Rev Bras Ciênc Esporte. 2017;39(4):398–407

Revista Brasileira de
CIÊNCIAS DO ESPORTE

www.rbceonline.org.br

ORIGINAL ARTICLE

Development and evaluation of an observational system for goalball match analysis

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Received 1 April 2016; accepted 9 August 2016
Available online 13 September 2016

KEYWORDS
Performance indicators;
Sport performance;
Paralympic team sports;
Visual impairment

Abstract Our purpose was to develop and evaluate an observational system for goalball match analysis. We used a non-participant systematic game observation method including eight elite games, video recorded, and randomly chosen. Observational categories and performance indicators were determined for each offensive (i.e., ball control, attack preparation, and throwing) and defensive principles (i.e., defensive balance, throw reading, and blocking). The comprehensive method of development and the ideal reliability levels (kappa coefficient of 0.81–1.00) of this protocol ensure the generation of quantitative and qualitative information for players and coaches and the rigor required for scientific use.

PALAVRAS-CHAVE
Indicadores de performance;
Desempenho esportivo;
Esporte coletivo paralímpico;
Deficiência visual

Desenvolvimento e avaliação de um sistema de observação para análise do jogo de goalball

Resumo Nosso objetivo foi desenvolver e avaliar um sistema de observação para análise do jogo no goalball. Foi usado um método de observação sistemática não participante, incluindo vídeos de oito jogos de elite escolhidos aleatoriamente. Categorias de observação e indicadores de desempenho foram determinadas para cada princípio ofensivo (i.e., controle de bola, preparação do ataque e efetivação do arremesso) e defensivo (i.e., balanço defensivo, leitura da trajetória e interceptação do arremesso). O abrangente método de desenvolvimento

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http://dx.doi.org/10.1016/j.rbce.2016.08.002

e os níveis de confiabilidade ideais (coeficiente kappa de 0,81-1,00) desse protocolo asseguram a geração de informações quantitativas e qualitativas para jogadores e treinadores e o rigor necessário para uso científico.

PALABRAS CLAVE
Indicadores de rendimiento;
Rendimiento deportivo;
Deporte de equipo paralímpico;
Deficiencia visual

Desarrollo y evaluación de un sistema de observación para el análisis del juego del *goalball*

Resumen Nuestro objetivo fue desarrollar y evaluar un sistema de observación para el análisis del juego del *goalball*. Se utilizó un método de observación sistemática no participante, que incluía vídeos de ocho juegos de élite elegidos al azar. Se determinaron las categorías de observación y los indicadores de rendimiento de cada principio ofensivo (p.ej., control del balón, preparación del ataque y lanzamiento) y defensivo (p.ej., equilibrio defensivo, lectura de la trayectoria e interceptación del lanzamiento). El método completo del desarrollo y los niveles de fiabilidad ideales (coeficiente kappa de 0,81 a 1,00) del presente protocolo aseguran la generación de información cuantitativa y cualitativa para jugadores y entrenadores, y el rigor necesario para el uso científico.

Introduction

In the context of team sports, researchers have assumed its inherent complexity and instability, acknowledging them as systems and broadened the research focus to the logic of the game and its patterns (Bar-Yam, 2003; McGarry et al., 2002; Reed and Hughes, 2006; Travassos et al., 2013). This trend presupposes the creation of models able to characterize: the relation between the quantities and qualities of the game actions, the organization of the game, the types of sequences that generate positive or negative results, the scenarios or geometry of the game in the evolution of teams in space and time, the interactions or co-adaptation between attackers and defenders (Barris and Button, 2008; Duarte et al., 2012; McGarry, 2009; Passos et al., 2013; Vilar et al., 2012).

