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Elite hit ball performance profile: technical, tactical and heart rate aspects, and effects of competition on jump and strength performance

Perfiles de rendimiento en hit ball de elite: aspectos técnicos, tácticos y frecuencia cardíaca, y los efectos de la competición en la capacidad de salto y rendimiento de fuerza

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Abstract

This study aimed to define a performance profile of elite hit ball matches. Eighty-six male Italian Serie A hit ball players (29.3±5.0 yrs) participated in the study. A technical and tactical analysis (18 indicators) was performed on eleven matches; heart rate (HR) was monitored during matches on 25 players; countermovement jump (CMJ) and maximal grip strength (GS) were measured on all participants before and after match. Differences ($P<0.05$) between winning (W) and losing (L) teams for technical and tactical analysis (Chi-square), and between match phases for HR, CMJ, and GS (ANOVA for repeated measurements) were tested. Hit ball teams meanly performed 297±10 rallies per match (W: 41±6 goals; L: 23±3 goals, P=0.042). No differences between quarters emerged for HR (171-190 bpm for 57±21 % of match duration). Opposite trends emerged for CMJ (after: 36.2±6.3 cm; before: 33.1±4.8 cm; P=0.001) and GS (after: 433±102 N; before: 463±98 N; P=0.018) performances. Findings show that hit ball is performed at high HR intensity, and that CMJ improves and GS declines after matches. This could be determined by a neuromuscular activation of lower limbs and repeated harm concussions due to shots.

Key words: technical indicators; tactical indicators; hear rate intensity; countermovement jump; handgrip.

Resumen

El estudio tenía como objetivo definir los perfiles de rendimiento en partidos de hit ball de elite. Un total de 81 jugadores italianos de la Serie A (29.3±5.0 años) tomaron parte en el estudio. El análisis técnico y táctico (18 indicadores) se realizó durante once partidos; la variable frecuencia cardíaca (FC) fue monitorizada durante los partidos en 25 jugadores; el test de salto en contramovimiento (SCM) y el test de fuerza máxima de prensión (FMP) se midieron antes y después de cada partido. Las diferencias ($P<0.05$) entre equipos ganadores (G) y perdedores (P) en los aspectos técnicos y tácticos se realizó mediante el test de Chi-cuadrado, y para las diferencias entre las fases del partido en las variables FC, SCM y FMP se empleó el ANOVA de medidas repetidas. Los resultados mostraron una media de 297±10 rallies por partido (G: 41±6 goles; P: 23±3 goles, P=0.042). No se encontraron diferencias entre los cuartos de juego para la variable FC (171-190 lpm en 57±21 % de la duración del partido). Se encontraron tendencias opuestas para el test SCM (después: 36.2±6.3 cm; antes: 33.1±4.8 cm; P=0.001) y para el test FMP (después: 433±102 N; antes: 463±98 N; P=0.018). Los resultados muestran que el deporte del hit ball se desarrolla con un rendimiento de alta FC, y con mejoras del SCM y descensos del FMP después del partido. Estos resultados pueden estar determinados por la activación neuromuscular de los miembros inferiores y el daño repetido de los golpeos debido a los lanzamientos en los brazos.

Palabras clave: indicadores técnicos; indicadores tácticos; frecuencia cardiac; contramovimiento; prensión manual.

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Introduction

Hit ball is a return, territorial (i.e., not invasion), and situational team sport officially originated in Turin (Italy) in the late seventies following an experimental work of a physical education teacher (Ictrilussa, 2017). This sport is now played in many countries around the world (Australia, India, France, Germany, or Spain). In Italy, this discipline is currently played in all the country with championships based on different competitive levels (i.e., Serie A1, A2, B1, B2, C1, C2) organized by the Italian Hit Ball Federation (Federazione Italiana Hit Ball, F.I.H.B.), which was founded in 1992.

