athletes to have a constant attitude, permanent tactics. strategic attitude (Greco & Fernández, 2012). In particular, this attitude can lead to a demand for diverse, fast, accurate and complex responses, often under high time pressure (Greco, 2001).

Ultimately, in sports with uncertainty, athletes immerse themselves in a variety of different but equally important stimuli. To develop successfully in this uncertain context, the ability to perceive (interpret) what is happening (interpret) and make the right decisions in the time available - often very short - is essential (Laguna, 2019). In addition to being an adaptive sport, handball as a TS it has two consequences: 1) Players must learn to coordinate with their teammates, that is, in addition to individual tactics, players must work on the common criteria of actions of the players. This is called "Group Tactics" 2) But it is not enough to cooperate well with other players, players must act according to the common organizational criteria of the team, which is called “Game System” (Laguna, 2019).

Team handball can be then seen as time-dependant invasive TS played at a fast pace by two teams of seven players each (one goalkeeper and six in-court players), highly structured, with a constant exchange in the possession of the ball between teams, developed at a high intensity (Karcher & Buchheit, 2014; Volossovitch, 2014). Like all TS, handball demands three categories of complexity analysis: a) space and time; b) information, and c) organization (Gréhaigne, 1991). These surrounding constraints (e.g. location of opponents, teammates, the ball and goals) shape players' coordination patterns in TS (Grehaigne et al., 1997).

Organization, space and time (of players and ball), location of opponents, game system, group tactics, all these previously mentioned terms refer in an indirect way to the relation between number of players of each team involved in certain time and space during the game. As stated by the rules of the game, this numerical relation is of "equality" (seven players a-side). However, this numerical equality situation may be transformed in numerical inequality situation. Indeed, it is important for players (and for a team too) to have the resources to disrupt this balance. Temporarily letting the opposing defenders at a numerical disadvantage is beneficial to the attacking interests of the attack, especially when the action/situation is located in an area with greatest chance of scoring (i.e. near 6 meter area). However, it is important to know that these advantageous situations do not last forever, on the contrary, is generally rather fleeting, as defenders fight to cushion them, they tend to do so in a short period of time (Laguna, 2019). Taking advantage of these often-transient situation, involve rapid and coordinated action by attackers engaging in such action. Therefore, it appears to be beneficial for the attacking team to have a numerical superiority context for a "long lasting" period of time, not ephemeral. On the other side, it might be an important challenge for the defensive team to fight against the numerical disadvantage for a "long period of time". As it is the case in other TS like ice-hockey, rugby and futsal, handball´s rules state that a "temporary stable numerical inequality situation" may arose when a 2-minute suspension is sanctioned.

After researching in the handball literature, one of the contextual game situations less studied in handball is the numerical inequality situation caused by exclusions, although exclusions and their consequences have been studied as a performance indicator in TS. Numerical inequality as a consequence of temporal or total exclusions of players and team performance during those game periods is a field of research in TS. Therefore, the relation between the number of players on the court of one team and the opponent can be seen as an important constraint.

2.5 Rules of the game: the impact on the numerical relationship of in-court players

2.5.1 2-minute suspensions in handball

Handball is an aggressive team sport, which means that a large amount of contact between players is allowed and is part of the game. However, to ensure the safety of the players, the referee may penalize some types of fouls. Normal fouls do not usually result in an individual penalty (progressive penalty, exclusion or disqualification) and are sanctioned with a free throw or a 7-meter throw. More serious fouls and unfair behavior will result in incremental individual penalties for players, often starting with a warning, followed by a suspension (exclusion), and eventually disqualification. Exclusions are always sanctioned by a 2-minute suspension for the offending player (other than a free throw or 7-metres).

The temporary exclusion of players who have acted contrary to the rules due to technical fouls or unsportsmanlike conduct is a penalty set forth in the International Handball Federation regulations (IHF, 2018) . Rules 8 and 16 describe situations in which a player can be sent off. The exclusion period is two minutes and includes suspension for the player who committed the sanctioned act. In case the sanctioned person is one of the officials, then an in-court player must leave the court for 2-minute. A player can be sanctioned with a 2+2-minute suspension (leading the length of the sanction to a total of four minutes). Teams are not allowed to substitute sanctioned players, so during this time the team has fewer players, depending on how many sanctioned players are sanctioned. When one of the teams playing keeps all of its players on the field, having one (or more) player outfield in the opposite team, then it generates a disadvantage for team with outfield players. The disqualified player's team will lose power for 2 minutes (provided that the opposing team has no suspended players at the time of the match). Moreover, the superiority created for the team with no sanctioned players is an advantage.

The following is a short description of the situations that a 2-minute suspension is the appropriate punishment:

- for a faulty substitution (an additional player enters the court, or a player interferes in the game from the substitution area
- for fouls that are mainly or exclusively aimed at the body of the opponent (if the player and/or his team has already received the maximum number of warnings)
- for fouls such as: i) high intensity or against an opponent who is running fast; ii) holding on to the opponent for a long time or pulling him down; iii) fouls against the head, throat or neck; iv) hard hitting against the torso or throwing arm, v) attempting to make the opponent lose body control; vi) running or jumping with great speed into an opponent.
- unsportsmanlike conduct by a player such as hitting the goalkeeper´s face when having a clear shot (like in a 7m shot, or a breakthrough); delaying the execution of a formal throw for the opponents, by not respecting the 3-metre distance or in some other way; through 'theatre', trying to mislead the referees regarding the actions of an opponent or exaggerating the impact of an action, in order to provoke a time-out or an undeserved punishment for an opponent; actively blocking a shot or pass by using a foot or lower leg; when there is a decision against a team in possession, and the player with the ball does not immediately make it available to the opponents by dropping it or putting it down on the floor; hitting the defender head in a throw off when the defender is at 3m and the defender is not moving his/her head.
- unsportsmanlike conduct by a player or official (that leads to a disqualification of the person) such as gesture, verbal aggression, protests (again players, official or public), particularly reckless or particularly dangerous action.

In this sense, the logic of the TS scene would lead us to think that team having more players in court, would take advantage of the situation (both in attack and in defense). Even though it could be considered as an advantage or disadvantage, what is important for coaches and researchers is the magnitude of this numerical inequality and its consequences in the final result (Prieto, Gómez, et al.,

2015). Given the the importance of game situations where instability, disturbance, or imbalanced circumstances alter the natural course of cooperation-opposition between teams influencing the final outcome of the game, those moment of a match can be considered as a crucial moment in the game (Ferreira, 2014).

2.5.2 2016 Change in the Rules of the Game – Playing with empty net

In 2016, the International Handball Federation (IHF) stablished a change on the Rules of the Game which was first applied at Rio 2016 OG. Before that tournament and according to rule 4.3, it was not allowed changing the goalkeeper for a field player wearing a field player clothing. If the goalkeeper was to be changed, the substitution player must wear the same colour of shirt than the goalkeeper (since rules of the game stated that at least one of the players must be identified from the rest as goalkeeper, being that way the colour of the shirt). Therefore, goalkeepers were substituted by goalkeepers. However, in certain circumstances goalkeepers were substituted by an in-court player wearing a shirt of the same colour of his/her goalkeeper teammate with a hole back and front which allows to see the number of the player (normally players dressed this jersey on top of the one that they were normally using when having goalkeeper at goal).

From July 1st 2016, a crucial modification in the rules of the game that would affect the organization of roles of players was applied. From then on, and according to IHF (2018; 4-3) "A player who is identified as a goalkeeper may become a court player at any time and similarly, a court player may become a goalkeeper at any time as long as he is identified as a goalkeeper with two main restrictions: i) all court player must wear identical uniforms; all player in the goalkeeper position must wear the same color that distinguishes them from court players and ii) a player who is switching between the court player and goalkeeper positions must wear the same number in both positions. In empirical terms: a team is allowed to play without goalkeeper at goal and with no player identified as it in-court. These might lead

to a situation where a team may have 7 in-court players and its opponent 6 in-court players affecting the numerical relationship mention by Laguna (2019) in the section 2.4.1 of this study.

Those changes in handball rules affected the context of exclusions. It concedes coaches the chance to leave the goal empty and get an extra court player in the offensive phase of the game, allowing the sanctioned team to change the goalkeeper (GK) for a field player playing then with empty net (EN), having a tactical impact in the game due to the possibility of playing in numerical equality when having players excluded (taking the risk of playing with “empty net”) compensating the numerical inferiority as a consequence of exclusions (Marczinka & Gál, 2018). An example of that strategy can be seen in figure 4, where having Netherlands one player excluded opted to play EN with 6 in-court players. Elapsing time of the 2-minute suspension (in this case 1:28) is indicated under team´s code (NED) and the overprint at left also indicates that NED is playing with “empty net”. Since the possibility of changing players (GK and in-court players) has almost no limitations on the quantity and moment of the game, handball coaches have an active role during the game managing the on-court players and strategies at any moment. In this sense, rule changes, such as the use of an extra in-court player in the offensive phase, can provide the opportunity for significant changes in the game of handball (Sevim & Bilge, 2007).

Considering that this regulatory change directly interferes with the game's strategic-tactical structure, creating opportunities for new individual and collective actions in the organization of offensive and defensive systems, situational performance analysis becomes important (Taylor et al., 2008). Therefore, it is necessary to identify the possible changes in the dynamics and strategic understanding of the game of handball from this rule change and to discuss the possibility of reorganizing individual tactical actions. and collectively, offensively, and defensively, by coaches and players (Krahenbühl, Menezes, et al., 2019).

Figure 4.

Netherlands (in orange) playing 6 against 6 with empty net when facing Spain (in black) at the Female Euro 2018

In previous studies, elite-level coaches have declared that they would use the EN tactic mainly to maintain numerical equality when their teams are suffering a 2-minute suspension, or to get numerical superiority in critical moments of closed games, and more often in male than in female teams (Krahenbühl, Menezes, et al., 2019). When analysing the use of the additional player at the male knockout phase at Rio 2016 OG, Krahenbühl, Sousa, et al. (2019) found that during a total of 8 games 85 out of 144 of the total situations where GK was changed were intended to compensate numerical inferiority. Marczinka and Gál (2018) studied 15 matches at the 2017 Men´s WCh exploring the use of EN strategy. Results showed that coaches used this offensive strategy during numerical inferiority as a consequence of exclusions more often than in numerical equality situations. At the same WCh of 2017, but played by

women Krahenbühl et al. (2021) registered that coaches decided to change the GK for a player on the field with the intention of equalizing the numerical disadvantage during a 2-minute suspension.

However, while the conclusions about the effectiveness of empty goal tactics are inconclusive, it seems that the opinions of international level coaches are quite negative. In a recent survey by German magazine 'Handball Woche' of 39 top coaches, 30 said they would like to go back to the old rules. For example, it has been argued that shots on an empty goal are unappealing to spectators and that the effect of the 2-minute suspension has now been reduced after replacing the GK so that it no longer applies a meaningful penalty for an aggressive and dangerous player defensive action (Iusepolsky et al., 2022). Moreover, when considering the GK´s opinion, results showed that keepers are not too enthusiastic about the rule; having women´s responses a slightly higher sense of approval than men did (Iusepolsky et al., 2022).

2.5.3 Approaches of the numerical inequalities as a consequence of sanctions in team sports

Players and teams are adaptive and goal-oriented; players in a match exist in interdependence and interact dynamically and nonlinearly, and those interactions can change according to constraints within the system (Perl & Memmert, 2018). TS as dynamical system can be characterized by a system state which varies over time during a match (Grehaigne et al., 1997; McGarry et al., 2002). Some authors have also proposed that a football match can be analyzed at various organizational levels of play: the match level, represented by two opposing teams; the team level, represented by teammates working in cooperation; subgroup level, represented by a smaller group of players cooperating or competing; and even the dyadic level, between two specific players in cooperation or competition (Gréhaigne & Godbout, 2014; Grehaigne et al., 1997).

Newell (1986) presented the concept of constraint defined as features that limit the degree of freedom of a system and further described three different types of constraints based on their origin: organismic constraints, environmental constraints, and constraints mission. Organismic constraints are

those within the system being analyzed (player, subgroup, team or match). Environmental constraints are those outside of the system being analyzed and can include factors such as weather, temperature, altitude, crowd support, friction, and type of playing surface. Task constraints are specific to the task being executed and are tied to the goals being performed or the rules that govern the task. Thus, the constraint framework complements the dynamic systems approach by helping to organize system interactions (Low et al., 2020). Therefore, the numerical relationship of players of each team can be considered an organismic constraint.

Numerical inequalities or asymmetries can be studied as an indicator itself (for example relation between the number of disqualifications a team received and the final outcome of a game) or to what extent this constraint modify behavior in players. In this sense, these numerical situations in the relation of the number of players per team are studied in different TS. In their study of 38 games at the 2014 Male Brazil FIFA World Cup, Liu et al. (2015) found that one extra Red Card would bring 39% and 14% lower likelihood of winning all games and close games in coincidence with the findings of Bar-eli et al. (2006) which suggested that dismissal of a player will weaken the performance of the sanctioned team in goal scoring and later reinforced by Vecer et al. (2009) who concluded that the expected number of goals decreases when a stronger or comparable team is penalized, while the expected number of goals can increase or stay the same when a weaker team is penalized. Moreover, teams participating in the German Male Bundesliga from 1999 – 2009 showed that sending-offs against home teams have a negative impact on their performance. However, for guest teams, the impact depends on the time remaining after the sending-off and can be positive if the sending-off occurs late in the game (Mechtel et al., 2010). Nevertheless, no significant relationship was found between red cards and the game outcome at the 2017 Male African Cup of Nation (Kubayi & Toriola, 2020).

Other TS shares with handball the rule that sanction a player with a temporary dismissal. Gómez et al. (2019) studied the performance of futsal male teams during dismissals in the regular Spanish

professional season, revealing that when a player was dismissed, the opponent's team has a 100% chance of shooting on goal and a mean of 3.18 attack actions during the 2-minute period. However, the chance of scoring increased less than expected (20%). Indeed, the away team may be adversely affected if outnumbered when preventing the home team from attempting to score within the 2-minute of exclusion.

Studies in water polo reflects the importance of the numerical inequality context, since it is included in most of the PIs of the sport. Escalante et al. (2011) in their study of male and female tournament at Beijing 2008 OG found that women had fewer exclusions, reflecting the greater aggressiveness of men in competition. Though, in both tournaments winners registered more shots than losing teams when having an extra player, being women´s mean significant better than men. At the FINA Women WChs from 2007 to 2011 and European Water polo Championships from 2008 to 2010, winning teams scored a mean of 19 goals more than losing when playing power play ($p<0.01$) and their goalkeepers did 11 goalkeeper saves more during inferiority context ($p<0.01$) during the preliminary round of the tournaments (Escalante et al., 2012). Results from all matches of the male Spanish regular season (2011-2014) found that successful shots during power play was one of the performance indicators differentiating between unfavorable, balanced and favorable games and that that winning teams (>3 goals), made more successful power-play attacks and shots (García Ordoñez & Touriño González, 2021). At the 2009 FINA Men WCh losing teams conceded more exclusions than winning and while playing power play winning teams showed their supremacy with respect to losing teams in terms of number of shots registered and number of goals (Lupo et al., 2012). Moreover, at the same female WCh winning teams playing close games reported more goals and no goal shots during power play than losing, and reported a reduced occurrence of failed shots with respect to their counterparts for no goal shots during power play, indicating their ability to profit from potential numerical advantage for the offensive players (Lupo et al., 2014).

In ice hockey Widmeyer and McGuire (1997) studied the aggression in male league. They found that teams presented more probability to suffer dismissals in those teams that play the interleague due to the fact that they play twice often against the same rival. Macdonald (2012) in their study of adjusted plus-minus rates for NHL players, identified the performance of the 10 best players during male leagues tournaments from 2007 to 2011, in terms of goals scored, during power play and shorthanded context of the games. When performing a spatial map of goalie performance during the 2009-10 male NHL, Schuckers (2011) represented Tim Thomas of the Boston Bruins for wrist shots faced during opponents power play and Ilya Bryzgalov (of Phoenix Coyotes) for slap shots taken during opponent´s power plays.

When assessing the possible explanations of the performance specially during numerical superiority (power play) literature indicates that this advantage may not be as significant as might be expected. This is mainly because psychological aspects such as stress, anxiety and suffocation can lead to poor performance in pressure situations where good performance is expected (DeCaro et al., 2011; Hill & Shaw, 2013). Several studies have analyzed pressure suffocation in situations requiring superior performance, such as Jordet (2009) in his study of penalty kicks in football.

2.5.4 Studies about exclusions in handball

Available research focused on numerical inequalities in handball has shown that at least 22% of the game time is played under numerical asymmetries as a consequence of exclusions (Ferrari et al., 2019; Gutierrez et al., 2010; Sierra-Guzmán et al., 2015). In other words, teams at a handball match might lead with around 7 minutes per game in one of the two contexts of asymmetry: inferiority or superiority. Given that presence in the game-time, Prieto, Gómez, et al. (2015) registered that exclusions are sanctioned within the last 10 minutes of the first half and the first 10 minutes of the second half, but decreasing in the last 20 minutes of the game. However, the percentage sanctioned in this last period was close to the one registered in central period of the game (43.2% vs 35.0%).

Srhoj et al. (2001) analyzed the relationships between types of attacks endings and game outcome, finding the relevance of making the opponent team receive a 2-minute suspension and winning/losing a match. The discriminative power of male teams participating at OG from 2005 to 2016 found no statistical significant differences between winning and losing teams in the means of 2-minute suspension sanctioned (Saavedra et al., 2017). Same study developed at female tournaments showed also no statistical significant differences between winning and losing teams in the means of 2-minute suspension sanctioned but registered a difference in the means with male. However, red cards (which also leads to a reduction in the number of court players of 2 minute) did present a statistically significant difference for winning and losing (Saavedra, Thornorgeirsson, et al., 2018). Table 3 presents the comparative results of both studies.

Table 3.

Means and standard deviation of 2-minute and red card sanctions in male and female Olympic Games (OG) from 2004 to 2016

	Female 2004-2016 OG		Male 2004-2016 OG	
	Winning	Losing	Winning	Losing
2-minute	3.9 ± 2.0	3.8 ± 2.0	4.2 ± 2.1	4.1 ± 2.0
Red cards	0.1 ± 0.3*	0.6 ± 0.2*	0.1 ± 0.3	0.2 ± 0.4

Note: * statistical significance $p<0.05$. Extracted from Saavedra et al., (2017) and Saavedra et al., (2018).

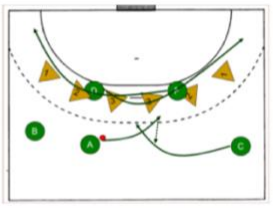
When analyzing the male European Championships (2002-2004) and the male WCh 2003, Gutierrez et al. (2010) concluded that the efficiency indexes obtained in situations of temporary numerical inequality, in offensive superiority, do not determine the condition of winner or loser of a match. On the contrary, the efficiency indexes in a situation of offensive inferiority, both those related to offensive efficiency and those related to defensive efficiency show better values in winning teams than in losing teams, so that they can be used as predictors of a winning team.

Moreover, Sierra-Guzmán et al. (2015) studied the offensive tactical situations of the Spanish men´s National Team over 2 European tournaments (2012 and 2014). They turned to found out that during inferiority wing-crossing and transformation of wing to pivot were the most used during Serbia 2012 and fixation of one of the back players (while pivot moves to open space) was the most used in Denmark 2014 (figure 5). In context of superiority (figure 6), the situation that was most used in 2012 was the unfolding of central back player followed by fixations (with pivot in 2-3) and the situation that was most carried out in 2014 was fixations with pivot in 2-3 (mostly on the left), followed by transformation of the central back player to pivot (mostly on the right). Remarkable to say that both tournaments were played under the 2010 IHF Rules of the game, therefore the use of playing EN during inferiority was not used.

Figure 5.

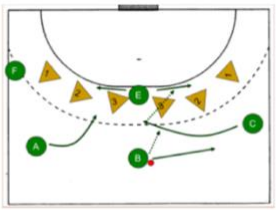
Tactical situations of Spanish Men´s National Team during inferiority at Serbia 2012 and Denmark 2014

Wing-Crossing: starting movements



Wing-Crossing: ending movements

Transformation of wing to pivot

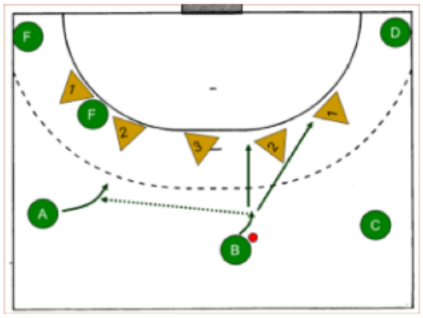


Fixation of one of the back players (while pivot moves to open space)

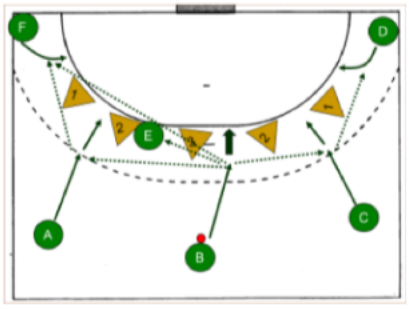
Note: Figures adapted from Sierra-Guzmán et al. (2015).

Figure 6.

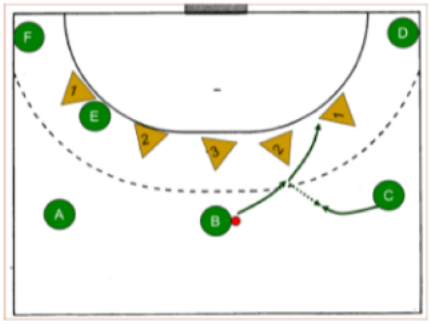
Tactical situations of Spanish Men´s National Team during superiority at Serbia 2012 and Denmark 2014



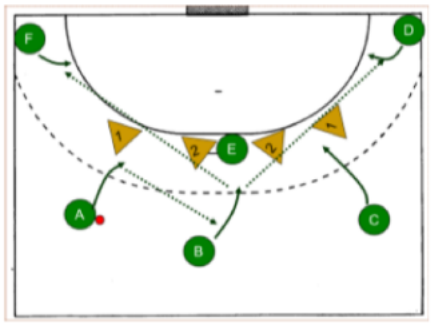
Central back player transforms to pivot (2012)



Fixation with pivot in 2-3 (2012)



Central back player transforms to pivot (2012)



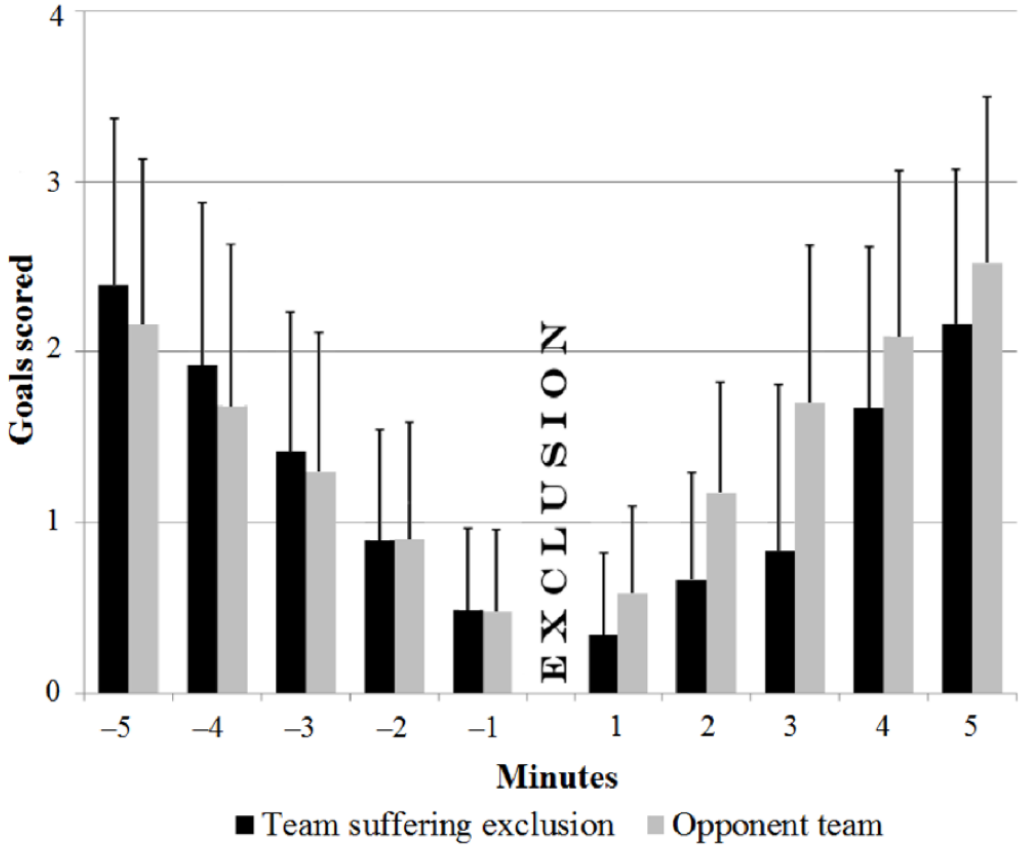
Fixation with pivot in 2-3 (2014)

Note: Figures adapted from Sierra-Guzmán et al. (2015).

In the need to deepening in the exclusion´s context, Prieto, Gómez, et al. (2015) studied the performance of the male teams during balance matches played at the Spanish league 2010-2011 (ASOBAL). Results showed that when a 2-minute suspension is sanctioned, the opposite team improve their scoring rate (not being affected by match status, game location, quality of opposition and game period), although the increment is less than expected for that context (figure 7).

Figure 7.

Goal scoring track prior and post a 2-minute suspension is sanctioned. The thin vertical lines represent the standard deviations



Note: adapted from Prieto, Gómez, et al. (2015).

More recently, Trejo-Silva and Planas (2018) analysed whether a relation existed between performance during exclusions and game outcome and final ranking in female handball. For this purpose, they registered finalizations during numerical inequalities as a consequence of 2-minute suspensions of nations ranked from 1st to 6th at Serbia 2013 WCh. The number of goals converted in any of the asymmetry context is higher for winners than for losers. Winners are more than twice as efficient in throwing and attacking efficacy as losers during inferiority. Therefore, there was a tendency to indicate

that an attack efficiency of approximately 44% could be associated with a game's "winner" status. Achieving an attacking efficiency of close to 58% can also be associated with winning the game. No significant correlation between throwing or attacking efficiency and final championship standings (tables 4 and 5).

It has been then proved that the new generated game situations as a consequence of an exclusion could affect technical and tactical aspects that have influence in the result. Studies in other TS are focused in identifying a relationship between the result of a match and the variable time. Those moments where performance has more influence in the final outcome of a match were named critic (Bar-Eli & Tractinsky, 2000), with teams needing to reorganize their technical-tactical aspects to manage the lack of players (Pueo & Espina-Agullo, 2017).

Table 4.

Summary of the efficacy values for winning and losing teams in situations of numerical inferiority and superiority

	Numerical Inequality Situation							
	Superiority				Inferiority			
	Winner		Loser		Winner		Loser	
	Throwing Efficacy	Attack Efficacy	Throwing Efficacy	Attack Efficacy	Throwing Efficacy	Attack Efficacy	Throwing Efficacy	Attack Efficacy
N	38	38	40	40	40	40	40	40
Mean (%)	71,55	59,387	53,3	43,845	58,31	44,398	27,47	20,505
Median (%)	71,4	59,15	55,6	46,1	55,8	41,45	20	14,3
SD (%)	23,361	22,4634	22,475	20,6493	27,795	26,6521	29,039	24,0009
CI (%)	63,9 to 79,2	52,0 to 66,8	46,1 to 60,5	37,2 to 50,4	49,4 to 67,2	35,9 to 52,9	18,2 to 36,8	12,8 to 28,2
Range	50	29,4	23	29,7	38	31,7	50	36,5
Minimum (%)	25	16,7	0	0	0	0	0	0
Maximum (%)	100	100	100	77,8	100	100	100	100

Note: retrieved from Trejo & Planas, 2018.

Table 5.

Efficacies and percentage of turnovers in superiority and inferiority by teams in Serbia 2013

	Numerical Inequality Situation					
	Superiority			Inferiority		
	Throwing Efficacy	Attack Efficacy	Turnovers	Throwing Efficacy	Attack Efficacy	Turnovers
Teams	Mean & SD	Mean & SD	Average	Mean & SD	Mean & SD	Average
1.Brazil	64 (±20)	57,5 (±21,3)	12,5	50 (±36)	40,0 (±28,0)	25,0
2.Serbia	62 (±29)	53,8 (±27,9)	17,1	52 (±34)	40,8 (±28,7)	23,3
3.Denmark	76 (±21)	53,7 (±13,8)	26,4	48 (±40)	39,4 (±39,8)	34,6
4.Poland	71 (±24)	58,1 (±27,1)	23,4	56 (±34)	44,7 (±29,3)	25,9
5.France	62 (±20)	46,8 (±16,9)	25,4	55 (±37)	31,4 (±20,7)	43,9
6.Norway	73 (±28)	64,2 (±26,1)	14,3	67 (±32)	53,9 (±30,7)	25,5

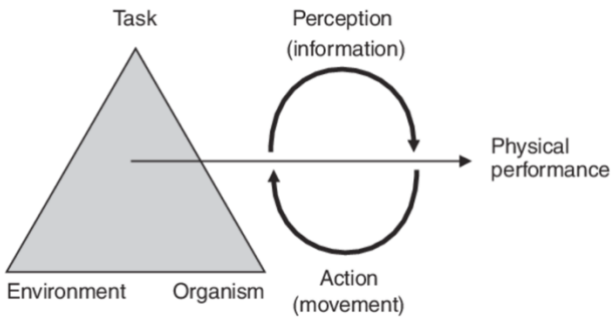
Note: data is presented upon teams´ final ranking; retrieved from Trejo & Planas, 2018.

2.6 Constraints

As it was presented, sports performance is governed by a complex interaction of variables such as physiological, psychological, physical-biomechanical proficiency, tactical awareness, the opponents, sociocultural aspects, among others. Some authors, also aligned with the system model, defined some concepts in order to model the perspective of the context and the interaction with the player. In that sense, Glazier (2017) proposed the so called Grand Unified Theory (GUT) of sports performance, based on the conceptual model introduced originally by Newel (1986) which may help sports scientists to better explain, and possibly predict sports performances, and even the process to teaching and training skills and abilities. A constraint based theory for sports. Taking Newel proposal, he distinguishes 3 types of constraints: organismic, environmental, and task constraints. Broadly defined, constraints are internal or external boundaries, limitations, or design features that affect the degree of freedom of a complex, impacting in the possible ways of relation/configuration of the parts. It sees abilities, learning, development and expertise as emerging properties of functionally adaptive and evolving relationships formed between individuals and their environmental constraints (figures 8 and 9).

Figure 8.

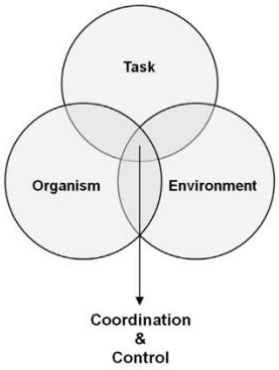
Newell's model of interacting constraints adapted to illustrate the resulting effects on variability of physical performance



Note: retrieved from (Davids et al., 2003).

Figure 9.

Constraints presented as a Venn diagram could better illustrates how behaviour (i.e., patterns of coordination and control) EMERGE from the confluence of interacting constraints (depicted by the dark grey area of intersection or overlap)



Note: adapted from (Glazier, 2017).

Organismic constraints are those constraints that reside within the boundaries of individual movement systems, they can be either structural (height, body mass composition, anthropometrics measures) or functional (heart rate, lactate concentrations, emotions, sensorial perceptions) having a relatively faster rate of change and tend to vary quite considerably over time. *Environmental constraints* are external to the movement system; like external forces that are acting on the system (weather, surfaces, sociocultural constraints, social expectations. *Tasks constraints* are specific to the task being performed, being directly related to the goal of the task and the rules governing it; for example, the rules of the game, strategic aspects prepared for a match, limitations/instructions during a task in a training session.

Moreover, Seifert et al. (2017) consider relevant that Glazier´s proposal would get credit from examining broader ontological positioning within the complexity science paradigm to benefit from conceptualizing athletes and sports teams as complex adaptive systems. As ecological dynamics is a multidimensional theoretical framework drawing from many related disciplines (including but not limited

to physics, biology, evolutionary sciences, mathematics, psychology and social sciences), it is possible that provides comprehensive rationale than constraint-driven approach. For this reason, it sounds appropriate to postulate the theory at the level of ecological dynamics, i.e. the constrain-led approach with its application in dynamical systems. It is relevant to see athletes and sports teams as complex adaptive systems that exhibit characteristics such as non-linearity and non-proportionality, questioning whether causal relationships between coordination patterns and performance outcomes are linear or non-linear, unidirectional or circular matter. In addition, brain and behavior must be considered together to analyze sport performance, as suggested in ecological dynamics (Davids et al., 2012).

The following section presents the identified constraints that might influence the performance of the teams while playing under superiority or inferiority contexts as a consequence of a 2-minute suspension.

2.6.1 Environmental constraints – The type of competition

Having a great importance in sports competition and therefore in the performance of teams and players, type of competition can be considered as environmental constraint. If a team is playing to add points to the regular season standings, other strategies can be used as opposed to going head-to-head with another team about to be eliminated from the playoff series (Gomez-Ruano et al., 2014). For example, in regular season play, field-goals and defensive rebounds have an important impact in the final outcome of a basketball game (Sampaio & Janeira, 2003). Studies in women basketball also registered differences in the performance during regular and playoff season at the Women National Basketball Association (Gómez et al., 2009). Moreover, the tournament format may create strange incentives for some teams to regulate the final outcome depending on the next stage of the championship (Csató, 2022) as it was the example at the 2021 handball women WCh when Spain, in its last game of the group phase, needed to win by 2 at the most to go through to the main round.

The importance of international competitions for national teams such as World and European Championships was reflected in the varied performances of players and teams in various TS such as basketball, football and volleyball. These studies point out the influence of top elite competitions on different game patterns, with particular emphasis on decision making by coaches and players during these games (Gomez-Ruano et al., 2014). In this respect, there is available research about performance at different levels of tournaments (WChs, OGs, Asian or European tournaments) in handball (Bilge, 2012; Hansen et al., 2017; Saavedra, Thornorgeirsson, et al., 2018). Those tournaments are meant to be the highest expression of level in their respective continent or world level. Indeed, the same continental tournament might not have the same importance (and therefore a possible psychological consequence of players and teams) depending on the relation of final ranking and forthcoming competitions. As an example, in the last 2023 Male Handball WCh at the final game Denmark, who was playing against France, had played not only for the direct qualification to 2024 OG, but also for being the first team in the history to win 3 WChs in a row (2019-2021-2023).

2.6.2 Environmental constraint - Game time

TS performance, as it is the case of handball, is time-dependent. Game period is a variable of great importance , which is directly linked to critical moment in sports (Bar-Eli & Tractinsky, 2000). During critical moments of the game players are psychological influenced and their performance might be decreased. During those moments, coaches need to break up an opponent´s momentum in order to their players can get back to their previous performance levels during these critical periods of the game (Gomez-Ruano et al., 2014). Exploring the time dimension is fundamental to understanding the ongoing, complex, and dynamic interactions that occur between players and teams as the game evolves over time, revealing the action and significance of the game. It can capture the immediate, short-term, medium-term, and long-term effects of major events (Sampaio et al., 2013).