Research regarding Paralympic team sports, still in its embryonic stage, has not consistently addressed this trend of match analysis to adapted sports, such as wheelchair basketball (Gómez et al., 2014; Wang et al., 2005), ice sledge hockey (Molik et al., 2012), and also goalball (Amorim et al., 2010; Mora, 1993). Goalball is a non-territorial invasion team sport created exclusively for people with visual impairment, which is based on hearing (ball with bells inside) and tactile (raised lines) clues. In this sport, two team with three athletes each stay positioned in the opposite end sides of a court with dimension similar to a volleyball court (18 m × 9 m), divided into two halves by a center line. From a restricted area, the attacking team throws a ball along the floor toward the opponent's goal. The defending team, positioned in an area with tactile markings, tries to block the thrown ball, usually by sliding on the floor (Gulick and Malone, 2011).

Assuming the complexity of team sports, Morato et al. (2012) identified the self-organizing cycle of goalball teams by using systematic video observation of an elite competition. These authors presented three principles each in the offensive (ball control, attack preparation and throwing) and defensive (defensive balance, throw reading and blocking) dimensions. While Team 1 attempts to control the ball after intercepting the throw by Team 2, the latter assumes a defensive balance, that is, the team returns to its tactical system and is attracted by the origin of the opponent throw to reconfigure itself, while moving as a block to rationally occupy the court (Fig. 1). As Team 1 controls the ball, it continues preparing its attack in order to throw the ball. Team 2 is still focusing on the defensive balance principle, changing the focus to read the throw as soon as the Team 1 thrower starts the run-up to throw the ball. When the attacker releases the ball, Team 2 will interpret the throw, defining its trajectory and categorizing it under time pressure in order to intercept it effectively. After intercepting the throw, Team 2 controls the ball and prepares the next attack while Team 1 moves from the offensive to the defensive dimension, focusing on the defensive principles until the thrown ball is recovered (see Video 1).

Thus, a game sequence includes one team's configuration to comply with the offensive principles, the configuration of the opponent team to comply with the defensive principles in response to the other team's attack, and the outcome of this interaction. The set of game sequences represents the goalball game, meaning the history of relations between the teams' opposite dimensions (Morato et al., 2012).

Based on the offensive and defensive principles of goalball, our purpose was to develop and evaluate an observational system for goalball match analysis.

