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Effect of contact and no-contact small-sided games on elite handball players

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ABSTRACT
This study aimed to investigate the effect of contact (C-SSG) and no-contact (NC-SSG) handball small-sided games (SSGs) on motion patterns and physiological responses of elite handball players. Twelve male handball players performed 10 C-SSG and 10 NC-SSG while being monitored through the heart rate (HR) and rate of perceived exertion (RPE) as physiological responses and time-motion activities profile using video-match analysis. Both game conditions resulted in similar HR responses ($P > 0.05$), but the NC-SSG led to a higher RPE scores. The time-motion activity analysis featured NC-SSG with a greater amount of walking (855.6 ± 25.1 vs. 690.6 ± 35.2 m) and backward movements (187.5 ± 12.3 vs. 142.5 ± 8.7 m) combined with fast running (232.3 ± 8.5 vs. 159.7 ± 5.7 m) and sprinting (79.5 ± 4.7 vs. 39.7 ± 3.7 m) activities ($P < 0.001$). Conversely, C-SSG had a higher percentage of jogging and sideway movements associated with greater frequency of jumping (0.87 ± 0.09 vs. 0.31 ± 0.06 nr) and physical contact (1.82 ± 0.55 vs. 0.25 ± 0.03 nr) events ($P < 0.001$). No between-regimen differences were found for the number of throws ($P = 0.745$). In addition, the RPE was significantly correlated with fast running relative distances ($r = 0.909$, $P < 0.001$) and sprinting relative distances ($r = 0.939$, $P < 0.001$). In conclusion, this investigation showed that both C-SSG and NC-SSG in team handball can effectively represent specifically oriented exercises, according to the sport-task and the performance demands.

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KEYWORDS
Notational analysis; heart rate; metabolic demand; rating perception effort; team sport

Introduction

Handball is a strenuous contact team sport that involves repeated bouts of highly demanding intermittent actions, such as short accelerations and decelerations, sprinting, jumping, turning, pushing, blocking, and throwing, interspersed by short periods of low intensity activities (Gorostiaga, Granados, Ibanez, Gonzalez-Badillo, & Izquierdo, 2006; Povoas et al., 2012). The recent knowledge gathered from both the scientific and technical literature reports that during a competitive game, players typically cover distances of 50 < 90 m/min, including 9 < 13 m/min at high intensity running, 3 < 5.5 m/min of sideways and backward movements, and 1.5 < 3 m/min at maximal sprint (Michalsik, 2011; Povoas et al., 2012). In addition to these running demands, due to the frequent occurrence of both attack and defence one-to-one game situations, handball players are frequently involved in physical collisions with an opponent, accounting for 0.45–2.67 events·min^{-1} during a competitive match, depending on the playing position (Michalsik, 2011; Michalsik, Aagaard, & Madsen, 2012). Thus, the requirement for frequent changes in the type of movements, speed, direction, and technical tasks is featured in the handball activity profile as intermittent in nature, and emphasises the predominant involvement of both phosphagens and glycolytic systems as energy suppliers (Povoas et al., 2012; Rannou, Prioux, Zouhal, Gratas-Delamarche, & Delamarche, 2001).

Relevant information about the physiological, physical, and playing demands of the game helps in outlining the related performance model of interest, and could be appropriately used when planning a daily practice, a weekly agenda, or a more long-term conditioning programme. In fact, such an evidence-based theoretical framework represents a means for optimising the design of handball-specific training drills with the aim of providing players with the most appropriate learning environments. These drills include well-designed technical, tactical, and handball-specific physical development programmes (Dello Iacono, Eliakim, Padulo, Ben-Zaken, & Meckel, 2016). In this context, by manipulating the exercise constraints and rules, coaches are likely to affect the physiological responses and both physical and technical demands of controlled game situations, with the aim of inducing the desired effects for maximal performance improvement.

In recent years, the small-sided games (SSG) training method has become the focus of scientific research, due to its ability to develop physical capacities together with sport-specific tactical and technical skills. SSG training has acquired great success, especially in soccer, where it offers many practical advantages that have led to its popularity as a training modality (Halouani, Chtourou, Gabbett, Chaouachi, & Chamari, 2014). The primary benefits of SSG training are that the game can replicate the movement patterns, as well as the physiological demands and