Previous studies in TS have identified critical moments in relation to game-time. In basketball, there are three psychological meaningful of each half: at the beginning, main and end phase; specially the researchers found that the end of a game (the last minutes) as the most critical (Bar-Eli & Tractinsky, 2000; Gómez et al., 2015; Navarro Barragan et al., 2009). During the last minutes of a game a decrease in the quality of decision making taken by players may be excepted. Gómez et al. (2011) found that offensive performances were better, when calling a time out, in the last 5 min of games, with the least differences when in balanced situations and greater differences when in winning situations, suggesting that coaches should examine offensive and defensive performances according to game period and differences in score when considering whether to call a timeout. Moreover, when explaining the USA basketball male tournament at Beijing 2008 OG, it was found that its performance in assertive game indicators was much better than the rest of the teams during the first half (Sampaio et al., 2010). When critical moments are identified, then an in deep study can be taken, as it occurred when analyzing the effect of ball screens in the Men´s 2019 Basketball World Cup during the last 5 minutes of the last quarter and extra time (Prieto-Lage et al., 2023). Indeed, players also perform at lower external intensities during overtime periods than earlier quarters during basketball games (Scanlan et al., 2019).

This dynamic, time-dependent perspective for evaluating performance in TS has gained importance in recent years, although it is still far from a static perspective. In this sense Vuleta et al. (2007) in their study of the 2003 Men´s WCh concluded that goals scored in the second and first 15 minutes of the game have the greatest impact on the final score. However, all 15 periods were assumed to be independent and possible effects between successive game episodes were not considered. Moreover, the identification of key game phases that have a large impact on the final result is also a relevant topic in handball research (Volossovitch, 2014).

2.6.3 Environmental Constraint - Match Status

Performance accomplishment is a powerful source of effectiveness expectations, and such expectations determine the task-related effort that must be expended. In sports, match status (as a consequence of game scoring) can be viewed as a measure of performance and thus can influence a player's effort (O'Donoghue & Tenga, 2001). Match status is determined by weather a team is winning, losing or drawing when a behavior/action is registered (Taylor et al., 2008). According to Bloomfield et al. (2005a) the importance of this environmental constraint is reflected in changing team and player strategies depending on the game situation. Soccer players have been found to spend a greater percentage of their game time in high-intensity activity when scores are even than when teams are winning or losing (Clark & O'Donoghue, 2013). In invasion TS matches start with a level score and one team make take and hold the lead during the match and until the end of it, or even may take the led only in the final moments of the game. For a low-scoring TS like football, there are only three main levels of game status to consider (win, lose, or draw). However, in high-scoring TS such as basketball, handball, and volleyball, the match status can be displayed in narrow, medium, or wide ranges (Marcelino et al., 2011).

Notational studies in football suggest that players regulate their intensity during a match. In fact, given being football a low-score TS, ball retaining looks like a logic strategy once a team gain a one goal lead (Bloomfield et al., 2005b). More recent studies found that team which scored the first goal did not keep the number of V-cut pass changes as well as the team that receive it, being this a fact that could have had an impact in the intention of the trailing team to draw the match; moreover, the distance covered per minute and path changes, declined for both teams after the first goal is scored (O'donoghue & Robinson, 2016). When considering corner kicks at Euro 2021, results showed that when teams are drawing or winning, they rather prevent the other team to score than prepare to counterattack; however when losing, teams performed an inswing trajectory corner kick, illustrating their intention of scoring (Prieto-Lage et al., 2023). A deeper study of 376 games of the Premier League, a predictive model found

that passing accuracy increased as goal difference in increased either positively (for the team that scores) or negatively (for the team that concedes the goal) across all playing positions and field locations; results suggested that passing accuracy (either how or away matches) and corner accuracy (again either playing away or home matches) changed systematically in relation to the goal difference (e.g., winning: +3, +2, +1, drawing: 0, or losing: -1, -2, -3 etc.) in a non-linear manner (Redwood-Brown et al., 2019).

In handball studies the score-line or match status can also be found is some studies. Prieto, Gómez, Volossovitch, et al. (2016) concluded that team time out (TTO) is mainly used by teams that are losing or that have had a negative partial on the scoreboard and want to restructure the team; coinciding with findings at male Euro 2012, OG 2012 and WCh 2013 where TTO was asked 53.7% for losing teams, 38.8% winning teams and 7.5% when the match status was a draw (Gutiérrez-Aguilar et al., 2016). During 2008-2009 to 2011-2012 ASOBAL seasons, results showed that away teams called more TTOs than home teams, but the number of TTOs called in home games was positively correlated with balanced current scores, and in away games, loss status was found to be significantly positively correlated with (Gomes et al., 2014). When it refers to conditional and physiological aspects, mean physical performance of the teams analyzed at 77 games of the German Male Bundesliga, showed no association with score-line, not in distance nor in equivalent distance covered (Bassek et al., 2022).

Lastly, in their study of player´s exclusions effect on scoring performance during close games Prieto, Gómez, et al. (2015) 2-minute suspensions presented a quite even distribution between winning and losing teams in all the game periods, independent from match status (46.4% occurred when the team was winning and 40.0% when the team was losing), showing that teams may play with the same defensive intensity or level of aggression whether they are momentary trailing or leading. Which is presented as opposite to what happen in football where players perform with less level of intensity when their match status is positive for their side.

2.6.4 Task Constraint - Game phase

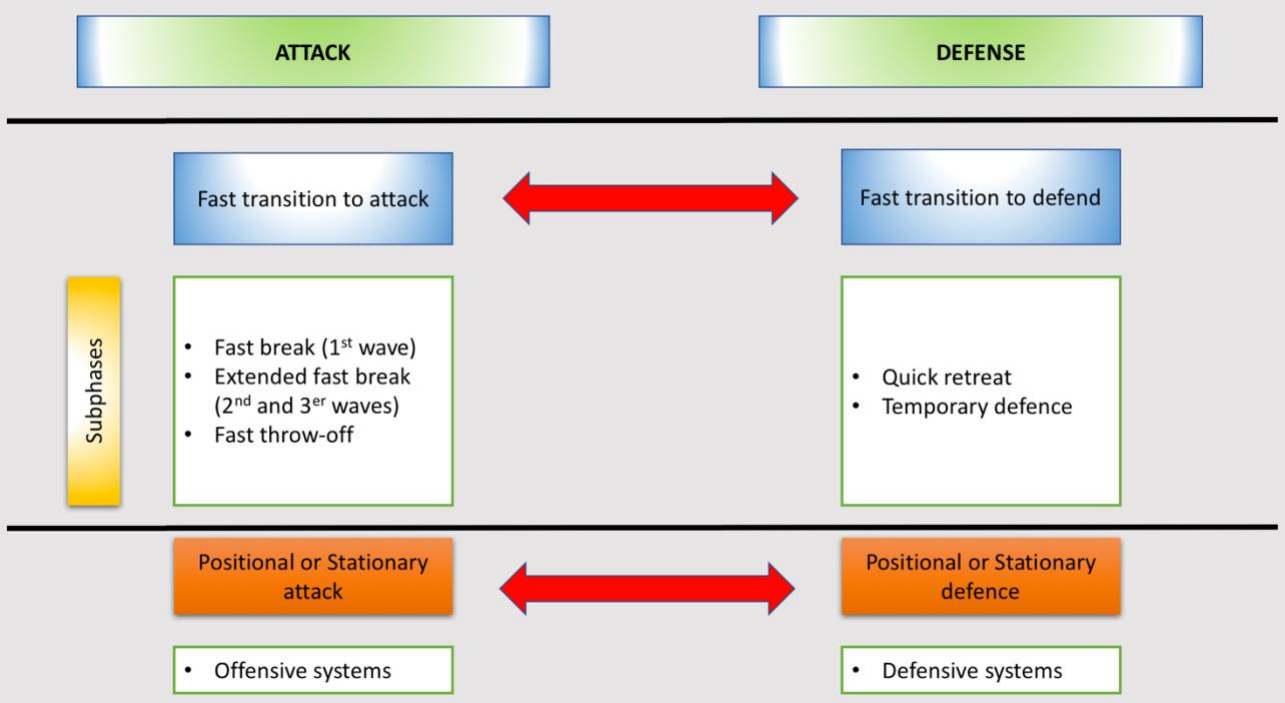
Field limits, distance to goal and rules of the game are examples of task constraints managed by coaches with intentions on developing certain technical-tactical aspects in trainings. The relative positioning of teammates and opponents are also task constraints that influence player´s performance. For instance, the distance between teammates or between attackers-defenders will influence in players´ behavior due to the time-gap they have for making a decision. However, while field boundaries and rules of the game remain unmodified during a match, players´ relative positioning is a task constraint that continuously changes due to constantly modifications in the distance between players (Passos, 2017b). For instance, in response to the positional changes of opponents (ball holders and supporters), defending players in turn adapt their positions (Passos & Davids, 2014). Moreover, these actions are taken under the *influence* of two dimensions: temporal and spatial. We then have that the players´ relative positions (the spatial dimension) must be analyzed together with "how fast" these relative positions change over time (the temporal dimension) (Passos, 2017b). Players stand or position themselves to some place, with higher or lower intensity, at a certain moment, in relation to the game configuration. When one of the players (attacker or defender) takes, in a short period of time, a considerable spatial advantage over the other, then forces the opponent to modified its positioning *earlier* than expected. In other words, interfering in the game phase. It the becomes relevant to identify and interpret substantial game behavior, based on *quantities of quality* of game playing, being "game flow" and its changes (Garganta, 2009).

Handball is composed of sequentially occurring phases which are related to a team having or not having possession of the ball (attack or defense respectively). The attacking phase starts once the team regains the ball possession. These two phases may present sub phases that tend to occur independently being not mandatory to go through all of them (Estriga, 2019). Having regained the ball, the team can move to the other side of the field (always with the intention to score) in a very fast/aggressive way (what

is called a counterattack, trying to surprise the rival) or more in a slow speed which will lead to face the opponent in what is called a positional or stationary attack. Figure 10 resumes those main moments.

Figure 10.

Handball game phases



Note: adapted from Estriga (2019).

Once the ball is regained (either by goalkeeper save, immediately after a shot went off the goal, stealing of causing a regulatory mistake in the opponent) the effectiveness of the fast transition depends not only in the place where the ball is regained (further or closer to the opposite goal) but also on the speed and accuracy of how the ball is transported to the other side of the court. In performing that phase(s) players advance forming *waves* (1st, 2nd and 3rd) each with different functions and characteristics (Späte cited in Estriga (2019)). Table 6 presents a summary of the characteristics of each sub phase. In allcases, all players are supposed to know their roles and act as fast as possible after regaining the ball. The *fast throw-off* (a possibility to counter attack after having conceded a goal) is considered as 3rd wave. In that sub phase the ball must get to the center line immediately after conceding a goal. Once the referee whistle allowing the game to restart, then offensive team tries to position one of the players in a 1 against

0 situation as soon as possible, or even *maintaining the pressure* on the defense by a sequence of passes/feints that generate advantages situations near the 6meter line.

Table 6.

Fast transitions' characteristics in handball

Forms	Starting conditions	Development	
Fast break		Creation of scoring chances via numerical superiority, or equality with spatial advantage	
	Ball is back to game by GK after a failed shot. Regain possession after interception/stealing.	Simple FB	Dribbling and no passes involved. 1 direct pass or a second pass right before throwing.
	Ball is back on game after opposite team makes a technical-regulatory mistake.	Extended FB (2nd wave)	3 o 4 passes, numerical superiority or temporal equality.
		Extended FB (3rd wave)	Numerical equality, 5 or more passes.
Fast throw-off	Immediately after a goal is conceded, ball is quickly put back into play from the centre line (referee must whistle authorising the action).		Same as above

Note: GK: Goalkeeper; FB: Fast break. Adapted from Estriga (2019, p. 90).

Once a team regains ball´s possession, it has the option the decide how *fast* they play the transition phase. Despite being a strategy of each team, the possibility to perform fast transitions with efficacy will depends not only upon its own players, but also on the defense reaction. If in the intention of playing fast transitions the opposite team retreats *on time*, the possibility to score will be reduced. However, each team may have its own *playing style*. Previous studies in basketball showed that men's teams increased the probability of obtaining a successful ball possession with only one pass or no passes at all during the first five minutes of the games. Probably both teams are trying to identify the opponents' weakness, and they use one-on-one situations and fast-breaks with only one pass more frequently, allowing them to receive a foul or score a basket (Gómez et al., 2013).

In handball, studies made when analyzing the impact of goals scored via fast breaks (in any of their waves) showed an increasing tendency from 1972 OG (where teams showed a mean of 8.6 % of the

total goals score via fast breaks) to 1997 WChs, where teams showed a mean of 20,3 % (Anton, 2000, p. 183). Reason of such an increment is sustained by the emerge of the 3rd wave promoted at the 90s by the Russian team (Anton, 2000, pp. 183-184) Yiannakos et al. (2005) when analyzing fast transitions (1st and 2nd waves) at the Greek's male handball league, found that most of these transitions (56,1%) occurred during first half, but 1st wave was used the most in the second half (63,3% against 45,9%). Teams ranked on top 8 at 2013 male WCh repeated the tactics of fast break (1st wave) with a 7.7% rate per match while teams ranked 9 to 16 and 17 to 24 implemented fast breaks in a 5.6% rate (Hassan, 2014). Moreover, Rogulj (2000) when studying 27 performance indicators related to the competitive success situation of teams' performance at 1999 WCh found that winning teams were more efficient in fast transitions and individual action of progressing in attack.

Once the team either opted to, or has been forced (as a consequence of having the defensive team retreated properly) not to finalize the attack during the transition phase, players starts to position order to be involved in the next stage: the buil-up attack, positional attack or stationary attack. This phase is characterized by the use of *offensive (for the team in possession of the ball) and defensive (for the opponent) system.* The playing system is the way in which players distribute in the space. Two concepts are taken into account when distributing players: width and depth. In the offensive side, by positioning players near the 6 meters line the team tries to be as deep as possible, and by position players at the sides is trying to be as width as possible. Usually the distribution is expressed in two numbers (e.g. 3:3) where the first indicates the number of players positioned *near its own goal* (they are known as back players) and the second indicates the number of players positioned *far from its own goal* (and are called pivot or wing). When attacking in the positional phase, the purpose is to create high-scoring situations through the defense (which is also defending under a system). This phase is characterized by sequences of actions in a *reduced space* in comparison to the fast transition sub phases. Therefore, its depends on tactical

intentions which aim to increase the real attacking space, whether to position a teammate in a 1 against 0 situation or 1 against 1 with open space (or unbalanced *strength levels*)

2.7 The use of performance analysis by coaches

Sports can be seen from four perspectives or areas of application: Sport and health; Sports and Leisure; Sports and Education; Sports and Performance (Anton, 2001). Coaches have their field of action mainly in "Sports and Performance" and "Sports and Education", which includes from players´ formation to elite areas/competitions, having the development of players´ and teams´ performance as their main aim. They develop their tasks through the sports training process.

Sport training process is defined as a complex process of actions whose purpose is to teach the sport technique and its improvement, in a simple and articulated way, individually, in group or team, and which tends to the development of the psychophysical qualities oriented to the achievement of sport results of maximum level, in relation to the capacities of the subject, group or team (Manno, 2004). Seirulo (1998), quoted by Arjol Serrano (2012) defines the planning of that process as the theoretical proposal constituted by the description, organization and design, of each and every one of the events of training, in a certain phase of the life of an athlete, as well as the control mechanisms that allow modifying those events in order to obtain an increasingly adjusted training process, so that the player can achieve the desired results in sporting competition. It is also conceptualized as a complex pedagogical process which aims to increasing conditional and theoretical/practical possibilities and (disposition to) sporting behavior (Siff & Verkhoshansky, 2004).

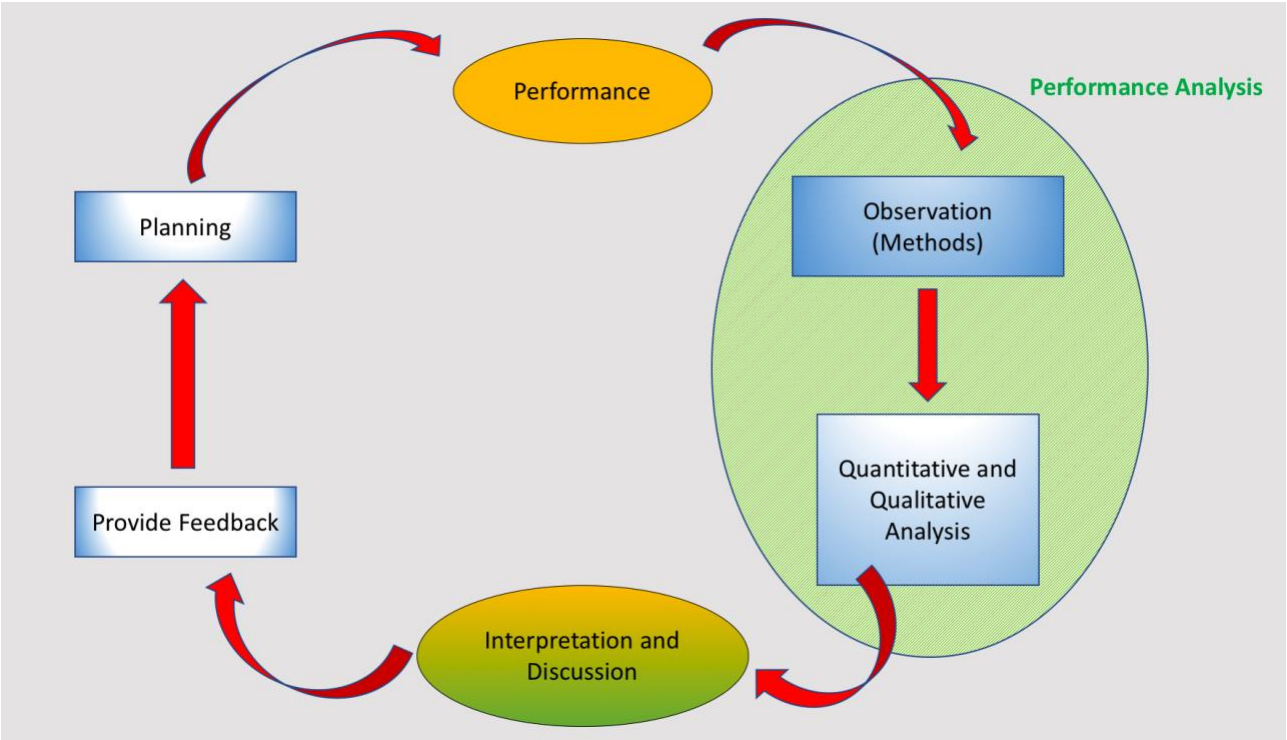
TS´ coaches have two moments of intervention: training sessions and competitions. In handball, their possibility of impacting on players´ behavior during matches is very important due to an open possibility to substitute players while the game is running without needing to advise or stop the game. In that sense, coaches are capable of directly impacting the game performance of their teams by regulating player´s on-court game (Büchel et al., 2019; Manchado et al., 2020), calling time-outs (Gutiérrez-Aguilar

et al., 2016) and even by levelling the aggressive defensive tactics related with fouls (Laxdal & Ivarsson, 2022; Wilhelm et al., 2019) and exclusions (Laxdal & Ivarsson, 2022; Prieto, Gómez, et al., 2015).

Information from players´ performance during competition may help coaches to create learning environments that help players and team to succeed. Those environments should be representative with respect to the contexts that players face during competitive situations, meaning that coaches (and other staff´s members) should be capable to analyze and identify key features which allow to *replicate* the general components of competitions in practice settings (Passos, 2017a). Capturing team and individual behavior through observation methods, provide databases for quantitative and qualitative analysis. That is the reason why performance analysis occupies a fundamental role in the cyclical process of coaching and mastering team players' performance (Figure 11).

Figure 11.

The role of performance analysis in the process of coaching

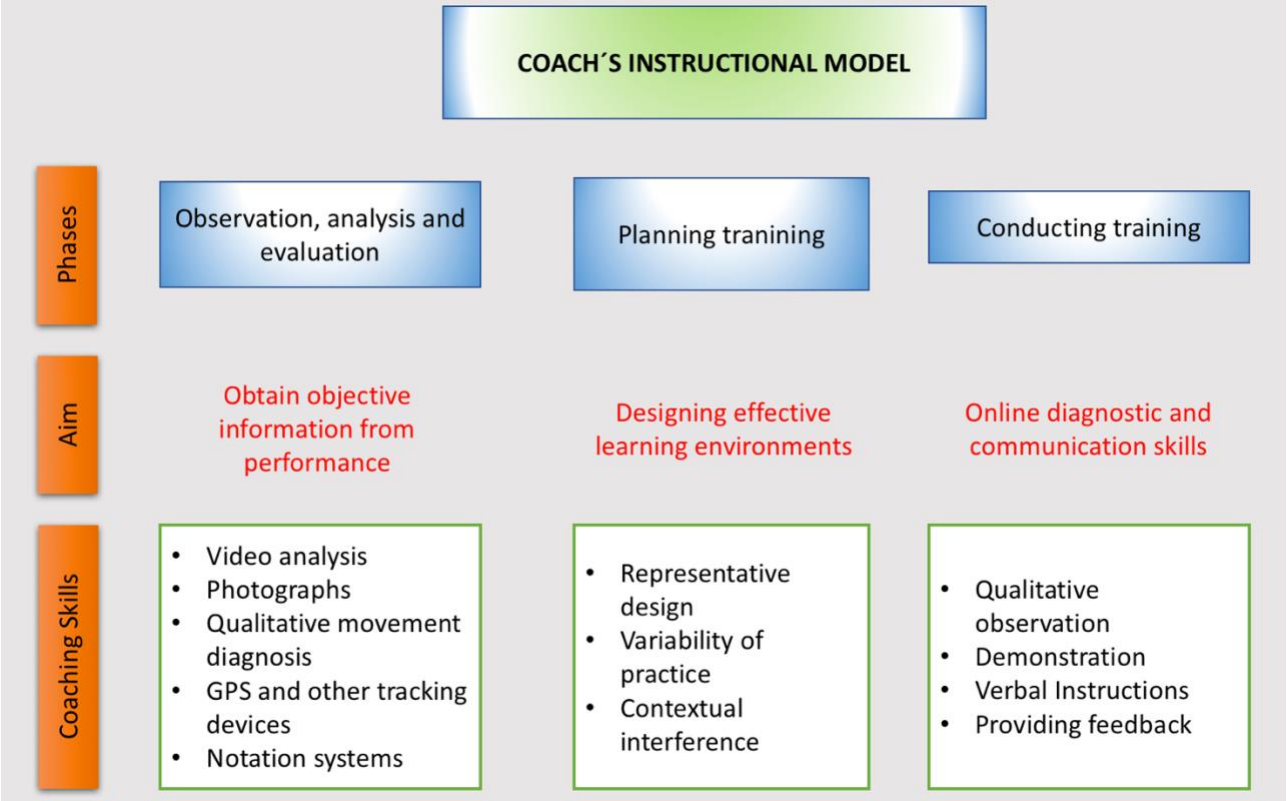


Note: adapted from Passos (2017a, p. 27).

To summarize, the coaching processes in TS are mainly concerned with three cyclical phases (Passos, 2017a): (i) observing, analyzing and evaluating performance; (ii) planning training; (iii) and conducting/leading training/practice. These phases include a variety of coaching skills which compound the Coach ´s Instructional Model (Figure 12).

Figure 12.

Coach´s Instructional Model



Note: adapted from Passos (2017a, p. 27).

Team player´s formation is a continuous process that evolves through different phases which occurs during training and competition. Those phases are: *training*-formation-control and evaluation-*competition*-control and evaluation-planning-*training.* Players evolve from an initial stage to an upper one. Coaches are in charge of that process. One of the characteristics that differentiates coaches' interventions from other professionals of physical activity is that the skills learned by players are contrasted against other players from other team, in other words: they compete. Competition becomes

then another formative means in the developing process of a player, therefore coaches must record player´s actions which are considered the most relevant and analyse them afterwards. Coaches´ practical experience and the information collected from competition are two important factors within the player´s developing process. Based on those two, coaches plan the training sessions, adjusting and modifying the original planning. Nowadays tendency in TS training in general, and in handball in particular, is to obtain as much objective information from competition as possible (Ibañez et al., 2018, pp. 168-170)

Therefore, it follows that research and production of knowledge about sport performance is a contribution to be used by coaches as input to the technical-tactical and physiological aspects of sport (depending on each sport modality and reality). Performance assessment may be conducted by a scout looking for interesting prospects, a group of analyst/researchers or by a coach attempting to improve the performance of the team or that of particular players. Indeed, performance analysis is mostly the use is by coaches/technicians/squad managers in a training/teaching environment to provide necessary feedback to players/athletes to improve their performance (O´Donoghue, 2014). Once they have the information, they can take decision to modify their practical interventions, either during training sessions or games.

Moreover, the need of recoding players and teams actions/situations is based on Laird and Waters (2008) which in their study with 8 adult qualified football coaches at the Scottish Football Association can record and recall less than 59% of the events that occur during a match, without taking into account that those memories may be misinterpreted or even influenced by emotional factors that are not directly measurable. Performance analysis enable coaches and team officials to gather objective PI from the game to understand and develop effective offensive and defensive strategies and individual or collective tactics. Recording data from multiple games allows coaches to identify patterns that they can use to prepare their strategy for the next game, based on the opponent's expected game strategy (Lord et al., 2020). The construction of the game model requires that coaches have a broad knowledge of the scientific

methodology in the programming of training, of the criteria in the selection of players and of the game models of the opponents. The latter being essential for the choice of group and team tactics, and above all an adequate structuring and hierarchizing of objectives and contents to be presented for the acquisition of the most effective decision making at the time of the competition (Mendes et al., 2021)

Wright et al. (2013) when analysing how and to what extent coaches declare to integrate performance analysis´ information in their coaching practice, surveyed 46 coaches with elite master coaches' level at United Kingdom (UKCC). Most coaches indicated that the information they receive in relation to performance analysis impacts all levels of coaching practice (93% say it will affect short-term plans, 80% medium-term plans and 70% long-term plans). Indeed 80% of coaches say they use performance analysis to change their strategy for the next game. The slightly lower percentage indicated that this affects long-term planning is likely due to long-term planning being less flexible and adaptable than expected. Most coaches surveyed show that they use key performance indicators (KPI) to encode important behaviors in their games. Nearly all coaches said their coaching philosophy influenced her KPI choices, but less than half said their intuition influenced their choices. In fact, indicators obtained by *environmental constraints* used in performance analysis (such as type of competition, game time or match status) can be used as *task constraints* in coaches training session when planning and/or implementing them (for example when developing training session during continental competition, and asking players to perform during a task with a "concrete frame time" under a "specific match status" obtained from performance analysis of rivals or their own ones.

The expert coaches emphasize the importance of initial and ongoing training, especially in methodological aspects and technical-tactical content. They mention the reading of online magazines, books and publications as a strategy to reach them (Abad et al., 2013). Handball coaches use academic training and experience as a player at the beginning of their professional careers. Those at the highest level and who only have the most academic training make more use of the knowledge acquired in the

different levels of learning (training and updating). Being lifelong learners of coaching and usually have a concern for self-training through research on an ongoing basis (Feu et al., 2012). The coaches themselves emphasize the importance of continuous training on physical and technical-tactical aspects of the sports they coach. Some of them have even completed studies for a degree in Physical Education and Sports as well as postgraduate studies in the same area of academic training (Pérez, 2012).

Coach effectiveness is underpinned by a body of knowledge and skills acquired over the course of a professional career, through a range of knowledge sources provided in mediated, unmediated and internal learning situations (Moon, 2013). Focusing on unmediated sources, handball coaches at Portuguese 1st division league, when having the possibility to choose stimuli to focus on, taking responsibility for what they intend to learn, declared that among sources perceived for reconstruction of knowledge they observe coach and read research and investigations (Cunha et al., 2014). In studies about the professional development of coaches, there is consensus that this occurs through different forms of formal, non-formal and informal education, highlighting the value of sources of knowledge from the experiences of professional practice, experiences in the communities of practice and sports career, as well as access to specific literature and training courses (Cunha et al., 2014; Gonzalez-Rivera et al., 2017).

2.8 Study designs in the tactical analysis of handball

Since primary performance analysis´ aim is to give information to teachers/coaches and/or players about player/team performance in order to plan practice and improve performance, performance analysis in invasion games needs objective recording and study of behavioural events of players (individually or as a group) during training or competitions (Lemmink & Frencken, 2013). In that sense, performance analysis is often used to generate a data compilation from matches or training sessions through a hand-based or computerized system, normally using video technology (Lemmink & Frencken, 2013). In TS, information about “what”, “when”, “where” and “how” is essential in the way to try to understand individual and group tactics. Moreover, notational analyses have been dominating the scientific literature on tactical

and technical performances for at least a couple of decades, being widely used by coaches in applied settings (Hughes & Franks, 2004). Next to real-time or day-after use of a game or training session, notational series can be used to study a series of matches during tournaments (Champions League, Continental tournaments, WChs, OG) and therefore a series of tournaments (Lemmink & Frencken, 2013). Retrospective analysis could also be undertaken to capture additional details post-match (O'Donoghue, 2006). Moreover, video analysis software was developed in the 1990s allowing synchronization of video and notations, enabling the chance to a faster and more accurate data recording (O'Donoghue, 2006). Such advance in technology has made it easier to detect events, record, collect and treat the data, as well as the creation of instruments "ad hoc" capable of obtaining a greater number of specific indicators for each investigation (Anguera & Hernández-Mendo, 2015). The use of *observation* is becoming a very valuable resource in the intention of optimizing teams and players performance (Garganta, 2000). Direct observation is one the most used methods to analyze game actions during competitions, allowing many variables to be taken into account when analyzing team or player´s performance (Anguera et al., 2005). It is in this scenario that emerged the observational methodology. González-García (2019) when assessing handball PI, mentioned that numerous research studies used observational methodology as the most appropriate tool to analyze the game. In the next section, specific issues and steps to follow regarding the observational methodology will be presented.

2.8.1 Observational Methodology

In order to achieve the objectives of this study, it has been decided to use the observational methodology. This methodology allows the study of behaviors performed spontaneously, without inciting the response, in real contexts (Anguera et al., 2011). The principal characteristics of the observational methodology that justified its use in the present research are here onwards described.

To study the actions carried out by the players in the TS, it is essential to understand the context in which they emerge, since that it is very risky to analyze invasion sports behaviors in isolation, without

having considered the context in which they take place; therefore, player's behaviors of both teams, as well as the presence of other factors (such as playing time, match status), decisively condition the actions that are performed.

However, the analysis of the behaviors that occurs in TS has had a static approach (Prieto, Gomez, et al., 2015), using data obtained once the match is over (match analysis) having then studies about frequency of certain actions and/or the percentage of success/failure obtained. These analyses leave aside some important aspects that may influence in the actions taken by the players, such as type of tournament, game phase and offensive system. Therefore, to assess the problem of how numerical offensive inequalities are managed during exclusions, a dynamic approach is needed. It is necessary that the instruments used inform about constraints influencing in the individual behaviors that are carried out during the finalizations of attack sequences, and even its immediate consequences.

Since observational studies are based on systematic observation (recording and quantifying actions in its natural context), the use of the observational methodology has been shown to be appropriate for studying the behaviors that emerge in TS (Chacon-Moscoso et al., 2018). This methodology presents advantage when comparing with other designs, such as the flexibility for adapting to different contexts, giving place to be used for specific purposes. This allows studies related to game aspects that a team develops or to know a general tendency of individual or group behavior in a certain context (Anguera & Hernández-Mendo, 2015).

Therefore, it is a scientific methodology that allows collecting behaviors performed by athletes spontaneously during training sessions and matches, showing their great ecological potential (Anguera & Hernández-Mendo, 2014). For that purpose the process of collecting information on the behaviors studied must be carried out in an objective and systematic way, and can also be performed using previously recorded images (Anguera & Hernández-Mendo, 2013). The observational methodology respects all stages of scientific logic, complying with all the requirements of objectivity and rigor. It also presents

specific demands, such as: perceptivity of behavior, regularity in the context, the spontaneity of the observed behavior, and the tailoring of observation instruments (Anguera et al., 2011).

In the field of match and notational analysis, the observational methodology is one of the methods that has been used the most in the studies about TS (Anguera et al., 2011; Portell et al., 2015). This methodology allows researchers to gather information in the sports field, via the identification, codification and recollection of multiple variables that concur and interact in TS competitions. No only those variables related to motor abilities but also those related to the context in which they are performed such as the type of activity (continental or world tournaments), phase of tournament, gender or specific game moments (related to game time, spatial zone of numerical relationship among players of each team) (Anguera & Hernández-Mendo, 2015).

2.8.2 Observational methodology and mixed methods

Without entering into debate over whether the quantitative paradigm is based on positivism and the qualitative paradigm on interpretivist and constructivism, it is certainly the case that a consistent tradition is now taking shape in which the qualitative and quantitative methodological perspectives are being combined (Sánchez-Algarra & Anguera, 2013). Qualitative research is often described as holistic, since it is related to the complexity of the relationships between human behaviors and around. This should be the starting point for approaching the observational methodology. The transposition of qualitative data collection to quantitative data analysis (by the means of descriptive and sequential statistical analysis), enable the complementation between those two approaches (Anguera, 2010; Anguera et al., 2007b). This path allows the investigations with a certain weakness in their theoretical framework to a dynamic exchange between theory, concepts and data (Anguera, 2010; Sánchez-Algarra & Anguera, 2013).

The observational methodology has then defined itself as a *mixed methods* based on specific designs that transfer qualitative data to quantitative data as well the altogether use of collecting data

instrument from both approaches (like the use of interviews and codification of behaviors) (Anguera & Hernández-Mendo, 2015). Moreover, previous studies in TS (Castañer et al., 2013; González-Ramírez & Trejo-Silva, 2021; Lara-Cobos et al., 2018) and in handball in particular (Botejara et al., 2012; González-Ramírez et al., 2016; Lozano et al., 2016) endorse the use of the observational methodology to study the actions of the players in their own natural context.

Anguera and Hernández Mendo (2013) propose the following steps in order to a correct use of the observational methodology: 1) delimitation of the problem and proposal of an observational design; 2) collection and optimization of data; 3) data analysis and 4) interpretation of the results. Characteristics of those steps in the present research are presented in the following section.

2.8.3 Problem delimitation and observational design

Delimit the problem of investigation it is considered by Anguera et al. (2007a) as the exploratory phase in observational studies. This phase is characterized by not only those aspects that conform part of the theoretical framework, but also intends to get the researcher familiarize with the situation to be observed. This phase intends to precise the problem of investigation, formulate the objectives of the research, raise the training level of the observer(s) and collect information that facilitates the type of register most appropriate as well as the sample plan.