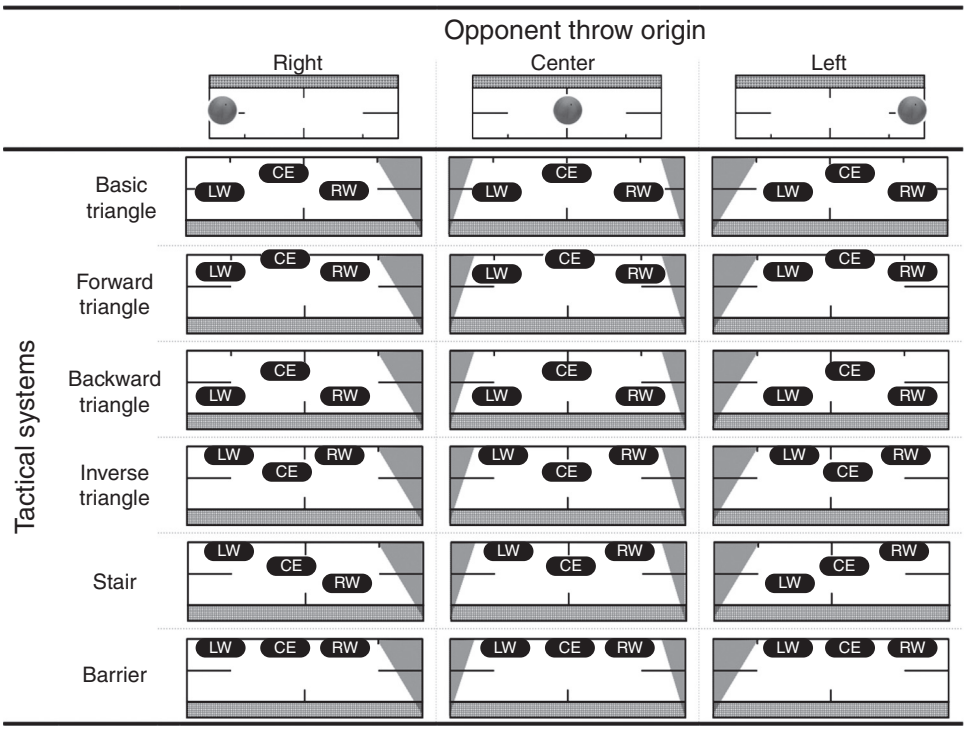

Figure 1 Rational court occupation in different tactical systems. White areas represent spaces to be occupied, and gray areas represent less dangerous areas for each opponent throw origin. *Legend*: LW, left wing; CE, central; RW, right wing. Adapted from Morato et al. (2012).

Methods

In this study, we used a non-participant systematic game observation method (Anguera, 1999; Thomas et al., 2011). Some basic principles should be followed in this method: elaborating an ad hoc instrument to record the categories and indicators that are considered fundamental in the theoretical and specific practical framework, preparing expert observers, preserving the spontaneity of the system observed, focusing on the actual game/competition situation, and maintaining the temporal continuity, so that the patterns can be found amidst changeable and random behaviors (Anguera and Hernández-Mendo, 2014). The study was conducted according to the Declaration of Helsinki and the research project was reviewed and approved with no restrictions by an institutional ethics committee.

Goalball match analysis instrument elaboration

The observational system is a basic match analysis instrument. The observer should elaborate it based on the reality distinguished in his conception of the game and the theoretical framework this reality is based on, attempting to answer questions about: who, when, where and how the actions are executed (Hughes and Bartlett, 2002; Wright et al., 2014). The categories formulated should be exhaustive (need to classify all actions of the game) and mutually exclusive (each action should refer to only one of the indicators per category) (Anguera and Hernández-Mendo, 2014).

Therefore, Anguera and Hernández-Mendo (2013) consider that it is fundamental to dedicate great time to the creation, reformulation and establishment of each model, with a view to covering the full spectrum of constraints the observer considers fundamental. These authors suggest non-systematic, exploratory observation sessions before starting a systematic study, aiming to delimit the research problem; elaborating the ad hoc instrument; training of the observers to reduce the occurrence of future errors; and collecting information for decision making about the research planning.

In that sense, departing from the conception of the goalball game proposed by Morato et al. (2012), the three offensive (ball control, attack preparation and throwing) and three defensive principles (defensive balance, throw reading and blocking) were adopted as the structural criteria of our observational system. Therefore, we observed eight goalball games video recorded and randomly chosen from the IBSA World Games 2007.

While observing the games, an open list of team conducts was elaborated while performing each principle. Each principle was observed exhaustively, that is, until perceiving that all possible situations that represented the performance indicators had been listed. After observing one principle, the next was observed until obtaining a list of events for each of the six principles. With the list of performance indicators for each principle in hand, a thematic grouping process was started, representing the identification of the observational categories.

The next step was to present the match analysis protocol, with its observational categories and respective