Hit ball is mainly played in-door by two teams of 5 players, who compete for two 15-min (first and second, respectively) and two 7.5 min (third and fourth, respectively) quarters of live time. The playing court has a parallelepiped form (width: 10m, length: 20m) divided by a line (the halfway line) that can never be crossed and that separates the two teams, two lateral walls, and one goal located at the bottom of each team court side (height: 2.3 m; width: 10 m). Each team's half court is divided into "defence" (width: 10m, length: 4m, occupied by 3 players who score 2 points in case of goal), "attacking" (same dimensions, occupied by 2 players who score 1 points for each goal), and a "neutral" (width: 10m, length: 4m, close to the halfway line, where not more than 2 players can play only to defend the opponents' hits, having the interdiction to score a goal) zones, respectively. The lateral walls, as well as the one above players (at 4 m of height) consist of methacrylate material and allow the rebound of the ball (consisting of rubber; weight: 260 gr; diameter: 21 cm). The ball is hit with an arm coated with a polyurethane protective cuff (around 20 cm of length; 8 mm of thickness) and like many other team sports a team's aim is to score goals (called Hits) in order to win the match by scoring more points than the opponent (Figure 1).

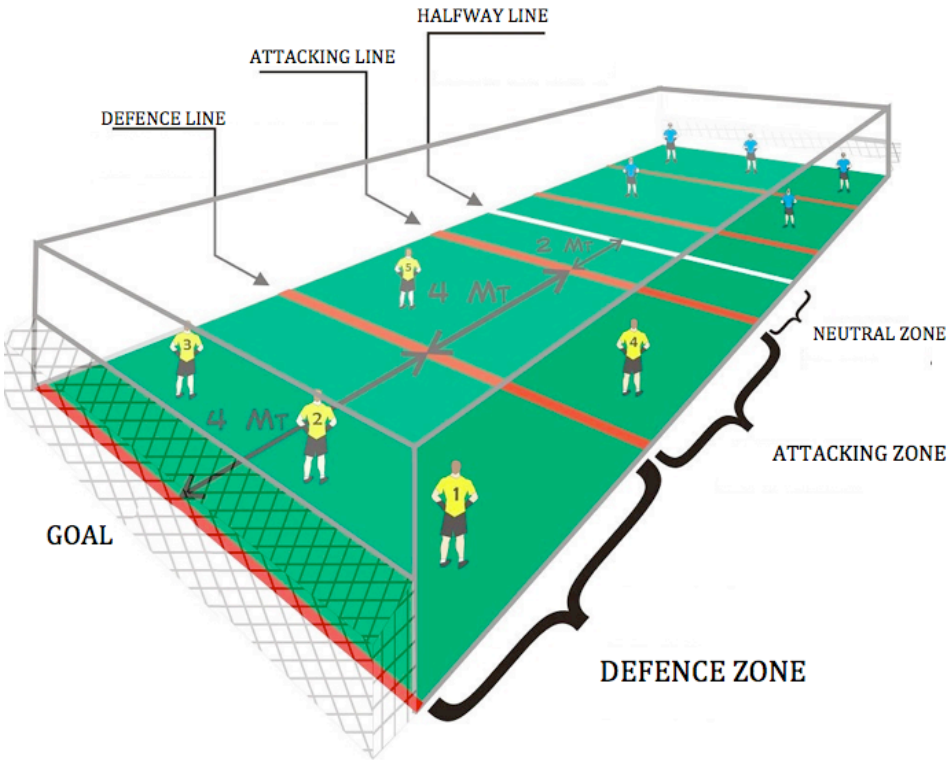

Figure 1. Hit ball court (Hit Ball Australia, 2016)

Although no studies on hit ball have been reported in literature yet, providing a performance analysis of this team sport could be beneficial for hit ball's coaches and physical trainers, as well as other net and wall (i.e., volleyball, tennis, paddle, squash) and invasion (i.e., handball) games disciplines which have similar playing structures (i.e. scoring points, playing situations).

Technical and tactical analyses suffer in terms of replication due to the complexity of their situational nature (Gómez, DelaSerna, Lupo, & Sampaio, 2014; Lupo & Tessitore, 2016; Tessitore, Perroni, Meeusen, Cortis, Lupo, & Capranica, 2012). Therefore, the progressive improvement of this type of information demonstrated to be crucial in increasing the knowledge for coaching team sports (Hughes & Franks, 2004), especially by discriminating winning and losing performances (Gómez et al., 2014; Gómez, DelaSerna, Lupo, & Sampaio, 2016; Lupo & Tessitore, 2016). In addition, even though no heart rate (HR) data has been reported for the analysis of hit ball matches, they could allow to profile the performance in terms of aerobic or anaerobic contribution of the energy systems, as already provided for other less known sports (Lupo, Ammendolia, Rizzuto, Capranica, & Tessitore, 2012) or competition level (Lupo, Capranica, Cugliari, Gómez, & Tessitore, 2016).

