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ORIGINAL ARTICLE

Faster balls increase the probability of scoring a goal in female and male elite goalball☆

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KEYWORDS
Paralympics;
Match analysis;
Team sport;
Athletes with visual impairments

Abstract We sought to investigate the influence of ball time, ball trajectory and ball type on the probability of scoring a goal in female and male elite goalball. We also aimed to categorize throw ball time, taking into consideration ball trajectory and ball type. Systematic video analysis of 1341 male and 1304 female throws was performed on 20 randomly selected matches from the Paralympic Games. In both genders, reducing ball time was associated with an increased probability of scoring a goal, while there was no association for ball trajectories or ball types. The proposed ball time categories are thought to be a useful tool for coaches and sport scientists, as it provides reference values on how fast a ball moves regarding different ball trajectories and ball types for each gender.

PALAVRAS-CHAVE
Paraolimpíadas;
Análise de jogo;
Esporte coletivo;
Atletas com deficiência visual

Bolas rápidas aumentam a probabilidade de marcar gol na elite do goalball masculino e feminino

Resumo Investigamos a influência do tempo de bola, da trajetória e do tipo de bola sobre a probabilidade de marcar gol na elite do goalball; e também o categorizamos em relação à trajetória e ao tipo de bola. Observamos sistematicamente vídeos de 1.341 arremessos masculinos e 1.304 femininos, de 20 partidas selecionadas aleatoriamente dos Jogos Paraolímpicos.

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Em ambos os sexos, a redução do tempo de bola foi associada a uma maior probabilidade de marcar um gol. Não houve associação para trajetórias ou tipos de bola. As categorias de tempo de bola propostas foram pensadas para ser uma ferramenta útil para treinadores e cientistas esportivos, pois fornecem valores de referência sobre quão rápido uma bola se move em relação a diferentes trajetórias e tipos de bola para cada gênero.

PALABRAS CLAVE
Juegos Paralímpicos;
Análisis del partido;
Deporte de equipo;
Jugadores con discapacidad visual

Los balones rápidos aumentan la probabilidad de marcar gol en la elite masculina y femenina del goalball

Resumen Se analizó la influencia del tiempo del balón, la trayectoria y el tipo de balón en la probabilidad de marcar gol en la elite del *goalball*. También clasificamos el tiempo de lanzamiento del balón en relación con su trayectoria y tipo. Observamos sistemáticamente vídeos de 1.341 lanzamientos de hombres y 1.304 de mujeres de 20 partidos seleccionados al azar de los Juegos Paralímpicos. En ambos sexos, la disminución del tiempo del balón se relacionó con mayor probabilidad de marcar un gol. No hubo relación con las trayectorias o los tipos de balón. Las categorías propuestas del tiempo del balón son una herramienta útil para los entrenadores y científicos del deporte ya que ofrecen puntos de referencia para cada sexo sobre la rapidez con que un balón se mueve en relación con diferentes trayectorias y tipos de balón.

Introduction

Goalball is a Paralympic team sport for athletes with visual impairments (Tweedy and Vanlandewijck, 2011). Based on touching and auditory perceptions (Colak et al., 2004; Stamou et al., 2007), three teammates (one center and two wings) stay positioned close to the end of their half court (volleyball dimensions). The attacking team throws a ball (with bells inside) from a restricted space (orientation and landing area) toward the opponent's goal (extending across each end of the court) in order to score. The defending team protects its goal by sliding on the floor to intercept the thrown ball, while positioned in the orientation area with tactile markings (Gulick and Malone, 2011). Since all athletes are blindfolded, their orientation on court relies on multiple clues, such as the goalpost, the raised lines marked on the floor, or by any audible sound provided by the ball or players (Furtado et al., 2016; Morato et al., 2012).