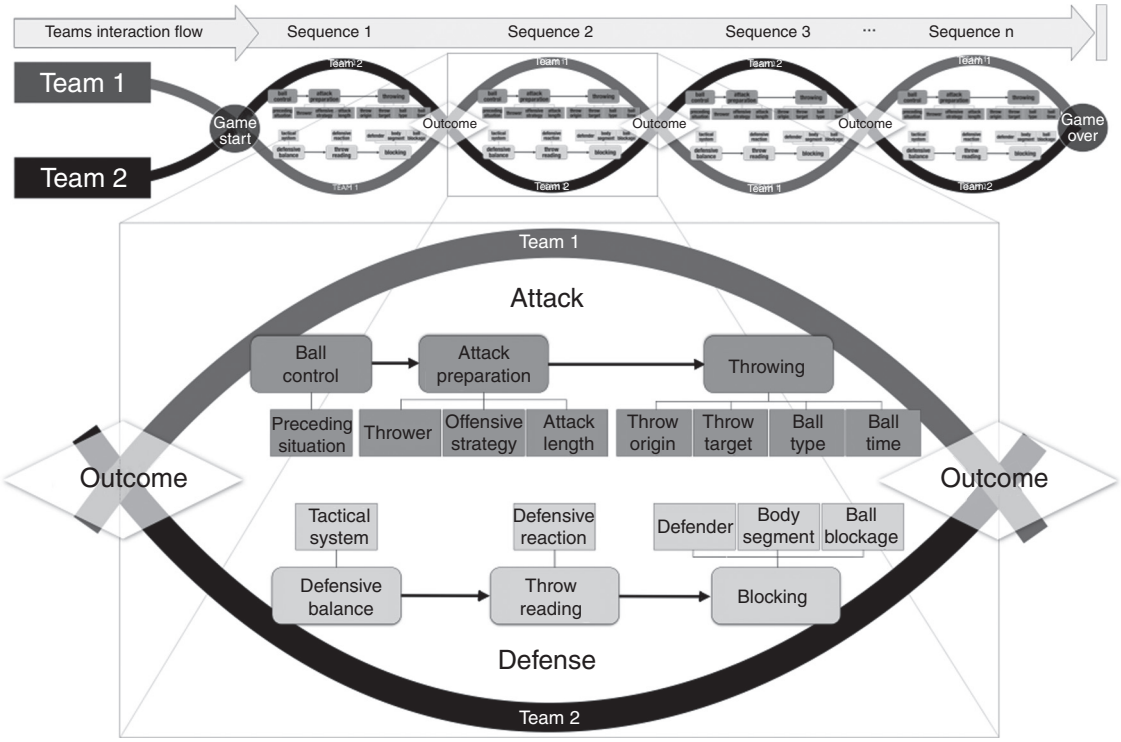

Figure 2 The graphic representation of a goalball game. The upper part displays a macro-view of a goalball game represented by the teams interaction. The lower part presents one game sequence and the proposed observational categories of the offensive and defensive principles.

performance indicators, to four experienced coaches (all having at least 6 years of coaching club teams; two of them coaching national teams). Performance indicators were discussed and the selected items were included in the protocol. Following, clear operational definitions were established and agreed upon by the coaches involved in the process (Wright et al., 2014).

Reliability assessment

Two expert observers (more than 2 years of experience as referees and goalball coaches) went through a learning process of the instrument. Initially, they received a protocol with the observational categories and their performance indicators. Next, two supervised training sessions were performed on different days for the identification of the different indicators per categories in the recorded images and the practical application of the data recording by completing the ad hoc instrument, elaborated in an electronic worksheet. As doubts emerged during the training, the observers returned to the protocol to reach a consensus. The training terminated after solving the doubts.

After the training, the observers started the video analysis of two randomly selected goalball games from the Beijing 2008 Paralympic Games. This represented a sample of 314 game sequences (attack/defense/results). The second observation of the games took place 15 days after the end of the first. We calculated the inter and intra-rater reliability by using Cohen's Kappa coefficient (Fleiss et al., 2013).

Results

In Fig. 2, we show the graphic representation of a goalball game. This model results from the systematic observation process of the offensive (ball control, attack preparation and throwing) and defensive principles (defensive balance, throw reading and blocking) of goalball.

Based on this goalball game model, at least one observational category with the respective performance indicators was obtained for each principle (see Tables 1–3).

The reliability (Kappa) coefficients of the proposed model are presented in Table 4.

Discussion

In this study we developed and evaluated an observational system for goalball match analysis. The observed categories and the performance indicators proposed in the instrument represent all possible actions available in the goalball game (exhaustiveness) for each of the offensive and defensive principles included in the model. Each game situation was categorized by a single indicator (mutual exclusivity), reducing any observation bias (Anguera and Hernández-Mendo, 2014). This can be observed in the Kappa coefficients, as demonstrated in Table 4, ensuring that the instrument is rigorous enough for scientific use. For all observational categories, the intra and inter-rater reliability assessment showed high agreement levels between 0.81 and 1.00 (Fleiss et al., 2013; Lames and McGarry, 2007).