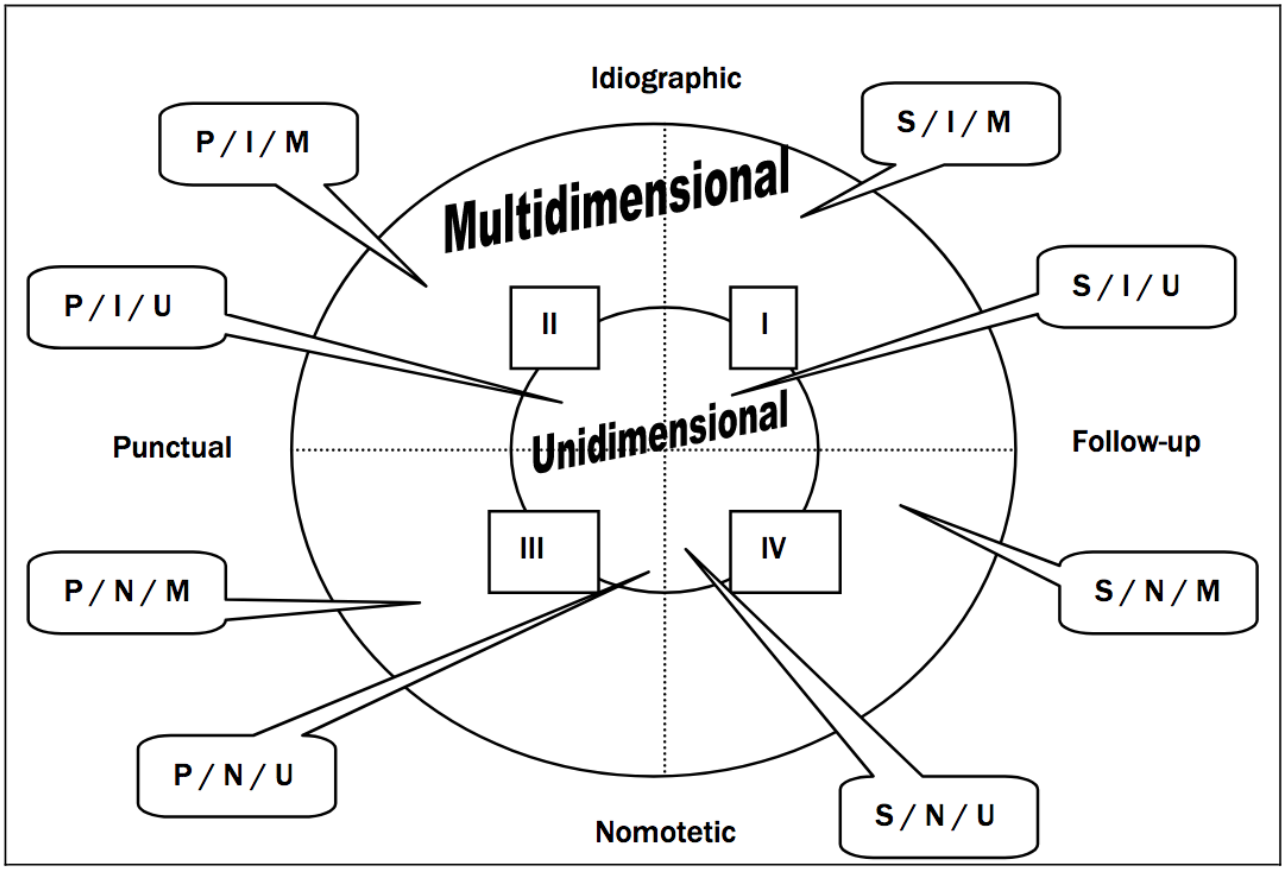
The observational design should be selected from one of the eight (Figure 13) based in 3 dichotomy criteria: unities of study; temporality and dimension (Anguera et al., 2018; Blanco Villaseñor et al., 2003) :

- Unities of study: design should be idiographic when a group of players or teams act as a unity; or nomothetic when different units are analyzed.
- Temporality: the design is tagged as follow-up when it intends to study changes in the behavior in different sessions or in a long period of time; the design is punctual when it is done in conducts presented in a specific period of time (such a specific tournament or number of trainings).

- Dimension: the design is one-dimensional when studies only one level of response; it is multidimensional when study different levels of response.

Figure 13.

Observational designs



Note: I: idiographic; N: nomothetic; S: follow-up; P: punctual; U: unidimensional; M: multidimensional. Adapted from Blanco Villaseñor et al. (2003).

Once the problem and the aims were defined (see chapter 3) this study follows an idiographic/punctual/multidimensional observational design. Idiographic because all individual behaviors were taken as a unit, not making a difference among individuals that executed the actions. Punctual, because despite a period of time was selected to analyze the possible changes during this period (2015-2018) each tournament was analyzed as an individual study. Multidimensional, because different levels

of response were studied, according to different criterion and categories described in the observational instrument.

2.8.4 Observational sample and observational unit

Hernández Sampieri et al. (2010, p. 176) mention that in non-probabilistic samples, the selection of the elements depends on characteristics of the research rather than on probability. In this sense procedures when choosing a non-probabilistic sample, it is neither mechanic nor based on probabilistic formula, but yes based on the decision-making process that the researcher makes. Therefore, the selected sample(s) obey to certain investigation´s criterion that researcher(s) established not depending on probability. To choose between a probabilistic or non-probabilistic sample depends on study´s aims, investigation scheme and contribution that the research may give to the academic and/or professional community. Non-probabilistic samples require a control and careful case selection with certain specific characteristics presented during the presentation of the problem of study (Hernández Sampieri et al., 2010, p. 190). Based on the previous statement, the sample of this research follows the characteristic of a non-probabilistic sample.

Offensive actions that occurs during exclusions in elite female handball matches were selected for this study. In this sense, sample is composed by all exclusions that occurs in all games during the following female handball championships: PPGG Toronto (PPGG) 2015; Rio 2016 OG; PCh 2017; Euro 2018. Table 7 presents the total number of games of each tournament and the total number of exclusions sanctioned in them.

Table 7.

Total number of games and 2-minute suspensions sanctioned in each tournament

Tournament	Total of games	Number of exclusions
PPGG Toronto 2015	14	107
OG 2016 Rio 2016	38	328
PCh Buenos Aires 2017	29	211
Euro France 2018	47	319

Note: PPGG: Panamerican Games; OG: Olympic Games; PCh: Panamerican Championship 2017.

To define the observational unit, a process that involves segmentation of the reality into observation units for its coding, registration and analysis shall be followed. Anguera et al. (2007b) presented some criteria to be taken into account when describing and defining and observational unit: a) they must be identifiable, separable and distinguishable from others; b) they must be nominable by means of the assignment of a name; and c) they must be definable, where the elements that characterize it remain specified Moreover, the following proceeding was follow: in each game, all offensive sequences of the match carried out while at least one of the teams was under 2-minute suspension were observed and registered. The offensive sequence was based on Antúnez et al. (2013) definition, determined from the moment that one team gains or obtains possession of the ball until one of the following occurs: a) the team in possession of the ball manages to execute a valid shot, and immediately after must restart the game via a sideline or corner launch; or b) the team in possession of the ball lost it because the opposite team regains possession. No offensive action or finalization was registered once the 2-minute suspension time came to an end.

In the first 3 studies, no offensive sequence was registered when both teams had the same number of court players (i.e., 6 × 6, 5 × 5, or 4 × 4). Since results from tournaments in 2016 and 2017 showed teams having a strategy to modify the numerical inequality in court players caused by exclusions, and following comments from experts when validating the observational instrument, offensive actions when the relationship in number of court players was 6 × 6, 5 × 5, or 4 × 4 were registered.

2.8.5 Observational instrument

Once the problem was delimited, the observational design was selected and the sample was decided, then the observational instrument is designed. According to Anguera and Hernández Mendo (2013) there are three types of basic observational instrument, each one of them with different characteristics that requires a specific construction: a) the category system, b) the field format and c) the scales of Code estimation or rating scales. The use of the estimation scales is residual, so the characteristics of the two main instruments will be specified below: systems categories and field format.

System of categories: it assigns to each behavior registered a unique category. Each category must be defined very precisely, requiring a recurrent process between reality and framework (Anguera et al., 2011). Categories should respect a double requirement: i) exhaustiveness, meaning that any behavior should be assigned to a category and ii) mutual exclusivity, meaning that each conduct should be assigned to only one category (Anguera et al., 2007b).

Field format: firstly, some criterion is defined based on the aims of the study. Secondly, a large list of behavior for each criterion is designed. Then, a code system is assigned to each conduct, reflecting the correspondent criterion. Lastly a list of configurations specifying the links between simultaneous or concurrent behaviors is designed.

Nowadays most of the observational instruments are made as a combination of the above-mentioned instruments: system of categories and field format. However, the combination respects the criteria of exhaustiveness and mutual exclusivity, for each conduct/behaviour observed.

For the purpose of this investigation, for each study an *ad hoc* instrument was designed. Each one of them was developed as a modification of the one used by Trejo-Silva and Planas (2018). Moreover, the steps followed when developing the instrument, were strictly the ones previously mentioned when designing an instrument made of a combination between system of category and field format. Table 8 presents the criteria and categories used by Trejo-Silva and Planas (2018).

Table 8.

Observational Instrument used by Trejo-Silva & Planas (2018)

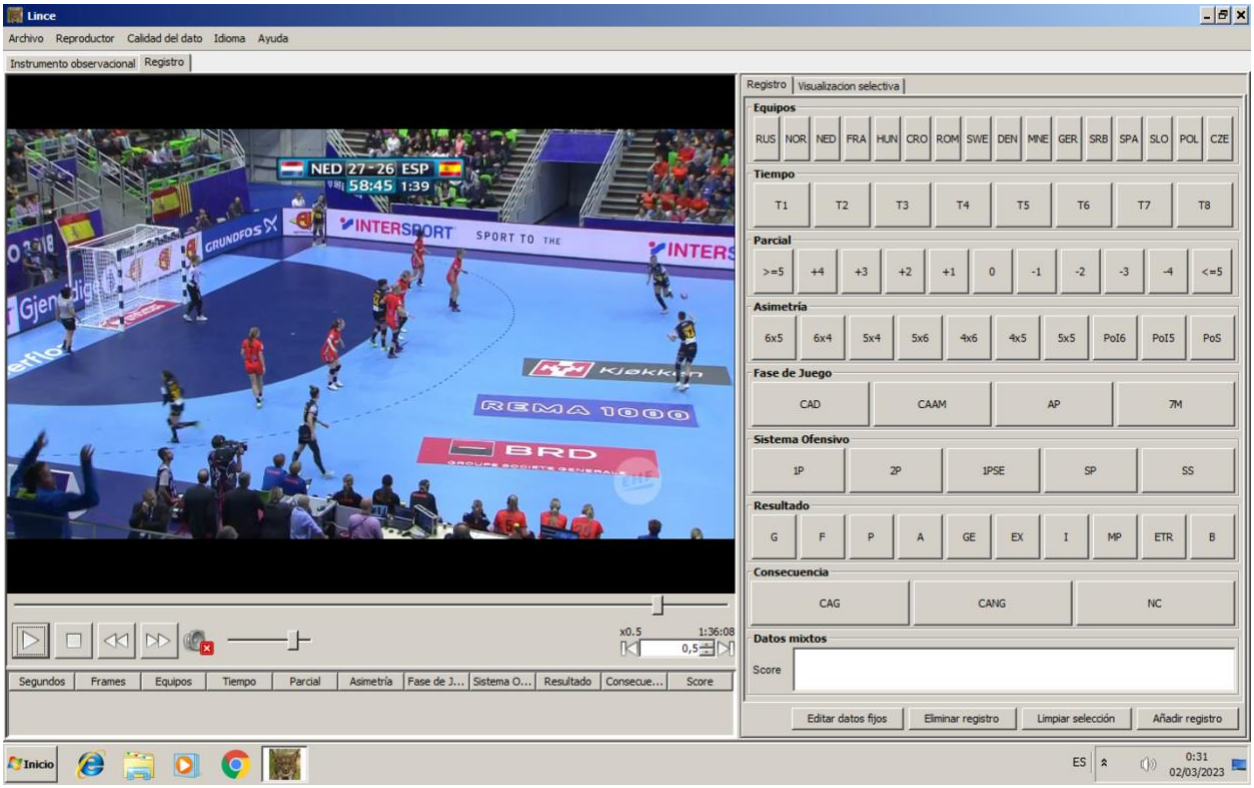
Criterion	Categories	Categorical core
Team	BRA, SRB, DEN, POL, FRA, NOR, RIV	BRA: Brazil; SRB: Serbia; DEN: Denmark; POL: Poland; FRA: France; NOR: Norway; RIV: any other team of the tournament
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
	T7	First Extra Time
	T8	Second Extra Time
Match Status	≥5, 4, 3, 2 y 1	Observer team leads by 5 (or more), 4, 3, 2 or 1.
	0	Teams are tied when behavior is registered
	≤5, -4, -3, - 2, -1	Observer team is down by 5 (or more), 4, 3, 2 or 1.
Type of Asymmetry	6x5, 5x4, 6x4	Attacker Superiority of 1 or 2 players.
	5x6, 4x5, 4x6	Attacker Inferiority of 1 or 2 players
	Pe	Attacker Inferiority with a player with a bib
Finalization		Goal
	G	Throw on post
	P	Goalkeeper save
	S	Throw not goal (not post, not goalkeeper save)
	Out	Blocked shot by defense player
	B	Goal and exclusion (in the same action)
	GE	Attacker causes a 2-minute suspension
	E	Defense player intercept a pass
	I	Error in passing the ball (not get it buy defender)
	BP	Regulatory or Technical error (attacking foul, double
	RTE	dribbling, steps, error while changing players, other sanctions)
Phase of the game	CAD	Direct counter attack
	CAAM	Expanded counter attack
	AP	Positional attack
	7M	Throw from 7 meter

2.8.6 Recording instrument

The recording instrument can be nowadays differentiated based on their specifications and nature. Most of them are software that allow the researcher to collect data in an easy and intuitive way, saving time and keeping accurate in the level of registration, though raising the limit and giving the chance to register more aspects associated with the behavior observed. The software used in this research was LiNCE v 1.4 (Gabin et al., 2012). Figure 14 shows a screen-caption of the recording instrument used to study PCh 2017.

Figure 14.

Recording Instrument. Screen capture of Lince Platform (instrument designed for Euro 2018)



2.8.7 Data quality

Control of data quality brings along two terms that must be combined in order to confirm the quality. Those terms are validity and specially, reliability and its variety of possibilities and shades.

2.8.7.1 Validity

To guarantee the validity of the observational the first step in the validation of an ad hoc instrument is a thorough search in the existent bibliography about the phenomena, being able to design the first list of criterion and categories (González-Ramírez & Trejo-Silva, 2021). In the case of instruments based totally or partially in an already published instrument, this part is reduced to determine the definitive list of criterion and/or categories, and in case is needed, a specific literature search on determined criterion or categories.

The following step is to register data from officials matches with a similar level to the ones that are will be studied in the research. This procedure allows the instrument to be changed, if necessary, in selected aspects. It also allows the researcher/s to get to an agreement in how to record specific situations of matches that may not be registered in a unique category. The data collected in those matches it is not included in the final data to be analyzed. After this process criterion and/or category/ies are finally modified, added or deleted.

The next step in the validity process is the “authority criterion” or “expert validity” (Hernández Sampieri et al., 2010). A query is made to experts/authorities in the phenomena to be studied, in the case of TS are considered specialists in the sport to be studied those persons that have not only an academic background (i.e. PhD with articles published, MSc. with articles published, coaches at national/international level) but also having a long history of competition. To those specialists a questionnaire is given, preferably by an interview, where questions about the level of agreement and disagreement for each criterion/category are asked. A place for specific observations considered by the expert is added. The questionnaire is presented together with a brief description of the aims of the study

and at the moment of the interview more details about the process can be given. Experts are encouraged to make suggestions they think relevant to each criterion/category, even agreeing with a criterion/category they can recommend reviewing of improving a certain aspect of it (González-Ramírez & Trejo-Silva, 2021). The questionnaire must be filled out by the experts marking whether they agree or disagree with each criterion and category. The agreement obtained in each of the criterion and categories that were part of the instrument, must obtained at least 80% agreement (González-Ramírez & Trejo-Silva, 2021).

Due to the changes in the Rules of the Game introduced in 2016, and for the purpose of the present research, the above-mentioned procedure was repeated four times, one for each tournament to be analyzed.

2.8.7.2 Reliability

Reliability is established by considering the different sources of error that can affect the measurement. An instrument is reliable when its records presents few measurement errors, showing stability, consistency, dependent on the variations of the elements and behaviors evaluated, and independent of other aspects that may influence the measurement (Arana et al., 2016). The analysis of the reliability is one of the most important issues in observational studies, becoming very important to estimate to what extent the observers are reliable, by analyzing the stability of the intra-session measure or stability intersessional (Blanco Villaseñor et al., 2014).

To determine the reliability of observational data, qualitative and quantitative approaches can be used. Qualitative approach refers to the use of a consensus agreement method, designed to arrive to an agreement between observers based on the exchange of interpretations of each code in relation to behavior/situation before it is recorded (Arana et al., 2016). Quantitative approach can be realized via: a) the concordance between observers, b) the psychometric theory and c) the theory of generalizability (González-Ramírez & Trejo-Silva, 2021).

When analyzing the level of concordance inter and intra observer from a quantitative perspective, agreement coefficients can be calculated (indicating the level of agreement). In this sense, one that is used the most is the Kappa index (Cohen, 1960). Its importance lies in the fact that this index represents the agreement between observers (and intra observers), correcting the chances of agreement due to chance. Landis and Koch (1977) propose a scale where values greater than 0.61 are considered good and 0.81 as very good, taking into account that 1.00 represents perfect agreement. In the present research, the study of the four tournaments used the previously mentioned index to assess the reliability of the data.

Moreover, certain specific aspects should be respect when preparing observers to collect data. According to Losada and Manolov (2015) observers may incur in three possible sources of errors: a) mechanical error during recording due to difficulties with the observation instrument or recording tool; b) errors of perception as a consequence of a bad location, difficulties with the focus of attention and the particularities of the stimuli; and 3) personal characteristics of the observer (biographical, psychological, professional, etc.). Therefore, observers should be train in order to ensure the reliability and precision of the observations made. In this sense, Medina and Noguera (1999) suggest two phases for the training of observers: a preparatory phase and an observation training phase. In the first one the observers get familiarized with the instruments, behaviors and forms of recording and in the second they develop abilities that guarantee the adaptation to the use and record data. For the preparatory phase, an observation manual is given to the observers. This manual presents the criterion and categories fully described and include examples of specific situations that may induce to more than one way of register it, on how to register them. González-Ramírez and Trejo-Silva (2021) suggest that observers should have an adequate knowledge of the sport and showing interest in being part of the study.

Once the observers have gone through the two phases, and the inter and intra observers Kappa index are adequate, the process is finished. A new session, using research sample, where all observers

gather together recording the same initial session is recommended in order to diminish the possibilities of non-expected errors at the moment of finally record data.

In the case of the four studies of this research, the previously described process was realized for each tournament. The reliability of the data was tested and confirmed for the four of them. One observer participated in 3 of the tournaments. Two other observers participated in 2 of them. In one of the tournament data was collected exclusively by the author of the research.

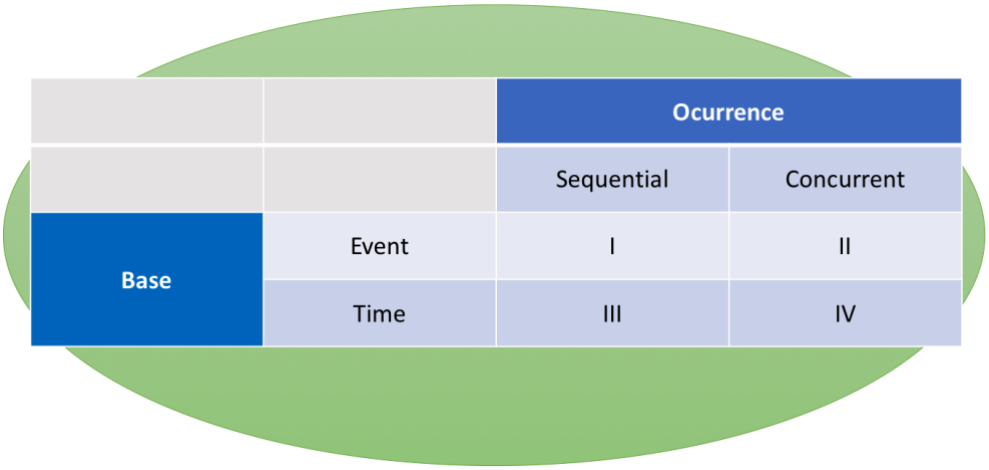
2.8.8 Data management and type of observational data

The recording instrument used allowed to record the parameters behaviors, such as frequency, order, and duration (Anguera & Hernández Mendo, 2013). Frequency is the number of occurrences of a certain category or code over the course of a period of time; the order allows the study of the sequentially of the conduct; and, finally, the duration indicates the number of units of time in which a behavior is developed (Anguera, 2003).

Bakeman and Gottman (1989) presented a data typology based on a double criterion: occurrences and basis. Data can be sequential or concurrent (occurrences) and event or time-based (basis). The combination of those 4 categories are summarize in figure 15.

Figure 15.

Type of observational data



Note: adapted from Bakeman and Gottman (1989).

To summarize the aspects of the figure and taking contributions from Anguera et al. (2011); Montoya (2010); Montoya and Anguera (2013), types of data can be described as follows:

a) Type I data (sequential and event-based)

The order of events, not their duration, is collected. The system of categories is mutually exclusive (only one behavior can occur at a time).

b) Type II data (concurrent and event-based)

As in the previous ones, the order of events is collected without taking into consideration its duration. Categories are mutually exclusive at a intra level and concurrent at a inter level., meaning that several events happen at the same time.

c) Type III data (sequential and time-based)

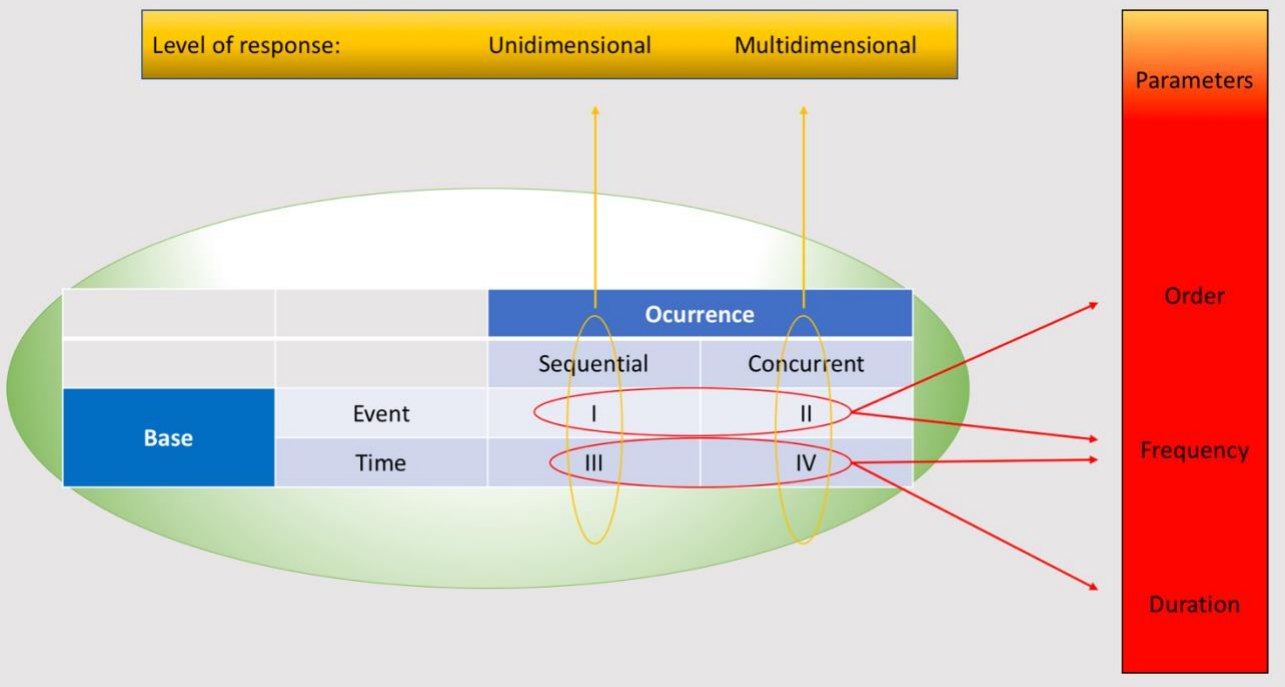
In this type of data, the order of occurrence of events and their duration is collected. Categories are mutually exclusive. Regarding the time, can be conceptualized as a sequence of intervals in which the unit of time is less than or equal to the shortest of the behaviors.

d) Type IV data (concurrent and time-based)

The duration of the events is collected, and the events may occur simultaneously. Consequently the category system is not mutually exclusive.

Figure 16.

Type of data and its relation with observational designs



Note: adapted from Anguera et al. (2011).

Based on this classification and considering that the observational instruments used are made upon a basis of a combination of field formats and category system (which allows to collect various events within the same observation unit in an orderly manner) it is possible to state that the types of data used are type II (concurrent and base event).

2.8.9 Data analysis

Since observational methodology was defined as a mixed method. Therefore specific designs transfer qualitative to quantitative data as well as the use of "qualitative instruments" (such as questionnaires) together with systematic observation (Anguera & Hernández-Mendo, 2015; Castañer et al., 2013) it is then assume the link between qualitative and quantitative approaches. Without being a restrictive imposition, the observational design provided a certain type of observational data, conditioning the analysis technique that might be more appropriate to carry out (Anguera & Hernández Mendo, 2013). However, from the perspective of the observational methodology the need of a relationship between

descriptive and inferential analysis has been frequently raised. Moreover, certain trends or usages that are highly incident in analytical techniques are possible to be detected in comparison to the incidental usage of other ones (Blanco Villaseñor et al., 2003).

Llopis (2015) (as cited in Lasierra (2017)) ensures that the descriptive analysis itself should be considered the end goal, while in inferential analysis the samples taken are means receiving two specific types of requests: targeted correlation of studied variables with variables in order to compare equality or differences between groups or populations. Anguera and Hernández-Mendo (2015) present a list of analytical techniques (Table 9) based on the one proposed by Blanco Villaseñor et al. (2003).

It can be then conclude that due to the flexibility presented at observational methodology, both quantitative and qualitative data analysis can be performed. This ensures an appropriate interpretation and contextualization of the results. Various analytical methods can be used for this purpose, such as descriptive statistics, ordinal correlation, chi-square, interlaced and interlaced sequential analysis, coordinate analysis polarization, log-linear analysis, multiple correlation, logistic regression, not parametric tests (Anguera & Hernández-Mendo, 2015)

Table 9.

Analytical techniques corresponding to the observational designs

Punctual/Idiographic/Unidimensional		Punctual/Idiographic/Multidimensional	
• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains	• Intrasessional and sequential analysis • Analysis of polar coordinates	• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis	• Analysis of polar coordinates • Log-lineal analysis • Intra-class correlation • Logistic regression • Non-parametric test
Punctual/Nomotetic/Unidimensional		Punctual/Nomotetic/Unidimensional	
• Descriptives statistics • Ordinal correlation • Linear correlation • Chi-square • First order Markov chains	• Intrasessional and sequential analysis • Analysis of polar coordinates • Non-parametric test	• Descriptives statistics • Ordinal correlation • Linear correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis	• Analysis of polar coordinates • Intra-class correlation • Logistic regression • Non-parametric test
Follow-up/Idiographic/Unidimensional		Follow-up/Idiographic/Unidimensional	
• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis • Intersessional and sequential analysis • Analysis of polar coordinates	• Intra-class correlation • Logistic regression • Panel analysis • Trend analysis • Temporal series • Analysis of variance • Analysis of variance for categorical data	• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis • Intersessional and sequential analysis • Analysis of polar coordinates	• Multiple correlation • Logistic regression • Panel analysis • Trend analysis • Multiple temporal series • Multivariate analysis of variance • Multiple dimensional scalling • Non-parametric tests
Follow-up/nomotetic/Unidimensional		Follow-up/nomotetic/Unidimensional	
• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis • Intersessional and sequential analysis • Analysis of polar coordinates	• Intra-class correlation • Logistic regression • Panle analysis • Trend analysis • Temporal series • Multiple temporal series • Analysis of variance • Analysis of variance for categorical data	• Descriptives statistics • Ordinal correlation • Chi-square • First order Markov chains • Intrasessional and sequential analysis • Intersessional and sequential analysis • Analysis of polar coordinates	• Multiple correlation • Logistic regression • Panel analysis • Trend analysis • Temporal series • Multiple temporal series • Multivariate analysis of variance • Multiple dimensional scalling

Note: Adapted from Anguera and Hernández-Mendo (2015).

Chapter 3. AIMS

3 AIMS

The main objectives of this Doctoral Thesis were:

- to analyze the performance at elite female handball during situations of players inequality due to exclusions;
- to study the impact of the change of the Rules of the Game 2016 on the performance during exclusions.

Therefore, to reach that main objectives, the following specifics aims were proposed:

Specific Aim 1: To describe the situations of numerical inequality due to exclusions during the Female Handball at Panamerican Games 2015.

Specific Aim 2: To analyse the efficacy during numerical inequalities at Female Handball at Panamerican Games 2015 and relate it with game outcome.

Specific Aim 3: To analyze the offensive performance during the different numerical asymmetry scenarios in exclusions at Rio 2016 female Olympic Games.

Specific Aim 4: To determine teams´ offensive performance indicators during exclusions related to the final ranking obtained at the Panamerican Championship 2017.

Specific Aim 5: To analyze offensive performance during exclusions at female Euro 2018 concerning the different numerical inequality contexts.

Chapter 4. METHODS

4 METHODS

Based on the observational methodology´s aspects previously presented and as it was stated in Chapter 2 (Section 2.8.4), all the studies comprised in this compendium of articles thesis recognize the following observational design: idiographic, punctual, and multidimensional.

For each study an *ad hoc* instrument was designed based on that used by Trejo-Silva and Planas (2018). All four of them were conformed as a combination of system of categories and field format, respecting exhaustiveness and mutual exclusivity. The following sections present sample, instrument, respective quality of data process realized respectively, procedures and description of statistical analysis performed for each study.

All matches were publicly available on tv streaming, and there were both people and teams with no expectations. Therefore, since the study involved observing players in a public environment (i.e via television and internet images), neither examination nor informed consent were required. This research follows the ethical principles established by the protection Law of personal data (WMA., 2013).

4.1 Study 1 - Offensive performance under numerical inequality during exclusions at female handball at the 2015 Panamerican Games.

4.1.1 Sample

The study was conducted on a sample of 14 matches from 2015 Women's Pan-American Handball Championship in Toronto. Those games were the total ones played by the national teams that finished the tournament in the four first places. A total of 107 exclusions occurred during those matches. The observation unit is considered as the period of time during which the team gets the ball possession until a collectable action (*finalization*) is produced. In the present study, was referred only to the situations that took place during an exclusion generating a numerical inequality. Actions in which there were numerical equality (i.e. 5x5 and 4x4) in both teams were not included in the analysis. The number of finalization

actions recorded was 464 and three of them were discarded due to the low quality of the recorded video. Therefore, the number of valid actions was 461

4.1.2 Instrument

The observational instrument combined the field format with the system of categories was designed based on that one used by (Trejo-Silva & Planas, 2018). The selected categories for each criterion contained exhaustiveness and mutual exclusivity at the system of categories. A total of 49 categorical cores and their correspondent register code were generated (Table 10).

Table 10.

Observational tool for Panamerican Games 2015

Criterion	Categories	Categorical core
Team	BRA, ARG, URU, MEX, RIV	BRA: Brazil; ARG: Argentina; URU: Uruguay; MEX: Mexico; RIV: any other team of the tournament
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
	T7	First Extra Time
	T8	Second Extra Time
Match Status	≥5, 4, 3, 2 y 1	Observer team leads by 5 (or more), 4, 3, 2 or 1.
	0	Teams are tied when behavior is registered
	≤5, -4, -3, - 2, -1	Observer team is down by 5 (or more), 4, 3, 2 or 1.
Type of Asymmetry	6x5, 5x4, 6x4	Each 3 types of numerical Superiority of 1 or 2 players.
	5x6, 4x5, 4x6	Inferiority of 1 or 2 players with GK at goal
	Pe	Inferiority of any kind but without GK at goal
Finalization	G	Goal
	P	Throw on post
	S	Goalkeeper save
	Out	Throw not goal (not post, not goalkeeper save)
	B	Blocked shot by defense player
	GE	Goal and exclusion (in the same action)
	I	Defense player intercept a pass
	BP	Error in passing the ball (not get it buy defender)
	RTE	Regulatory or Technical error (attacking foul, double dribbling, steps, error while changing players, other sanctions)

4.1.3 Quality of data

A theoretical framework and the authority criteria sustained the validity of the construct. These latter one was covered with the response of 5 Pan-American elite coaches to a specific survey. The level of agreement in the totality of the items included in the questionnaire was higher than 90%. The reliability of the instrument was confirmed by undertaking quality control tests and inter-observers and intra-observers' concordance. Kappa coefficient values at those items showed 0.85 and 0.93 respectively.

4.1.4 Procedure

The final condition of the match (winner, looser or draw) was directly inserted in the registration sheet, being part of the variables studied. Finalizations´ records were firstly grouped in: Goal (G and GE), No Goal (P, S, Out and B) and No shot (I, BP and RTE). For a second analysis, finalizations were grouped in Goal (G and GE), Throw out (P and Out); Goalkeeper Save (S) and No shot (I, BP and RTE).

The definition of attack and throwing efficacy proposed by Gutierrez et al. (2010) and Trejo-Silva and Planas (2018) was taken as a reference, so used with the following definitions:

- Throwing Efficacy (TE) = [(number of goals x 100) / Number of throws];
- Attack Efficacy (AE) = [number of goals / (number of throws + turnovers)].

The results of attacks ending in interception (I), bad pass by attacking player (MP) and technical or regulatory mistake (ETR) were considered "turnovers".

4.1.5 Statistical analysis

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, IL, USA). Frequencies were obtained for the different variables. Differences among different categories were analysed using Chi-square test for contingency tables. Period and consequence or type of inequality and consequence were the variables included in the chi-square analysis to determine differences in periods during the

matches or among type of inequalities. When a general difference was observed, a chi-square test was performed in the specific category. Statistical significance was considered when $p < 0.05$.

4.2 Study 2 – Multivariate analysis of offensive performances during numerical asymmetries in female handball games at Rio 2016.

4.2.1 Sample

Intersessional sample consisted of the total number of exclusions (n= 328) sanctioned during the total number of matches played at Rio 2016 OG (n= 38). Intra-sessional sample consisted of every attack finalization during 2-minute suspensions 'offensive sequence, which involved numerical asymmetry in the court players relationship (n= 1,065). The offensive sequence was based on Antúnez et al. (2013) definitions. It was determined from the instant when one team recovers or gets the possession of the ball, until any of the followings occurs: a) the opposite team gets the possession of it; b) team in possession of the ball must restart the game from a side line or corner launch, immediately after taking a valid throwing. Every offensive action of the game executed while at least one exclusion had been previously sanctioned, was observed and registered. No offensive action was registered after a 2-minutte suspension was sanctioned if it happened during the time of a previous exclusion. Actions happened while both teams had the same number of court players (i.e. 6x6, 5x5 or 4x4) and GK at goal, were no registered. No offensive sequence was registered when occured once the 2-minute exclusion time ended.

4.2.2 Instrument

An observation tool that combines a field format and a category system, modified from (Trejo-Silva & Planas, 2018) was designed. Categorical cores (n=61) with their respective codes were determined, grouped in 8 criterions, and regarding exhaustiveness and mutual exclusivity (Table 11). A coded record of all data was exported in Excel format.

Table 11.