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technical requirements of competitive match play (Dellal et al., 2011), while also requiring players to make decisions under the opponent's pressure and fatigue conditions. In addition, compared with traditional fitness training sessions, SSG training is thought to increase player compliance and motivation, since it is perceived to be sport-specific exercise that maximises the training time spent with the ball (Buchheit et al., 2009a). To date, there have been only a small number studies on the effectiveness of SSG as a training method in handball (Buchheit et al., 2009a, 2009b; Dello Iacono, Ardigò, Meckel, & Padulo, 2016; Dello Iacono, Eliakim, & Meckel, 2015). Previous researchers have documented the physiological responses (Corvino, Tessitore, Minganti, & Sibila, 2014) and long-term training effects of SSG training in handball on metabolic (Buchheit et al., 2009a) and explosive-like abilities (Dello Iacono, Ardigò, et al., 2016; Dello Iacono et al., 2015). To our knowledge, only one study has focused its interest on the physiological workload and activity pattern profile of SSGs that include drills featuring constrained tasks (Corvino et al., 2014). Specifically, Corvino et al. (Corvino et al., 2014) investigated the effect of three different court dimensions on the internal and external load during handball SSGs, finding that changing court dimensions can be used to manipulate both the external and internal responses of the players. At present, no data are available on the effects of SSGs characterised by either the inclusion or prohibition of physical contact. A previous review highlighted that the tactical roles of each position generate many instances of body contact and duels during competitive matches. Specifically, pivots deal with a greater number of physical contacts due to the higher occurrence of duels in which they were involved. Conversely, wings have largely fewer physical contacts than all back players, and are also involved in substantially fewer duels. These play demands obviously have direct implications for the design of specific training programmes for these different positions. Moreover, the controlled presence or absence of such events during handball-based SSGs may have a large impact on the activity patterns and the associated physiological responses of the players. Accordingly, a deeper overall comprehension of the contact-induced effects during SSGs could offer insights about the practical applications of similar training regimens, given that they could be integrated into the regular handball training plan for inducing specific adaptations and enhancing performance levels. Therefore, the aim of this study was to investigate the effect of contact (C-SSG) and no-contact (NC-SSG) handball SSGs on the activity profile (assessed by video-match analysis) and physiological responses [assessed by heart rate (HR) and rate of perceived exertion (RPE)] of elite handball players. It was hypothesised that the exclusion of physical contact from handball SSG would result in reduced physiological/internal load responses and a different activity profile compared to SSG with contact.

Methods

Participants

Twelve highly trained male handball players (age 19.3 ± 0.4 years; height 1.86 ± 0.84 m; weight 86.8 ± 8.4 kg; maximal HR [HRmax] 201.2 ± 1.6 b·min^{-1}; fat mass percentage: 11.3 ± 1.4%; sum of the skin-folds: 87.2 ± 9.2 mm) participated in the study. All players belonged to the same national junior handball team and participated in European Cup tournaments during the season. The study was conducted during the second half of the regular handball season, when the players are in their best physical shape. The participants had 8.4 ± 1.1 years of training experience, practicing 8 times per week and playing a weekly official match, for a total of 11.5 ± 1.1 h of weekly handball activities. Written informed consent was obtained from the participants after they received an explanation of the purpose, benefits, and potential risks of the study. The study was approved by the Institution's Ethical Committee for Human Research and was conducted according to the Declaration of Helsinki.

Experimental approach

A counterbalanced design was used in this study. Physiological responses (HR and RPE) and a time-motion activities profile (video-match analysis) were monitored during 20 SSGs (10 C-SSG and 10 NC-SSG). In order to evaluate the possible effects of the number of repeated physical contacts during C-SSG, a full control condition that included the same training stimulus while avoiding physical contacts (NC-SSG) was added to the research design. Therefore, players completed two experimental trials five days apart, involving a standardised warm-up followed by either C-SSG or NC-SSG. Specifically, players were randomly divided into 4 teams with teams 1 and 2 playing the C-SSG first and the NC-SSG 5 days later and teams 3 and 4 playing the SSGs in the reverse order. In this way, the order in which the experimental protocols were completed was counterbalanced for each participant, and the order of conditions was determined by block randomisation (Schulz & Grimes, 2002) using an online randomisation tool. In addition, special emphasis was placed on ensuring the reliability of locomotor observation during the SSG. The reliability of this procedure was assessed by the inter-day test–retest and the intra-day re-analysis of a random subsample of 10 SSGs (5 C-SSG and 5 NC-SSG) by the observer. The number of exact agreements observed between each of the two analyses provided the level of agreement for the evaluation of time-motion analysis variables within SSGs, expressed as the 95% Limit of agreement (LoA) and the Intra-class Correlation Coefficient (ICC).