In this non-territorial invasion sport, the defensive system is particularly influenced by the opponent's offensive actions. An attack sequence includes ball control, attack preparation and throwing of the ball. Traditionally, centers are more responsible for the defence while wings more often perform the attacks. Attackers seek to use different ball types (i.e., rolling, bouncing and curve) and ball trajectories (i.e., parallel or diagonal) in an attempt to beat defenders. A regular defensive sequence comprises the defensive balance, throw reading and blocking of the ball. Following auditory cues, once the attacker starts to run the defending team often move as a block toward the opponent's throw origin and, after detecting the thrown ball feature, position their body to block it. Most likely, the defending team succeeds if ball trajectory, ball type, and ball time (i.e., how long the throwing ball takes to cross the court) are identified (Morato et al., 2012, 2016).

Similar to other sports, in which the ball throwing is one of the main technical skills, faster balls are supposed to be more advantageous in reducing the amount of time the opposite team has to react and block/hit the ball, such as in handball (Gorostiaga et al., 2005; Laffaye et al., 2012; Wagner et al., 2012; Ziv and Lidor, 2009), water polo (Freeston et al., 2014; Platanou and Varamenti, 2011), tennis (Martin et al., 2012), and baseball (Pugh et al., 2001; Stodden et al., 2005; Werner et al., 2008), we hypothesize that faster throws are more effective than slower throws to score a goal in goalball. Besides that, as different ball types and ball trajectories require defenders to act accordingly in order to intercept the coming ball (Morato et al., 2012), we wonder if there is a more effective strategy regarding these two offensive variables in goalball.

Thus, we sought to investigate the influence of ball time, ball trajectory and ball type on the probability of scoring a goal in female and male elite goalball matches. We also aimed to categorize throw ball time, taking into consideration ball trajectory and ball type.

Method

Systematic video analysis was performed in 20 goalball matches (ten per gender), randomly selected from the 2008 Paralympic Games. The study was conducted according to the Declaration of Helsinki and the research project was reviewed and approved by an Institutional Ethics Committee.

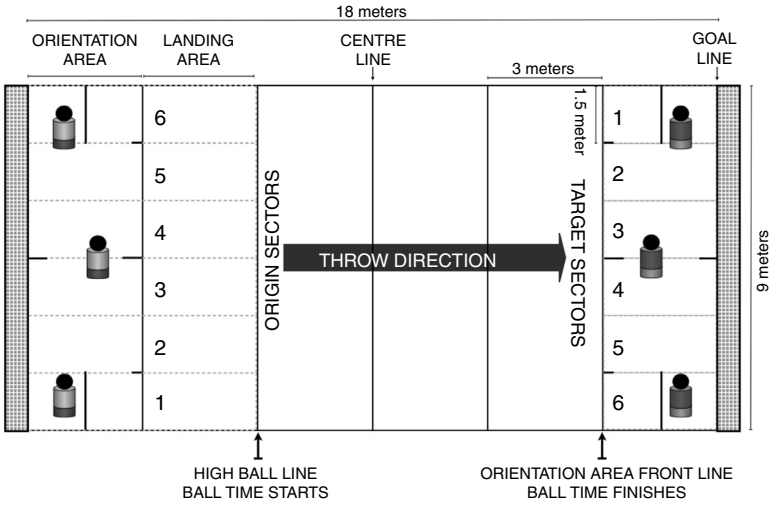

Figure 1 Goalball court diagram with origin and target sectors (1–6) and reference lines to ball time.

Procedures

Image acquisition was obtained by one Sony Handycam – DCR-HC46 (frequency of 29.97 Hz), positioned at a point where the complete goalball court could be video recorded. The videos were analyzed by the first author using Kinovea (v0.8.15), a free motion analysis software.