Observational instrument for Rio 2016 Olympic Games

Criterion	Categories	Categorical core
Team	RUS, FRA, NOR, NED, BRA, SPA, SWE, ANG, ROM, KOR, MNE, ARG.	In order of final ranking, from 1st to 12th: RUS: Russia; FRA: France; NOR: Norway; NED: Netherlands; BRA: Brazil; SPA: Spain; SWE: Sweden; ANG: Angola; ROM: Romania; KOR: South Korea; MNE: Montenegro; ARG: Argentina.
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
	T7	First period of extra time
	T8	Second Period of extra time
Match Status	≥5, 4, 3, 2 y 1	Observer team leads by 5 (or more), 4, 3, 2 or 1.
	0	Teams are tied when behavior is registered
	≤5, -4, -3,- 2, -1	Observer team is down by 5 (or more), 4, 3, 2 or 1.
Type of Asymmetry	6x5, 5x4, 6x4	Numerical Superiority of 1 or 2 players.
	5x6, 4x5, 4x6	Inferiority of 1 or 2 players with GK at goal
	EN	Inferiority of 1 or 2 players with Empty Net
Game Phase	FB	Fast break attack (1st wave)
	CA	Counter attack (2nd and 3rd wave)
	PA	Positional attack
	7M	7M Throw
Offensive System	3:3	3:3 with 1 pivot and 2 wings
	3:3 (2)	3:3 with 2 pivots and 1 wing
	2:4	2 back players, 2 wings, 2 pivots
	3:2	3 back players and 2 wings
	3:1:1	3 back players, 1 wing, 1 pivot
	NS	No System (counter attacks and 7M throws)
Finalization	G	Goal
	P	Throw on post
	S	Goalkeeper save
	Out	Throw not goal (not post, not goalkeeper save)
	B	Blocked shot by defense player
	GE	Goal and exclusion (in the same action)
	I	Defense player intercept a pass
	BP	Error in passing the ball (not get it buy defender)
	RTE	Regulatory or Technical error (attacking foul, double dribbling, steps, error while changing players, other sanctions)
Consequence of the finalization	NC	Observer team receives No Counter Attack
	CNG	Observer team receives Counter Attack No Goal
	CG	Observer team receives Goal by Counter attack

4.2.3 Quality of data

The steps to verify the quality of the data following Anguera and Hernández-Mendo (2014) indications were respected. Five experts (all of them coaches with a minimum of 10 years of experience at club level and at least one of experience as national coach; 3 of them with postgraduate qualifications) received a questionnaire and arrived to a 95% of agreement. Cohen´s Kappa coefficient values were rated as very good (K≥0,89) for both intra and inter-observer reliability concordance

4.2.4 Procedures

Game outcome (winner, loser, draw) and final ranking of participating teams (1 to 12) were directly allocated in the final data sheet. Teams were garranged in 3 groups: teams ranked 1st to 4th; teams ranked 5th to 8th and teams ranked 9th to 12th. Several criteria were transformed into new variables for this study. Asymmetry was classified into three types of asymmetry: (i) superiority: all finalizations registered under the context of 6 × 5, 5 × 4, 6 × 4 and ENS; (ii) Goalkeeper at goal: all finalizations registered under the context of 5 × 6, 4 × 5, 4 × 6; (iii) Empty Net: all finalizations registered under the context ENI. Play time is grouped into two time periods using previous researches (Prieto, Gómez, et al., 2015; Trejo-Silva et al., 2020) that found critical moments of the game when exclusions are sanctioned: critical moments (T2, T4, T5) and no critical (T1; T3; T6; T7; T8). Match status regrouped in (i) 2 goals (all finalizations registered when the difference in the score was of 2 goals or less); (ii) 3-4 goals (all finalizations registered when the difference in the score was of 3 or 4 goals); (iii) 5 or more (all finalizations registered when the difference in the score was of 5 goals or more). Finalizations were grouped in: (i) Goal (finalizations registered as G or GE); (ii) No Goal (finalizations registered as P, S, Out, B); (iii) Turnovers (finalizations registered as I, BP, RTE).

4.2.5 Statistical Analysis

Crosstabs command between the type of asymmetry (superiority, inferiority played with GK at goal and inferiority played with EN) and contextual indicators (game outcome, finalization, phase of the

game, offensive system, game time, match status, final ranking arranged in 3 groups) was used to study the relationship among them. Pearson´s Chi-square test was performed. When Expected Frequency Distribution was lower than 5 or the count of cases in one cell was lower or equal to 5, the Fisher's exact test was applied (Field, 2013). First, the Effect Size (ES) and the independence of the variables' cross-section were analysed via Cramaer´s V test. To deepen the appreciation of the importance of variables, adjusted residuals or adjusted normalized residuals tests were performed (Haberman, 1973), in order to determine a statistically significant relationship between the variables according to the *normalized z-score.* In those values , < 1.96 indicate stimulus patterns and values > -1.96 represented inhibition model of the relationship between variables.

Secondly, an Exhaustive CHAID (Chi-squared automatic interaction detection) classification tree analysis was used to determine the differences between the performance of the 3 types of asymmetries and the contextual indicators. All analyses were run in SPSS (v25, IBM, Corp., Armonk, NY, United States) statistical software package. Data were presented as frequencies and percentages. The confidence interval was set at 95% and the statistically significant relationship was found when $p < 0.05$. Results were presented in terms of frequencies or percentages.

4.3 Study 3 - Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball at the Panamerican Championship 2017.

4.3.1 Sample

The sample consisted of 29 matches from the 2017 Pan-American Female Championship played by 10 national teams. In each game, all offensive sequences of the match carried out while at least one of the teams was under exclusion penalty were observed and registered. No offensive sequence was registered when both teams had the same number of court players (i.e., 6 × 6, 5 × 5, or 4 × 4). An offensive sequence has been defined according to aspects mentioned by Antúnez et al. (2013). Determined from the moment that one team regains or obtains possession of the ball (most of the times immediately after an exclusion is sanctioned) until either (a) the ball is lost because the opposite team regains possession, or (b) the team in possession of the ball gets to make a valid throwing, and immediately after must restart the game via a sideline or corner launch. No offensive sequence was studied once the 2-min suspension time ended.

4.3.2 Instrument

The observational instrument combined the field format with the system of categories was designed based on the one used by (Trejo-Silva & Planas, 2018). The selected categories for each criterion contained exhaustiveness and mutual exclusivity at the system of categories. A total of 55 categorical cores and their correspondent register code were generated (Table 12).

Table 12.

Observational instrument for Panamerican Championship 2017

Criterion	Categories	Categorical core
Team	BRA, ARG, PAR, URU, USA, PUR, CHI, DOM, COL, GUA.	In order of final ranking, from 1st to 10th: BRA: Brazil; ARG: Argentina; PAR: Paraguay; URU: Uruguay; USA: United States of America; PUR: Puerto Rico; CHI: Chile; DOM: Dominican Republic, COL: Colombia; GUA: Guatemala
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
	T7	First period of extra time
	T8	Second Period of extra time
Match Status	≥5, 4, 3, 2 y 1	Observer team leads by 5 (or more), 4, 3, 2 or 1.
	0	Teams are tied when behavior is registered
	≤5, -4, -3,- 2, -1	Observer team is down by 5 (or more), 4, 3, 2 or 1.
Type of Asymmetry	6x5, 5x4, 6x4	Numerical Superiority of 1 or 2 players.
	5x6, 4x5, 4x6	Inferiority of 1 or 2 players with GK at goal
	EN	Inferiority of 1 or 2 players with Empty Net
Game Phase	FB	Fast break attack (1st wave)
	CA	Counter attack (2nd and 3rd wave)
	PA	Positional attack
	7M	7M Throw
Offensive System	3:3	3:3 with 1 pivot and 2 wings
	3:3 (2)	3:3 with 2 pivots and 1 wing
	2:4	2 back players, 2 wings, 2 pivots
	3:2	3 back players and 2 wings
	3:1:1	3 back players, 1 wing, 1 pivot
	NS	No System (counter attacks and 7M throws)
Finalization	G	Goal
	P	Throw on post
	S	Goalkeeper save
	Out	Throw not goal (not post, not goalkeeper save)
	B	Blocked shot by defense player
	GE	Goal and exclusion (in the same action)
	I	Defense player intercept a pass
	BP	Error in passing the ball (not get it buy defender)
	RTE	Regulatory or Technical error (attacking foul, double dribbling, steps, error while changing players, other sanctions)
Consequence of the finalization	NC	Observer team receives No Counter Attack
	CNG	Observer team receives Counter Attack No Goal
	CG	Observer team receives Goal by Counter attack

4.3.3 Quality of data

The theoretical framework and the authority criteria sustained the validity of the construct. These last one was covered with the response of 5 experts' elite coaches (all coaches with national team experience as well as 10 years' experience as coaches at the club level) to a specific survey. The level of agreement in the totality of the items included in the questionnaire was higher than 90%. The reliability of the instrument was confirmed undertaking tests of quality control and concordance at inter-observers and intra-observers. Kappa coefficient values at those items showed $K \geq 0.89$ in both cases.

4.3.4 Procedure

The final condition of the match (winner, looser or draw) was directly inserted in the registration sheet, being part of the variables studied (none of the matches ended in a draw). Final ranking of each team was obtained by transforming each team code into their respective final place in the tournament (e.g. BRA was recoded to "1"). For the study, 3 Ranking Groups were formed using the following criteria. Group I (GI): teams ranked 1st to 3rd; Group II (GII): teams ranked 4th to 6th; Group III (GIII): teams ranked 7th to 10th. Game time was arranged into two groups, based on previous studies which found critical moments of the game where exclusions occurred (Prieto, Gómez, et al., 2015; Trejo-Silva et al., 2020), i.e., critical moments (game time 2, 4, 5) and non-critical moments (game time 1, 3, 6). Match status was arranged into three groups: 2 goals (all actions registered when the difference in the score was 2 goals or less); 3–4 goals (all actions registered when the difference in the score was of 3 or 4 goals up or behind); 5 or more goals (when the difference in the score was 5 goals or more). The asymmetry was grouped into two types of asymmetry. Superiority (all actions registered when the numerical inequality was 6 against 5, 5 against 4, or 6 against 4), and inferiority (all actions registered when the goalkeeper was in goal and the numerical inequality was 5 against 6, 4 against 5, or 4 against 6 and playing with an empty net). Moreover, when analyzing only numerical inferiority, actions were grouped into 'with the goalkeeper in goal' (all actions registered when the goalkeeper was in goal and the numerical inequality was 5 against

6, 4 against 5, or 4 against 6) and empty net (all actions registered during inferiority and the observed team played with empty net). Finalizations were arragned into three groups: goal (goal and "goal and exclusion"); no goal (throw on post, goalkeeper save, blocked shots, throwing out the goal), and turnover (all finalizations not involving throwing).

4.3.5 Statistical Analysis

Deviation in normality was determined using the Kolmogorov-Smirnoff test. Crosstab commands were used to study the relationships (Pearson's chi-square test) between the groups concerning final ranking (medalist and other 2 groups) and the type of numerical inequality and contextual indicators (final condition, finalization, type of play, system of play). Fisher's exact test (f) with the Monte Carlo method was applied when the Expected Frequency Distribution was lower than 5, or the count of cases in one cell was lower or equal to 5 (Field, 2013). To estimate effect sizes (ES), Cramer's V test was used. Adjusted Standardized Residual (ASR; critical value = 1.96 and $p = 0.05$) was used to determine which cross-section was responsible for the independence of the variables. Secondly, to identify the variables that best explain the teams' performance, an exhaustive CHAID (Chi-squared automatic interaction detection) classification tree analysis was used in order to determine the differences between the performances of the 3 groups of teams (medalist, best in their continent, last positioned) according to the temporal and contextual indicators. The SPSS v.25 for Mac software (IBM, Corp., Armonk, NY, United States) was used to perform the statistical analysis. Data were presented as frequencies and percentages. The confidence interval was set at 95%. A statistically significant relation was found when $p < 0.05$.

4.4 Study 4 – Analysis of the offensive performance during exclusions in handball at female Euro 2018.

4.4.1 Sample

The intersessional sample was composed of all exclusions sanctioned (n=319) during all matches played at the Female Handball Euro 2018 (n=47). The intra-sessional sample included 1,130 attack finalizations registered when at least one of the participating teams was sanctioned with a 2-minute suspension as a consequence of exclusion. The offensive sequence was based on the definition of Antúnez et al. (2013), determined from the moment when one team gains or obtains possession of the ball until one of the following occurs: a) the team in possession of the ball manages to execute a valid shot, and immediately after must restart the game via a sideline or corner launch; or b) the team in possession of the ball lost it because the opposite team regained possession. No offensive action or finalization was registered once the 2-minute suspension time came to an end.

4.4.2 Instrument

An ad hoc instrument composed of a field format and category systems, modifying the one proposed by Trejo-Silva and Planas (2018) was designed. The selected categories for each criterion contained exhaustiveness and mutual exclusivity at the system of categories. A total of 63 categorical cores and their correspondent register code were generated (Table 13).

Table 13.

Observational tool for Euro 2018

Criterion	Categories	Categorical core
Team	FRA, RUS, NED, ROM, NOR, SWE, HUN, DEN, MNE, GER, SRB, SPA, SLO, POL, CZE, CRO.	In order of final ranking, from 1st to 16th: FRA: France; RUS: Russia; NED: Netherlands; ROM: Romania; NOR: Norway; SWE: Sweden; HUN: Hungary; DEN: Denmark; MNE: Montenegro; GER: Germany; SRB: Serbia; SPA: Spain; SLO: Slovenia; POL: Poland; CZE: Czech Republic; CRO: Croatia.
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
Match Status	≥5, 4, 3, 2 y 1	Observer team leads by 5 (or more), 4, 3, 2 or 1.
	0	Teams are tied when behavior is registered
	≤5, -4, -3,- 2, -1	Observer team is down by 5 (or more), 4, 3, 2 or 1.
Type of Asymmetry	6x5, 5x4, 6x4	Numerical Superiority of 1 or 2 players.
	5x6, 4x5, 4x6	Inferiority with GK at goal
	5x5, 4x4	Simultaneous exclusions for teams and GK at goal
	EN6x5	Simultaneous exclusions for teams and EN
	EN7x5	Any kind of superiority and EN
	EN6x6	Numerical equality of field players, with EN
Game Phase	FB	Fast break attack (1st wave)
	CA	Counter attack (2nd and 3rd wave)
	PA	Positional attack
	7M	7M Throw
Offensive System	3:3	3:3 with 1 pivot and 2 wings
	3:3 (2)	3:3 with 2 pivots and 1 wing
	2:4	2 back players, 2 wings, 2 pivots
	3:2	3 back players and 2 wings
	3:1:1	3 back players, 1 wing, 1 pivot
	NS	No System (counter attacks and 7M throws)
Finalisation	G	Goal
	P	Throw on post
	S	Goalkeeper save
	Out	Throw not goal (not post, not goalkeeper save)
	B	Blocked shot by defense player
	GE	Goal and exclusion (in the same action)
	I	Defense player intercept a pass
	BP	Error in passing the ball (not get it buy defender)
	RTE	Regulatory or Technical error (attacking foul, double dribbling, steps, error while changing players, other sanctions)
Consequence of the finalisation	NC	Observer team receives No Counter Attack
	CNG	Observer team receives Counter Attack No Goal
	CG	Observer team receives Goal by Counter attack

4.4.3 Quality of data

The theoretical framework and the authority criteria sustained the validity of the construct. The quality of the data was verified by six experts (all coaches with national team experience as well as a minimum of 10 years of experience as coaches at the club level). Intra and inter-observer reliability were assessed using Cohen´s Kappa coefficient (Cohen, 1960). Intra-observer reliability presented a value that was considered very good (K>0.90) and inter-observer reliability a value that was also considered very good (K>0.87).

4.4.4 Procedure

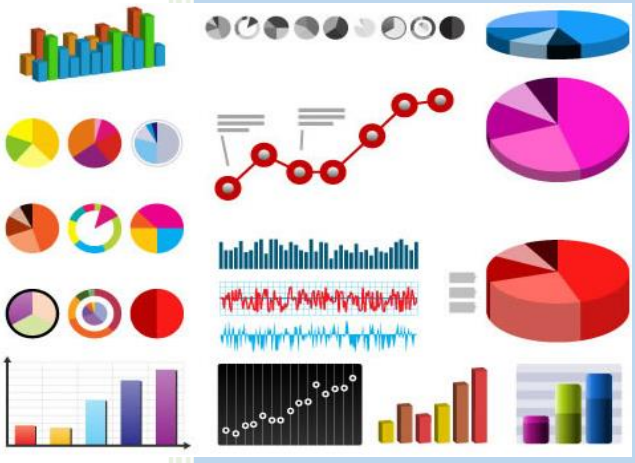
The final condition of the match (winner, looser or draw) was directly inserted in the registration sheet, being part of the variables studied (none of the matches ended in a draw). Final ranking of each team was obtained by transforming each team code into their respective final place in the tournament (e.g. FRA was recoded to "1"). For the purpose of the study, some criteria were transformed into new variables. The asymmetry was grouped into three types of asymmetry: (i) Superiority (all finalizations registered when the numerical relationship of court players was 6 against 5, 7 against 5 with EN, 5 against 4 and 6 against 4); (ii) Inferiority with GK at goal (all finalizations registered when the numerical relationship of court players was 5 against 6, 4 against 5, 4 against 6; 5 against 5, 4 against 4); and (iii) EN (all finalizations registered when the numerical relationship of court players was 6 against 5 with EN, 6 against 6 with EN). Since referees are encouraged not to sanction three parallel 2-minute suspensions for a team, 3 against 6 (or 6 against 3) rarely occurs and if they did appear, observers were trained to register the situation under "4 against 6" or "6 against 3". Game time was grouped into two periods, using previous research that found critical moments of the game when exclusions are sanctioned (Prieto, Gómez, et al., 2015; Trejo-Silva et al., 2020). Considering: Critical moments (game time 2,4,5) and Non-critical moments (game time 1,3,6). Critical moments for exclusions are defined as those moments of the game when exclusions tend to appear; previous studies (Prieto, Gómez, et al., 2015; Trejo-Silva et al., 2020) specified

that 2-minute suspensions are sanctioned in the above-mentioned moments. In fact, since T6 represents the last moment of the game, teams tend not to be sanctioned with exclusions so as can play full squad in those moments of the game. Match status was classified into three groups: (i) 2 goals (finalizations registered when the team registered was 1 or 2 goals ahead or behind, including a draw); (ii) 3-4 goals (finalizations registered when the team registered was 3 or 4 goals ahead or behind); and (iii) 5 or more goals (finalizations registered when the team registered was 5 or more goals ahead or behind). Finalizations were grouped into three groups: (i) Goal (finalizations registered as goal and goal-and-exclusion); (ii) Not goal (finalizations registered as throwing on the post, throwing out of the goal, blocked shots, GK save); and (iii) Turnover (all finalizations not involving throwing). Final ranking was pooled into 4 groups: (i) 1st to 4th (teams ranked 1 to 4); (ii) 5th to 8th (teams ranked 5 to 8); (iii) 9th to 12th (teams ranked 9 to 12); and (iv) 13th to 16th (teams ranked 13 to 16).

4.4.5 Statistical analysis

Firstly, frequency distribution of the variables was realized. Then a nominal regression test was performed, having “Types of asymmetry” as the dependent variable and the rest of the categories as the independent variables. The non-linear models produced an odds ratio (OR) and 95% confidence intervals (CI) for all independent variables. Finally, a correspondence analysis was run to strengthen the relationships established between the categorical variables. The analyses were performed setting the significance level at $p < 0.05$, with significance accepted as much as the 95% confidence interval of the OR.

Chapter 5. RESULTS



5 RESULTS

5.1 Study 1 – Offensive performance under numerical inequality during exclusions in female handball at the 2015 Panamerican Games

AIMS

Specific Aim 1

To describe the situations of numerical inequality due to exclusions during the Female Handball at PPGG 2015.

Specific Aim 2

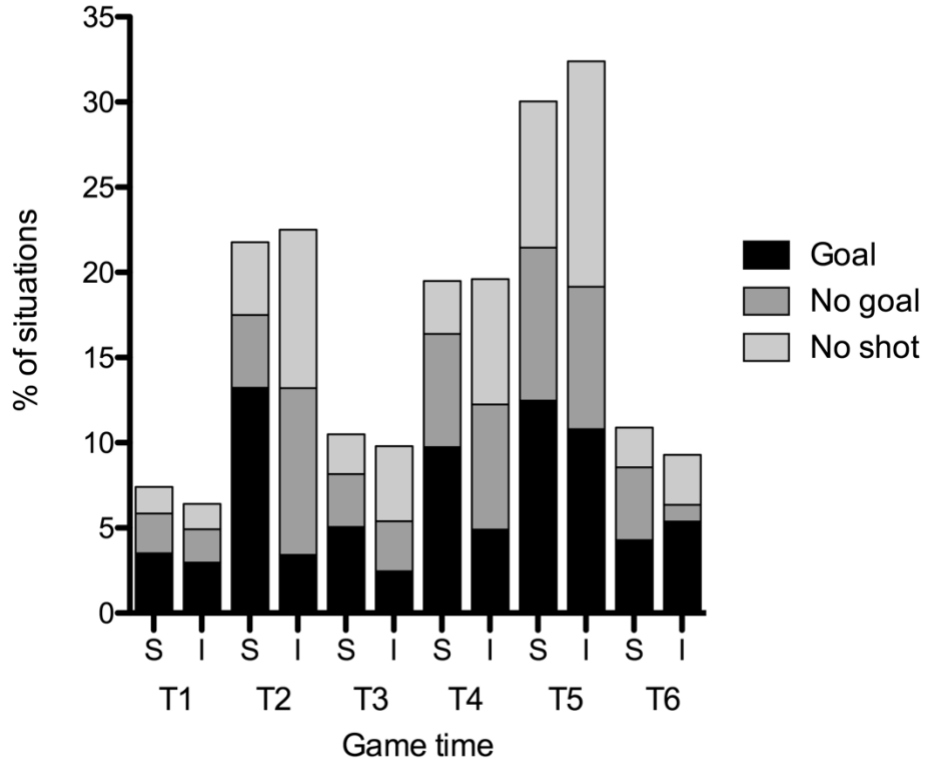
To analyse the efficacy during numerical inequalities at Female Handball at PPGG 2015 and relate it with game outcome.

During the 14 matches analysed, 107 exclusions occurred, which represents an average of 7,6 exclusions per match and then an average of around 15 minutes per match in situations during which numerical inequality actions appeared. A total of 461 situations of numerical inequality were analysed in the tournament (55.7% in superiority and 44.3 in inferiority). Ten of these situations finished with exclusion and the rest were registered as shot on target (divided in two categories: goal or no goal) and no shot. Figure 17 shows the distribution of the situations of numerical inequality divided by situations in superiority (which includes all actions of asymmetry registered as 6x5, 5x4 or 6x4) and inferiority (which includes all actions of asymmetry registered as 5x6, 4x5, 4x6 or PE) during the match and its consequences. The major number situations were concentrated during the second part of the match (60.7%); being the T5 the highest represented game time (31.0% in total). The majority of the situations of numerical inequality finished in shot and most of them in goal, with the highest percentage during the T5 as well. The statistical analysis did not show statistical differences between the number of situations in numerical inequality among the different game times. The analysis by numerical inequality showed that in T2 the

goals converted in superiority are more than those converted in inferiority even when the T2 actions represents similar percentages respect to the total actions during the match (21.8 and 22.5% respectively). During the lass part of the game (T6) the teams in inferiority converted more goals than those in superiority.

Figure 17.

Percentage of situations in numerical inequality by game time and its consequences



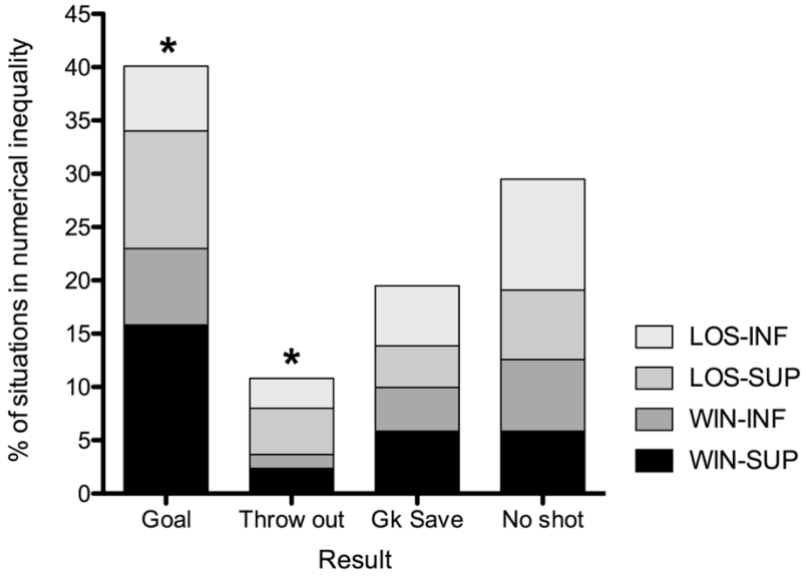
Note: T1 to T6: Game time splatted in 6 periods; S: Superiority; I: Inferiority.

The figure 18 shows the distribution of the situations related to the type of finalization according to the game outcome. Winner teams converted more goals (57.3% of the total of finalizations, which are 39.5% in superiority and 17.8% in inferiority) than the loser teams (42.7%) of the total of finalizations,

which are 27.6% in superiority and 15.1% in inferiority), showing a statistically significant difference ($p<0.05$, $V=0.16$). Also, winner teams had a statistically significant lower percentage of throws out (34.0%, which are 22.0% in superiority and 12.0% in inferiority) in comparison to loser teams (66.0%, which are 40.0% in superiority and 26.0% in inferiority) during the situations of numerical inequality. In the rest of the finalizations (goalkeeper saves or turnovers,) no statistically differences between winner and loser teams were observed, nevertheless the loser teams presented the lowest percentage of goalkeeper saves (48.9%) and winner teams the lowest percentage of turnovers (42.6%).

Figure 18.

Percentage of situations under numerical inequality divided by team and numerical inequality condition



Note: Gk Save: Goalkeeper save; WIN: Winner team; LOS: Loser team; SUP: Superiority; INF: Inferiority.

* Statistically significant differences between winner and loser teams ($p < 0,05$).

Regarding the efficacy during the situations of numerical inequality (Table 14), winner teams had a higher TE and a higher AE in comparison with loser teams in superiority (TE: 8.5%; AE: 10.9%) and

inferiority contexts (TE: 15.1%; AE: 13.1%). Winner teams presented a statistically significant AE ($p<0.05$) while playing in inferiority in comparison with loser teams (37.9 and 24.8%, respectively).

Table 14.

Efficacy in situations under numerical inequality

	Superiority		Inferiority	
	Winner	Loser	Winner	Loser
Throwing Efficacy (Min-Max)	65.8 (56.5-74.0)	57.3 (46.8-67.2)	56.9 (43.8-69.1)	41.8 (30.5-54.0)
Attack Efficacy (Min-Max)	54.5 (45.9-62.8)	43.6 (34.8-52.8)	37.9 (28.3-48.6)	24.8 (17.6-33.6) *

Note: Data are presented as CI 95 % and expressed in percentage (%); * Statistically significant differences respect to winner teams ($p < 0,05$).

5.2 Study 2 – Multivariate analysis of offensive performances during numerical asymmetries in female handball games at Rio 2016.

AIM

Specific Aim 3

To analyze the offensive performance during the different numerical asymmetry scenarios in exclusions at Rio 2016 female Olympic Games.

A total of 1.065 actions during the 328 exclusions sanctioned in 38 games were registered, resulting in an average of 8.6 ± 3.6 exclusions per game. Of those actions, 590 were registered under superiority context and 475 under inferiority context. Playing with EN represented 35.0% of the total actions registered during inferiority context and playing with GK at goal 65.0%. Table 15 presents the frequency distribution of offensive situations under numerical inequality situations as a consequence of

exclusions. Game outcome, finalization, consequence of the finalization, game phase and offensive system presented a statistically significant relationship with type of asymmetry. Winning teams presented a statistically significant relationship ($p<0.05$; ASR -2.0) with playing with EN during inferiority contexts. The AE, represented by the percentage of goals in the total of finalizations, was 58.0% during superiority showing a statistically significant relationship ($p<0.01$, ASR 8.2 and 2.1) in comparison with all finalizations. AE when playing EN was 37.5% and with GK at goal 30.3%. Turnovers (25.6% during EN and 26.7% during GK at goal) showed a statistically significant relationship ($p<0.01$, ASR 3.6 and 2.1) when played during inferiority situations. In addition, being sanctioned with a 7m throw for, and play 1st, 2nd and 3rd wave phases of attack were statistically significant related ($p<0.01$; ASR 8.1, 2.9 and 7.9) with the context of superiority. Positional attack presented a statistically significant relationship ($p<0.01$; ASR 7.1) with the context of inferiority. Using the 3:3 (with one pivot) offensive system appeared with a statistically significant relationship, specifically during the context of playing with EN under inferiority situations ($p<0.001$; ASR 8.0).

Table 15.

Frequency distribution of offensive situations under inequality during Rio 2016 Olympic Games

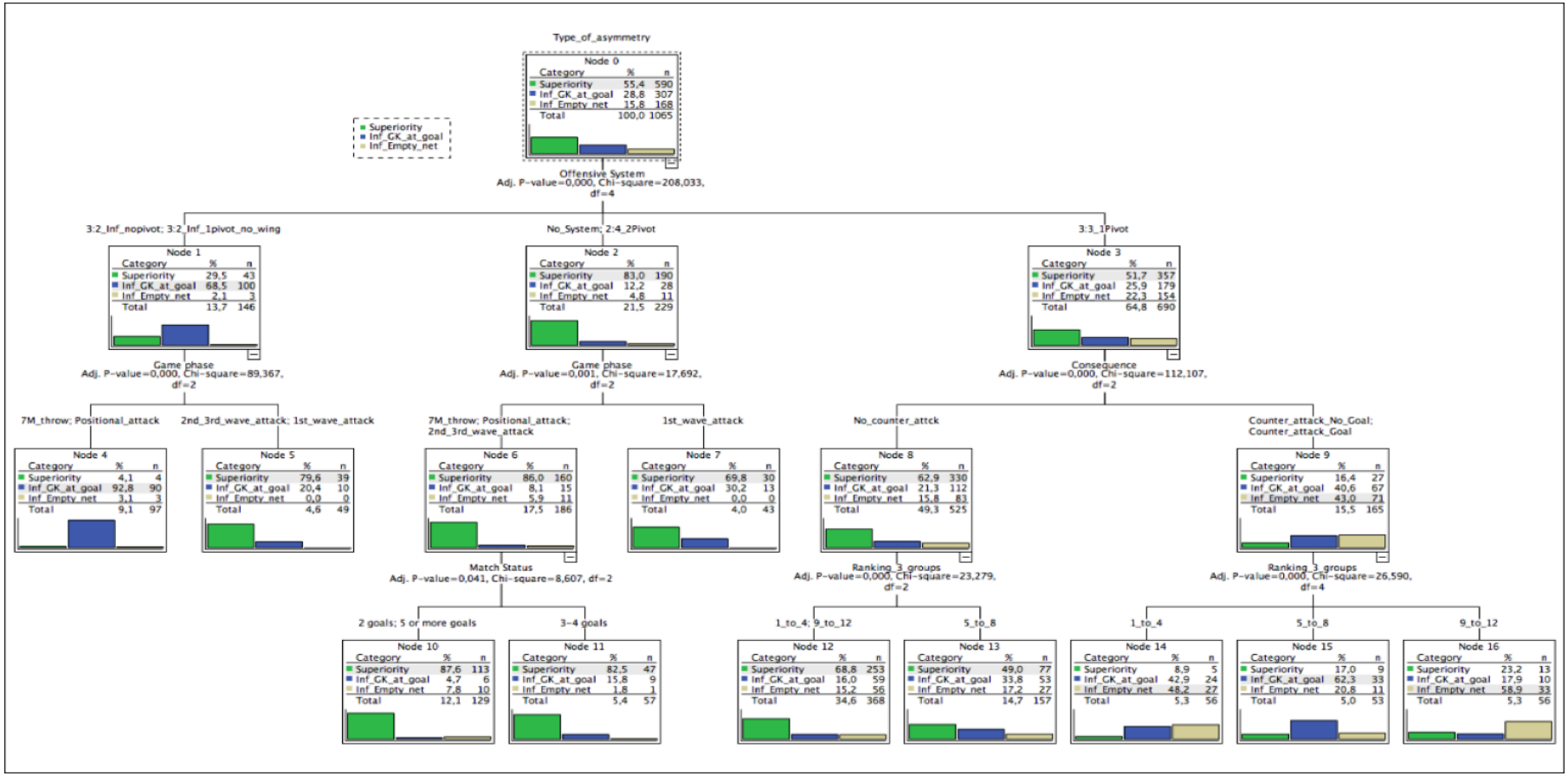
	Superiority *n* = 590		GK at goal *n* = 307		Empty net *n* = 168		χ^2	p	ES	ES p
	(%)	ASR	(%)	ASR	(%)	ASR				
Game outcome							17.250	<0.05	0.90	<0.05
Winner	48.6	*0.7*	49.8	*0.9*	40.5	*-2.0*				
Loser	47.8	*-0.6*	48.9	*0.1*	51.2	*0.7*				
Draw	3.6	*-0.2*	1.3	*-2.6*	8.3	*3.5*				
Finalization							70.634	<0.01	0.18	<0.01
Goal	58.0	*8.2*	30.3	*-6.9*	37.5	*-2.6*				
No goal	27.6	*-4.5*	43.0	*4.2*	36.9	*1.0*				
Turnover	14.4	*-4.9*	26.7	*3.6*	25.6	*2.1*				
Consequence										
No counter attack	94.4	*13.8*	61.9	*-8.6*	55.4	*-8.1*	197.474	<0.01	0.35	<0.01
Counter attack no goal	3.2	*-9.2*	21.2	*6.6*	20.8	*4.3*				
Counter attack goal	2.4	*-9.2*	6.9	*4.8*	23.8	*6.5*				
Game phase							161.039	<0.001	0.28	<0.001
Positional Attack	56.1	*-12.1*	87.6	*7.5*	94.0	*7.1*				
1st wave	8.6	*2.9*	6.5	*-0.1*	0	*-3.8*				
2nd and 3rd wave	14.2	*7.1*	2.6	*-4.5*	0.6	*-4.1*				
7 meter	21.0	*8.1*	3.3	*-6.2*	5.4	*-3.3*				
Offensive system							357.739	<0.001	0.58	<0.001
3:3_1_Pivot	61.4	*-3.1*	58.3	*-3.1*	92.3	*8.0*				
2:4_2 Pivots	5.1	*5.0*	0	*-3.5*	0	*-2.4*				
3:2_No Pivots	0	*-11.2*	29.3	*15.3*	1.2	*-3.7*				
No system	33.6	*9.8*	9.8	*-6.3*	6.0	*-5.6*				
3:2,1 Pivot.No wing	0.0	*-3.4*	2.6	*5.0*	0	*-1.0*				
Final ranking										
1st to 4th	94.4	*1.8*	61.9	*-2.0*	55.4	*0.1*	28.600	<0.01	0.12	<0.01
5th to 8th	3.2	*-3.4*	21.2	*5.2*	20.8	*-1.8*				
9th to 12th	2.4	*1.5*	6.9	*-3.0*	23.8	*1.7*				
Match status							0.657	>0.05	0.02	>0.05
2 goals	46.8		48.9		48.8					
3-4 goals	28.0		28.0		27.4					
5 or more goals	25.3		23.1		23.8					
Game time grouped							0.453	>0.05	0.02	>0.05
Periods 2,4,5	75.9		77.5		75.0					
Periods 1,3,6	24.1		22.5		25.0					

Note: Data presented as absolute frequencies (percentage). ES: Effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); ASR: Adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p<0.05$).