Table 1 Offensive principles to goalball match analysis: observational categories, performance indicators and its description.

Principles	
Observational categories	
Performance indicators	
Ball control	
Attacking team: Team that recovers the ball	
Three-letter initials of the country	
Preceding situation: Link with the previous game sequence to indicate how the team conquered the ball possession	
RB:	Received ball from the main referee at the beginning of the first or second half of the game
DE:	Defense of opponent throw
OU:	Out side throw
BO:	Block out
IN:	Infraction by the opponent
PE:	Penalty by the opponent
DP:	Defense of penalty shot
GA:	Goal against
TTO:	Team time out
OTO:	Official time out
SUB:	Substitution
Attack preparation	
Thrower: Identification of the player performing the attack	
1–9:	Jersey number
LW:	Left wing
CE:	Center
RW:	Right wing
Offensive strategy: The strategy the attacking team uses for the throw	
RE:	Regular: player throws the ball from the same or surrounding sector in which (s)he defended or received a pass. For example, if (s)he defended the throw in sector 2, the throw from sector 1, 2 or 3 is considered regular (see Fig. 3)
FL:	Fluctuation: player defends the ball or receives a pass and, before throwing, changes the sector beyond the neighboring sectors. Example: (s)he defended in sector 2 and throw from 4, 5 or 6 (see Fig. 3)
DB:	Delivered ball pass: attacker receives a hand-to-hand passing before throwing
SP:	Set piece: organized and practiced move, other than FL and DB.
CA:	Counter-attack: attack is performed within four seconds after defense
QA:	Quick attack: subsequent to an interruption, attack is performed within two seconds after referee calls ''quiet please, play''
SB:	Safety ball: when the player throws the ball so as not to commit penalties or to prioritize the defensive balance
SL:	Slow ball: strategy used at the final moments of the games by the leading teams to spend the game time left
Attack length: Time the team uses to perform the attack	
SH:	Short attack: up to 4 seconds after defense
ST:	Standard attack: between 4 and 7 after defense
EX:	Extended attack: more than 7 s after defense
Throwing	
Throw origin an throw target: Categorization of the throw trajectory, based on court division presented in Fig. 3	
O1-6:	Sector in which the ball had the first contact with the ground after being thrown by the attacker, independently of his/her movement to perform the attack
T1-6:	The place where the ball thrown reaches the orientation area front line of the opponent team
Ball type: Thrown ball feature	
BO:	Bouncing: ball bounces at least once after the high ball line
RO:	Rolling: ball straight and constantly touching the floor
CU:	Curve: rolling ball with side spin
Ball time: Duration of thrown ball	
Thrown ball duration to cross the distance between the high ball line to opposite orientation area front line	

Table 2 Defensive principles to goalball match analysis: observational categories, performance indicators and its description.

Principles	
Observational categories	
Performance indicators	
Defensive balance	
Defending team: Team that misses the ball possession	
Three-letter initials of the country	
Tactical system: The team configuration when waiting for the opponent attack (see Fig. 1)	
TR:	Basic triangle
FT:	Forward triangle
BT:	Backward triangle
IT:	Inverse triangle
ST:	Stair
BA:	Barrier
Throw reading	
Defensive reaction: Defender response to the ball sound after opposite throw	
ER:	Early reaction: defender reacts too soon to any thrown ball sound by the opposite team
CR:	Coherent reaction: defender reacts timely to the ball sound
LR:	Late reaction: defender reacts too late to the ball sound, remaining no time to finish the defensive technique
NR:	No reaction: defender does not react to the ball sound
Blocking	
Defender: Identification of the player who performs the first defensive interception	
1–9:	Jersey number
LW:	Left wing
CE:	Center
RW:	Right wing
Body segment: Body part used by player to block the ball	
UR:	Upper region: for head, shoulders, arms, forearms and hands
CR:	Central region: for chest, abdomen, hips and thighs
LR:	Lower region: for knees, legs, and feet
NC:	No defensive contact with the ball
Ball interception: Characterization of the blocking, referring to the result of the application of the defensive technique	
NR:	No rebound: defender intercepts and keeps the ball under control
FR:	Frontal rebound: the blocked ball moves towards the center of the court
LR:	Lateral rebound: the ball moves towards the lateral lines after the defense
BR:	Backward rebound: the ball continues towards the goal line
NC:	No defensive contact with the ball