To perform goalball match analysis an observational protocol was developed comprising the following set of variables (Morato et al., 2016): (1) Gender: female or male; (2) Ball type: bouncing (ball bounces at least once after the high ball line), rolling (ball straight and constantly touching the floor) or curve (rolling ball with side spin); (3) Origin and target: sector in which the ball had the first contact with the ground after being thrown by the attacker and the place where the ball thrown reaches the orientation area front line of the opponent team, respectively (Fig. 1); (4) Ball time start and finish: moment (video frame) in which the thrown ball crosses the high ball line (start) and touches a defender or reaches the opposite orientation area front line (finish); (5) Outcome: goal or defence (blocked out and ball over were considered defences). Penalties and balls out were not considered in the outcome indicator, because in both cases we could not determine the starting and finishing frames for ball time measurement (the ball did not cross/reach one of the reference lines). Penalty shots were also excluded from the analysis. The ball trajectory was defined by a combination of origin and target sectors (Table 1). Ball time (in seconds) was calculated as follows: (ball time finishing frame − ball time starting frame)/29.97.

Sample

A total of 2645 throws was considered, 1304 throws performed by 29 female elite athletes from seven different national teams and 1341 throws performed by 39 male elite goalball players from nine national teams (Table 2).

Reliability

Two observers had 6 h of training regarding the protocol established for data collection. Reliability was assessed using two randomly selected games (10% of the sample), which were observed in two different days, 15 days apart. The kappa index was used for categorical variables (Fleiss et al., 2013) and the Intraclass Correlation Coefficient (ICC) for numeric variables (Hopkins, 2000a, 2000b). The intra and inter-observer kappa index ranged from 0.94 to 1.00 and from 0.87 to 1.00, respectively, for gender, ball type, origin, target, and outcome. For ball time, the ICC was 1.00 for intra-observer and from 0.99 to 1.00 for inter-observer reliability.

Table 1 Ball trajectory categories in goalball according to origin and target sectors.

Origin sector	Target sector				
	Parallel	Short diagonal	Medium diagonal	Long diagonal	Extreme diagonal
1	6	5	4	3	1 or 2
2	5	4 or 6	3	2	1
3	4	3 or 5	2 or 6	1	–
4	3	2 or4	1 or 5	6	–
5	2	1 or 3	4	5	6
6	1	2	3	4	5 or 6

Table 2 Sample descriptive statistics.

	Female		Male	
	Total ($N = 1304$)	Goal ($N = 42$)	Total ($N = 1341$)	Goal ($N = 81$)
Ball trajectory				
Parallel	306 (24%)	9 (21%)	355 (26%)	25 (31%)
Short diagonal	434 (33%)	15 (36%)	477 (36%)	34 (42%)
Medium diagonal	303 (23%)	8 (20%)	314 (23%)	13 (16%)
Long diagonal	187 (14%)	9 (21%)	156 (12%)	9 (11%)
Extreme diagonal	74 (6%)	1 (2%)	39 (3%)	0 (0%)
Ball type				
Bouncing	942 (72%)	31 (74%)	963 (72%)	55 (68%)
Rolling	304 (23%)	8 (19%)	306 (23%)	20 (25%)
Curve	58 (5%)	3 (7%)	72 (5%)	6 (7%)
Ball time (s)				
Mean ± SD	1.01 ± 0.17	0.92 ± 0.15	0.73 ± 0.18	0.68 ± 0.15

Statistics

Data analysis was performed using the SPSS for Windows statistical package (v. 17.0). The chi-square test was performed to examine if ball types and ball trajectories were equally distributed intra and inter gender; to compare the number of throws and the probability of scoring a goal between women's and men's matches. The *t*-test was applied to compare the mean ball time between genders (female vs. male) and outcomes (goal vs. no goal). The analysis of variance (ANOVA), with Bonferroni post hoc test, was considered to compare ball time between ball trajectories and ball types, in each gender. Finally, a binary logistic regression was performed to ascertain the effects of ball time, ball trajectory, and ball type on the likelihood of scoring a goal. As a consequence, ball time was categorized as fast, regular or slow, for each combination of ball trajectory and type (e.g., parallel-rolling, parallel-bouncing). We assumed the 2nd and 3rd quartiles as regular balls; distal quartiles, 1st and 4th, represented fast and slow balls, respectively. Statistical significance level was set at 5%.