Figure 19 shows the decision tree model results (exhaustive CHAID) predicting the offensive performance during exclusions according to the type of asymmetry. The model presented an estimation of 94.7% for Superiority, 40.1% for Inferiority with GK at goal and 35.7% for Inferiority with EN (69.7% of the variance; estimated risk 0.30; SD 0.14). Specifically, the Node 6 predicted that the transition phases (2nd and 3rd waves) and positional attacks are the main phases that predominate during superiority contexts ($p<0.001$; $x^2=17.692$) followed by the 1st wave (Nodes 5 and 7). In addition, Node 2 predicted teams using a 2:4 offensive system and the use of *No system* while Node 3 predicted the use of the 3:3 classic formation within the context of superiority ($p<0.001$; $x^2=208.033$). Moreover, Node 4 predicted that the positional attack was the phase used the most when playing with GK at goal ($p<0.001$; $x^2=89.367$). Moreover, node 1 predicted that the offensive system with 3 back players (3:2 without pivot and 3:2 with one of the wings moving to pivot position) is the preferred formation when leaving the GK at goal during inferiority context ($p<0.001$; $x^2=208.033$). However, in the same numerical asymmetry context of inferiority, node 16 predicted that teams ranked 9 to 12 tends to play with EN ($p<0.001$; $x^2=26.590$) but receiving as a consequence of their finalizations a counter attack (node 9; $p<0.001$; $x^2=112.107$). Lastly, Nodes 14 and 16 predicted a similar use of the EN strategy for those teams playing for winning a medal than those placed at the bottom of the ranking ladder. Node 10 and 11 ($p<0.05$; $x^2=8.607$) showed that during superiority context, using 2:4 formation (when being in positional attack) and no-system (transitions) was influenced in the same way by match status.

Figure 19.

Exhaustive CHAID decision predicting the offensive performance during numerical asymmetry as a consequence of exclusions according to types of asymmetries at Rio 2016 Olympic Games



5.3 Study 3 – Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball at the 2017 Panamerican Championship.

AIMS

Specific Aim 4

To determine teams´ offensive performance indicators during exclusions related to the final ranking obtained at the Panamerican Championship 2017.

Results during Numerical Inequality Context as a Consequence of Exclusions

During the 29 games of the tournament, 211 exclusions were sanctioned (an average of 7.3 exclusions per game), and a total of 812 actions were registered. Table 16 presents the frequency distribution of offensive situations under numerical inequality situations. A statistically significant relationship ($p < 0.01$) was found between final classification and type of asymmetry (superiority and inferiority), game outcome, finalization, match status, phase of the game, and offensive system. GI and GII teams presented a statistically significant relationship ($p < 0.01$; ASR 5.0 and 2.6) when playing in superiority and GIII when playing in inferiority ($p < 0.01$; ASR 7.1). A statically significant relationship ($p < 0.01$, ASR 3.0) was found between GIII teams and ending attacks in turnovers. GI teams tended to use 1st, 2nd, and 3rd wave counterattacks when playing transitions ($p < 0.01$; ASR 3.5 and 2. 2).

Table 16.

Frequency distribution of offensive situations under inequality during Panamerican Championship 2017

	1st–3rd ***n*** **= 236**	**4th–6th** ***n*** **= 270**	**7th–10th** ***n*** **= 306**	**s.t.**	***p***	**ES**	**ESp**
Asymmetry				53.561	<0.001	0.26	<0.001
Superiority	163(69.1)	167(61.9)	121(39.5)				
ASR	5.0	2.6	−7.1				
Inferiority	73 (30.9)	103(38.1)	185(60.5)				
ASR	−5.0	−2.6	7.1				
Game outcome				202.504	<0.001	0.50	<0.001
Winner	204(86.4)	136(50.4)	76 (24.8)				
ASR	12.8	−0.3	−11.7				
Loser	32 (13.6)	134(49.6)	230(75.2)				
ASR	−12.8	0.3	11.7				
Finalization				36.038	<0.001	0.21(14)	<0.001
Goal	134(56.8)	113(41.9)	99 (32.4)				
ASR	5.2	−0.3	−4.6				
No goal	65 (27.5)	81 (30.0)	110(35.9)				
ASR	−1.6	−0.7	2.1				
Turnover	37 (15.7)	76 (28.1)	97 (31.7)				
ASR	−4.2	1.1	3.0				
Match status				36.392	<0.001	0.15	<0.001
2 goals	73 (30.9)	108(40.0)	62 (20.3)				
ASR	0.4	4.4	−4.7				
3–4 goals	25 (10.6)	43 (15.9)	36 (11.8)				
ASR	−1.2	1.9	−0.7				
5 or more goals	138(58.5)	119(44.1)	208(68.0)				
ASR	0.4	−5.4	4.8				
Game phase				36.591	<0.001	0.15	<0.001
Positional Attack	141(60.0)	185(68.5)	249(81.4)				
ASR	−4.4	−1.1	5.1				
1st wave	36 (15.3)	21 (7.8)	21 (6.9)				
ASR	3.5	−1.3	−2.1				
2nd and 3rd wave	28 (11.9)	25 (9.3)	16 (5.2)				
ASR	2.2	0.5	−2.6				
7 m	30 (12.8)	39 (14.4)	20 (6.5)				
ASR	1.0	2.2	−3.1				
Offensive system				38.057	<0.001	0.15	<0.001
3:3 1_Pivot	141(59.7)	139 (51.5)	171 (56.1)				
ASR	1.5	−1.7	0.2				
3:3 2 Pivots	3 (1.3)	13 (4.8)	11 (3.6)				
ASR	−2.1	1.7	0.3				
3:2 No Pivots	52 (22.0)	63 (23.3)	93 (30.5)				
ASR	−1.5	−1.1	2.5				
No system	39 (16.5)	41 (15.2)	19 (6.2)				
ASR	2.4	1.8	−4.0				
1 Pivot no wing	1 (0.4)	14 (5.2)	11 (3.6)				
ASR	−2.9	2.3	0.5				
Game time grouped				9.516	0.095	0.11	0.095
Periods 2,4,5	152 (64.4)	207 (76.7)	210 (70.1)				
Periods 1,3,6	84 (35.6)	63 (23.3)	96 (29.9)				

Note: Data presented as absolute frequencies (percentage). n: absolute frequencies of actions registered for each ranking group; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact Test as applicable; *p*: *p*-value; ES: effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); ESp: *p*-value for Cramer's V; ASR: adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

Results during Superiority Situations

Table 17 presents frequency distribution during superiority situations. A statistically significant relationship was found between final classification and game outcome, finalization, match status, game time grouped ($p < 0.01$), and game phase ($p < 0.05$). National teams of GI tended not to end in turnovers ($p < 0.01$; ASR −2.8). AE decreased from GI to GIII (63.2%, 49.1%, and 41.3%), while turnovers increased from GI to GIII. GI teams tended to use direct counterattacks ($p < 0.01$; ASR 2.2), while GIII teams showed a tendency to use positional attacks ($p < 0.01$; ASR 3.4). GI national teams presented a statically significant relationship of using power plays in non-critical moments of the game ($p < 0.01$; ASR 2.6).

Table 17.

Frequency distribution of offensive situations under superiority during Panamerican Championship 2017

	1st–3rd ***n*** **= 163**	**4th–6th** ***n*** **= 167**	**7th–10th** ***n*** **= 121**	**s.t.**	***p***	**ES**	**ESp**
Game outcome				68.234	<0.001	0.39	<0.001
Winner	139(85.3)	98(58.7)	46(38.0)				
ASR	7.4	−1.4	−6.6				
Loser	24 (14.7)	69(41.3)	75(62.0)				
ASR	−7.4	1.4	6.6				
Finalization				15.496	<0.005	0.13	<0.01
Goal	103(63.2)	82(49.1)	50(41.3)				
ASR	3.5	−1.0	−2.8				
No goal	39 (23.9)	47(28.1)	41(33.9)				
ASR	−1.5	0.0	1.6				
Turnover	21 (12.9)	38(22.8)	30(24.8)				
ASR	−2.8	1.2	1.6				
Match Status				20.578	<0.001	0.15	<0.001
2 goals	50 (30.7)	66(39.5)	24(19.8)				
ASR	−0.1	3.0	−3.1				
3–4 goals	15 (9.2)	29(17.4)	17(14.0)				
ASR	−2.0	1.8	0.2				
5 or more goals	98 (60.1)	72(43.1)	80(66.1)				
ASR	1.5	−4.0	2.8				
Game phase				15.060	<0.05	0.13	<0.05
Positional Attack	79 (48.8)	87(52.1)	83(68.6)				
ASR	−2.1	−1.1	3.4				
1st wave	27 (16.7)	18(10.8)	10 (8.3)				
ASR	2.2	−0.7	−1.6				
2nd and 3rd wave	26 (16.0)	25(15.0)	11 (9.1)				
ASR	1.0	0.6	−1.7				
7 m	30 (18.5)	37(22.2)	17(14.0)				
ASR	−0.1	1.5	−1.5				
Time period grouped				6.763	<0.05	0.12	<0.05
Periods 2,4,5	104(63.8)	126(75.4)	91(75.2)				
ASR	−2.6	1.5	1.1				
Periods 1,3,6	59 (36.2)	41 (24.6)	30(24.8)				
ASR	2.6	−1.5	−1.1				
Offensive system				11.619	0.081	0.11	0.081
1_Pivot	96 (58.9)	88(52.7)	75(62.0)				
3:3_2 Pivots	3 (1.8)	9 (5.4)	10 (8.3)				
3:2 No Pivots	29 (17.8)	31(18.6)	20(16.5)				
No system	35 (21.5)	39(23.4)	16(13.2)				
1Pivot_No wing	0 (0)	0 (0)	0 (0)				

Note: data presented as: n : absolute frequencies of actions registered for each ranking group; absolute frequencies (percentage); n:; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact

Test as applicable; ES: Effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); Esp: *p*-value for Cramer's V; ASR: Adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

Results during Inferiority Situations

Frequency distribution during numerical inferiority context can be seen in Table 18. A statistically significant relationship ($p < 0.01$) was found between final classification and game outcome, offensive system, and inferiority disposition; with match status and game time grouped ($p < 0.05$). Teams grouped in GIII showed a statistically significant relationship with suffering exclusions when the difference in the score was of 5 or more goals ($p < 0.01$; ASR 3.8) and teams of GII showed a statistically significant relationship with suffering exclusions when the difference in the score was of 2 or fewer goals ($p < 0.01$; ASR 2.6; ASR 3.3), presenting a tendency of using a 3:2 offensive system with 1 pivot ($p < 0.01$; ASR 3.0). GI presented better AE and TE than the other two groups. When analyzing the strategic use of the new rule, a statistically significant relationship ($p < 0.01$) was found between final classification and playing or not with an empty goal ($p < 0.001$; ES 0.41). In total, 84.2% of the attacks were played with the goalkeeper on the court and 15.8% with an empty net. GI teams decided to change the goalkeeper for a court player most often ($p < 0.01$; ASR 7.7). In this respect, it is important to mention that only the teams ranked 1st and 2nd (Brazil and Argentina) opted to play with an empty net.

Table 18.

Frequency distribution of offensive situations under inferiority during Panamerican Championship 2017

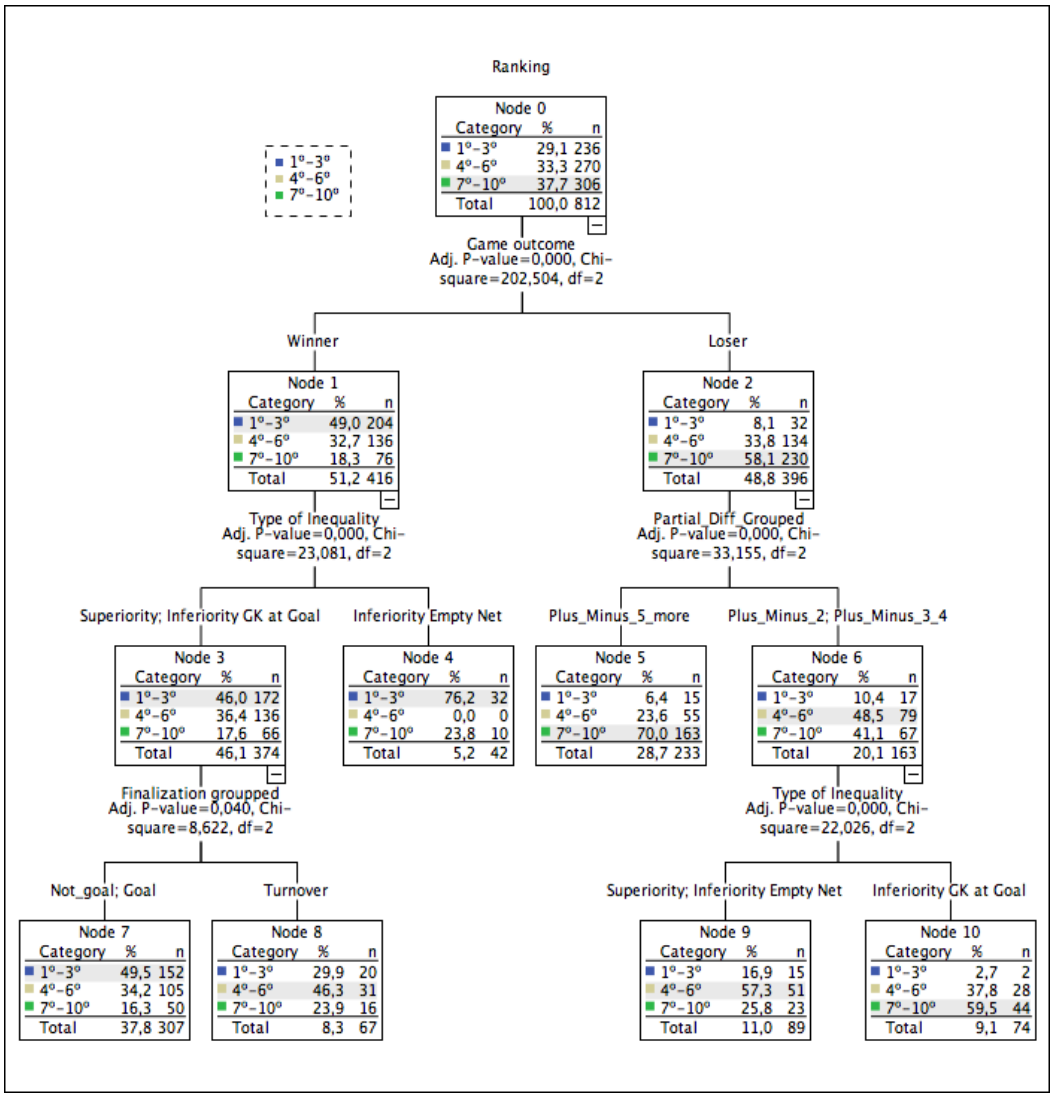
	1st–3rd ***n*** **= 73**	**4th–6th** ***n*** **= 103**	**7th–10th** ***n*** **= 185**	**s.t.**	**ES**	***p***	**ESp**
Game outcome				119.306	0.55	<0.001	<0.001
Winner	65 (89.0)	38 (36.9)	30 (16.2)				
ASR	10.4	0.0	−8.3				
Loser	8 (11.0)	65 (63.1)	155 (83.8)				
ASR	−10.4	0.0	8.3				
Offensive system				20.098	0.18	<0.01	<0.01
3:3 1_Pivot	45 (61.6)	51 (49.5)	96 (52.2)				
ASR	1.6	−0.9	−0.5				
3:3 2 Pivots	0 (0.0)	4 (3.9)	1 (0.5)				
ASR	−1.1	2.6	−1.4				
3:2 No Pivots	23 (31.5)	32 (31.1)	73 (39.7)				
ASR	−0.8	−1.1	1.7				
No system	4 (5.5)	2 (1.9)	3 (1.6)				
ASR	1.8	−0.4	−1.1				
1 Pivot No wing	1 (1.4)	14 (13.6)	11 (6.0)				
ASR	−2.2	3.0	−0.9				
Partial difference				17.152	0.15	<0.05	<0.05
2 goals	23 (31.5)	42 (40.8)	38 (20.5)				
ASR	0.6	3.3	−3.4				
3–4 goals	10 (13.7)	14 (13.6)	19 (10.3)				
ASR	0.5	0.6	−1.0				
5 or more goals	40 (54.8)	47 (45.6)	128 (69.2)				
ASR	−0.9	−3.4	3.8				
Game time grouped				6.675	0.14	<0.05	<0.05
Periods 2, 4, 5	48 (65.8)	81 (78.6)	119 (64.3)				
ASR	−0.6	2.6	−1.8				
Periods 1, 3, 6	25 (34.2)	22 (21.4)	66 (35.7)				
ASR	0.6	−2.6	1.8				
Inf. disposition				60.307	0.41	<0.001	<0.001
With goalkeeper	40 (54.8)	97 (94.2)	167 (90.3)				
ASR	−7.7	3.3	3.2				
Empty net	33 (45.2)	6 (5.8)	18 (9.7)				
ASR	7.7	−3.3	−3.2				
Finalization				8.390	0.11	0.078	0.078
Goal	31 (42.5)	31 (30.1)	49 (26.5)				
No goal	26 (35.6)	34 (33.0)	69 (37.3)				
Turnover	16 (21.9)	38 (36.9)	67 (36.2)				
Game phase				10.042	0.12	0.084	0.084
Positional Attack	62 (84.9)	98 (95.1)	166 (89.7)				
Direct counterattack	9 (12.3)	3 (2.9)	11 (5.9)				
2nd and 3rd wave	2 (2.7)	0 (0.0)	5 (2.7)				
7 m	0 (0.0)	2 (1.9)	3 (1.6)				

Note: Data presented as n: absolute frequencies of actions registered for each ranking group; absolute frequencies (percentage).; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact Test as applicable; ES: Effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); Esp: *p*-value for Cramer's V; ASR: adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

Figure 20 presents a decision tree using the exhaustive CHAID algorithm to predict offensive performance during exclusions related to the final ranking. The dependent variable was Ranking (GI, GII, and GIII). Independent variables were game outcome, critical periods of the game, offensive system, asymmetries grouped, partial difference in the score, phase of the game, and finalizations. The model obtained explained 58.3% of the variance (estimated risk of 0.42; SD 0.02), estimating 78.0% for GI, 67.6% for GIII, and 30.4% for GII. Node 1 predicts winners belonging to GI at 49.0%, while Node 2 predicts losers belonging to GIII at 58.1%. Node 4 shows that playing with an empty net during inferiority situations predicts winners belonging to GI. Node 5 shows that playing under numerical inequality (superiority or inferiority) when the difference in the score is of more than 5 goals predicts being ranked in GIII. In contrast, node 9 shows that in a context of 4 goals (for or against), playing at inferiority with an empty net, and having superiority situations (that is to say that rivals suffered exclusions), is a predictor of belonging to GII. Node 10 notes that in the context of a difference in the score, playing in inferiority situations with the goalkeeper in goal is a predictor of losers belonging to GIII.

Figure 20.

Decision tree using the exhaustive CHAID algorithm to predict the offensive performance during exclusions according to the final ranking at Panamerican Championship 2017



5.4 Study 4 - Analysis of offensive performance during exclusions in female handball Euro 2018.

AIM

Specific Aim 5

To analyze offensive performance during exclusions at female Euro 2018 concerning the different numerical inequality contexts.

Across 47 matches, 319 2-minute suspensions occurred (6.8 ± 2.9 exclusions per match; 7.6 ± 2.4 in group stage, 6.0 ± 3.1 in main and knockout round). A total of 1138 finalizations were recorded (56% in superiority and 44% in inferiority). Playing EN accounted for 61.7% of all actions during inferiority. Table 19 shows the frequency distribution (expressed in relative frequency within type of asymmetry) of variables in each of the three-asymmetrical context.

Table 19.

Frequency distribution of the variables among type of asymmetry (Superiority, Inferiority with GK at goal and Inferiority with EN) at Euro 2018

		Type of asymmetry		
		Superiority	Inferiority with GK at goal	Inferiority with EN
Game time	Critical moments	72.4%	66.7%	76.4%
	Non-critical moments	27.6%	33.3%	23.6%
Match Status	Difference of 2 or less	45.1%	41.7%	45.3%
	Difference of 4 or 4	23.1%	21.9%	20.7%
	Difference of 5 or more	31.9%	36.5%	34.0%
Game phase	Positional attack	61.4%	74.5%	96.1%
	1st wave	10.2%	9.9%	0%
	2nd and 3rd wave	10.2%	2.1%	0%
	Penalty throw	18.2%	13.5%	3.9%
Offensive System	1 pivot	54.0%	16.1%	86.1%
	2 pivots	13.7%	1.0%	6.1%
	No pivot	1.7%	23.4%	1.0%
	No system	30.6%	24.5%	3.9%
	1 pivot no wing	0%	34.9%	2.9%
Type of finalization	Goal	58.4%	44.3%	39.8%
	Shot Not Goal	25.7%	38.0%	36.2%
	Turnover	15.9%	17.7%	23.9%
Consequence	No counterattack	95.1%	76.0%	56.0%
	Counterattack goal	2.8%	14.6%	25.6%
	Counterattack no goal	2.0%	9.4%	18.4%
Game outcome	Draw	1.1%	1.6%	0.6%
	Winner	47.9%	54.7%	47.6%
	Loser	51.0%	43.8%	51.8%
Ranking	Ranked 1 to 4	25.0%	40.1%	11.0%
	Ranked 5 to 8	27.5%	9.9%	36.9%
	Ranked 9 to 12	27.3%	21.9%	29.1%
	Ranked 13 to 16	20.3%	28.1%	23.0%

Note: GK: Goalkeeper; EN: Empty Net

Table 20 presents the adjusted model of the multinominal regression only with the variables that showed a statistical significant relationship ($p<0.05$; $p<0.01$ or $p<0.001$) with the numerical inequality context. It can be highlighted that throwing but not scoring increased it chance to appear when compared superiority with both numerical inferiority contexts ($p<0.001$; OR 2.80 for EN and $p<0.05$; OR 2.38 for GK at goal). However, chance of throwing and scoring a goal increased when compared superiority to playing with EN ($p<0.05$; OR 1.94). The possibility of winning the match increased ($p<0.05$; OR 1.673) when compared finalizations registered during superiority context with GK at goal. Moreover, teams were more prone to receive counterattacks as a consequence of finalizations when playing EN in comparison with superiority ($p<0.01$; OR 0.06). Playing with a 3:3 (1 pivot) or 2:4 ($p<0.001$; OR 0.02) decreased when comparing playing with GK at goal and EN, during inferiority context. Moreover, winning ($p<0.05$; OR 1.73) and not receiving a counterattack after the attacking sequence finished ($p<0.05$; OR 2.77) increased their possibilities of occurring when comparing EN with GK at goal.

Table 20.

Multinominal Regression Model adjusted with significant variables for offensive performance during exclusions at Euro 2018

	p	OR	95% CI	
			Lower Bound	Upper Bound
EN vs Superiority				
Game time				
Critical Moments	.037*	1.48	1.00	2.2
Finalization				
Goal	.016*	1.94	1.14	3.30
Shot not goal	<.001**	2.80	1.62	4.80
Consequence of finalization				
No counter attack	<.001**	.06	.03	.12
Team ranking				
Ranked 1 to 4	<.001**	.36	.20	.64
Gk at goal vs Superiority				
Game Phase				
Positional Attack	.031*	14.64	1.28	168.26
Finalization				
Shot not goal	.035*	2.38	1.06	3.54
Consequence of finalization				
No counter attack	.002**	.15	.048	.49
Game Outcome				
Winner	.047*	1.66	1.00	2.73
Team ranking				
Ranked 5 to 8	.008**	.37	.18	.76
Ranked 9 to 12	.005**	.39	.20	.75
Gk at goal vs EN				
Offensive system				
3:3	<.001**	.02	.01	.03
2:4	<.001**	.02	.01	.08
Consequence of finalization				
No counter attack	.049*	2.77	1.01	7.61
Game Outcome				
Winner	.048*	1.73	1.02	3.01
Team ranking				
Ranked 5 to 8	.002**	.29	.14	.63

Note: * indicates a significant relationship with p<0.05; **indicates a significant relationship with p<0.01; EN: Inferiority played with the empty net; GK: Inferiority played with goalkeeper; OR: Odd Ratio. CI: Confidence Interval. Baseline categories set a value of 1. The reference categories were Game minute= Non-critical moment; Game phase=7m; Offensive system= 3:2 (1 pivot. No wing); Finalization = turnover; Consequence of finalization= counter attack goal; Match outcome= loser; Team Ranking= ranked 13 to 16.

The following figures (21 and 22) show the results of the analysis of correspondence´s results between the type of asymmetry and game phase, offensive system, type of finalization, the consequence of the finalization and the final ranking. Figure 21 presents results of the contextual variables game phase (left side) and offensive system (right side). A significant relationship ($\chi 2 = 139.099$, $p<0.001$) was found between the type of asymmetry and game phase, two dimensions were set with the following values of inertia: dimension 1: 11.6% and dimension 2: 0.7%. Fast transitions (1st, 2nd and 3rd wave) and penalty throws were associated with the context of superiority, whereas positional attack was associated with inferiority types of asymmetry (EN and GK at goal). The offensive system presented a statically significant relationship ($\chi 2 = 627.705$, $p<0.001$), established with the following values of inertia: dimension 1: 44.7% and dimension 2: 10.4%. Playing with no system or with 2 pivots, was associated with the context of superiority, whereas during the inferiority context playing with a 3:3 (1pivot) system was associated with playing EN and the team tactic of playing 3:2 was associated with playing GK at goal.

Figure 21.

Correspondence analysis between type of asymmetry, game phase and offensive system at Euro 2018

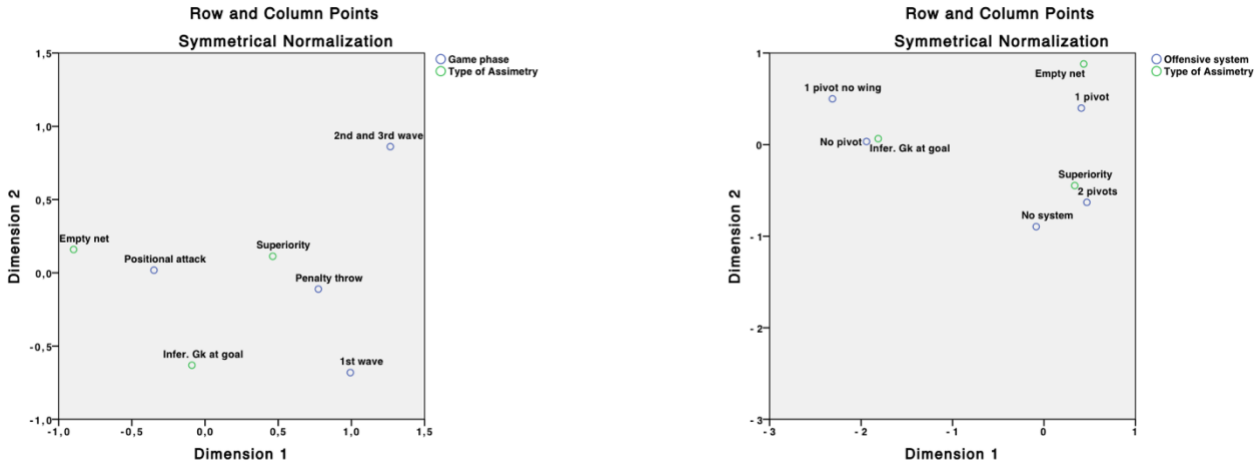
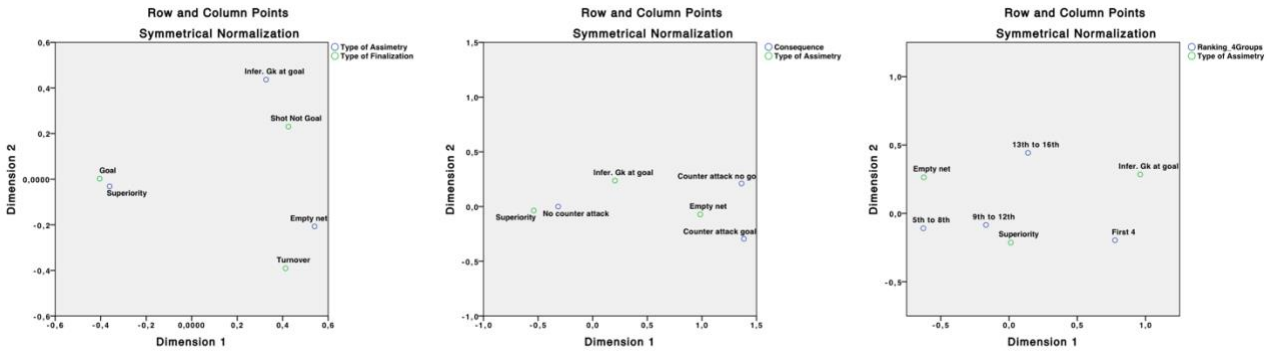


Figure 22 presents results of the finalizations (left side), consequence of the finalizations (middle) and the final ranking of teams (grouped as stated in section 4.4.4) on the right side. There was a significant relationship with the type of finalization ($\chi 2 = 35.171$, $p<0.001$), presenting two set dimensions with the following values of inertia: dimension 1: 2.9% and dimension 2: 0.2%. Teams at Euro 2018 tended to score during superiority context, to finalize their possessions with a throwing (but not score) during an inferiority context with GK at goal, and to finalize in turnovers when playing EN during an inferiority context. Results of the consequence of the finalization ($\chi 2 = 213.916$, $p<0.001$; values of inertia: dimension 1: 18.8% and dimension 2: 0%) found a homogeneous profile in not having a counterattack as a consequence of the finalizations during superiority, and receiving a counterattack (ending or not in goal) when playing with EN during the inferiority context. Final ranking presented a statistically significant relationship ($\chi 2 = 81.771$, $p<0.001$; values of inertia: dimension 1: 6.8% and dimension 2: 0.3%). Heterogeneous profiles emerged for the four ranking groups and types of asymmetry, but highlighting the relationship of both inferiority contexts and the teams placed in the last four places.

Figure 22.

Correspondence analysis between type of asymmetry, finalization, consequence of the finalization and final ranking at Euro 2018



Chapter 6. DISCUSSION

6 DISCUSSION

The aims of the present study were to analyze the offensive performance at elite female handball during situations of players inequality due to exclusions and to study the impact of the 2016 change of the Rules of the Game on the offensive performance during exclusions.

Results from the four studies showed that around 25 % of the game time in elite female handball is played under numerical inequality as a consequence of 2-minute suspensions regardless the level of tournament analyzed, which are similar with previous studies at male Spanish league (Gutierrez et al., 2010), major tournaments at world and European level during 1982-2014 (Pueo & Espina-Agullo, 2017) and male OG from 2004 to 2016 (Saavedra et al., 2017). However, exclusions in female games are less sanctions than in male games. Reason of that could be that hostile aggression is more frequent in male than in female competitions (Coulomb-Cabagno & Rascle, 2006) and influence of gender stereotypes (Souchon et al., 2010). Moreover, exclusions are sanctioned during game time that can be called as *critical moments for exclusions*. In line with previous studies (Prieto, Gómez, et al., 2015), sanctions occurred between minute 10:00 to 26:00 and mostly during second half (minute 30:00 to 54:59).

Superiority context situations prevailed over inferiority context during the attack phase. The main reason for this seemed to be on regulatory basis. Rules of the Game (IHF, 2018) estipulate that in the event of a 2-minute suspension or disqualification, the referee must call a time-out and the opposing team that receives the sanction may continue playing with a free throw. Meaning that the team which restarts the game (the team that profited from opponent´s dismissal) registered the first action of the numerical asymmetric period. Top ranked teams registered most of the situations, therefore lower ranked teams are sanctioned the most, coinciding with previous studies in male and female elite tournaments (Saavedra, Kristjansdottir, et al., 2018; Vinhas de Paula et al., 2020). Winners scored more than losers during this context, probably as a consequence of having played fast transitions which positioned players in a better position against GK, which increased TE (Amatria et al., 2020).

During inferiority context in the attack phase, offensive performance was negatively affected in comparison with superiority context. PI showed teams playing less effective (lower AE and TE). Despite having used a *less risky team tactic* (positional attack prevailed over fast transitions with almost 90% of the situations registered) AE was near 40 %. Indeed, in the Pan-American context, difference among winners and losers´ AE was statistically significantly related. Reason of such a *low performance* could be the mishandling of the ball, causing turnovers to be increased, in coincidence with previous studies at female WChs (Vinhas de Paula et al., 2020). Moreover, players skills and abilities might have affected ball handling (Ziv & Lidor, 2009).

Referring to the impact of the change of the rules implemented in August 2016 which allows changing the GK for an in-court player (without the obligation of using same shirt´s color as GK) playing with EN, results showed an increased tendency of choosing this strategy (from no use at all at PPGG 2015 till 61.7 % at Euro 2018). This trend reflects coaches' opinion who declared to play EN with the intention of balancing the numerical inequalities caused during exclusions (Krahenbühl, Menezes, et al., 2019). Moreover, the fact that most of the records of EN corresponded to low ranked teams is sustained in studies that explain the intention of trailing underdogs teams to overcome the difference in abilities (Neuberg & Thiem, 2022; Skinner & Goldman, 2016).

6.1 Study 1 – Offensive performance under numerical inequality during exclusions at female handball at the 2015 Panamerican Games.

When analysing the performance of teams at PPGG 2015, the following aims were addressed:

Specific Aim 1

To describe the situations of numerical inequality due to exclusions during the Female Handball at PPGG 2015.

Specific Aim 2

To analyse the efficacy during numerical inequalities at Female Handball at PPGG 2015 and relate it with game outcome.

The outcomes of the study show that these numerical inequality situations are principally located during the second part of the matches. Besides winner teams convert significantly more goals and show a lower percentage of throws out during these inequality situations.

In the PPGG 2015 approximately a quarter of the total playing time was played in an unequal numerical situation. This result is in line with previous studies made in Spanish handball league where 20% of game time teams played under numerical inequality situations (Gutierrez et al., 2010) and during the period 1982-2014 in European, World and Olympic finals matches where exclusions lasted 30% of the total game time (Pueo & Espina-Agullo, 2017). The last five minutes of the second half (T6) presented a low number of situations under numerical inequality, meaning low number of exclusions as well. Most of the exclusions were concentrated during the second part of the match, especially in the range from 40:00 to 54.59 minutes. This is consistent with previous studies in other TS (Bar-eli et al., 1990; Bar-Eli & Tractinsky, 2000; García-Martín et al., 2015), where the second part of the match was the most crucial. Sampaio, Lorenzo, et al. (2006) found that those moments appeared in the second half of a basketball match. These results agree with studies made in handball where the number of exclusions increased in the second half of a match (Prieto, Gómez, et al., 2015; Pueo & Espina-Agullo, 2017). Application of rules (IHF, 2010) as well as psychological player´s crisis could explain these findings (Bar-Eli & Tractinsky, 2000). The scale of sanctions may cause on players´ behaviour an increase of the expected and fair actions (Bar-eli et al., 1990). Thus, the players could tend to behave in a way that allow them to stay in court in order to maintain the equality in the number of players (Bar-eli et al., 1990).

Previous studies in another TS, some of them including handball, reported that the goals scored in the first half had higher impact on the final score goal difference (Gómez-Ruano et al., 2014; Lago-Peñas et al., 2013; Prieto, Gómez, & Sampaio, 2016) however in the present study it was found out that the last period of a handball match could be the most productive in terms of goals, going in line with previous research in handball (Oliveira et al., 2012) were winners were more efficient in the last minutes of each half.