In general, the maximal grip strength (GS) is considered a critical factor to sustain and control the ball especially for grasping, catching, passing, and throwing actions (Visnapuu & Jűrimäe, 2007). In previous studies carried out on different sports, the comparison of GS performances before and after situational sport performances (Chiodo, Tessitore, Cortis, Lupo, Ammendolia, & Capranica, 2012) highlighted a reduction (around 7%) of GS in both genders, which has been attributed to both the activities executed by the upper limbs (i.e. holding, punching, and body-to-body contact) and the effects of the repeated contusions exerted on the upper limbs while protecting against an opponent's kicks and punches. According with this observed aspect, the present work could indicate whether the same effect can be confirmed or not in hit ball, especially for the shooting upper-limb, which is usually characterized by repeated concussions caused by shooting. Conversely, in other studies on male taekwondo athletes (Chiodo et al., 2012), it was showed a significant increase in countermovement jump (CMJ) performance at the end of the fighting despite the high prevalence of kicks (Tasika, Boutios, & Fisentzidis, 2009), as well as in female volleyball players (Marques, Tillaar, Vescovi, & Gonzalez-Badillo, 2008), where professional athletes increased their vertical jump performance after training. In particular it has been highlighted that combat does not attenuate the power performances of taekwondo athletes, and fatigue resistance reflects the stretch shortening cycle properties of the muscle. Specifically, it has been speculated that gender-related differences in concentrations of hormones was able to influence neuromuscular activation especially in male athletes (Bosco, Tihani, Rivalya, Parlato, Tranquilli, Pulvirenti, et al., 1996; Bosco, Colli, Bonomi, von Duvillard, & Viru, 2000; Chiodo, Tessitore, Cortis, Lupo, Ammendolia, Iona, et al., 2011). Therefore, CMJ trials performed before and after official hit ball matches could clarify if the same effect related to a potential neuromuscular activation could be speculated also for this team sport. Thus, in consideration of the absence of scientific literature related to hit ball competitions, the aim of this study was twofold: 1) to investigate the technical and tactical (i.e., winning and losing performance), and physiological (i.e., HR) profiles of Italian elite hit ball players (i.e., Serie A1-A2); and 2) to assess the effects of hit ball competition on players' jump (i.e., CMJ) and strength (i.e., GS) performances.

Method

Sample

The local Institutional Review Board approved this study to investigate the technical and tactical aspects and HR aspects, and the effects of competition on CMJ and GS performances in Italian elite hit ball players. In addition, the coaches of Italian Serie A1 and Serie A2 hit ball teams gave their approval for video recording and analysis of the matches (played between 7 and 10 p.m. in every day of week excepting Sundays and Mondays).

Eighty-six male players (29.3±5.0 years; height: 1.81±0.06 m; body mass: 78±14 kg) were recruited in the study. According to some Italian coaches (with more than 5 years of coaching experience), the training of these players is characterized by a minimum of three (i.e., 1-3 technical and tactical plus not more than 2 strength and conditioning units) to a maximum of six (i.e., 4-5 technical and tactical plus not more than 2 strength and conditioning units) units per week, where each training unit generally consists of 60-120-min, and the players have trained at least for 5 years.

Procedures

Eleven Italian elite hit ball matches were video recorded by means of a camera (HD Hero, GoPro; San Mateo, California, USA) positioned along a side of the hit ball court, at the level of the midfield line, at a height of 2 m and at a distance of 8 m from the court. The operator pointed the camera to cover all game actions, making possible to collect all the data of this study. Successively, a notational analysis for each team for all the eleven matches was provided considering 18 indicators grouped in five categories (Table 1).

Table 1. Hit ball tactical and technical indicators.

#	*General indicators*
1.	Duration of the match – which included also quarter intervals and minor interruptions (i.e., injuries, referee needs, teams' change of court between the third and fourth quarter);
2.	Occurrence of ball possession performed;
3.	Passes executed (or not) in each single ball possession (i.e., no pass; 1 pass, 2 passes, ≥ 3 passes);
4.	Players involved (i.e., who took the ball) in a single possession (i.e., 1 player, 2 players, ≥ 3 players);
	Origin zone of the hits
5.	Hits from the attacking zone;
6.	Hits from the defence zone;
	Rally outcomes
7.	Points scored;
8.	Hits ended out of the court;
9.	Hits saved (and not blocked by opponents);
10.	Hits blocked (and successively played with a ball possession by the opponents);
	Type of game infringement
11.	Double touch (i.e., infringement due to a double touch of a single players within a single ball possession);
12.	Withheld ball (i.e., infringement due to a withheld or accompanied of the ball);
13.	Over 5 s (i.e., infringement due to ball possession longer than 5 s);
14.	Overstepping (i.e., infringement due to a overstepping into the opponent's court which lead to an advantage or danger);