Results

The binary logistic regression showed that in both genders reducing ball time was associated with an increased probability of scoring a goal for women and men. Conversely, there was no significant association for ball trajectories or ball types in the probability of scoring a goal (Table 3). The probability of scoring a goal according to ball trajectories (parallel, short diagonal, medium diagonal, long diagonal, and extreme diagonal, respectively) was: 2.9%, 3.5%, 2.6%, 4.8%, and 1.4% in female; and 7.0%, 7.1%, 4.1%, 5.8%, and 0% in male. The probability of scoring a goal according to ball types (bouncing, rolling, and curve respectively) was: 3.3%, 2.6%, and 5.2% in female; and 5.7%, 6.5%, and 8.3% in male.

When comparing ball time among each ball trajectory, a shorter time was found in the parallel and in the short diagonal trajectories for female, $F(4,1299) = 31.92$, $p < 0.01$ (Fig. 2A) and male, $F(4,1336) = 35.65$, $p < 0.01$ (Fig. 2B). Short diagonal and parallel were, respectively, the most used trajectories in female (33% and 24%), X^2 (4, $N = 1304$) = 284.37, $p < 0.01$, or male throws (36% and 26%), X^2 (4, $N = 1341$) = 441.28, $p < 0.01$.

Bouncing balls were the most common ball type in female (72%), X^2 (2, $N = 1304$) = 957.83, $p < 0.01$, and in male attacks (72%), X^2 (2, $N = 1341$) = 954.73, $p < 0.01$. In female, rolling and bouncing balls were faster than curve balls, $F(2,1301) = 18.83$, $p < 0.01$ (Fig. 3A), whereas in male, rolling balls were the fastest balls, $F(2,1338) = 111.12$, $p < 0.01$ (Fig. 3B).

We also found no significant differences in the number of throws between gender, X^2 (1, $N = 2645$) = 0.52, $p = 0.47$. However, the probability of scoring a goal was greater in male matches (6.0% vs. 3.2%), X^2 (2, $N = 2645$) = 11.85, $p < 0.01$, and ball time was shorter in male when compared to female attacks (0.73 ± 0.18 vs. 1.01 ± 0.17), $t(2643) = 40.56$, $p < 0.01$.

Taking into consideration these results, we categorized ball time as a function of ball trajectory and ball type by gender (Table 4).

Discussion

The aim of the present study was to investigate the influence of ball time, ball trajectory and ball type on the probability of scoring a goal in female and male elite goalball matches. Our results showed the higher likelihood of attack success when faster balls were thrown, irrespective of ball trajectory and ball type. Based on these findings we categorized throw ball time, taking into consideration ball trajectory and ball type.

These findings highlight the importance of designing training plans aimed at improving throwing techniques, as well as specific physical abilities. Regarding the techniques, Bowerman et al. (2011) analyzed different types of throws in goalball and described their corresponding phases of movement, providing a useful means for developing specific

Table 3 Results of the binary logistic regression for estimating the probability of scoring a goal.