Results showed that winners scored more goals than losers while being in superiority. This coincides with previous research in other TS where winners' performance indicators are better than losers. In water polo winners shot more time than losers when playing power play (Escalante et al., 2011); goals achieved by winner teams in water polo were considerably more as compared to the ones scored by loser team (Platanou, 2004) and a statistic significant difference between winners and losers was found in all the coefficient of performance in teams with an extra man (Argudo et al., 2010). In ice hockey, winners have better performance than losers while being in power play (5vs4 and 5vs3) even pulling the goalie out (Beaudoin & Swartz, 2010). Gutierrez et al. (2010) in their study of European and World Handball Championship between 2002 and 2004 found out that during inferiority situations losers present worst performance than winners. In handball, since the aim of the game for a team is to score more goals than the opponent, winners end scoring more than losers. It is then important to find out when, how and why winners score the most. Results of the study at PPGG 2015 showed that winners scored more than losers during the periods of games that exclusions are sanctioned by referees. Therefore, winners are more effective than losers during those periods of the game, especially during superiority situations. They have the capacity to take more advantage of these situations in comparison to losers. This coincides with performances of teams at the Male OG 2008-2012 where winners perform better than losers while being in superiority (Pueo & Espina-Agullo, 2017). The characteristics of the players (Wagner et al., 2014); the improvement in shot efficacy and efficiency (Aguilar-Martínez et al., 2012; Wagner & Müller, 2008); the

handle of the game time (Gomes et al., 2014) and the tactical intention of throwing from the 6-meter line (Sierra-Guzmán et al., 2015) can be considered the reasons why winners are more effective in superiority situations. Nevertheless, future studies should be focussed on the causes of increased efficacy observed in winner teams.

Failed throws (shots that ended at posts or out of the target) showed a statistically significant relation among numerical inequalities. Losers playing under numerical superiority presented higher number of these actions during the games analysed. Shot efficiency relates goals with the total number of throws that a team makes (Gutierrez et al., 2010; Trejo-Silva & Planas, 2018). Shots out of target have then an impact in the shot efficiency. Losers team had more shots stopped by goalkeepers (Karastergios et al., 2017) having also a significant impact in their shot efficiency; losers at PPGG 2015 showed that throwing out of target had a negative impact in their shot efficacy.

The efficacy was evaluated in the study of teams' performance at PPGG 2015 through AE and TE. Similar to previous researches in handball, loser teams presented an AE and a TE less efficient than winner teams (Gutierrez et al., 2010). Generally, an AE below 50% is considered as low efficacy. Although both superiority (44.5%) and inferiority (24.8%) situations presented a low AE in losers' female handball teams at the 2015 PPGG, the performance in situations of unequal numerical of inferiority was especially affected. This goes in line with the study of the Female Handball WCh played in 2013 where results showed that efficacy during these numerical inequality situations could have a high influence on the likelihood to be the winner or loser team (Trejo-Silva & Planas, 2018).

Some limitations of this study are worth noting. Recordings did not allow seeing some actions, having to have them discarded. Only the best 4 teams of the tournament were analysed, having no data of the rest of the teams participating. Finally, actions taken by the defensive teams were not taken into account. Contextualising the studies (taking into account the difference in the score, the level of the opponent, the phase of the tournament, the type of defence, the offensive system used) should give more

accurate information for coaches to prepare their players. Anyway, due to the lack of high-quality studies, especially in female handball, more studies should be developed in order to confirm these results.

6.2 Study 2 – Multivariate analysis of offensive performances during numerical asymmetries in female handball games at Rio 2016.

When analysing the performance of teams at Rio 2016 OG, the following aims were addressed:

Specific Aim 3

To analyze the offensive performance during the different numerical asymmetry scenarios in exclusions at Rio 2016 female Olympic Games.

Findings in the study of Rio 2016 female handball showed that 8.6 exclusions per game were sanctioned, meaning that: (i) around 17 minutes out of 60 were played either in superiority or inferiority; and (ii) the recently change of the game rules applied for the first time at Rio 2016 did not have an important impact in the average number of exclusions per game. Those results are similar to previous studies which found that around 30 % of the game time is played under numerical asymmetries as a consequence of exclusions in elite handball matches of OG (Saavedra et al., 2017) and PPGG 2015 (Trejo-Silva et al., 2020). However, exclusions at female handball occurred to be slightly fewer than in male games, coinciding with previous studies where hostile aggression appeared to be more frequent in male than in female competitions, indeed the upper the level the higher the difference (Coulomb-Cabagno & Rascle, 2006). This could be due to a difference in the criterion used by referees of male and female tournaments at the moment of sanctioning with exclusions those situations where the use of strength in one to one situations is evaluated, as found in previous studies in invasive TS (Zhang et al., 2022).

When a team is sanctioned with an exclusion, they must play with a numerical disadvantage for a period of time with the opposite team having possession of the ball in order to restart the game (exception is when game time is stopped). Since finalization actions were gathered solely during moments when an

exclusion has been sanctioned in a match, the first finalization of each exclusion corresponds to a team playing in a superiority context. This resulted in 55.4% of the total actions occurring during superiority context and 44.6 % during inferiority context. Recent studies confirm these differences in the number of possessions for both numerical asymmetry contexts (Ferrari et al., 2022). In competition contexts, psychological crisis during certain moments or situations of the game are associated with exclusions or dismissals (Bar-eli et al., 1990; Bar-Eli & Tractinsky, 2000). However, players tend to have control over their actions and attitudes in order not to be excluded in balanced games (Bar-eli et al., 1990; Bar-Eli & Tractinsky, 2000; García-Martín et al., 2015). This body of research may explain why losing teams tend to play in inferiority during imbalanced contexts (namely when the difference in the score was 5 or more goals).

6.2.1 Context of superiority

KPIs often used in handball are AE, TE, Turnovers, Throwing Position in the Court and GK Saves. However, the relationship of KPIs with other contextual factors is scarce, as well as when studying other collective aspects of the game such as game phase. In particular, transition can be performed via two main ways: a "fast-break" or 1st wave and "collective fast-break" or "2nd and 3er wave". In both of them the intention is to create open spaces and quick actions to shoot from 6m, relying in players´ quality and strategic spatial distribution.

Offensive system aims to distribute players in the space, fundamentally during set (or so called positional) attacks. During superiority situations, teams may choose to keep a balanced use of the depth and width of the court (using a 3:3 with 1 pivot offensive system) or locate more players near the 6m line, getting then a deeper use of the court (2:4 offensive system). Results in this study show that 3:3 classic formation, followed by 2:4 offensive system and "*no system*" where the most used during superiority contexts, being also the first independent variable related to game outcome. Moreover, the classification tree model, links 2:4 with positional attack, and "*no system*" with 7m throws and collective fast-break (2nd

and 3er wave). Therefore, it may be argued that teams during superiority try to play faster the transitions phase, leading to positioning players in a better situation of scoring (that is to say near the 6m zone, facing a duel with an advantage against the GK), coinciding with previous research made on female elite handball in the same numerical context (Amatria et al., 2020). In addition, when playing positional attack, the strategic option of playing with 2 pivots (again intending to throw via easy breakthrough, pivots or wings with higher throwing´s angle) was the preferred one. Therefore, it may be argued that teams prefer to play fast transitions rather than set piece attack during superiority. Match status is a contextual variable that influence on team´s performance. At Rio 2016 teams´ performance during superiority presented statistical significant relationship with using extended fast break (2nd and 3rd waves) and when playing positional attack dispose players in a 2:4 formation, regardless the match status. It might be asses that teams could not perform 1st wave counter attack due to proper retrieves of opponents, but strategically kept on pushing fast transitions.

All these facts can support the high level of AE (58.0%), being also scoring (among all types of finalizations selected in this research) the type of finalization that had the stronger statistically significant relationship among both contexts (superiority and inferiority). Results in these specific contexts are sustained by a required aspect of the game that is to locate a player in open and clear situations allowing to throw, heavily related with the concepts of depth and throwing´s angle (Laguna, 2019, pp. 55-56). Tactical intention of throwing from 6m zone in superiority it is also highlighted by Sierra-Guzmán et al. (2015) who revealed that they have increased in the last 8 years (Meletakos et al., 2020). Indeed, AE found at female Rio 2016 OG handball tournament during superiority context was higher than in previous studies in female Pan American Games (Trejo-Silva et al., 2020). Particularly, performance at 2010 female Euro tournament showed that winning teams realized more counter attack than losing teams where wings and pivots increased their participation between 70% and 76%, improving the AE in those phases (Ohnjec et al., 2015). AE could also been affected by an increase in the TE as a consequence of the quality and

characteristics of players (Wagner et al., 2014); the improvement of the strength which is directly related with the success of the throws (De Conti et al., 2020) as well as the throwing skill (variable and adaptive) of players (Vila et al., 2020).

6.2.2 Context of inferiority

AE can be considered a KPI due to its association with the overall offensive performance of a team. Results at Rio 2016 OG showed that offensive performance during inferiority context was negatively affected, since AE presented a reduction from 58% in superiority context to 37.5% during EN, and 30.3% with GK at goal. The statistically significant findings of turnovers as a consequence of bad handling of the possession affected the chances of scoring during the numerical disadvantage context. Set piece was the game phase that presented a tendency to be used by teams playing in numerical disadvantage at Rio 2016 OG, adopting preferably a 3:2 offensive system (with no pivot or with one pivot and without one wing) leaving their GK at goal. Despite playing in a game phase where the speed of the plays is slower than in transition phases, the mishandling of the ball (registered at levels of 25% or higher) affected negatively the AE. These results of turnovers and AE are similar to the findings in 2007 to 2017 female WChs (Vinhas de Paula et al., 2020).

Rio 2016 OG was the first tournament where the possibility that a player (wearing a court player outfit) can substitute the GK in any moment of a match. This change of the rules allowed teams sanctioned with an exclusion to equalize (or even reduce in case they have more than one player excluded) the numerical asymmetry of players. Coaches have stated that the main use of this new rule is under this context of inferiority so as they can play in *numerical equality* (Krahenbühl, Menezes, et al., 2019) but leaving EN. The use of this strategy (35.0% of the total in context of inferiority) represented an increment from previous international tournaments played before (Beiztegui-Casado et al., 2019; Trejo-Silva et al., 2020). Results showed that female teams at Rio 2016 OG started to explore the effect of the change in

the rules related to GK substitution, mainly during exclusion contexts. However, CHAID test showed that teams ranked at the bottom of the ranking used this strategy in a statistically significant frequency.

Since weaker teams need to improve many aspects of their performance in order to get better results, taking advantage of the *surprise* factor can be argued as the reason of them playing most of the EN situations in the championship. Previous studies in futsal (sport that also allowed the change of the GK for a court player) have found same results, sustaining this approach (Mendez et al., 2019). Moreover, teams playing for medals at Rio 2016 OG also showed a tendency of playing with EN, which is also sustained with other previous studies in futsal presenting results in line with best ranked teams using the rule that allows changing the GK as a *surprise* factor in even games (Gómez et al., 2019). Remarkable is to say that results in the present study differs from those found at the male tournament in Rio 2016 OG where at knock out stages 86.7% of the inferiority actions where played with EN (Krahenbühl, Sousa, et al., 2019). Indeed some studies argued that coaches of male teams prefer to use this team tactic more than coaches of female teams do (Krahenbühl, Menezes, et al., 2019).

Counter attacks ending in goals or not appeared the most (in comparison with no counter attacks) when playing with EN during inferiority context. This tendency showed that teams playing with EN are more likely to receive fast transitions as a consequence of their finalization, whether they managed to score or not. Female elite handball teams that played against an opponent that has EN, were more likely to use 1st , 2nd and 3rd wave phase of attack, as observed in male handball clubs competitions (Gümüs & Gençoğlu, 2020). This fact could be due to bad decisions taken by offensive players of teams playing with EN when attempting to keep longer possession of the ball (Korte & Lames, 2019), reflected in having the ball intercepted or not being able to shot (Prudente et al., 2019). Finally it can be argued that coaches of female handball at Rio 2016 OG opted to start exploring in maintaining the equality of court players during inferiority, even though they took the risk of leaving the EN while their players develop individual and collective actions in this new offensive game structure (Musa et al., 2017).

6.3 Study 3 – Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball at the 2017 Panamerican Championship.

When analysing the performance of teams at PCh 2017, the following aim was addressed:

Specific Aim 4

To determine teams´ offensive performance indicators during exclusions related to the final ranking obtained at the PCh 2017.

6.3.1 General

A total of 812 actions were registered during the 211 sanctioned exclusions at 2017 FPHCh (an average of 7.3 exclusions per game). Almost a quarter of the total game time (around 15 minutes) was played under numerical inequality situations. These results are similar to the 7.9 exclusions per game at the female OG (Saavedra et al., 2017) and the 7.6 exclusions per game found at the 2015 female Pan-American Games (PPGG) (Trejo-Silva et al., 2020). They are similar to results found at the male elite international level, where almost 30.0% of the game time is played under exclusions (Saavedra et al., 2017). Two reasons may explain this fact. One could be that female handball defense is “less aggressive” than male defense. The other could be that, based on the fact that referees at male and female championships are not always the same, the criterion used might be different.

6.3.2 Exclusion as Indicator

A total of 56.8% of the total actions occurred during superiority, and 43.2% during inferiority. The main reason for this appeared to be regulatory. Rules 2 and 13 in Rules of the Game state that when a 2-minute suspension or a disqualification (red card) is sanctioned, referees must call for a timeout, and the opposing team that receives the exclusion may restart the game with a free throw (IHF, 2018). This means that the team restarting the game (the one that benefited from the exclusion of its opponent) will register the first finalization of the period of asymmetry. Therefore, since the number of actions in inferiority

increased from GI to GIII, it can be said that the number of exclusions also increased from the group of top-ranked teams compared to the group at the bottom, coinciding with the performance of winning and losing women teams at the 2004 to 2016 OG (Saavedra, Thornorgeirsson, et al., 2018) and 2007 to 2017 female WCh (Vinhas de Paula et al., 2020). Exclusions and dismissals are associated with psychological players' crisis in the competition context (Bar-Eli & Tractinsky, 2000). Indeed, players tend to behave in a way that does not lead to an exclusion in equal games (Bar-Eli & Tractinsky, 2000; García-Martín et al., 2015). Since GIII teams registered a tendency to lose, it can be argued that the reason those teams received more exclusions may be due to being disadvantaged during the games. This is sustained (in comparison to GI) by registering more finalizations when the difference in the score was 5 or more goals (an unequal game context).

6.3.3 Context of Superiority

AE is one of the performance indicators used to compare and explain performance in handball. The studied teams ranked 1 to 8 in the all-male OG, WCh, and European Championships between 2004 and 2010 presented an AE mean of 50.9% per game for the entire match (Bilge, 2012). Since attacking in superiority can be linked to having the possible advantage of overcoming the opposition, having found that teams of GI at the 2017 FPHCh had an AE of 63.2% can be considered similar to the elite international level. To achieve victory in a handball game, teams should create situations where the possibility of scoring is facilitated. A temporal numerical advantage in the number of players is undoubtedly an advantage. Should a team want to win a game, it may also perform better than the opponent in those temporal moments. The CHAID study showed that ranking between 1st to 7th (GI and GII) is predicted when winners play under superiority conditions; therefore, winners in those groups may have a better AE (better performance) than losers.

This coincides with studies in this context concerning a numerical advantage of players at Serbia 2013 Women's WCh (Trejo-Silva & Planas, 2018) and Toronto 2015 Female Handball PPGG (Trejo-Silva et

al., 2020). However, it is notable that the AE during superiority at 2017 PCh Female Handball had a statistically significant relationship with the final ranking, not coinciding with results in Serbia 2013 (Trejo-Silva & Planas, 2018). The characteristics of the players (Wagner et al., 2014), the improvement in TE through the impact of programs focused on the enhancement of strength (De Conti et al., 2020) game time handling (Gomes et al., 2014) and the tactical intention of throwing from the 6-m line (Sierra-Guzmán et al., 2015) are the possible aspects that determine winners more effective performance during temporal superiority situations. Nevertheless, future research might target the specific reasons for the increased efficacy observed in the winning teams.

Gruic et al. (2006) found the impact of turnovers as a predictor of performance in male handball. Following this line, it was found that teams of GIII doubled the percentage of turnovers of GI teams. Technical-regulatory errors in the attack may be caused by deficiencies in the players' abilities (especially of the back-court players who are in charge of organizing the game in all phases, and also those most in contact with the ball) or by the high-quality either of defensive players or defensive systems. During the context of superiority in offensive situations, the skills of players of the attacking team should be more relevant than the opposition. Therefore, it is possible to state that GIII teams (the lowest quality of the tournament, reflected in their final score differences in all games) made many mistakes during their attacks while having superiority, mainly because their players may not be good enough to handle possessions ending with a throw. The fact that GIII teams have less experienced players (or at least some who haven't participated in youth and junior WCh) may also explain the performance in this context since expert players are better at predicting and anticipating responses during game situations.

6.3.4 Context of Inferiority

The offensive performance of teams that suffered an exclusion tends to be negatively influenced, creating difficulties in scoring goals and impacting their AE (Prieto, Gómez, et al., 2015). Despite the fact that results about offensive performance at 2017 FPHCh have not presented a statistically significant

relationship between AE and final ranking, the differences in the AE were very important, with GI teams performing similarly to the top 6 teams ranked in the Serbia 2013 WCh (Trejo-Silva & Planas, 2018). It is relevant to mention that GII and III teams ended in turnover 36.9% and 36.2% of their attacks (while GI teams presented 21.9% of turnovers), concurring with the performance of losing teams during the 2007 to 2017 female WCh (Vinhas de Paula et al., 2020). Match status is a game context introduced into performance analysis as another important situational variable. Results from the 2017 FPHCh suggested that playing in a context of inferiority and keeping the goalkeeper in goal when the match status was balanced or moderate was a predictor of losing teams ending in GII or GIII. It appeared that this strategic behavior was affected by match status, leading the teams not to take risks when match status was moderate or balanced.

Since 2016, the opportunity to equalize (or even reduce) the numerical inequality suffered after exclusions has existed, through playing with EN and with all court-players wearing the same clothing as their teammates. In this respect, Brazil and Argentina made an important change in Pan-America since they played almost 50% of their inferiorities with EN, in contrast to results at the PPGG 2015, where in none of the attacks was the GK substituted (Trejo-Silva et al., 2020). This important percentage of use of the rule by Brazil is sustained by brazilian elite coaches who stated that during exclusions they mainly use a court player substituted for the GK to play in numerical equality (Krahenbühl, Menezes, et al., 2019).

Since a statistically significant relationship was found between using or not using this strategic rule change and final ranking, this tactical decision taken by national coaches may have influenced the final position of Brazil and Argentina at the top of the ranking. The fact that less than a fifth of the total offensive actions registered were played with EN differs from results presented at 8 games in the knockout phase of the male Rio 2016 OG, where 85 out of 98 finalizations during an inferiority context were played with EN (Krahenbühl, Sousa, et al., 2019). The reason for this difference is sustained by coaches, who stated that male teams had used the rule more than female did (Krahenbühl, Menezes, et al., 2019).

However, the significant difference in the AE of medalist teams and those ranked in the last 4 found at 2017 FPHCh (42.5% and 26.5%, respectively) do not coincide with results from the best 8 male teams at Rio 2016 (Krahenbühl, Sousa, et al., 2019). The decision to use this strategy verifies the importance stated by coaches to maintaining numerical equality in court players (even taking the risk of leaving EN), showing interest in the offensive game structure and the development of individual and collective actions (Musa et al., 2017).

6.4 Study 4 – Analysis of offensive performance during exclusions in female handball Euro 2018.

When analysing the performance of teams at Euro 2018, the following aim was addressed:

Specific Aim 5

To analyze offensive performance during exclusions at female Euro 2018 concerning the different numerical inequality contexts.

Results of the study on offensive performance during exclusions at Euro 2018 confirmed that at least 23% of the game time in elite female handball is played under numerical inequality as a consequence of exclusions (Saavedra, Kristjansdottir, et al., 2018). However, 2-minute suspensions are still fewer than the 8.1 suspensions per game seen in previous studies of men studies (Almeida et al., 2020; Saavedra et al., 2017). In this sense, the results were compared with previous studies showing that aggressive behaviour occurs and is more frequently observed in men than in women (Coulomb-Cabagno & Rascle, 2006). Reason why could be: (a) due to anthropometric reasons, male players occupy more space than females leading to a more frequent number of collisions (Camacho-Cardenosa et al., 2018; Wagner et al., 2019); (b) Referees' decisions about aggressive behaviour during handball matches are influenced by gender stereotypes (Souchon et al., 2010).

Exclusions were sanctioned during *critical moments for exclusions* coinciding with previous studies (Prieto, Gómez, et al., 2015; Trejo-Silva et al., 2020). Despite dismissals are associated with psychological crisis arousing at certain moments of games (Bar-Eli & Tractinsky, 2000) players tend to control their aggressive behavior towards the last minutes of the game, specifically during balanced ones (Bar-eli et al., 1990; García-Martín et al., 2015). Moreover, important decisions are not taken by referees at the beginning of the games (Gómez-Ruano et al., 2016) in their intention of managing their degree of freedom (Unkelbach & Memmert, 2008).

6.4.1 Context of superiority

Teams ranked in top positions had more situations of finalizations when having numerical superiority advantage (n=159) representing 58.9% of the total situations during exclusions; in line with Saavedra, Kristjansdottir, et al. (2018). AE of teams when playing in superiority was better than when playing in inferiority, coinciding with previous studies about exclusions in handball (Ferrari et al., 2022; Gryko et al., 2018). Reason of such performance could be the game phase in which the attack was performed, and the offensive system used. From the correspondence analysis, the use of fast transitions (1st wave -or fast-break- and 2nd and 3rd wave -including fast throw-off) was strongly associated with the superiority context, showing the intention of locating players in an advantageous spatial situation, especially in a 1-on-1 duel against the GK; coinciding with the performance of teams at previous female Euro 2016 (Amatria et al., 2020) and Euro 2010 (Ohnjec et al., 2015). The offensive system "No system" appeared highly associated with superiority, due to the fact that it was registered under the context of fast transitions (1st and 2nd wave) and 7m. Moreover, when playing set-piece attack, the strategic idea of locating more players in 6m (2 pivots) via a 2:4 offensive system was also strongly associated with superiority, similar to what it was mentioned by Sierra-Guzmán et al. (2015).

Individual factors can also explain superiority score performance, such as the high level of TE which is enhanced by the quality and characteristics of players in various attacking positions (Michalsik et al., 2015); the improvement of the strength and variability (De Conti et al., 2020; Vila et al., 2020).

6.4.2 Context of Inferiority

Results showed that the bottom four ranked teams were associated with inferiority context, meaning that most of the sanctioned exclusions corresponded to them, consistent with the results of previous studies conducted on female OG and WCh from 2004 until 2017 (Saavedra, Kristjansdottir, et al., 2018; Vinhas de Paula et al., 2020).

In terms of finalization, the team's performance at Euro Women 2018 was negatively affected in comparison with the superiority context, reflected in shots that no end in scoring. As for game phases, playing positional build-up attacks was the game phase that seemed to be associated with both forms of inferiority, coinciding with previous research that found that teams intended to hold offense longer to make more passes, especially if they chose to play in the EN (Korte & Lames, 2019; Prudente et al., 2019). However, teams presented a mishandling of the ball, aspect that might have been influenced by the less expertise of players which leads them to be less precise in predicting and anticipating actions (Ziv & Lidor, 2009).

A special analysis about the impact of the change of the rule that allows changing the GK for a field player need to be addressed. Previous studies about the use of playing with EN (Marczinka & Gál, 2018; Maroja et al., 2020) confirmed coaches' statements when saying that they use this strategy to play in *numerical equality in in-court players* during inferiority contexts (Krahenbühl, Menezes, et al., 2019) having higher level of approval among female GKs than male GKs (Iusepolsky et al., 2022). Results at Euro 208 with 61.7% of the total actions during inferiority played with EN confirmed the tendency in increasing the use of this strategy (Gümüs & Gençoğlu, 2020; Krahenbühl et al., 2021), although is still used less than

the 77.8 % found (86.7% during knock-out stages) by males teams at Rio 2016 (Krahenbühl, Sousa, et al., 2019; Montoya, 2016).

The correspondence analysis found that teams ranked 1st to 4th opted to play GK at goal (77 finalizations against 34 of EN), while teams ranked 5th to 8th and 9th to 12th preferred to play EN. Additionally, winning teams were more likely than losers to use GK at goal strategy and losers were more likely to use EN strategy (51.8 % of the total of EN situations registered, while winners presented 47.6 %). Important to notice is the fact that Russia (who finished 2nd in the final ranking) registered no finalization of EN and 27.1 % of the total finalization of Gk at goal of the tournament. These facts are shown in other handball studies in which underdog teams choose to take riskier strategies (playing with EN) in the need to improve their performance; taking the risk of a strategy (playing in EN) that may lead to unwanted actions (easier scores of their rivals via counterattacks) during a match (Neuberg & Thiem, 2022). Same performance is found in futsal where lower ranked teams also use this strategy as a way to overcome the difference in abilities (Mendez et al., 2019). In basketball, underdog teams can improve their chances of winning a match when taking risky strategies (Skinner & Goldman, 2016). On the contrary, teams ranked 1 to 3 at 2017 PCh Female Handball opted to play EN most of their situations in inferiority (Trejo-Silva et al., 2022).

Receiving a counterattack appeared to be strongly associated with EN, coinciding with results at male handball clubs competitions where teams playing with EN are more likely to suffer fast transitions as a consequence of their finalizations (Gümüs & Gençoğlu, 2020), most likely due to the tendency of finalizing in turnovers when playing EN.

Highlights of this study showed that :(i) fast transitions are commonly used during the superiority context, explaining the better AE obtained in comparison with inferiority; (ii) playing with EN represented 61,7 % of the total situations of inferiority; (iii) teams ranked in the last 4 places used the EN strategy the

most; and (iv) with the EN tactical approach, teams tended to receive a counterattack as a consequence of their finalizations.

On the other hand, the current trends can be of interest to be investigated and applied in other contexts of play in handball or in other TS where contextual superiority/inferiority appears such as futsal (e.g., GK as an outfield player), water polo (exclusions) or field hockey (exclusions). Moreover, the study at Euro 2018 had several limitations that should be considered in future investigations, including the zone of the field where the finalizations took place and the role of the player who finalize, the interaction with defensive actions as well as the influence of coaches when training and developing strategies. Another limitation of the study was the tournament format, which could create strange incentives for some teams. Team winning their first two games (securing their qualification to the main round) could play the final game of the group stage without incentives or even may play the last game needing a win by no more than 2 goals in order to go through the next stage of the tournament with more points (Csató, 2022). This context influences team´s performance and intentions to win games (for example, Spain won its last game by 2 goals and found Spanish players celebrating rival´s last goal). However, in order to analyze tournaments, it is necessary to register data of these games.

Chapter 7. CONCLUSIONS

7 CONCLUSIONS

The following conclusions are presented linked to the specific aims established in this Doctoral Thesis. Therefore, the conclusions are the following ones:

Specific aim 1: "To describe the situations of numerical inequality due to exclusions during the Female Handball at Panamerican Games 2015"

Main number of numerical inequalities in field players as a consequence of exclusions at an international elite female handball tournament at Panamerica is distributed between minutes 10 to 26 and between minutes 30 to 55 of game time, representing critical moments of the game, lasting around 25% of the total game time.

Specific aim 2: To analyse the efficacy during numerical inequalities at Female Handball at PPGG 2015 and relate it with game outcome

Winners at PPGG 2015 scored more than losers in both numerical inequality contexts, having the goals scored during superiority context a significant impact on the game outcome. Shots that not ended in goal or were save by the opponent goalkeeper, showed a significant record for losers during superiority. AE and TE were better for winners than for losers, highlighting an AE below 25% during inferiority context, associated with losing the game.

Specific aim 3: To analyze the offensive performance during the different numerical asymmetry scenarios in exclusions at Rio 2016 female Olympic Games.

Low ranked teams were sanctioned the most, leading top ranked teams at Rio 2016 OG to register most of the superiority finalizations. Fast transitions (1st, 2nd and 3erwave, quick throw-off) were the game phases used the most during this numerical inequality context, helping top ranked teams to have a better AE and TE than lower ranked teams. Moreover, with closed or wide-opened match status, teams opted to position their players in a 2:4 system with one pivot, when facing a positional attack.

Positional attack was the dominant game phase during the numerical inferiority context (whether playing with GK at goal or EN) at Rio 2016. The offensive system used the most in this environment was 3:3 with one pivot followed by 3:2 (3 back players, 1 pivot, 1 wing), showing the intention to positioning at least 1 player in the 6 meters zone.

Change of the rules implemented for the first time in Rio 2016 OG had an effect in the offensive strategies and tactics of teams when playing numerical inequalities as a consequence of 2-minutes suspensions. The use of changing the GK for an in-court player in order to balance the numerical inequality during inferiority contexts as a consequence of exclusions in 35% of the finalizations, showed a coincidence with coaches' opinion. Low and top ranked teams were the ones that played the most with EN, receiving a fast transition from the opponent as a consequence of ending in turnovers their finalizations.

Specific aim 4: To determine teams´ offensive performance indicators during exclusions related to the final ranking obtained at the PCh 2017.

Teams ranked 1 to 6 at PCh 2017 registered a statistical significant relationship with finalizing their attacks during superiority context, meaning they faced teams suffering an exclusion the most. Meanwhile, turnovers were found statistically related to teams ranked 7 to 10. Finalizations under a superiority context predicted top ranked teams' inclusion. Indeed, medalist tended to score in most of their finalizations and used 1st wave counterattacks with statistically significant frequency, presenting an AE similar to elite international level.

Substituting the goalkeeper for a court player in an inferiority context (playing 6 against 6 with EN) was a predictor of belonging to the top 3 teams, while playing with the GK at goal (playing 5 against 6) when the match status was balanced or moderate, predicted the loser teams ending up in places 7 to 10.

Specific aim 5: To analyze offensive performance during exclusions at female Euro 2018 concerning the different numerical inequality contexts.

Teams ranked on top at Euro 2018 registered most of the finalizations under superiority contexts, presenting a better AE than when playing in inferiority. The use of all forms of fast transitions (1st, 2nd and 3rd wave as well as fast throw-off) was strongly associated with numerical advantage context, as well as the use of a 2:4 offensive system during the stationary attack.

In spite of the fact that teams at Euro 2018 showed a tendency of increasing the resource of playing with EN during a numerical inferiority context (61.7% of all finalizations in that asymmetry situation), teams ranked 1st to 4th presented a tendency to play with their GK at goal. Moreover, this tactical situation was associated with turnovers and receiving counterattacks from the opposite team as a consequence.

Chapter 8. STRENGTHS, LIMITATIONS, PRACTICAL APPLICATIONS AND FUTURES PROSPECTIVES

8 STRENGTHS, LIMITATIONS, PRACTICAL APPLICATIONS AND FUTURE PERSPECTIVES

8.1 Strengths

I. A holistic study was developed with the purpose of encompassing different contextual variables that may interact during temporal numerical inequalities in elite female handball tournaments.

II. The context in which the study develops is ecological, since every registered behavior was registered from official competition video images in order to preserve the ecological validity of the study.

III. Observational and recording tools respected quality of data process, ensuring a high standard due to the validation endowed by coaches and academics and the high rate of reliability of the research team.

IV. A contribution to increase and enhance the body of studies on female performance in team sports in general, and in handball in particular.

V. It contributes to the development of handball performance analysis in South America.

VI. Strengthening the use of notational studies in sports performance analysis in Uruguay.

VII. It contributes to the production of knowledge regarding a specific context within handball playing that needed to be approached.

8.2 Limitations

I. It is important to highlight the absence of official competitions from other confederations (Africa and Asia) in the scope of the research. Nonetheless, the main interest was to study Panamerica competitions and contrast them with European and World level tournaments.

II. It revealed the difficulties in obtaining the videos of every game for each selected tournament, indeed this was the reason for not being able to include and analyses South-Central American Championship 2018 in this research.

III. The sample size of the Panamerican Games 2015 was small, although it still made it possible to describe the female offensive performance during exclusions at the most important event in the continent (Panamerican Games is the only event bestowing direct qualification to the Olympic Games). Only the best 4 teams of this competition were studied, a selection based on the qualification criteria, which stated that those teams playing for medals either qualify directly to the Rio 2016 OG or move up to the next stage.

IV. Had it been the case, analyzing the Euro 2016 would have provided valuable information about the impact set off by the change in the rules of the game, not only from the perspective of European teams, but also from the time-line perspective.

V. In similar way, if the World Championship 2017 had been analyzed it would have very likely delivered important information on the impact of the change in the rules of the game, from a time perspective in an event with teams from the 5 continents.

VI. Some variables could not be analyzed in adequate depth (e.g. goalkeeper saves, match status).

VII. Certain aspects of the defense were not considered (e.g. defensive system, level of opposition when finalizing the attack).

VIII. Some variables were not discriminated as to be studied. For example, *"Direct Goals"* (i.e. the defending goalkeepers scores after throwing from its own area) were not differentiated since they were registered as "counter attack and goal; counter attack and no goal); also, quick throw-offs were not differentiated in a more specific way (they were registered as *"2nd and 3er wave"*).

8.3 Practical applications.

Results and conclusions from this Doctoral Thesis may produce diverse practical applications ina variety of areas, providing support and resources to:

a) Coaches working at initiation/formation level (both during training and competition environments);

b) Coaches working at senior/elite level (both during training and competition environments);

c) Lecturers at courses/workshops organized by national or continental confederation;

d) Universities lectures in charge of handball lessons.

Coaches at senior/elite level might use the results of these studies in the context of competitions. For example, in order to mentally prepare players in anticipation of those critical moments of the game when exclusions showed to be more fluently sanctioned. Or, since coaches can handle players substitution with complete freedom, they might let in players with special characteristics to perform better in a "possible new context" (for example to play fast transitions while playing during superiority, or even to perform fast retrieves when playing during inferiority context).

Since performance indicators are used during matches as input for coaches (e.g. goalkeeper saves percentage, turnovers, throwing efficacy from different zones), data presented in this thesis regarding turnovers, throwing and attack efficacy might work as a performance reference during exclusions to kept in mind while coaching during a game (e.g. 26.5% TE during inferiority was associated with low ranked teams, and 42.5% with top ranked in Panamerica 2017). Decisions adopted by coaches may lead, for example to request a time out and organize the team when facing a 2-minute suspension context.

Coaches at any level might use data from this thesis when planning their training sessions. As was previously stated in the section 2.9, handball specialists do make use of academic research´s data in order to carry on with their never-ending formation process, or to update their knowledge. Environmental

constraints such as game time, can be transformed into a task constraint (e.g. when playing friendly match, make an intentional numerical inequality in the middle of the first half and requesting certain performance indicators from players in attack and/or defense). Moreover, from the pedagogical/didactic point of view, the chance of presenting exercises or "game forms" where numerical inequality is stated and indicate certain task constraints (e.g. the use of fast transitions in attack when playing superiority, or playing positional attack with 3:3 offensive system during inferiority). Same reasoning may be also used for indicators like turnovers, throwing and attack efficacy (e.g. training with exercises or "game forms" requesting certain percentage of throwing or attack efficacy; or limiting the number of turnovers).

Data from this thesis reveals that playing in inferiority with EN tends to increase its use. Therefore, coaches should prepare their training sessions focused in a *new issue* referring to goalkeepers´ task and conditional training. Since this strategy needs goalkeepers to re-enter the field aiming to get back to goal as fast as possible, two main aspects must be trained with specific didactic/pedagogical approaches: the coordination of the substitution of an in-court player for the goalkeeper and goalkeepers´ running speed in order to get back to goal as soon as possible.

Indeed, since playing with EN presented a significant association with receiving a counter attack, with the goalkeeper of the opponent being the first responsible to initiate this phase, it emerges as an important skill to be developed in goalkeepers, being able to throw from its goal with the intention of scoring a direct goal (while the goalkeeper of the other team is yet entering the field). This ability, while being in the offensive phase, looks like a *must* in the forthcoming future for goalkeepers, aside from being able to perform a long accurately pass (around 30 meters) to a teammate in a 1st wave.