Technical type of hits

15. Armful (i.e., hit performed by moving the harm, forward, along the transversal axis, at the height of shoulder);
16. Bowling (i.e., hit performed by moving the harm, forward, from bottom to top, along the sagittal axis, hitting the ball under the height of hip);
17. Diving (i.e., hit performed in diving);
18. Smash (i.e., hit performed by moving the harm, forward, from top to bottom, along the sagittal axis, hitting the ball above the height of shoulder).

To avoid inter-observer variability, a single observer (more than one year of specific experience in analyzing hit ball matches) scored all matches. However, to assess reliability, the observer who completed this study analyzed a randomly chosen match twice, each observation separated by 14 days, reporting a high intra-observer test-retest reliability (Intraclass Correlations, ICC = 0.97).

During six hit ball matches, the HR response of 25 players (from 9 different teams) were continuously recorded with a sampling frequency of 1 s, by means of HR monitors with internal memory (Polar Team System, Polar, Kempele, Finland). Successively to matches, HRs data were downloaded onto a computer and recordings between quarters were discarded. In particular, HRs were classified in relation to the HR peak recorded during the game (%HRpeak; ≤60%, 61-70%, 71-80%, 81-90%, 91-100%), the theoretical maximal HR values (%HRmax; 220-age; ≤60%, 61-70%, 71-80%, 81-90%, 91-100%), and classes of interval of 10 beats.min-1 (i.e., ≤140, 141-150, 151-160, 161-170, 171-180, 181-190, 191-200, >200 bpm), both in relation to absolute duration (min) and percentage (%) of total match duration.

Before (i.e., after the warm-up and before the starting of the match) and after the same six matches, CMJ and GS performances were measured on 86 male hit ball players (from 12 different teams). In particular, CMJ Jump performances were measured by means of an optical acquisition system (Optojump, Microgate, Bolzano, Italy), developed to measure with 10^{-3} seconds precision all flying and ground contact times. The Optojump photocells were placed at 6 mm from the ground. They were triggered by the feet of the participant at the instant of take-off and were stopped at the instant of contact upon landing. Then, the jump height calculation was made. For the CMJ test, from the standing position, the hit ball players were required to bend their knees to a freely chosen angle, followed by a maximal vertical thrust. The effect of the arm swings was minimized requiring the athletes to keep their hands on their hips during the entire duration of the test. Because it was assumed that participants maintained the same position at take-off and landing, they were instructed to keep their body vertical throughout the jump and to land with knees fully extended. Any jump that was perceived to deviate from the required instructions was repeated. For the assessment of GS of both upper limbs, the athletes were standing with their arms located vertically and beside their body and asked to make their strongest grip possible on the ergonomically formed measuring beam (range 0-1000 N) of a mechanical handgrip dynamometer (Hydraulic Hand Dynamometer, Baseline, Irvington, USA) connected to an amplifier and displayed on-line. Before and after the hit ball match, two trials with a 1-min pause in between were performed by each upper limb, and the highest values (i.e., hitting and not-hitting upper limb) were used for statistical analysis.

Statistical analysis

For each of the 18 technical and tactical indicators, HR classifications, CMJ and GS results, means and standard deviations (SD) were calculated. Statistical analyses were conducted using SPSS (21.0; SPSS, Inc., Chicago, IL) and the criterion for significance was set at $P \leq 0.05$.

To discriminate winning and losing technical and tactical performance, the chi-square test was used. In particular, the expected occurrences according to a coefficient related to the number of ball possession were considered on all indicators (excepting for match duration which is the same in winning and losing teams). Then, to provide meaningful analysis for pairwise comparisons between winning and losing teams, the Cohen's *d* was also calculated, considering 0.1, 0.3, 0.5 as small, medium, and large Cohen's *d*, respectively (Huck, 2000). On the other hand, ANOVA for repeated measures was applied to test differences between match phases for HR (i.e., between quarters), as well as GS and CMJ (i.e., before and after match). Successively, Cohen's effect sizes (ESs) (Cohen, 1988) were calculated for differences, considering an ES ≤ 0.2, from 0.3 to 0.6, from 0.7 to 1.2, and > 1.2, as trivial, small, moderate, and large, respectively (Hopkins, 2008).