	Female			Male		
	B (S.E.)	*p* value	Exp(*B*) [95% C.I.]	*B* (S.E.)	*p* value	Exp(*B*) [95% C.I.]
Trajectory						
Parallel		0.31			0.67	
Short diagonal	0.15 (0.43)	0.74	1.16 [0.50–2.70]	0.03 (0.27)	0.91	1.03 [0.60–1.77]
Medium diagonal	0.11 (0.50)	0.82	1.12 [0.42–2.98]	−0.46 (0.36)	0.19	0.63 [0.32–1.27]
Long diagonal	0.97 (0.51)	0.06	2.63 [0.98–7.08]	−0.00 (0.41)	0.99	1.00 [0.44–2.24]
Extreme diagonal	−0.04 (1.09)	0.97	0.96 [0.11–8.07]	−18.23 (6383.13)	1.00	0.00 [0.00]
Type						
Bouncing		0.24			0.59	
Rolling	−0.24 (0.41)	0.55	0.78 [0.35–1.74]	−0.13 (0.29)	0.64	0.87 [0.50–1.54]
Curve	0.96 (0.65)	0.14	2.60 [0.73–9.27]	0.38 (0.45)	0.40	1.46 [0.60–3.55]
Time	−4.79 (1.33)	<0.01	0.01 [0.00–0.11]	−1.74 (0.87)	0.04	0.18 [0.03–0.96]

B, regression coefficient; S.E., standard error; Exp(*B*), odds ratio; CI, confidence interval. Female: Pseudo $R^2 = 0.02$ (Cox & Snell), 0.06 (Nagelkerke). Model $X^2(8) = 6.07$.
Male: Pseudo $R^2 = 0.01$ (Cox & Snell), 0.03 (Nagelkerke). Model $X^2(8) = 4.39$.

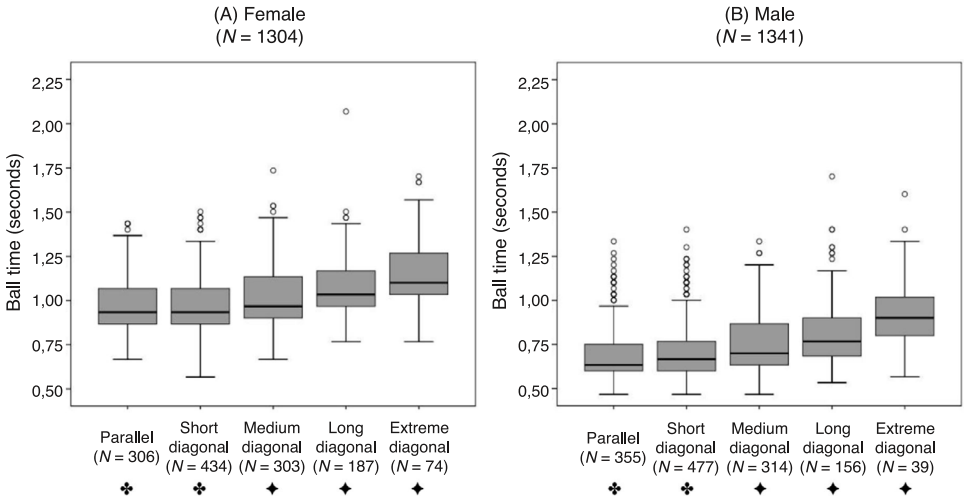

Figure 2 Comparison of ball time according to ball trajectories in female (A) and male (B) elite goalball throws. Legend: a Bonferroni post hoc test revealed that: ✣ $p < 0.01$ vs. medium diagonal, long diagonal and extreme diagonal; ✦ $p < 0.01$ vs. all others trajectories.

throwing skills. Whereas specific sport-related physical training using medicine balls has been supported in other sports (Hermassi et al., 2015; Van den Tillaar and Marques, 2013), resistance training for developing power and maximal strength is also consistent to increase throwing performance (DeRenne et al., 2001; Hermassi et al., 2010, 2011). Regarding gender, we found that male's throws were faster than the female's, which corroborate the findings of a previous study with goalball (Bowerman et al., 2011) and in other elite sports such as in baseball pitching (Chu et al., 2009) and in beach volleyball serving (Palao and Valades, 2014).