Lecturers at courses/workshops organized at national or continental confederation ought to, perhaps, presents "approaches to performance during exclusions" as a topic and shares with the attendants the importance of taking into account those offensive performance issues showed in this thesis. Turnovers, throwing and attack efficacy in superiority, inferiority with goalkeeper at goal,

inferiority with EN are performance indicators that might help guiding coaches´ work to help them position their teams as high as possible in the ranking of the tournaments they take part into. Practical sessions may include aspects such as playing fast transitions during superiority and playing inferiority with EN more often than goalkeeper at goal. Those two topics need tactical means to be develop in order both to score and to prevent receiving goals.

Lecturers at universities where *"Handball"* is one of the contents included in their respective bachelor (Physical Education or Sport Sciences undergraduate programs) or postgraduate courses (Master or PhD Degrees), may address the results about should address results of the offensive performance during numerical asymmetries studied in this research. Approaching how to teach/train *temporal numerical superiorities* is one of the basic aspects for individual/group tactics, as well as *temporal numerical inferiorities* as a consequence of exclusions.

Results from this thesis may have brought light to an issue with possible influence in this regard, since temporal numerical inferiorities may no longer exist due to the possibility of playing *numerical equalities in field players* taking the risk of leaving the empty goal.

8.4 Research prospective

I. Future studies should continue researching about female handball performance.

II. Future investigations should also be conducted on other continental competitions and on male handball.

III. Studies with a greater sample size are needed (e.g. inlcude at least two tournaments at Panamerica level).

IV. Studies should be carried out at local leagues level (e.g. Uruguayan league) in order to contrast the strategy chosen by coaches when playing inferiorities against the continental/world reality.

V. More research is needed to study the effects of playing inferiorities with EN in young players (under 18, 16, 14).

VI. It is certainly interesting to contrast the results obtained in this study with results obtained in the context of other team sports that shares same internal logic, displaying similar numerical asymmetry contexts (exclusions and/or playing with EN), in order to look for differences and similarities.

VII. More studies are needed that collect coaches´ opinion about strategies to address the moment of playing in numerical inequality context.

VIII. It may prove itself recommended to study other contextual variables, such as diverse offensive and defensive individual/group tactics used; defensive systems, finalization zones, home advantage effect.

Chapter 9. REFERENCES

9 REFERENCES

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Chapter 10. ANNEXES

10 ANNEXES

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Offensive performance under numerical inequality during exclusions in female handball

Rendimiento ofensivo en situaciones de desigualdad numérica durante las exclusiones en balonmano femenino

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Abstract

The aims of this study were: i) to describe the situations of numerical inequality due to exclusions during the Female Handball at Panamerican Games Tournament 2015; ii) to analyse the efficacy to relate these situations with the final performance and results. All matches played by teams ranked 1 to 4 in the tournament were analysed using the observational methodology. An ad hoc tool was created in order to develop the observation. A total of 14 matches were analysed in which 461 situations of numerical inequality occurred. Differences among different categories were analysed using chi-square test. Statistical significance was considered when $p < 0.05$. The main number of actions was concentrated during the second part of the matches ($p < 0.05$). Results showed the winners being more efficient than losers in the majority of the variables studied ($p < 0.05$). Winner teams scored a higher percentage of goals and showed a lower percentage of throws out than loser teams. Winner teams showed a more efficient performance in their attack efficacy (number of goals scored in relation to the number of attacks) while playing in inferiority. It was concluded that winner teams convert more goals than loser teams and they are more efficient during actions under numerical inequality.

Key words: female handball; numerical inequality; exclusions; efficacy; offensive performance.

Resumen

Los objetivos de este estudio fueron: 1) describir las situaciones de desigualdad numérica como consecuencia de exclusiones durante el torneo de balonmano femenino en los Juegos Panamericanos 2015; 2) analizar la eficacia para relacionarla con el resultado final de los partidos. Todos los partidos jugados por los equipos clasificados del puesto 1 al 4 en el torneo fueron analizados, utilizando la metodología observacional. Se construyó un instrumento ad hoc para realizar la observación. Un total de 14 partidos fueron analizados, en los cuales ocurrieron 461 acciones de desigualdad numérica. Las diferencias estadísticas entre las categorías analizadas fueron comprobadas usando el test de chi-cuadrado. Diferencia estadísticamente significativa fue considerada cuando $p < 0.05$. La mayor cantidad de acciones se concentró durante la segunda parte de los partidos ($p < 0.05$). Los resultados mostraron a los ganadores siendo más eficaces que los perdedores en la mayoría de las variables estudiadas ($p < 0.05$). Los equipos ganadores convierten el mayor porcentaje del total goles convertidos y mostraron un porcentaje menor de lanzamientos fuera. Los ganadores mostraron un mejor rendimiento en su eficacia de ataque (números de goles en relación al número de ataques/posesiones) cuando juegan en inferioridad. Se concluyó que los equipos ganadores convierten más goles que los perdedores en estas situaciones y que son más eficaces durante las acciones de desigualdad numérica.

Palabras clave: balonmano femenino; desigualdad numérica; exclusiones; eficacia; rendimiento ofensivo.

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Introduction

The study and understanding of the situational variables describing team sport performance is likely to be an important income for coaches to plan trainings and prepare competitions (Marcelino, Sampaio, & Mesquita, 2012; Ruano, Serna, Lupo, & Sampaio, 2016). Hughes & Bartlett (2002) mentioned that performance indicators, obtained from the selection or combination of action variables, can be used by coaches either to compare with opponents or own past performances, or even in isolation. And they suggest that it must be taken into account that analysing data without contextualising them may mislead to false interpretation. An example of contextualising was given by Robertson, Back, & Bartlett (2015) when including the opposition in their method of preparing matches.

The success of an offensive action during a match of handball depend on, among others, the ability of teams and individuals to adjust their behaviours to the changes that occur over time in the offensive context of the handball game (Volossovitch, 2005). In order to develop a reliable interpretation of the efficacy of the attack, some patterns such as centres or a line, the speed of shootings, the time of the preparation of the attack, could be considered. Besides, the scoring efficiency has been studied previously to determinate which player's actions are that most influence in handball games. Thus, the highest effectiveness of the shots for the winner teams was obtained in short distance shots (7-meter throws and 6-meter centre) and wing shots (Srhoj, Rogulj, Padovan, & Katic, 2001; Vuleta, Milanovic & Sertic, 2003). Besides, the five variables that could have a high influence in the final results of the match were: number of shots, number of shots saved by the goalkeepers, number of blocks, side shot throwing efficiency and number of failed passes (Volossovitch & Gonçalves, 2003). The attack efficiency at the men Olympic Games 2004 differed in a significantly way from the 2006 European championship and 2007 world championship, while throwing efficiency was similar in those tournaments (Bilge, 2012).

Manifestation of those performance indicators could be observed whether in training sessions (Andersen, Fimland, Cumming, Vraalsen, & Saeterbakken, 2018; Hartz, Sindorf, Lopes, Batista, & Moreno, 2018; Mazurek et al., 2018) or official competitions (Cardinale, Whiteley, Hosny, & Popovic, 2017; Hansen et al., 2017). One of the main goals for a national handball team is to compete at the Olympic Games. The International Handball Federation -IHF- leaves to each Continental Federation´s decision the criteria to qualify to them. For those American teams, Pan-American Games (PPGG) represents a good opportunity. Considering the importance of the tournament, it is relevant to state that PPGG is the last stage where the best 8 teams of the Americas compete for only one spot to the Olympic Games, that the IHF gives to the continental federation. At the 2015 Toronto Games, in case Brazil would have reached the first place, the team that would finished second would have obtain the direct qualification to Rio 2016. The team that obtained the Bronze medal got the opportunity to fight for another spot in Rio at a tournament together with 3 Europeans national teams. Given the importance of the tournament, it is the last milestone of a 4-year planning made by each National Handball Federation. Therefore, this tournament is the highest expression of level in the Americas. Performance indicators in these handball important competitions have been previously studied (Bilge, 2012). Numerical inequality, as a consequence of exclusions, is one of the context in which performance

is analysed (Milanovic, Vuleta, & Ohnjec, 2018; Saavedra, Thornorgeirsson, Chang, Kristjansdottir, & Garcia-Hermoso, 2018).

Temporal exclusions of players who generate actions against the rules through technical faults or unsportsmanlike attitude is a predicted sanction in the International Handball Federation regulation (IHF, 2010). Rule 8 describes the situations in which a player may be excluded. The duration of an exclusion is two minutes and consists in a suspension for the player who has committed the conduct to be punished for. The team is not allowed to replace the player sanctioned, therefore, during this time the team has less players, according to the number of players sanctioned with exclusion. When the opponent keeps all its players on the court, this inferiority of numbers of field players in one team versus the other team is a disadvantage for that team while the superiority generated to the opponent is an advantage, in case the opponent has not any player excluded. Even though it could be considered as an advantage or disadvantage, what is important for coaches and researchers is the magnitude of this numerical inequality and its consequences in the final result (Prieto, Gómez, & Sampaio, 2015). It is necessary to mention that the 2015 Handball Tournament at the Pan-American Games was held under the 2010 IHF Rules of the Game (IHF, 2010). According to rule 4.8, it was not allowed changing the goalkeeper for a field player wearing a field player clothing. This rule has changed from August 2016 onwards.

Therefore, exclusions of players in a handball match have an important influence in the tactical aspect of the game, due to the possibility of playing in numerical equality when having players excluded (taking the risk of playing with "empty net"). In addition, these numerical situations in the relation of the number of players per team are studied in different team sports which have similar rule´s criteria in terms of penalising with the exclusions of players for certain period of time. Some studies take the exclusion itself as a performance indicator in handball (Debanne, 2018; Lago-Peñas, Gómez, Viaño, González-García, & Fernández-Villarino, 2013). Indeed, some studies may relate red cards (one of the possibilities of having an exclusion during a handball match) and the possibility of winning or losing (Saavedra et al., 2018). It is possible to find studies in football (Liu, Gómez, Lago-Peñas, & Sampaio, 2015), futsal, ice hockey (Widmeyer & McGuire, 1997) and water polo (Escalante, Saavedra, Mansilla, & Tella, 2011; Escalante et al., 2012; García-Martín, Argudo Iturriaga, & Alonso Roque, 2015; Gómez, Serna, Lupo, & Sampaio, 2014; Lupo, Condello, Capranica, & Tessitor, 2013; Lupo, Condello, & Tessitor, 2012; Platanou, 2004; Ruano et al., 2016) where performance of teams during the period of time of exclusions is studied. These kinds of situations are relatively frequent during a handball match completing a 20% of the total game time (Gutierrez, Fernández, & Borrás, 2010). However, it is known that the pressure generated to the team with superiority may generate a lower performance in these situations (Schucker, Hagemann, & Strauss, 2013), being a possible reason to explain the unexpected result of actions under numerical superiority found in previous research (Prieto et al., 2015).

This fact generates a change in the tactical schema for both teams and can influence in the result at short term, giving advantage for the teams in numerical superiority (Prieto et al., 2015) or at long term, increasing the likelihood to be the winner or loser team (Trejo & Planas, 2018). Also, the new generated game situations could affect technical and tactical aspects that have influence in the result. The performance of the Spanish male national handball team was studied from a tactical point of view during the European championships 2012 and 2014 (Sierra-Guzmán, Sierra-Guzmán, Sánchez

Sánchez, & Sánchez Sánchez, 2015). In other sense, (Gutierrez et al., 2010) reported that during the matches played in the Male World Championship 2003 and the Male European Championships 2002 and 2004 the losing teams presented worse efficient performance at throwing efficacy and attacking efficacy during numerical inferiority. Studies in other team sports are focused in identifying a relationship between the result of a match and the variable time. Those moments where performance has more influence in the final outcome of a match were named critic (Bar-Eli & Tractinsky, 2000). Sampaio, Lorenzo, & Ribero (2006) found that those moments appeared in the second half of a basketball match. Oliveira, Gomez, & Sampaio (2012) found out that in handball, winners were more efficient in the last minutes of each half.

The literature has reported not too many studies focused on this issue. From the same point of view, being in inferiority is important for coaches and researchers in order to study the team performance during these temporal situations. Up to our best knowledge, there are no studies regarding this issue in elite female handball. For this reason the aim of the present study was to describe the situations of numerical inequality due to exclusions during a female handball international tournament and to analyse the efficacy to relate these situations with the final performance in the different periods of the match.

Methods

Sample

The study was conducted on a sample of 14 matches from 2015 Women's Pan-American Handball Championship in Toronto. Those games were the total ones played by the national teams that finished the tournament in the four first places. A total of 107 exclusions occurred during those matches.

The number of finalization actions was 464 and three of them were discarded because of the low quality of the recorded video. Therefore, the number of valid actions was 461. These actions were registered when the result of them was shot on target (divided as goal or no goal) or no shot (i.e. loosing possession of the ball). A total of 325 actions ended on shot on target and 136 in no shot. Actions in which there was numerical equality (i.e. 5x5 and 4x4) in both teams were not included in the analysis.

Since public videos where used to extract the actions, it was not necessary the informed consent of the participants.

Instrument

Observational methodology was used. Then, the observational instrument combined the field format with the system of categories. The final condition of the match (winner, looser or draw) was directly inserted in the registration sheet, being part of the variables studied. "Tournament phase" was a fixed criterion, categorizing the phases in "group phase", "play offs" and "medal". The selected categories for each criterion contained exhaustiveness and mutual exclusivity at the system of categories. A total of 49 categorical cores and their correspondent register code were generated (Table 1).

Table 1. Criteria and categories of the observational instrument

Criteria	Categories	Categorical core
Team	BRA, ARG, URU, MEX, RIV	Teams to be analysed. BRA: Brazil; ARG: Argentina; URU: Uruguay; MEX: México. It is considered as "Rival" (RIV) any other team of the tournament
Game time	T1	Interval 0 to 9:59
	T2	Interval 10:00 to 25:59
	T3	Interval 26:00 to 30:00
	T4	Interval 30:01 to 39:59
	T5	Interval 40:00 to 54:59
	T6	Interval 55:00 to 60:00
Asymmetry	6x5, 5x4, 6x4	Superiority of 1 or 2 players
	5x6, 4x5, 4x6	Inferiority of 1 or 2 players
	Pe	Inferiority of any kind but with a field player using a bib.
Attack result	G	Goal
	F	Throw not on goal
	A	Goalkeeper get the throw
	P	Throw on post
	B	Defensive Block
	GE	Goal and exclusion in the same action
	E	Attacking player generates an exclusion
	I	Defensive interception of the ball
	MP	Bad Pass by attacking player
	ETR	Technical or regulatory mistake

The observational instrument was uploaded to the software Lince 1.1, whose validation in the field of physical education and sports science was performed by Gabin, Camerino, Anguera, & Castañer (2012). Videos were watched by the research team and data collected. The unity of observation is considered as the period of time in which the team get the ball possession until a collectable action (result) is produced. In the present study it was referred only to the situations that take place during an exclusion that generates a numerical inequality.

Procedures

A theoretical framework and the authority criteria sustained the validity of the construct. These last one was covered with the response of 5 Pan-American elite coaches to a specific survey. The level of agreement in the totality of the items included in the questionnaire was higher than 90%. The reliability of the instrument was confirmed undertaking tests of quality control and concordance at inter-observers and intra-observers. Kappa coefficient values at those items showed 0.85 and 0.93 respectively.

The definition of attack and throwing efficacy proposed by Gutierrez et al. (2010) and Trejo & Planas (2018) was taken as a reference, having then the following definitions:

Throwing Efficacy (TE) = [(number of goals x 100) / Number of throws];

Attack Efficacy (AE) = [number of goals / (number of throws + turnovers)].

The results of attacks ending in interception (I), bad pass by attacking player (MP) and technical or regulatory mistake (ETR) were considered "no shot (turnovers)".

Statistical analysis

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, IL, USA). Frequencies were obtained for the different variables. Differences among different categories were analysed using Chi-square test for contingency tables. Period and consequence or type of inequality and consequence were the variables included in the chi-square analysis to know differences in periods during the matches or among type of inequalities. When a general difference was observed, a chi-square test was performed in the specific category. Statistical significance was considered when $p < 0.05$.

Results

During the 14 matches analysed, 107 exclusions occurred, which represents an average of 7.6 exclusions per match and then an average of around 15 minutes per match in situations during which numerical inequality actions appeared. A total of 461 situations of numerical inequality were analysed in the tournament (55.7% in superiority and 44.3% in inferiority). Ten of these situations finished with exclusion and the rest were registered as shot on target (divided in two categories: goal or no goal) and no shot. Figure 1 shows the distribution of the situations of numerical inequality divided by situations in superiority (which includes all actions of asymmetry registered as 6x5, 5x4 or 6x4) and inferiority (which includes all actions of asymmetry registered as 5x6, 4x5, 4x6 or Pe) during the match and its consequences. A remarkable result is that no action from category "Pe" was registered, meaning that no team changed its goalkeeper for a field player. The majority of the situations of numerical inequality finished in shot and the most of them in goal, with the highest percentage during the T5 as well. The statistical analysis did not show statistical differences between the number of situations in numerical inequality among the different game times. The analysis by numerical inequality showed that in T2 there the goals converted in superiority are more than those converted in inferiority even when the T2 actions represents similar percentages respect to the total actions during the match (21.8% and 22.5% respectively). During the lass part of the game (T6) the teams in inferiority converted more goals than those in superiority.

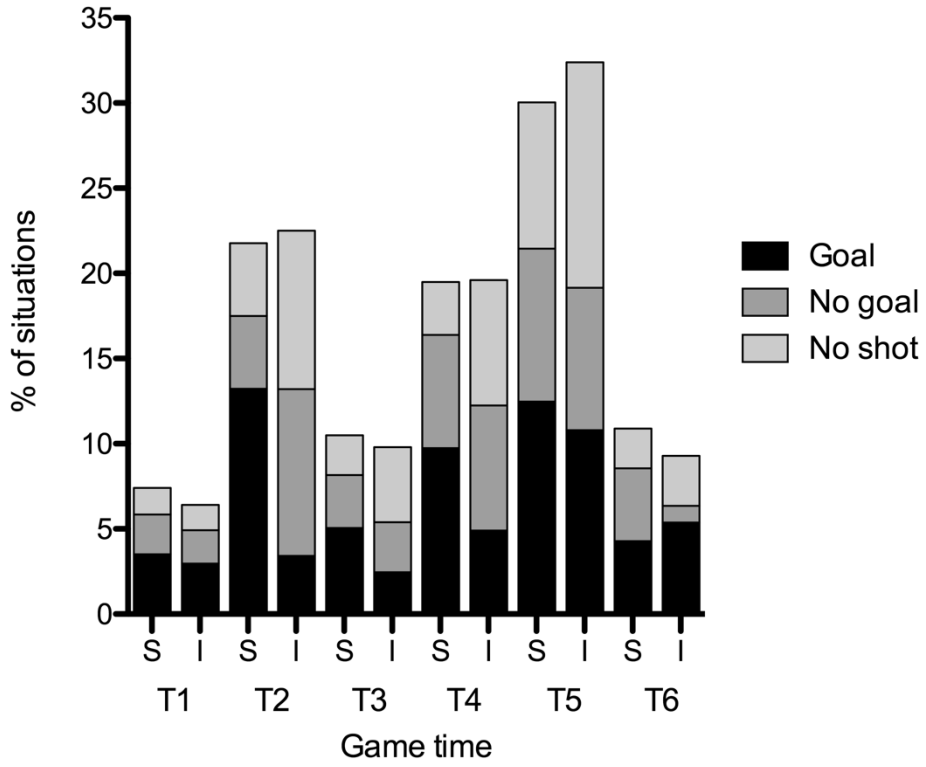

Figure 1. Percentage of situations in numerical inequality by game time and its consequences.

T1 to T6: Game time splatted in 6 periods; S: Superiority; I: Inferiority.

The figure 2 shows the distribution of the situations related to the type of finalization and in function of the final result of the match (win or lose). Winner teams converted more goals (57.3% of the total of finalizations, which are 39.5% in superiority and 17.8% in inferiority) than the loser teams (42.7%) of the total of finalizations, which are 27.6% in superiority and 15.1% in inferiority), showing a statistically significant difference ($p<0.05$, $V=0.16$). Also, winner teams had a statistically significant lower percentage of throws out (34.0%, which are 22.0% in superiority and 12.0% in inferiority) in comparison to loser teams (66.0%, which are 40.0% in superiority and 26.0% in inferiority) during the situations of numerical inequality. In the rest of finalizations (goalkeeper saves or turnovers) no statistically differences between winner and loser teams were observed, nevertheless the loser teams presented the lowest percentage of goalkeeper saves (48.9%) and winner teams the lowest percentage of turnovers (42.6%).

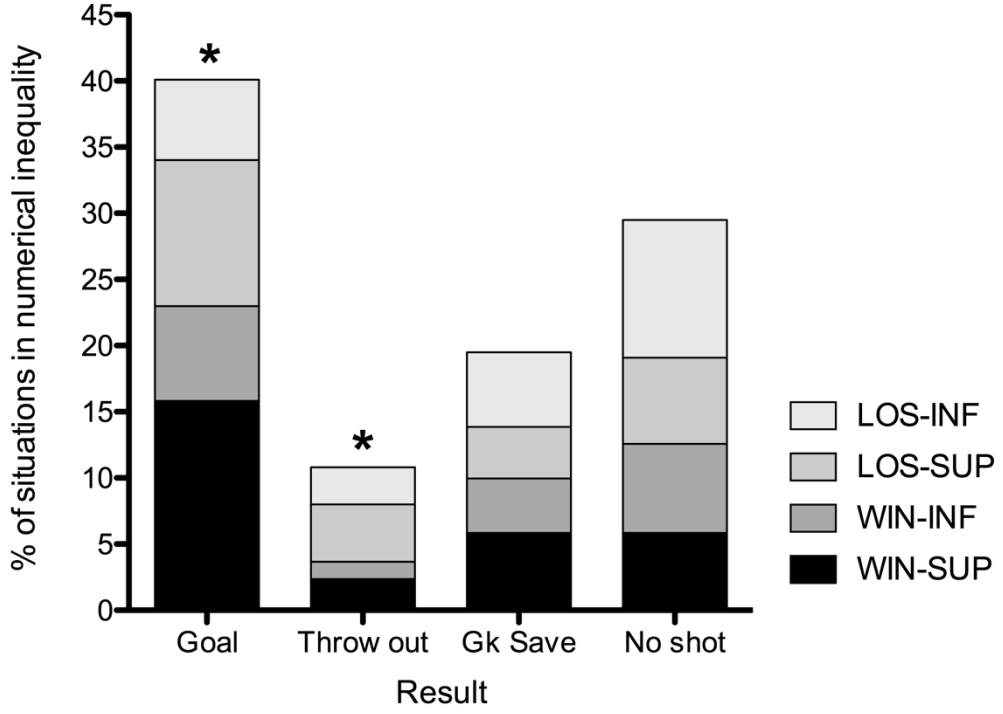

Figure 2. Percentage of situations under numerical inequality divided by team and numerical inequality condition.

*Gk Save: Goalkeeper save; WIN: Winner team; LOS: Loser team; SUP: Superiority; INF: Inferiority. * Statistically significant differences between winner and loser teams (p < 0,05).*

Regarding the efficacy during the situations of numerical inequality (Table 2), the winner teams had a higher throwing efficacy and a higher attack efficacy in comparison with loser teams in superiority (ΔTE: 8.5%; Δ AE: 10.9%) and inferiority as well (ΔTE: 15.1%; Δ AE: 13.1%). The winner teams presented a statistically significant ($p<0.05$) higher percentage in the attack efficacy while playing in inferiority in comparison with the loser teams (37.9% and 24.8%, respectively).

Table 2. Efficacy in situations under numerical inequality.

	Superiority		Inferiority	
	Winner	Loser	Winner	Loser
Throwing Efficacy (%)	65.8 (56.4-74.0)	57.3 (46.8-67.2)	56.9 (43.8-69.1)	41.8 (30.5-54.0)
Attack Efficacy (%)	54.5 (45.9-62.8)	43.6 (34.8-52.8)	37.9 (28.3-48.6)	24.8 (17.6-33.6) *

Data are presented as CI95%; * Statistically significant differences respect to winner teams (p < 0,05)

Discussion

The aim of the present study was to describe the situations of numerical inequality due to exclusions during a female handball international tournament and to analyse the efficacy to relate these situations with the final performance. The outcomes of the present study show that these numerical inequality situations are principally located during the second part of the matches. Besides winner teams convert significantly more goals and show a lower percentage of throws out during these inequality situations.

In the PPGG 2015 approximately a quarter of the total playing time was played in an unequal numerical situation. This result is in line with previous studies made in Spanish handball league where 20% of the time teams played under numerical inequality situations (Gutierrez et al., 2010) and during the period 1982-2014 in European, World and Olympic finals matches where exclusions lasted 30% of the total game time (Pueo & Espina-Agullo, 2017). In the present study, the last five minutes of the second half (T6) presented a low number of situations under numerical inequality, meaning low number of exclusions as well. The majority of the exclusions were concentrated during the second part of the match, especially in the range from 40:00 to 54:59 minutes. This is consistent with previous studies in other team sports (Bar-eli, Tenenbaum, & Elbaz, 1990; Bar-Eli & Tractinsky, 2000; García-Martín et al., 2015), where the second part of the match was the most crucial. Sampaio et al. (2006) found that those moments appeared in the second half of a basketball match. These results are in agreement with studies made in handball where the number of exclusions increased in the second half of a match (Prieto et al., 2015; Pueo & Espina-Agullo, 2017). Application of rules (IHF, 2010) as well as psychological player´s crisis could explain these findings (Bar-Eli & Tractinsky, 2000). The scale of sanction may cause on players´ behaviour an increase of the expected and fair actions (Bar-eli et al., 1990). Thus, the players could tend to behave in a way that allow them to stay in court in order to maintain the equality in the number of players (Bar-eli et al., 1990).

Previous studies in another team sports, some of them including handball, reported that the goals scored in the first half had higher impact on the final score goal difference (Gómez et al., 2014; Lago-Peñas et al., 2013; Prieto, Gómez, & Sampaio, 2016) however in the present study it was found out that the last period of a handball match could be the most productive in terms of goals, going in line with previous research in handball (Oliveira et al., 2012) were winners were more efficient in the last minutes of each half.

Results in the present study show that winners scored more goals than losers while being in superiority. This coincides with previous researches in other team sports where winners' performance indicators are better than losers. In water polo winners shot more time than losers when they have an extra man (Escalante et al., 2011); goals achieved by the winner teams in water polo were considerably more as compared to the ones of the loser team (Platanou, 2004) and a statistic significant difference between winners and losers was found in all the coefficient of performance in teams with an extra man (Argudo, Ruiz, & Abraldes, 2010). In ice hockey, winners have better performance than losers while being in power play (5x4 and 5x3) even pulling the goalie out (Beaudoin & Swartz, 2010). Gutierrez et al., (2010) in their study of European and World Handball Championship between 2002 and 2004 found out that during inferiority situations losers present worst performance than winners. In handball, since the aim of the game for a team is to score more goals than the opponent, winners ends scoring more than losers. It

is then important to find out when, how and why winners score the most. Results of the research shows that winners scored more than losers during the periods of games that exclusions are sanctioned by referees. Therefore, winners are more effective than losers during those periods of the game, specially during superiority situations. They have the capacity to take more advantage of these situations in comparison to losers. This coincides with performances of teams at the Male Olympic Games 2008-2012 where winners perform better than losers while being in superiority (Pueo & Espina-Agullo, 2017). The characteristics of the players (Wagner et al., 2014); the improvement in shot efficacy and efficiency (Wagner & Müller, 2008; Aguilar-Martínez et al., 2012); the handle of the game time (Gomes, Volossovitch & Ferreira, 2014) and the tactical intention of throwing from the 6-meter line (Sierra-Guzman et al., 2015) can be considered the reasons why winners are more effective in superiority situations. Nevertheless, future studies should be focussed on the causes of increased efficacy observed in winner teams.

Throws out of target (shots that ended at posts or out of the target) showed a statistical significant relation among numerical inequalities. Losers playing under numerical superiority presented higher number of these actions during the games analysed. Shot efficiency relates goals with the total number of throws that a team makes (Gutierrez et al., 2010; Trejo & Planas, 2018). Shots out of target have then an impact in the shot efficiency. Losers team had more shots stopped by goalkeepers (Karastergios, Skandalis, Zapartidis, & Hatzimanouil, 2017) having a significant impact in their shot efficiency; losers in the present study showed that throwing out of target had a negative impact in their shot efficacy.

The efficacy was evaluated in the present study through AE and TE. Similarly to previous researches in handball, loser teams presented an AE and a TE less efficient than winner teams (Gutierrez et al., 2010). Generally, an AE below 50.0% is considered as low efficacy. Although both superiority (44.5%) and inferiority (24.8%) situations presented an AE low in losers female handball teams at the 2015 PPGG, the performance in situations of unequal numerical of inferiority was especially affected. This goes in line with the study of the Handball World Championship played in 2013 where results showed that efficacy during these numerical inequality situations could have a high influence on the likelihood to be the winner or loser team (Trejo & Planas, 2018).

Some limitations of this study are worth noting. Recordings did not allow seeing some actions, having to have them discarded. Only the best 4 teams of the tournament were analysed, having no data of the rest of the teams participating. Finally, actions taken by the defensive teams were not taken into account. Contextualising the studies (taking into account the difference in the score, the level of the opponent, the phase of the tournament, the type of defence, the offensive system used) should give more accurate information for coaches to prepare their players. Anyway, due to the lack of high quality studies, especially in female handball, more studies should be developed in order to confirm these results.

Conclusions

It can be concluded that the main number of numerical inequalities in an international female handball tournament occurs during the second part of the game, that may be related with the applications of the sanction´s scale of progression applied by referees.

Winner teams scored a higher percentage of goals and showed a lower percentage of throws out than loser teams. Winner teams showed a more efficient performance in their attack efficacy (number of goals scored in relation to the number of attacks) while playing in inferiority. Thus, coaches and technician in handball should take into account these findings to developed different strategies that allow them to achieve better goal scores in inequality situations. These strategies may go, for example, in order to prepare their teams how to perform in the different moments of the line-time of a match taking into account the exclusions impact between the first and second half of the match. It can also go in the way of taking into account which level of efficacy during exclusions their teams may achieve pursuing in reducing the possibility of losing a match (for example training in order to score more than 2 out of 10 attacks during inferiority may move teams away of being losers).

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Relation of Offensive Performance during Exclusions and Final Ranking in Female Handball

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Abstract: The aim of this study was to determine team offensive performance indicators during exclusions related to the final ranking obtained in the tournament. Twenty-nine matches from the 2017 Pan-American Female Championship played by 10 national teams were analyzed using observational methodology. Cramer's V and Fisher's exact test were applied to identify associations between the variables. The Chaid algorithm was used to identify performance variables during inequality situations associated with the final ranking. Results showed that teams ranked 1st to 3rd presented a statistically significant relationship ($p < 0.001$; ASR 5.2) of being in superiority, scoring on 56.8% of their finalizations, while teams ranked 7th to 10 th showed a tendency of ending their attacks in turnovers under inequality situations ($p < 0.00$; ASR 3.1). Playing with an empty net during inferiority situations was a predictor of winners belonging to the medalist teams in 76.2% of the analyzed situations. It can be concluded that during numerical superiority, the best-ranked teams better handled their possessions. The substitution of the goalkeeper for a court player during inferiority was a predictor of belonging to the medalist group. Playing with the goalkeeper in goal (playing 5 against 6) when the match status was balanced or unbalanced, was a predictor of losing teams that did not end up in the medalist groups.

Keywords: numerical inequality; empty net; offensive performance indicators; medalist; Pan-American handball

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1. Introduction

The development of team sports gains important income from game analysis, which is used to improve the training quality and tactical aspects of teams during the game [1]. Coaches adapt their training and match interventions taking data from the analysis performed into account [2]. Nevertheless, team sports performance indicators need to be contextualized [3] since the environment of performance, the characteristics of the tournament, the culture of sport, or the level of competition in different countries or regions may offer constraints or limitations to the player's performance [3].

Studies of performance indicators in handball have increased in the last decade [4]. Handball is a complex, multifactorial game, and it is difficult to identify factors that influence player and team performance [5]. The relation of performance to a team's final ranking has been studied in other team sports due to the relevance of knowing how best-ranked teams perform. In handball, Montoya and Anguera [6] determined that medallist teams in the 2008 Olympic Games (OG) finalized their attacks more frequently from the wings than low-ranked teams did. Oliveira et al. [7] stated that the home advantage effect at ASOBAL (the Spanish regular league) during the 2007/2008–2008/2009 seasons was higher (71%) when playing balanced teams (ranked at the same level) than when playing unbalanced teams (54%). The association between the save percentage of goalkeepers and the level of success in championships showed other approaches that researchers have made in this area [8]. Handball performance at the World Championships (WCh), OG, and continental tournaments (i.e., Asian and European) have been studied from different perspectives [1], a study of the variables influencing the final team ranking being one among them.

There are fewer studies on female handball compared to male handball, leading to less new knowledge in this area [9]. In this sense, research about anthropometric aspects [10,11]; injuries assessments [12,13]; the effect of relative age [14]; the position of the player's indicators [15,16]; throwing performance [17]; effects of training tasks upon performance [18–20] and match analysis [21,22] have been developed in recent years. Research about female Pan-American handball tournaments started to be recently carried out.

One of the game situations less studied in handball is the numerical inequality situation caused by exclusions, although exclusions and their consequences have been studied as a performance indicator in other team sports. Numerical inequality as a consequence of temporal or total exclusions of players and team performance during those game periods is a field of research in team sports. Temporal or total exclusion of a player occurs in handball under the circumstances described in Rules 8 and 16 of the International Handball Federation (IHF) Rules of the Game [23]. The 2017 Female Pan-American Handball Championship (2017 FPHCh) was the first tournament played in the Americas under the last change of the rules (applied for the first time at Rio 2016 OG). One of the main changes is expressed in Rule 4.1, which states that the goalkeeper can be substituted for a court player (if identified as one, wearing the same clothing as their teammates) at any time, as long as the requirements for substitutions, in general, are respected.

Thus, studying the situational context of the numerical relationship of players and the impact on the final result of a handball match may be relevant for both trainers and academics [24]. In this respect, some studies found a relationship between the number of fouls, exclusions, or red cards and the winning or losing of a game. However, not many studies have focused on analyzing the moments of the game where one of the two teams has a numerical inferiority of players [7]. In this sense, a recent study by Krahenbühl et al. [25] analyzed the effect of playing with an empty net during inferiority at the OG. Results of this study showed that 65% of the total attacks where the goalkeeper was changed for a field player were done in a numerical inferiority context, and 85 out of 98 of the total actions were registered in this numerical inequality context. Moreover, there was no statistical relationship between attack efficiency and changing (or not) the goalkeeper, nor between scoring a goal or not after a counterattack when playing with an empty net.

Assuming that this relationship between players could be relevant for training and game situations, it is important to study the relationship between performance during exclusions and the final ranking of teams in an elite female tournament. Therefore, the aims of the present study were (a) to determine team offensive performance indicators during exclusions in relation to the final classification achieved at the 2017 FPHCh, and (b) to analyze how teams from different ranking positions perform during offensive numerical inequality situations.