Results

Means and standard deviations (i.e., all teams, winning teams, losing teams), and differences ($P \leq 0.05$) of the technical and tactical aspects between winning and losing Italian elite hit ball teams (and Cohen's *d*) were reported in table 2. In particular, only the occurrence of goals scored resulted significantly different ($P=0.042$) in terms of match outcome with a small ES (0.3). No difference between quarters emerged for HR values; however, a regular presence of values close to the 100% HRpeak (90-100%HRpeak: 25±10 min, 74±15%), and %HRmax (90-100%HRmax: 20±11, 57±25%; >100%HRmax: 4±8, 14±23%) were reported (Table 3). The predominance of high HR response has been highlighted also in relation to the maximal theoretical values (171-190bpm: 19±8 min; 57±21%; Figure 2).

Table 2. Means and standard deviations (SDs) (i.e., all teams, winning teams, losing teams), and differences (P≤0.05) between winning and losing (and Cohen's *d*) of the technical and tactical aspects of the Italian elite hit ball teams.

		All teams		Winning teams		Losing teams		Effects
		Mean	SD	Mean	SD	Mean	SD	P (Cohen's *d*)
	General indicators							
1	Duration of the match (in min:s)	34:18	11:12					
2	Occurrence of ball possession performed	297	10	305	6	289	6	
3	Passes executed							
	no pass	55	5	59	4	52	3	0.71
	1 pass	215	4	218	4	213	4	0.74
	2 passes	25	3	27	3	23	3	0.67
	≥3 passes	1	0	1	1	1	0	0.98
4	Players involved in a single action							
	1 player	39	7	44	3	35	6	0.4
	2 players	170	17	173	20	166	13	0.85
	≥3 players	88	16	88	18	88	15	0.72
	Origin zone of the hits							
5	Hits from the attacking zone	178	3	177	3	178	3	0.6
6	Hits from the defence zone	97	7	100	6	95	7	0.99
	Rally outcomes							
7	Points scored	32	10	41	6	23	3	0.042 (0.3)
8	Hits ended out of the court	134	12	135	14	132	11	0.81
9	Hits saved	48	2	48	2	48	3	0.81
10	Hits blocked	61	18	60	19	63	17	0.55
	Type of game infringement							
11	Double touch	14	2	14	2	14	2	0.97
12	Held ball	3	2	2	2	3	2	0.39
13	Over 5 s	1	1	1	1	1	1	0.98
14	Overstepping	4	1	4	1	4	1	0.94
	Technical type of hits							
15	Armful	7	3	10	1	4	3	
16	Bowling	255	8	253	6	257	10	
17	Diving	6	3	7	3	6	2	
18	Smash	7	3	8	4	6	2	

Table 3. Mean and standard deviation (SD) of heart rate (HR) absolute duration (min) and percentage (over total duration of match) values in relation to the maximal theoretical (theoretical scale; 220-age) and HR pick recorded during the match (HR match pick scale; %HRpeak) parameters.

	Theoretical scale (220-age)				HR match peak scale			
	in min		% match duration		in min		% match duration	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
≤60%	0	0	0	1	0	0	0	1
61-70%	0	0	1	2	0	0	1	2
71-80%	2	2	5	7	2	2	5	6
81-90%	8	9	23	22	7	5	20	10
91-100%	20	11	57	25	25	10	74	15
>100%	4	8	14	23	-	-	-	-