The use of this observational system to deal with performance analysis in goalball can help to evolve the base knowledge on technical and tactical aspects of this particular sport. This method is an inexpensive way of providing quantitative and qualitative feedback to players and coaches of how individual players can influence team patterns (Barris and Button, 2008; Hughes and Bartlett, 2002; Vilar et al., 2012). Up to now, there have been only a few studies trying to characterize particular situations of goalball (Amorim et al., 2010; Mora, 1993). Our model expands on the theme, proposing means to assess all the key elements occurring in male and female elite goalball games. We believe the interactive way the instrument was created, by gathering feedback through constant exchange of ideas with elite coaches, led us to comprehensively determine which were the most relevant offensive (how the ball is controlled; how the attack is prepared; and how the throw is performed) and defensive (how the team is positioned on the court; how the athletes reacted to the opponent's throw; and how the ball is blocked) aspects of the game.

Offensive principles

The opponent's throwing outcome is the starting point to the ball control principle. From our experience, this offensive principle is most commonly noted as a defense of the opponent's throw, as a ball controlled after a rebound or as the ball received from the referee. Different preceding situations will influence the offensive strategy choice in the following principle (attack preparation). For example, a ball controlled without a rebound or the one given by the referee after a ball out will allow less time pressure to build the attack within the ten seconds of ball possession a team has to attack. On the other hand, the ball controlled after a long rebound or given by the referee after a block out will reduce the available time to the throwing, hence reducing the possible offensive strategies.

The attack preparation principle is aimed to determine how the attack is planned. The identification of athlete's position and roles on court can clarify the throwing frequency executed by wing and center players providing

Table 3 Attack/defense interaction and game notes to goalball match analysis: observational categories, performance indicators and its description.

Principles
Observational categories
Performance indicators
Attack/defense interaction
Outcome: Result of the interaction between the offensive dimension of one team and the defensive dimension of the other
DE: Defending team blocks the ball which remains inside their half court
BO: Ball passes the limits of the court after being blocked by the defenders
OU: Ball thrown out without contact with the defenders
IN: An infraction occurs
PE: A penalty occurs
GO: Attacking team scores
PD: Defender blocks the penalty shot
PO: Attacker throws the penalty shot out side
PP: Thrower commits a penalty in a penalty shot
PG: Penalty shooter scores
Game notes: observations for references of each game sequence
Gender
F: Female
M: Male
Game period
1: First half
2: Second half
Game number
According to the list of games observed

relevant information for training specificity. For instance, based on eight games from the Barcelona 1992 Paralympic Games, Mora (1993) showed that wing players tend to attack more frequently than centers. Although this is an important information of the game patterns, the author did not take into consideration the teams' tactical systems. The athletes' role and their spatial occupation on court is likely to be determined by the tactical system adopted by each team (Morato et al., 2012), which may further influence the frequency of attacks per players. When assessing the attack length one may find whether shorter or longer attacks are more effective under different scenarios. We also believe it is very important to identify how different offensive strategies (i.e., regular, fluctuation, delivered ball pass, set piece, counter-attack, quick attack, safety ball, or slow ball) influence the defensive balance of the defending team and its respective outcome.

Throwing, as the last attack principle, is thought to characterize how the throw is performed in a goalball game. The efficacy of ball type and ball time can be determined and its relation to throw origin and throw target can later be established. In practical terms, the initial application of our protocol allowed us to investigate the incidence of different ball types and the origin and target throws in elite level goalball. Among the identified three types of ball seen in goalball (rolling, bouncing, and curve) we found that the rolling balls were more common in females when compared to males and that the rolling and bouncing balls were more frequent than the curves balls for both genders (Morato et al., 2014). In another study, we detected higher occurrence of throws from the wing sectors in both genders, similar to Amorim et al. (2010), and higher incidence of balls arriving at the central sectors of the opposing team area (Morato et al., 2013).