2. Methods

2.1. Sample

The sample consisted of 29 matches from the 2017 Pan-American Female Championship played by 10 national teams. In each game, all offensive sequences of the match carried out while at least one of the teams was under exclusion penalty were observed and registered. No offensive sequence was registered when both teams had the same number of court players (i.e., 6 × 6, 5 × 5, or 4 × 4). The offensive sequence has been defined according to aspects mentioned by Antúnez et al. [26]. Determined from the moment that one team regains or obtains possession of the ball (most of the times immediately after an exclusion is sanctioned) until either (a) the ball is lost because the opposite team regains possession, or (b) the team in possession of the ball gets to make a valid throwing, and immediately after must restart the game via a sideline or corner launch. No offensive sequence was studied once the 2-min suspension time ended.

2.2. Instrument

Observational methodology procedures used in sports research [27] were followed to register the actions. A mixed ad hoc instrument, modified from [28], consisted of a field format with category systems duly validated by five experts (all coaches with national team experience as well as 10 years experience as coaches at the club level). Criteria and their respective categories included exhaustiveness and mutual exclusivity into the category system. A total of 49 categorical cores and their corresponding register codes were generated (Table 1) and grouped into 7 criteria (team, game time, type of asymmetry, match status, game phase, offensive system, and finalization).

Table 1. Observational instrument.

Criterion	Category	Categorial Core
Team	BRA, ARG, PAR, URU, USA, PUR, CHI, DOM, COL, GUA.	In order of final ranking, from 1st to 10th: BRA: Brasil; ARG: Argentina; PAR: Paraguay; URU: Uruguay; USA: United States of America; PUR: Puerto Rico; CHI: Chile; DOM: Dominican Republic, COL: Colombia; GUA: Guatemala
Game Time	T1	Minute 0 a 9:59
	T2	Minute 10:00 a 25:59
	T3	Minute 26:00 a 30:00
	T4	Minute 30:01 a 39:59
	T5	Minute 40:00 a 54:59
	T6	Minute 55:00 a 60:00
	T7	First period of extra time
	T8	Second period of extra time
Match Status	≥5, 4, 3, 2 y 1	Observed team leads by 5 (or more), 4, 3, 2, or 1 goal
	0	Teams are tied at the moment the action is registered
	≤5, −4, −3,−2, −1	Observed team is behind in 5 (or more), 4, 3, 2 or 1 goal
Type of Asymmetry	6 × 5, 5 × 4, 6 × 4	Each of 3 types of numerical Superiority of 1 or 2 players.
	5 × 6, 4 × 5, 4 × 6	Each of 3 types of numerical Inferiority of 1 or 2 players.
	EN	Numerical equality with Empty Net
Game Phase	FB	Fast break attack (1st wave)
	CA	Counterattack (2nd and 3rd wave)
	PA	Positional attack
	7M	7M Throw

Table 1. *Cont.*

Criterion	Category	Categorial Core
Offensive System	3:3	3:3 with 1 pivot and 2 wings
	3:3 (2)	3:3 with 2 pivots and 1 wing
	2:4	2 back players, 2 wings, 2 pivots
	3:2	3 back players and 2 wings
	3:1:1	3 back players, 1 wing, 1 pivot
	NS	No System (counterattacks and 7M throws)
Finalization	G	Goal
	P	Throw on post
	S	Goalkeeper saves
	Out	Throw not goal (not post, not goalkeeper save)
	B	Blocked shot by a defense player
	GE	Goal and exclusion (in the same action)
	I	Defense player intercepts a pass
	BP	Error in passing the ball (not getting it past the defender)
	RTE	Regulatory or Technical error (attacking foul, double dribbling, steps, error while changing players, other sanctions)

2.3. Procedures

The research team reviewed the videos and collected data using the software Lince 1.2.1 [29]. Intra- and inter-observer reliability concordance was verified using Cohen's Kappa coefficient [30], registering values rated as very good ($K \geq 0.89$). The final position of the teams in the tournament (1 to 10) and final condition (winner, loser, draw) was directly inserted onto the registration sheet, being part of the studied variables. None of the matches ended in a draw.

For the study, 3 Ranking Groups were formed using the following criteria. Group I (GI): teams ranked 1st to 3rd; Group II (GII): teams ranked 4th to 6th; Group III (GIII): teams ranked 7th to 10th. Game time was grouped into two groups, based on previous studies which found critical moments of the game where exclusions occurred [24,31], i.e., critical moments (game time 2, 4, 5) and non-critical moments (game time 1, 3, 6). Match status was grouped into three groups: 2 goals (all actions registered when the difference in the score was 2 goals or less); 3–4 goals (all actions registered when the difference in the score was of 3 or 4 goals up or behind); 5 or more goals (when the difference in the score was 5 goals or more). The asymmetry was grouped into two types of asymmetry. Superiority (all actions registered when the numerical inequality was 6 against 5, 5 against 4, or 6 against 4), and inferiority (all actions registered when the goalkeeper was in goal and the numerical inequality was 5 against 6, 4 against 5, or 4 against 6 and playing with an empty net). Moreover, when analyzing only numerical inferiority, actions were grouped into 'with the goalkeeper in goal' (all actions registered when the goalkeeper was in goal and the numerical inequality was 5 against 6, 4 against 5, or 4 against 6) and empty net (all actions registered during inferiority and the observed team play with empty net). Finalizations were grouped into three groups: goal (goal and "goal and exclusion"); no goal (throw on post, goalkeeper save, blocked shots, throwing out the goal), and turnover (all finalizations not involving throwing).

Ethics principles established in the Helsinki Declaration [32] were followed. Neither examination nor informed consent was necessary since the study involved observing persons in a public environment. People and teams had no expectations (matches were streamed via television and the internet), and the researchers did not interfere with the teams studied.

2.4. Statistical Analysis

Deviation in normality was determined using the Kolmogorov-Smirnoff test. Crosstab commands were used to study the relationships (Pearson's chi-square test) between the

groups concerning final ranking (medalist and other 2 groups) and the type of numerical inequality and contextual indicators (final condition, finalization, type of play, system of play). Fisher's exact test (f) with the Monte Carlo method was applied when the Expected Frequency Distribution was lower than 5, or the count of cases in one cell was lower or equal to 5 [33]. To estimate effect sizes (ES), Cramer's V test was used. Adjusted Standardised Residual (ASR; critical value = 1.96 and $p = 0.05$) was used to determine which cross-section was responsible for the independence of the variables. Secondly, to identify the variables that best explain the teams' performance, an exhaustive CHAID (Chi-squared automatic interaction detection) classification tree analysis was used to determine the differences between the performance of the 3 groups of teams (medalist, best in their continent, last positioned) according to the temporal and contextual indicators. The SPSS v.25 for Mac software (IBM, Corp., Armonk, NY, United States) was used to perform the statistical analysis. Data were presented as frequencies and percentages. The confidence interval was set at 95%. A statistically significant relation was found when $p < 0.05$.

3. Results

3.1. Results during Numerical Inequality Context as a Consequence of Exclusions

During the 29 games of the tournament, 211 exclusions were sanctioned (an average of 7.3 exclusions per game), and a total of 812 actions were registered. Table 2 presents the frequency distribution of offensive situations under numerical inequality situations. A statistically significant relationship ($p < 0.01$) was found between final classification and type of asymmetry (superiority and inferiority), game outcome, finalization, partial difference in the score, phase of the game, and offensive system. GI and GII teams presented a statistically significant relationship ($p < 0.01$; ASR 5.0 and 2.6) when playing in superiority and GIII playing in inferiority ($p < 0.01$; ASR 7.1). A statically significant relationship ($p < 0.01$, ASR 3.0) was found between GIII teams and ending attacks in turnovers. GI teams tended to use 1st, 2nd, and 3rd wave counterattacks ($p < 0.01$; ASR 3.5 and 2. 2).

Table 2. Frequency distribution of offensive situations under inequality during the tournament.

	1st–3rd ***n* = 236**	**4th–6th** ***n* = 270**	**7th–10th** ***n* = 306**	**s.t.**	***p***	**ES**	**ESp**
Asymmetry				53.561	<0.001	0.26	<0.001
Superiority	163(69.1)	167(61.9)	121(39.5)				
ASR	5.0	2.6	−7.1				
Inferiority	73 (30.9)	103(38.1)	185(60.5)				
ASR	−5.0	−2.6	7.1				
Game outcome				202.504	<0.001	0.50	<0.001
Winner	204(86.4)	136(50.4)	76 (24.8)				
ASR	12.8	−0.3	−11.7				
Loser	32 (13.6)	134(49.6)	230(75.2)				
ASR	−12.8	0.3	11.7				
Finalization				36.038	<0.001	0.21(14)	<0.001
Goal	134(56.8)	113(41.9)	99 (32.4)				
ASR	5.2	−0.3	−4.6				
No goal	65 (27.5)	81 (30.0)	110(35.9)				
ASR	−1.6	−0.7	2.1				
Turnover	37 (15.7)	76 (28.1)	97 (31.7)				
ASR	−4.2	1.1	3.0				

Table 2. *Cont.*

	1st–3rd n = 236	4th–6th n = 270	7th–10th n = 306	s.t.	p	ES	ESp
Match status				36.392	<0.001	0.15	<0.001
2 goals	73 (30.9)	108(40.0)	62 (20.3)				
ASR	0.4	4.4	−4.7				
3–4 goals	25 (10.6)	43 (15.9)	36 (11.8)				
ASR	−1.2	1.9	−0.7				
5 or more goals	138(58.5)	119(44.1)	208(68.0)				
ASR	0.4	−5.4	4.8				
Game phase				36.591	<0.001	0.15	<0.001
Positional Attack	141(60.0)	185(68.5)	249(81.4)				
ASR	−4.4	−1.1	5.1				
1st wave	36 (15.3)	21 (7.8)	21 (6.9)				
ASR	3.5	−1.3	−2.1				
2nd and 3rd wave	28 (11.9)	25 (9.3)	16 (5.2)				
ASR	2.2	0.5	−2.6				
7 m	30 (12.8)	39 (14.4)	20 (6.5)				
ASR	1.0	2.2	−3.1				
Offensive system				38.057	<0.001	0.15	<0.001
3:3 1_Pivot	141(59.7)	139 (51.5)	171 (56.1)				
ASR	1.5	−1.7	0.2				
3:3 2 Pivots	3 (1.3)	13 (4.8)	11 (3.6)				
ASR	−2.1	1.7	0.3				
3:2 No Pivots	52 (22.0)	63 (23.3)	93 (30.5)				
ASR	−1.5	−1.1	2.5				
No system	39 (16.5)	41 (15.2)	19 (6.2)				
ASR	2.4	1.8	−4.0				
1 Pivot no wing	1 (0.4)	14 (5.2)	11 (3.6)				
ASR	−2.9	2.3	0.5				
Game time grouped				9.516	0.095	0.11	0.095
Periods 2,4,5	152 (64.4)	207 (76.7)	210 (70.1)				
Periods 1,3,6	84 (35.6)	63 (23.3)	96 (29.9)				

Data presented as absolute frequencies (percentage). n: absolute frequencies of actions registered for each ranking group; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact Test as applicable; p: p-value; ES: effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); ESp: p-value for Cramer's V; ASR: adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

3.2. Results during Superiority Situations

Table 3 presents frequency distribution during superiority situations. A statistically significant relationship was found between final classification and game outcome, finalization, match status, game time grouped ($p < 0.01$), and game phase ($p < 0.05$). GI national teams tended not to end in turnovers ($p < 0.01$; ASR −2.8). The attack efficacy (AE) decreased from GI to GIII (63.2%, 49.1%, and 41.3%), while turnovers increased from GI to GIII. GI teams tended to use direct counterattacks ($p < 0.01$; ASR 2.2), while GIII teams showed a tendency to use positional attacks ($p < 0.01$; ASR 3.4). GI national teams presented a statically significant relationship of using power plays in non-critical moments of the game ($p < 0.01$; ASR 2.6).

Table 3. Frequency distribution of offensive situations under superiority during the tournament.

	1st–3rd ***n* = 163**	**4th–6th** ***n* = 167**	**7th–10th** ***n* = 121**	**s.t.**	***p***	**ES**	**ESp**
Game outcome				68.234	<0.001	0.39	<0.001
Winner	139(85.3)	98(58.7)	46(38.0)				
ASR	7.4	−1.4	−6.6				
Loser	24 (14.7)	69(41.3)	75(62.0)				
ASR	−7.4	1.4	6.6				
Finalization				15.496	<0.005	0.13	<0.01
Goal	103(63.2)	82(49.1)	50(41.3)				
ASR	3.5	−1.0	−2.8				
No goal	39 (23.9)	47(28.1)	41(33.9)				
ASR	−1.5	0.0	1.6				
Turnover	21 (12.9)	38(22.8)	30(24.8)				
ASR	−2.8	1.2	1.6				
Match Status				20.578	<0.001	0.15	<0.001
2 goals	50 (30.7)	66(39.5)	24(19.8)				
ASR	−0.1	3.0	−3.1				
3–4 goals	15 (9.2)	29(17.4)	17(14.0)				
ASR	−2.0	1.8	0.2				
5 or more goals	98 (60.1)	72(43.1)	80(66.1)				
ASR	1.5	−4.0	2.8				
Game phase				15.060	<0.05	0.13	<0.05
Positional Attack	79 (48.8)	87(52.1)	83(68.6)				
ASR	−2.1	−1.1	3.4				
1st wave	27 (16.7)	18(10.8)	10 (8.3)				
ASR	2.2	−0.7	−1.6				
2nd and 3rd wave	26 (16.0)	25(15.0)	11 (9.1)				
ASR	1.0	0.6	−1.7				
7 m	30 (18.5)	37(22.2)	17(14.0)				
ASR	−0.1	1.5	−1.5				
Offensive system				11.619	0.081	0.11	0.081
1_Pivot	96 (58.9)	88(52.7)	75(62.0)				
3:3_2 Pivots	3 (1.8)	9 (5.4)	10 (8.3)				
3:2 No Pivots	29 (17.8)	31(18.6)	20(16.5)				
No system	35 (21.5)	39(23.4)	16(13.2)				
1Pivot_No wing	0 (0)	0 (0)	0 (0)				
Time period grouped				6.763	<0.05	0.12	<0.05
Periods 2,4,5	104(63.8)	126(75.4)	91(75.2)				
ASR	−2.6	1.5	1.1				
Periods 1,3,6	59 (36.2)	41 (24.6)	30(24.8)				
ASR	2.6	−1.5	−1.1				

Data presented as absolute frequencies (percentage)n: absolute frequencies of actions registered for each ranking group; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact Test as applicable; ES: Effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); Esp: *p*-value for Cramer's V; ASR: Adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

3.3. Results during Inferiority Situations

Frequency distribution in an inferiority context can be seen in Table 4. A statistically significant relationship ($p < 0.01$) was found between final classification and game outcome, offensive system, and inferiority disposition, with match status and game time grouped ($p < 0.05$). Teams grouped in GII showed a statistically significant relationship with suffering exclusions when the difference in the score was of 2 or fewer goals ($p < 0.01$; ASR 2.6; ASR 3.3), presenting a tendency of using a 3:2 offensive system with 1 pivot ($p < 0.01$; ASR

3.0). GI presented better AE and throwing efficacy (TE) than the other two groups. When analyzing the strategic use of the new rule, a statistically significant relationship ($p < 0.01$) was found between final classification and playing or not with an empty goal ($p < 0.001$; ES 0.41). In total, 84.2% of the attacks were played with the goalkeeper on the court and 15.8% with an empty net. GI teams decided to change the goalkeeper for a court player most often ($p < 0.01$; ASR 7.7). In this respect, it is important to mention that only the teams ranked 1st and 2nd (Brazil and Argentina) opted to play with an empty net.

Table 4. Frequency distribution of offensive situations under inferiority during the tournament.

	1st–3rd ***n* = 73**	**4th–6th** ***n* = 103**	**7th–10th** ***n* = 185**	**s.t.**	**ES**	***p***	**ESp**
Game outcome				119.306	0.55	<0.001	<0.001
Winner	65 (89.0)	38 (36.9)	30 (16.2)				
ASR	10.4	0.0	−8.3				
Loser	8 (11.0)	65 (63.1)	155 (83.8)				
ASR	−10.4	0.0	8.3				
Finalization				8.390	0.11	0.078	0.078
Goal	31 (42.5)	31 (30.1)	49 (26.5)				
No goal	26 (35.6)	34 (33.0)	69 (37.3)				
Turnover	16 (21.9)	38 (36.9)	67 (36.2)				
Offensive system				20.098	0.18	<0.01	<0.01
3:3 1_Pivot	45 (61.6)	51 (49.5)	96 (52.2)				
ASR	1.6	−0.9	−0.5				
3:3 2 Pivots	0 (0.0)	4 (3.9)	1 (0.5)				
ASR	−1.1	2.6	−1.4				
3:2 No Pivots	23 (31.5)	32 (31.1)	73 (39.7)				
ASR	−0.8	−1.1	1.7				
No system	4 (5.5)	2 (1.9)	3 (1.6)				
ASR	1.8	−0.4	−1.1				
1 Pivot No wing	1 (1.4)	14 (13.6)	11 (6.0)				
ASR	−2.2	3.0	−0.9				
Partial difference				17.152	0.15	<0.05	<0.05
2 goals	23 (31.5)	42 (40.8)	38 (20.5)				
ASR	0.6	3.3	−3.4				
3–4 goals	10 (13.7)	14 (13.6)	19 (10.3)				
ASR	0.5	0.6	−1.0				
5 or more goals	40 (54.8)	47 (45.6)	128 (69.2)				
ASR	−0.9	−3.4	3.8				
Game phase				10.042	0.12	0.084	0.084
Positional Attack	62 (84.9)	98 (95.1)	166 (89.7)				
Direct counterattack	9 (12.3)	3 (2.9)	11 (5.9)				
2nd and 3rd wave	2 (2.7)	0 (0.0)	5 (2.7)				
7 m	0 (0.0)	2 (1.9)	3 (1.6)				
Time period grouped				6.675	0.14	<0.05	<0.05
Periods 2,4,5	48 (65.8)	81 (78.6)	119 (64.3)				
ASR	−0.6	2.6	−1.8				
Periods 1,3,6	25 (34.2)	22 (21.4)	66 (35.7)				
ASR	0.6	−2.6	1.8				

Table 4. *Cont.*

	1st–3rd $n = 73$	4th–6th $n = 103$	7th–10th $n = 185$	s.t.	ES	p	ESp
Inferiority disposition				60.307	0.41	<0.001	<0.001
With goalkeeper	40 (54.8)	97 (94.2)	167 (90.3)				
ASR	−7.7	3.3	3.2				
Empty net	33 (45.2)	6 (5.8)	18 (9.7)				
ASR	7.7	−3.3	−3.2				

Data presented as absolute frequencies (percentage). n: absolute frequencies of actions registered for each ranking group; s.t.: statistical test value for the Pearson Chi-Square Test or Fisher's Exact Test as applicable; ES: Effect size (Cramer's V for asymmetric tables and Contingency coefficient for symmetric tables); Esp: p-value for Cramer's V; ASR: adjusted standardized residual, calculated only for those variables that presented a statistically significant relationship ($p < 0.05$).

Figure 1 presents a decision tree using the exhaustive CHAID algorithm to predict offensive performance during exclusions related to the final ranking. The dependent variable was Ranking (GI, GII, and GIII). Independent variables were the game outcome, critical periods of the game, offensive system, asymmetries grouped, partial difference in the score, phase of the game, and finalizations. The model obtained explained 58.3% of the variance (estimated risk of 0.42; SD 0.02), estimating 78.0% for GI, 67.6% for GIII, and 30.4% for GII. Node 1 predicts winners belonging to GI at 49.0%, while Node 2 predicts losers belonging to GIII at 58.1%. Node 4 shows that playing with an empty net during inferiority situations predicts winners belonging to GI. Node 5 shows that playing under numerical inequality (superiority or inferiority) when the difference in the score is of more than 5 goals predicts being ranked in GIII. In contrast, node 9 shows that in a context of 4 goals (for or against), playing at inferiority with an empty net, and having superiority situations (that is to say that rivals suffered exclusions), is a predictor of belonging to GII. Node 10 notes that in the context of a difference in the score, playing in inferiority situations with the goalkeeper in goal is a predictor of losers belonging to GIII.

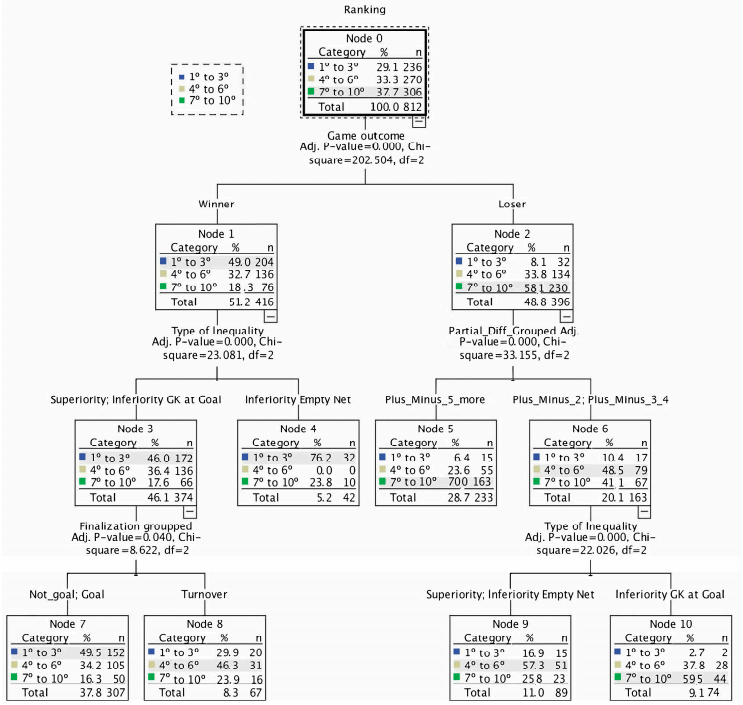

Figure 1. Decision tree using the exhaustive CHAID algorithm to predict the offensive performance during exclusions according to the final ranking.

4. Discussion

4.1. General

A total of 812 actions were registered during the 211 sanctioned exclusions during the tournament (an average of 7.3 exclusions per game). Almost a quarter of the total game time (around 15 min) was played under numerical inequality situations. These results are similar to the 7.9 exclusions per game at the female OG [34] and the 7.6 exclusions per game found at the 2015 female Pan-American Games (PPGG) [31]. They are similar to results found at the male elite international level, where almost 30.0% of the game time is played under exclusions [34]. Two reasons may explain this fact. One could be that female handball defense is "less aggressive" than male defense. The other could be that, based on the fact that referees at male and female championships are not always the same, the criterion used might be different.

4.2. Exclusion as Indicator

A total of 56.8% of the total actions occurred during superiority, and 43.2% during inferiority. The main reason for this appeared to be regulatory. Rules 2 and 13 in Rules of the Game state that when a 2 min or a disqualification is sanctioned, referees must call for a timeout, and the opposing team that receives the exclusion may restart the game with a free throw [23]. This means that the team restarting the game (the one that benefited from the exclusion of its opponent) will register the first finalization of the period of asymmetry. Therefore, since the number of actions in inferiority increased from GI to GIII, it can be said that the number of exclusions also increased from the group of top-ranked teams compared to the group at the bottom, coinciding with the performance of winning and losing women teams at the 2004 to 2016 OG [35] and 2007 to 2017 female WCh [22]. Exclusions and dismissals are associated with psychological players' crises in the competition context [36]. Indeed, players tend to behave in a way that does not lead to an exclusion in equal games [36,37]. Since GIII teams registered a tendency to lose, it can be argued that the reason those teams received more exclusions may be due to being disadvantaged during the games. This is sustained (in comparison to GI) by registering more finalizations when the difference in the score was 5 or more goals (an unequal game context).

4.3. Context of Superiority

AE is one of the performance indicators used to compare and explain performance in handball. The studied teams ranked 1 to 8 in the all-male OG, WCh, and European Championships between 2004 and 2010 presented an AE mean of 50.9% per game for the entire match [1]. Since attacking in superiority can be linked to having the possible advantage of overcoming the opposition, having found that teams of GI at the 2017 FPHCh had an AE of 63.2% can be considered similar to the elite international level. To win in a handball game, teams should create situations where the possibility of scoring is facilitated. A temporal numerical advantage in the number of players is undoubtedly an advantage. Should a team want to win a game, it may also perform better than the opponent in those temporal moments. The CHAID study showed that ranging between 1st to 7th (GI and GII) is predicted when winners play under superiority conditions; therefore, winners in those groups may have a better AE (better performance) than losers. This coincides with studies in this context concerning a numerical advantage of players at the Serbia 2013 women's WCh [28] and the Toronto 2015 Female Handball PPGG [31]. However, it is notable that the AE during superiority in the present study had a statistically significant relationship with the final ranking, not coinciding with results in Serbia 2013 [28]. The characteristics of the players [5], the improvement in TE through the impact of programs focused on the enhancement of strength [38], game time handling [39], and the tactical intention of throwing from the 6-m line [40] are the possible aspects that determine winners more effective performance during temporal superiority situations. Nevertheless, future research might target the specific reasons for the increased efficacy observed in the winning teams. Gruic et al. [41] found the impact of turnovers as a predictor of performance in

male handball. Following this line, it was found that teams of GIII doubled the percentage of turnovers of GI teams. Technical-regulatory errors in the attack may be caused by deficiencies in the players' abilities (especially of the back-court players who are in charge of organizing the game in all phases, and also those most in contact with the ball) or by the high-quality either of defensive players or defensive systems. During the context of superiority in offensive situations, the skills of players of the attacking team should be more relevant than the opposition. Therefore it is possible to state that GIII teams (the lowest quality of the tournament, reflected in their final score differences in all games) made many mistakes during their attacks while having superiority, mainly because their players may not be good enough to handle possessions ending with a throw. The fact that GIII teams have less experienced players (or at least some who haven't participated in youth and junior WCh) may also explain the performance in this context since expert players are better at predicting and anticipating responses during game situations.

4.4. Context of Inferiority

The offensive performance of teams that suffered an exclusion tends to be negatively influenced, creating difficulties in scoring goals and impacting their AE [24]. Despite the fact that results in the present research have not presented a statistically significant relationship between AE and final ranking, the differences in the AE were very important, with GI teams performing similarly to the top 6 teams ranked in the Serbia 2013 WCh [28]. It is relevant to mention that GII and III teams ended in turnover 36.9% and 36.2% of their attacks (while GI teams presented 21.9% of turnovers), concurring with the performance of losing teams during the 2007 to 2017 female WCh [22]. Match status is a game context introduced into performance analysis as another important situational variable. Results from the 2017 FPHCh suggest that playing in a context of inferiority and keeping the goalkeeper in goal when the match status was balanced or moderate was a predictor of losing teams ending in GII or GIII. It appears that strategic behavior was affected by match status, leading the teams to not take risks when match status was moderate or balanced. Since 2016, the opportunity has existed to equalize (or even reduce) the numerical inequality suffered after exclusions, through playing with an empty net and with all players wearing the same clothing as their teammates. In this respect, Brazil and Argentina made an important change in Pan-America since they played almost 50% of their inferiorities with an empty net, in contrast to results at the PPGG 2015, where in none of the attacks was the goalkeeper substituted [31]. This important percentage of use of the rule by Brazil is sustained by Brazilian elite coaches who stated that during exclusions they mainly use a court player substituted for the goalkeeper to play in numerical equality [42]. Since a statistically significant relationship was found between using or not using this strategic rule change and final ranking, this tactical decision taken by national coaches may have influenced the final position of Brazil and Argentina at the top of the ranking. The fact that less than a fifth of the total offensive actions registered were played with an empty net differs from results presented at 8 games in the knockout phase of the male 2016 OG, where 85 out of 98 finalizations during an inferiority context were played with an empty net [25]. The reason for this difference is stated by coaches, who stated that the male teams had used the rule more than the female [42]. However, the significant difference in the attack efficacy of medalist teams and those ranked in the last 4 found in this study (42.5% and 26.5%, respectively) do not coincide with results from the best 8 male teams at Rio 2016 [25]. The decision to use this strategy verifies the importance stated by coaches to maintaining numerical equality in court players (even taking the risk of leaving the empty net), showing interest in the offensive game structure and the development of individual and collective actions [43].

5. Conclusions

In conclusion, during the 2017 FPHCh, finalizations under a superiority context predicted GI team inclusion. Indeed, GI teams tended to score in most of their finalizations

and used 1st wave counterattacks with statistically significant frequency. Substituting the goalkeeper for a court player in an inferiority context (playing 6 against 6 with an empty net) was a predictor of belonging to GI, while playing with the goalkeeper in goal (playing 5 against 6) when the match status was balanced or moderate, predicted the loser teams ending up in GII or GIII. This information is likely to be used by coaches as they plan specific tasks accounting for indicators presented here, especially when training to play with an empty net during inferiority situations, as teams tend to have a better AE when using this strategy.

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Analysis of offensive performance during exclusions in female senior handball

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1º CONGRESSO BRASILEIRO DOS JOGOS ESPORTIVOS COLETIVOS

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CERTIFICADO

CERTIFICAMOS QUE O TRABALHO INTITULADO **"ANÁLISIS DEL RENDIMIENTO OFENSIVO EM SITUACIONES DE DESIGUALDAD NUMÉRICA EM BALONMANO FEMENINO EM RIO 2016"**, DOS AUTORES **ALEJANDRO TREJO, MATÍAS DE PABLO, LUCÍA ALVAREZ** E **JAVIER BRAZO-SAYAVERA** FOI APRESENTADO COMO **PÔSTER** NO **1º CONGRESSO BRASILEIRO DOS JOGOS ESPORTIVOS COLETIVOS – 1CBJEC**, OCORRIDO NOS DIAS 19, 20 E 21 DE OUTUBRO DE 2018, NO CENTRO UNIVERSITÁRIO ESTÁCIO DE BRASÍLIA, COM CARGA HORÁRIA DE **30 HORAS**.

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Alejandro Trejo

Opatija, Croatia

September 19 – 23 2

Chairman of Organizing Committee

Prof. Tomislav Krističević, PhD

II CONGRESO INTERNACIONAL DE BALONMANO

Innovación e Investigación en el Entrenamiento y la Competición desde la Etapa Formativa

CERTIFICADO

El Comité Científico del Congreso Internacional de Balonmano informa que la comunicación titulada:

PERFORMANCE ANALYSIS DURING EXCLUSIONS ACCORDING TO THE FINAL POSITION AT THE 2017 PANAMERICAN FEMALE CHAMPIONSHIP

cuyos autores son:

Trejo, A., Camacho-Cardenosa, A.; Camacho-Cardenosa, M.; Brazo-Sayavera, J.

ha sido presentada dentro del programa del 2do CONGRESO INTERNACIONAL DE BALONMANO, "Innovación e Investigación en el Entrenamiento y la Competición desde la Etapa Formativa", organizado por el Grupo de Optimización del Entrenamiento y el Rendimiento Deportivo (GOERD) de la Universidad de Extremadura y la Federación Extremeña de Balonmano. En este congreso colaboran la Facultad de Ciencias del Deporte y el Departamento de Didáctica de la Expresión Musical, Plástica y Corporal de la Universidad de Extremadura.

En Cáceres, a 28 de noviembre de 2019

Benito González García
Presidente de la Federación Extremeña de Balonmano

María de las Mercedes Macías García
Decana de la Facultad de Ciencias del Deporte

Javier García-Rubio
Secretario del Comité Científico

Patrocinan: DIPUTACIÓN DE CÁCERES

Colaboran: SAFYDE Universidad de Extremadura

24th annual Congress of the
EUROPEAN COLLEGE OF SPORT SCIENCE
UNITING THE WORLD THROUGH SPORT SCIENCE
3rd - 6th July 2019, Prague - Czech Republic
Hosted by: Charles University Prague - Venue: Prague Congress Centre

EUROPEAN COLLEGE OF SPORT SCIENCE

Feldblumenweg 26
50858 Cologne

GERMANY

VAT-ID: DE251715668 - St.Nr.: 223/5905/0216
register of associations: VR12508

Prague, 17.07.2019 - 22:48:25

Confirmation of Presentation

This is to certify that the following title has been presented at the 24th Annual Congress of the European College of Sport Science between 3 - 6 July 2019 in Prague - Czech Republic.

Alejandro Trejo

UDELAR-ISEF; IUACJ
Juan de Dios Peza 2037 / 1
11400 Montevideo, Uruguay

Abstr.-ID: 1356, Presentation format: CP-poster , Session name: CP-PM18 - Team sports
Title: Performance during exclusions in female handball: results from the 2017 Panamerican Championship
Authors: Trejo, A.1, Camacho-Cardenosa, M.2, Camacho-Cardenosa, A.2, Brazo-Sayavera, J.3
Institution: 1 Universidad de la República-ISEF; IUACJ. Uruguay. 2 Faculty of Sport Sciences. University of Extremadura. Spain. 3 Universidad de la República-ISEF. Uruguay
Presentation date: 05.07.2019, 13:30, Lecture room: South Hall 2B , No: 3

Faculty of Physical Education and Sport, Charles University

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CERTIFICATE OF ACCEPTANCE

This is to certify that the paper from

“ Alejandro Trejo ”

has been accepted for presentation on

Asia-Pacific Conference of Performance Analysis of Sport 2019

Executive Committee

Koh Sasaki, PhD

佐々木康

CERTIFICATE OF ATTENDANCE

This is to certify that

"Alejandro Trejo "

Participated in the

Asia-Pacific Conference of Performance Analysis of Sport 2019

From 14 to 17 October 2019

Executive Committee

Koh Sasaki, PhD

佐々木康

Friday, 24 February 2023

Confirmation of Participation and Presentation

To whom it may concern,

Alejandro Trejo attended the 25th annual Congress of the ECSS held virtually, (28 - 30 October 2020) and the oral presentation submitted

"PERFORMANCE ANALYSIS DURING EXCLUSIONS IN FEMALE HANDBALL ACCORDING TO THE FINAL RANKING AT RIO 2016 OLYMPIC GAMES"

was accepted and presented.

Yours sincerely,

Thomas Giel
Managing Director

European College of Sport Science
Thomas Delaveaux, Executive Director, Aachener Strasse 1053-1055, 50858 Cologne, Germany
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VAT-ID: DE251715668 - St.Nr.: 223/5905/0216
register of associations: VR12508

Cologne, 10.09.2021 - 14:43:30

Confirmation of Presentation

This is to certify that the following title has been presented at the 26th Annual Congress of the European College of Sport Science between 8 - 10 September 2021.

Alejandro Trejo

UDELAR-ISEF; IUACJ
Juan de Dios Peza 2037 / 1
11400 Montevideo, Uruguay

Abstr.-ID: 609, Presentation format: Oral , Session name: OP-AP07 - Statistics and Analyses of Sports
Title: Multivariate analysis of female handball offensive performance during exclusions at the Euro 2018
Authors: Trejo, A.1, Gómez Ruano, M.2, Brazo Sayavera, J.3
Institution: <1> UDELAR-ISEF and IUACJ; <2> Universidad Politécnica de Madrid; <3> Universidad Pablo de Olavide
Presentation date: 11.09.2021, 00:00, Lecture room: -Track 4, No: 8

European College of Sport Science

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ISPAS IACSS ComputerScienceSport

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CERTIFICATE OF ORAL PRESENTATION

This certificate was awarded to certify the presentation of

"Multivariate analysis of female handball at Rio 2016 during exclusions"

Alejandro Trejo-Silva

at the 9th International Performance Analysis Workshop and Conference & 5th IACSS Conference, organised by the University of Vienna, held online, on the 30th and 31st of August 2021

This is given on 1st of September, by

Arnold Baca
President of the Conference and
Head of the Centre for
Sport Science and University Sports–University of Vienna

QUALISYS

hudl

SIMI reality motion systems