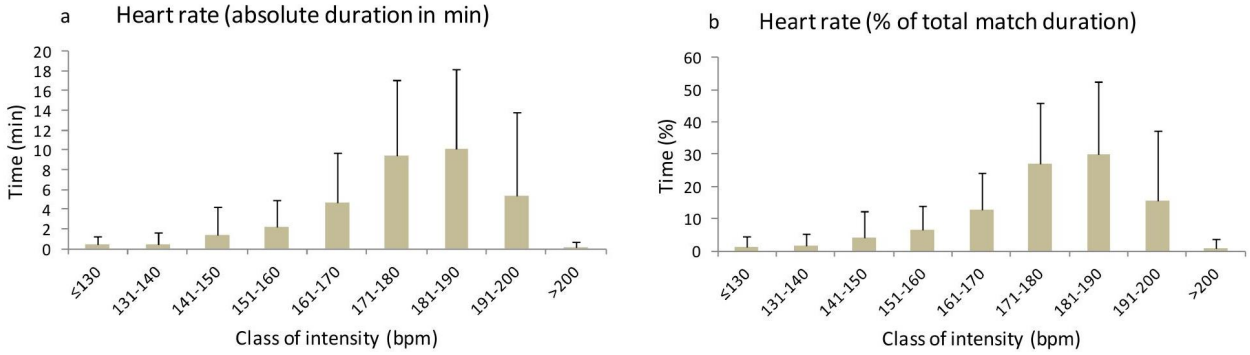

Figure 2. Mean and standard deviation (SD) of heart rate (HR) absolute duration (min; graphic a) and percentage (over total duration of match; graphic b) values in relation to the class of intensity (i.e., ≤130, 131-140, 141-150, 151-160, 161-170, 171-180, 181-190, 191-200, >200 bpm).

Finally, for CMJ, higher values were reported after match (36.2±6.3 cm) than those reported before match (33.1±4.8cm; P=0.001, moderate ES=0.6). Conversely, for GS related to the shooting upper-limb, lower values were recorded after match (433±102N) with respect to those recorded before (463±98N, P=0.018, small ES=0.3). For the other upper-limb, no difference emerged between the grip force performed before (452±99N) and after (442±95N) match.

Discussion

Considering the absence of research investigating the hit ball performance, the present work represents the first analysis on this sport. For this reason this study had a twofold aims: 1) to investigate the technical, tactical, and physiological profiles of Italian elite hit ball players (i.e., Serie A1-A2); 2) to assess the effects of hit ball competition on players' CMJ and GS performances. Similarly to previous studies on team sports players (Glazier, 2010; Lupo et al., 2012, 2016), an integrated experimental approach including all these aspects (i.e., technical, tactical and HR profiles, and CMJ and GS performances) in both pre-before and after matches is able to provide a good picture of the hit ball performance, even providing interesting aspects, which could be referred in favour of contiguous sports.

Although no particular results emerged between winning and losing teams' technical and tactical performance, hit ball coaches could benefit from these results. As expected, the occurrences of goals reported an effect in terms of match successful. However, despite no other effect emerged between winning and losing teams, valuable information is also provided by the other indicators, regardless of the latter rationale and benefiting from general descriptive data. In particular, considering the high number of ball possessions (i.e., around 300 per team) performed during a match of around 31 min, it could speculate that hit ball is characterized by quick game actions. In addition, hit ball team actions were mainly played by means of 1 pass between 2 players, with hits performed from the attacking zone, thus highlighting a tendency to play simple playing patterns (2 players-1 pass) and to effectuate hits from the closest zone with respect to the opponents' goal. Nevertheless, the majority of hits ends out of the goal target, pointing out how performing hits in goal is highly contrasted by the 5 opponent players. The technical analysis of hits showed that the "bowling" execution is the most adopted one, probably because it is the most comfortable to shot the ball with the highest power. Finally, the game infringements occur with a low frequency (i.e., around 7%) with respect to the total rallies performed during a hit ball match by a single team.

Italian elite hit ball match imposes a considerable HR response on players, which resulted higher than in other return sport performances such as elite volleyball (Bara Filho, de Andrade, Nogueira, & Nakamura, 2013) and tennis (Fernandez et al., 2006), probably for the above mentioned quickness and duration of the game actions, despite these are not analyzed. In line to this interpretation, exercise intensity recorded during Italian elite hit ball matches is often reported at the highest normalized (i.e., 91-100% of the theoretical and HR match peak scales) and absolute (i.e., 181-190 bpm) levels with reduced occurrences for the lowest intensities, tending to speculate that this performance is not characterized by substantial rest periods which are mostly due to short breaks between rallies, rather than unsatisfactory players' recovery capability. In addition, the latter suggestion is also supported by the absence of any difference in comparing HRs related to the four quarters. In fact, the absence of any HR decline at the final quarters highlights that hit ball players are able to maintain a high exercise intensity for all match duration.