Defensive principles

For the first defensive principle, defensive balance, we sought to identify how the team is positioned on the court (tactical system). The possible identification of throwing patterns, as discussed in the offensive principle, can contribute to the teams' organization to effectively comply with the defensive balance principle concept, moving as a block toward the opponent's throw origin (Morato et al., 2012). In addition, differences in the defensive tactical systems effectiveness can be identified with regard to the rational space occupation (see Fig. 1).

Besides the spatial issue, the model also enables the recognition of rhythms inherent to the game. In this way, in the second defensive principle (throw reading) the focus was to understand how athletes reacted to the opponent's throwing (defensive reaction). According to the observers who took part in the reliability testing stage of the study, the subjectivity may play some role in this principle when one tries to note an early, coherent or late defender's reaction to block the ball. However, although among the lowest values of inter-rater reliability, a good level of agreement was achieved (Kappa 0.82). In goalball, as the defenders identify the opponent's throw trajectory under a time pressure condition (Morato et al., 2012), it is relevant to understand if different ranges of attack ball possession or throwing ball time interfere in the defensive efficacy, as seem in other sports (Freeston et al., 2014; Wagner et al., 2012).

For the last defensive principle, blocking, our model permits to understand how the ball is blocked (defender number, defender position, body segment, and ball interception). Traditionally, goalball teams assume a triangular positioning, in which the center, more advanced on court, play the principal role of defending, while wings have the main role of attacking (Morato et al., 2012). However, this may not be true for the all of the possible defensive tactical systems, as proposed in Fig. 1. Another relevant issue of investigation refers to which body segment is more and less efficient to block the ball. From our experience, it seems reasonable that defending the ball with the body extremities may be less effective to securely control the ball than defending it with the trunk, hip and thigh, and the use of protocol can help to test this hypothesis.

Possible interactions between the principles

In team sports with field invasion, the game patterns derive from the continuous interaction between attackers and defenders, mainly in a tight spatial relation. Both teams constantly re-organize their position on field according to the

Table 4 Intra and inter-rater reliability of the goalball observational categories.

Principles	Kappa		
Observational categories	Intra		Inter
	Observer 1	Observer 2	Observers
Ball control			
Attacking team	1.00	1.00	1.00
Preceding situation	0.99	0.95	0.98
Attack preparation			
Thrower number	0.99	1.00	0.99
Thrower position	1.00	1.00	1.00
Offensive strategy	0.84	0.83	0.82
Attack length	0.94	0.91	0.94
Throwing			
Throw origin	0.94	0.90	0.89
Throw target	0.95	0.91	0.90
Ball type	0.89	0.86	0.83
Ball time	0.89	0.81	0.81
Defensive balance			
Defending team	1.00	1.00	1.00
Tactical system	1.00	0.98	0.99
Throw reading			
Defensive reaction	0.89	0.95	0.82
Blocking			
Defender number	1.00	0.97	0.98
Defender position	1.00	0.97	0.99
Body segment	0.96	0.91	0.89
Ball interception	0.87	0.92	0.85
Attack/defense interaction			
Outcome	0.99	0.98	0.99
Game notes			
Gender	1.00	1.00	1.00
Game period	1.00	1.00	1.00
Game number	1.00	1.00	1.00

Note: A kappa coefficient of 0.81–1.00 indicates almost perfect agreement (Landis and Koch, 1977).

opponent's unpredictable behaviors, depending on spatial-time information from the game, which is clearly visual and acoustic (Passos et al., 2013). In goalball, where field invasion is not allowed, the temporal restriction is more noticeable in the defensive principles of throw reading and blocking, which exclusively depend on the auditory perception to identify the characteristic, rhythm and speed of the opponent's throw. From another perspective, provided that the ball is controlled effectively, teams in the offensive situation have more freedom to prepare the attack sequence.