Training plans should be tailored to the position and role of each athlete in the team. In goalball, throws are mainly performed by the two wings, while center players tend to perform the majority of defences (Morato et al., 2012). Despite that, the athlete's visual classification seems to influence the efficiency in defensive and offensive actions. Athletes with visual impairment (low vision) presented higher performance in attacking, while blind athletes demonstrated higher performance in blocking the ball (Molik et al., 2015). Its is likely that by dealing with the complete lack of vision in their daily routine, blind athletes become more aware of their senses, helping them to detect and respond to ball time, ball trajectory and ball type during defence. On the other hand, players with residual vision may take advantage from their coaches' visual instructions and even from incidental learning that occurs during interpersonal interaction and trial-and-error experimentation.

Here, we presented novel methods to analyze parameters associated with the goalball game. For example, with the aim of providing a useful means for coaches and athletes to assess ball trajectories and ball time, we proposed a court categorization in which it was divided in six sectors of 1.5 meters width. This allowed further

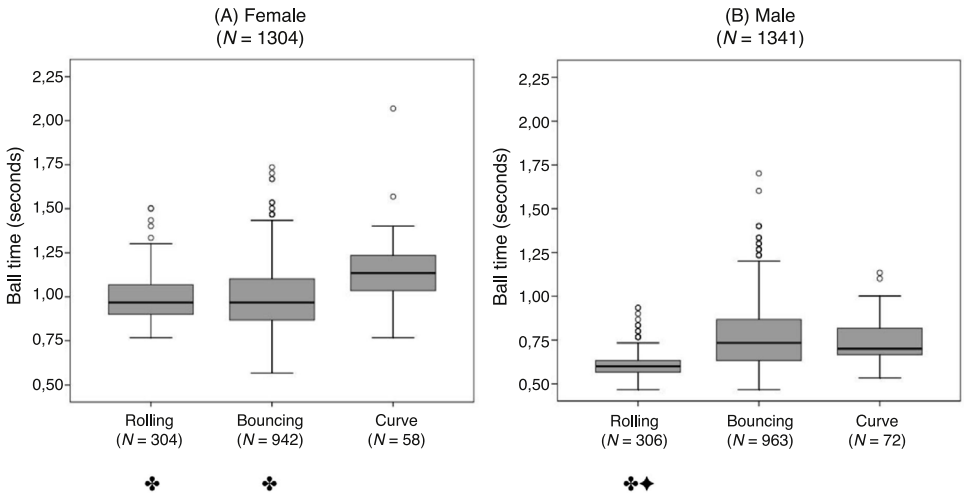

Figure 3 Comparison of ball time according to ball type in female (A) and male (B) elite goalball throws. Legend: a Bonferroni post hoc test revealed that: ✣ $p < 0.01$ vs. curve ball; ✦ $p < 0.01$ vs. bouncing ball.

Table 4 Ball time (seconds) categories in elite goalball throws.

Type	Female			Male		
Trajectory	Fast	Regular	Slow	Fast	Regular	Slow
Rolling						
Parallel	<0.87	0.87–1.03	>1.03	<0.53	0.53–0.63	>0.63
Short diagonal	<0.87	0.87–1.04	>1.04	<0.53	0.53–0.63	>0.63
Medium diagonal	<0.90	0.90–1.03	>1.03	<0.57	0.57–0.70	>0.70
Long diagonal	<0.97	0.97–1.13	>1.13	<0.59	0.59–0.70	>0.70
Extreme diagonal	<1.00	1.00–1.20	>1.20	<0.70	0.70–0.93	>0.93
Bouncing						
Parallel	<0.83	0.83–1.07	>1.07	<0.60	0.60–0.80	>0.80
Short diagonal	<0.83	0.83–1.07	>1.07	<0.60	0.60–0.80	>0.80
Medium diagonal	<0.90	0.90–1.13	>1.13	<0.67	0.67–0.93	>0.93
Long diagonal	<0.93	0.93–1.17	>1.17	<0.70	0.70–0.93	>0.93
Extreme diagonal	<1.05	1.05–1.27	>1.27	<0.80	0.80–1.07	>1.07
Curve						
Parallel	<0.98	0.98–1.20	>1.20	<0.63	0.63–0.85	>0.85
Short diagonal	<0.92	0.92–1.17	>1.17	<0.67	0.67–0.80	>0.80
Medium diagonal	<1.04	1.04–1.36	>1.36	<0.69	0.69–0.79	>0.79
Long diagonal	<1.10	1.10–1.23	>1.23	<0.73	0.73–0.82	>0.82
Extreme diagonal	<1.05	1.05–1.45	>1.45		0.87[a]	