Similarly to other situational sports, the effects of competition were tested in terms of jump (Chiodo et al., 2011, 2012; Marques et al., 2008) capability. In particular, despite time-motion analysis in elite hit ball player has not been studied, from the HR evaluation and technical and tactical analysis, it could be speculated that elite hit ball players usually perform quick movements at high intensity which determine substantial grades of fatigue on lower limbs. However, despite a small ES, the significant improvement of the jump capability reported by the elite hit ball players at the end of the game suggests an alternative interpretation. For instance, in elite taekwondo performance (Chiodo et al., 2011, 2012), which is highly

characterized by a high occurrence of kicks (Tornello, Capranica, Chiodo, Minganti, & Tessitore, 2013; Casolino, Cortis, Lupo, Chiodo, Minganti, & Capranica, 2012), the improvements of jump trials at the end of matches were interpreted in favour of a high neuromuscular activation of the lower limbs determined by the match performance. Similarly, in female volleyball players, a neuromuscular actiovation has been speculated in response to training (Marques et al., 2008). Therefore, in line to these studies (Chiodo et al., 2011, 2012; Marques et al., 2008), it could be inferred that hit ball match does not attenuate the power performances in their elite athletes' lower limbs, but is probably characterized by an intermittent exercise alternating all-out performances with sufficient active recovery which is able to enhance the postmatch neuromuscular function of athletes.

Although the same experimental design of CMJ trials has been also provided on GS ones, hit ball players performed lower strength levels at the end of match with respect to those of the session prior to competition. In particular, the attenuation in GS observed at the end of hit ball competition on the shooting upper limb suggests that the frequent use of this upper limb in performing hits toward the opponents' goal imposes substantial demands upon the corresponding musculature. Despite, similarly to CMJ trials, difference between GS trials were associated to a small ES, this finding confirms previous results which showed that performance impose strong and frequent concussions on upper limbs (Chiodo et al., 2011, 2012), whereas no evident relationship between competition and GS decline seems emerged in those disciplines where the use of upper limbs is frequent but not related to concussion (Cortis, Tessitore, Lupo, Pesce, Fossile, Figura, et al 2011; Lupo et al., 2012). Nevertheless, this interpretation is not strengthened by the absence of any difference in the before and after match GS trials effectuated with the other hit ball players' upper limb. In fact, despite players often contrast opponents' hits by opposing their upper limbs (even from reduce distances) during defensive hit ball actions, the same picture is not showed. Therefore, further studies could promote a clarification of this issue in hit ball as well as in other sports where the use of upper limbs refers to different performance demands.

However, relevant limitations characterize the present study. Firstly, the absence of any study specifically focused on hit ball limits the interpretation of the results, making possible comparisons only with other similar sports. Secondly, the number of matches and players monitored in terms of HR were quite reduced, limiting the reliability and interpretation of these results. Therefore, further studies involving a larger number of hit ball players could increase and promote knowledge about this sport and other adjacent return disciplines, also supporting new and alternative practice, education methods, and performance planning. In particular, more technical and tactical data are needs to promote analyses specifically orientated on different match phases (Gómez et al., 2014) or margins of victory (Lupo & Tessitore, 2016), as well as further studies on alternative analysis such as matche effects on inter-limb coordination (Tessitore, Perroni, Cortis, Meeusen, Lupo, & Capranica, 2011) or time motion analysis (Conte, Favero, Lupo, Francioni, Capranica, & Tessitore, 2015). Finally, considering that the present study provided the first model to gather information in hit ball performance, further studies could be provided by replicating the same analysis in other samples of subjects (i.e., different genders, competition levels, age categories).

Conclusion

Although the present study is the first attempt to provide data on hit ball performance, this integrated analysis represents valuable practical references for coaches working on this sport as well as other adjacent return sports. Findings related to technical and tactical aspects and HR response, as well as competition effects on jump and strength capabilities could effectively contribute in planning training with a higher awareness and coherence to the performance profile. In particular, hit ball coaches should provide training sessions which mainly consider high intensity of game, with quick movements and ball actions, trying to simultaneously develop technical and conditional capabilities. Nevertheless, considering that high HR response is regularly high during match, exclusive conditional training session should be also planned to specifically stimulate and develop anaerobic energy system and aerobic capacity to obtain a satisfactory performance in terms of high speed of game and movement, and recovery capability during breaks among rallies, respectively (Chiodo et al., 2011). In addition, according to the competition effects on CMJ and GS trails, an opportune activation of lower limb muscles, as well as maintaining of a high level of strength of the shooting upper limb, could benefit the optimization of elite hit ball performance.

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