Therefore, changes in the game strategies represent fluctuations in the system (Morato et al., 2012) and the proposed protocol can identify them by recording the event history of each game. With this register in hand, the most appropriate statistical methods still need to be identified to define the secrets of the goalball game. The use of complex mathematical models can contribute to the identification of predictive factors of competitive performance in goalball, positively influencing the teams' preparation process in the training and choice of appropriate strategic plans for competitions (Duarte et al., 2012; Hughes, 2004; Memmert and Perl, 2009; Perl, 2004).

To investigate spatial-time configurations among athletes and teams, different methods are available for the cinematic analysis of athletes in competitive situations (Barris and Button, 2008; Bourbousson et al., 2010; Travassos et al., 2013; Vilar et al., 2014). These methods employ manual or semi-automatic image capturing and data treatment techniques and, while promising for match analysis, they are costly tools that would limit their use in a team sport with amateur characteristics and low budget, which is the case in goalball. In that sense, the model here proposed is democratic, as analysts who are novel in this sport can easily learn it, besides the fact this is a low cost tool. Using an open software (e.g., Kinovea) can favor more refined analysis of the game and provide consistent data when compared to

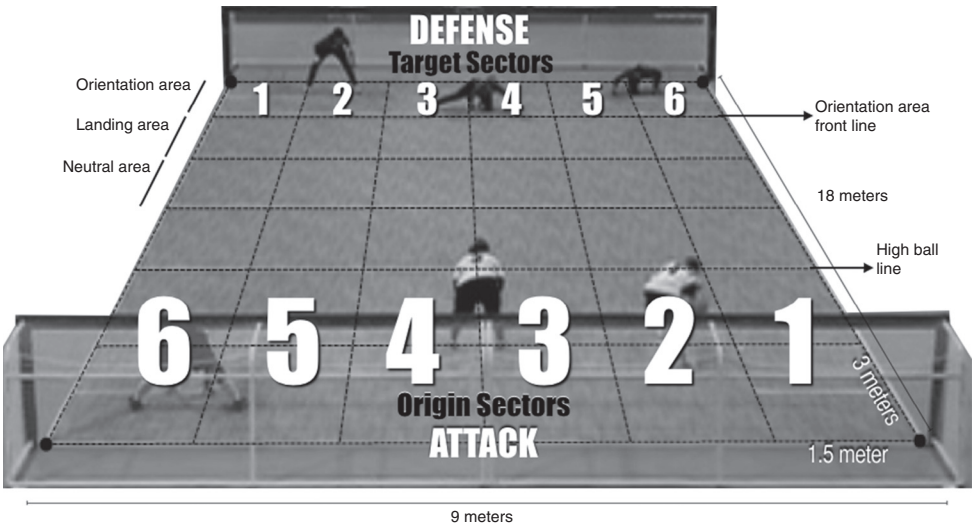

Figure 3 Goalball court diagram and its origin and target sectors. The origin sector is determined when the thrown ball first touches the floor in the orientation or landing areas (sectors 1–6). The target sector is determined when the ball reaches the orientation area front line or touches a defender.

the analysis *in loco* (e.g., ball time with manual chronometer versus frame-by-frame video analysis). In addition, the real-world demands of an elite competition ensured that ecological validity was maintained to examine the game characteristics.

Conclusions

The observational system for goalball match analysis here presented is thought to represent all possible actions available in the offensive (how the ball is controlled; how the attack is prepared; and how the throw is performed) and defensive principles (how the team is positioned on the court; how the athletes reacted to the opponent's throw; and how the ball is blocked) of the sport. The comprehensive method of development and its ideal reliability levels ensure the generation of quantitative and qualitative information for players and coaches and the rigor required for scientific use. Finally, we understand this innovative and low budget tool is a rare and important work dedicated to systematically study goalball (Fig. 3).

Financial support

This work was supported by the National Council of Scientific and Technological Development (CNPq/Brazil).

Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.rbce.2016.08.002.

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