[a] Only one case.

categorization of ball time as a function of ball type and also according to ball trajectory. Overall, our findings confirm that ball time is dependent on ball trajectory and ball type (see Figs. 2 and 3). For example, Table 4 depicts balls with the same trajectory being either classified as fast (curve) or regular (rolling or bouncing). This gender-related ball time classification for elite goalball players may serve to guide coaches and athletes seeking higher levels of performance.

Auditory cues are key to orientate defenders (Morato et al., 2012). From the moment the ball is released by the attacking player, defenders usually have less than a second to block the ball, either for male or female teams. For example, in the parallel or short diagonal trajectories (representing more than 60% of all shots – see Table 2), with a rolling ball type, males may have even half of a second to act. Therefore, any sound made by the attacking team can be useful to determine the throwing origin and help the defensive team to move as a block toward that area. This defensive strategy allows more time for the identification of ball type and ball trajectory, diminishing the need for players to slide or dive in the blocking process. Thus, athletes have more time to lay stretched on the floor (for rolling and curve balls) or slightly lifted (for bouncing balls).

The study's limitations include the use of ball time instead of ball speed, in which the later could be a more accurate parameter to assess attackers' performance related to the probability of scoring a goal. However, advanced and expensive equipment (e.g., radars or multiple

camera for 3D testing) would be necessary but not accessible to most professionals involved in this low budget sport. On the other hand, by performing video analysis using a free software, we were able to assess ball time reliably and affordably. Also, by categorizing ball time regarding ball trajectory and ball type we offered reference values for ball time comparison either for research or practice. For an actual assessment of throw performance during training sessions or competitions, ball time can easily be measured by using a manual chronometer, however, its validity and reliability have not yet being determined. Further, we understand that, despite the high levels of reliability achieved during systematic observation, the low rate of the video recording (29.97 fps) could have slightly biased our results and affected the ball time categories thresholds. In this matter, higher frame rates are preferred to assess the game performance indicators and will provide even more accuracy in data analysis.

From our findings we can draw some implications to improve goalball practice. Here, we presented a division of the team area comprising six sectors of 1.5m. Whereas this division seem to be arbitrary, our practical experience and the discussion with other coaches ensure this is a common and valuable way to provide feedback to athletes about ball trajectories during training and competition (Morato et al., 2016). The location of these six sectors on court can easily be taught to athletes by adding raised lines in the team area. To perform a more refined match analysis of goalball one can employ the Kinovea software, which showed to have a perspective grid tool to determine throws origin and target sectors reliably. Since most attacks are performed by wings (Morato et al., 2012), we highlight the importance of designing specific training plans to develop their power and maximal strength as well as the throwing techniques in order to reduce the ball time and increase the probability of scoring a goal.

Conclusions

To our knowledge, the present match analysis adds new and relevant information about goalball elite athletes performance during their highest level event. Our results showed that faster balls significantly increased the likelihood of scoring a goal, while ball trajectories and ball types influenced this outcome in a non-significant lower degree. Short diagonal and bouncing ball were the most common ball trajectory and ball type used in attacks, respectively, whereas men threw faster balls and had greater probability of scoring a goal. The proposed ball time categories are thought to be a useful tool either for coaches and sport scientists, as it provides reference values on how fast a ball moves regarding different ball trajectories and ball types for each gender.

Conflicts of interest

The authors declare no conflicts of interest.

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