Procedures

Five days before the initiation of the experimental trials, the participants performed a familiarisation session to get acquainted with the training protocols. Additionally, the physiological and time-motion outcomes collected during the familiarisation sessions were analysed with the aim of assessing the test–retest reliability and consequently providing the consistency of the measures. On the same day, measurements of height and body mass (SECA model 284, Germany) were taken, and body fat percentage was calculated from measurements of seven skin-fold thicknesses (Jackson & Pollock, 1978). Finally, two days before the first experimental trial, the Yo–Yo intermittent recovery test Level 1 (YYIRTL1) was performed to determine the maximum HR (HRmax) values further used for the calculation of exercise internal loads during SSGs. The validity of the YYIRTL1 and its relevance for the assessment of intermittent high-intensity endurance in young male team handball players was previously described (Souhail, Castagna, Mohamed, Younes, & Chamari, 2010). All tests were performed on a regular indoor court, and participants completed all trials at the same time of the day (11:00 a.m.–01:00 p.m.) and in similar ambient conditions of temperature (20.5 ± 0.5°C) and relative humidity (60.0 ± 4.5%). In order to prevent unnecessary fatigue effect, the players and coaches were instructed to avoid intense training 24-h prior to each testing day. Additionally, the participants were also asked to avoid eating 2-h before each testing session.

Small-sided games protocols

C-SSG and NC-SSG were performed in two training sessions, five days apart. Both games included regular small-sided handball matches and were organised in 3-a-side teams including goalkeepers, as regularly used by the coaches during training. The only difference between the two games was the inclusion or prohibition of upper body use for physical contact in the C-SSG and NC-SSG, respectively. Players were divided into four teams with team 1 and 2 playing the contact game first and the non-contact game 5 days later; teams 3 and 4 played the games in reverse order. Each game consisted of 5 bouts (3 min each) with a passive recovery of 1 min in-between, played on a regular handball court (40 × 20 m). Some playing rules were created in order to prevent game breaks, ensuring continuity and high exercise intensity. For example, standing and dribbling were not allowed, defence stops due to regular fouls (only for C-SSG) were sanctioned with ball turnover, and the maximal time to complete an attack before losing ball possession was preset at 20 s. In addition, several balls were placed around the sided games area for immediate availability in order to avoid game stop. Finally, in case of penalty, the same was considered as a regular goal and no free throws were assigned. Except for the physical contacts, there was no difference in the pitch size, player number, rules, verbal encouragement, or training methodology between the contact and non-contact games.

Match time-motion analysis

Game time-motion analysis for 20 SSGs (10 C-SSG and 10 NC-SSG) was assessed by two synchronised cameras (Casio Exilim FH-100, Japan) positioned (frontal and sagittal planes) (Padulo, Haddad, Ardigo, Chamari, & Pizzolato, 2015) at the midline 8 m away from the sideline and elevated 10 m, to allow for full coverage of the court. The sample rate of the cameras was fixed at 100 Hz. The players were video-recorded in order to establish motion patterns according to the methods used by Povoas et al. (2012). Data were downloaded to a laptop (500T1C-K03; Samsung Electronics Co., Ltd., Suwon, South Korea) and subsequently analysed frame-by-frame with an accuracy of 0.02 s (Dartfish 6.0, Fribourg, Switzerland). Players' displacements were coded into 6 locomotor categories, considering the specific movements in handball. The locomotor categories were defined as follows: (1) walking (<1.6 $m \cdot s^{-1}$), (2) jogging (<2.2 $m \cdot s^{-1}$), (3) fast running (<5 $m \cdot s^{-1}$), (4) sprinting (<8.3 $m \cdot s^{-1}$), (5) backwards movement, and (6) sideways movement. The mean velocity of each category was determined by a detailed analysis of match images, using the lines of the playing court as reference. The distance covered in each category equalled the product of the total time and the mean speed for that activity. For each locomotor category, the percentage of total distance in terms of relative distance was determined. The total distance covered during a match was calculated as the sum of the distances for each type of activity. In addition, 3 types of specific handball playing actions were also collected: (a) jumps, (b) throws, and (c) physical contacts or stops. For the purposes of this study, a physical contact was defined as an event lasting at least 1 s, wherein players, by the use of the upper limbs, halted the progress of an opponent in possession of the ball (Barris & Button, 2008). The same experienced observer performed all the analyses to prevent inter-observer variability.

Heart rate responses

HR responses were monitored during the SSG bouts and expressed as relative to the maximal HR (HRmax) corresponding to the highest value measured at the end of the YYIRTL1 test for each player. Specifically, the mean and peak HR values of the experimental training sessions, were calculated as percentage of HRmax and reported as %HRmean and %HRpeak, respectively (Padulo et al., 2015). The %HRmean for SSGs was calculated by taking the means of both experimental protocols, and the % HRpeak was considered as the highest value reached during the experimental sessions. HR responses were recorded via a telemetry system (Hosand Technologies Srl, Verbania, Italy) at 5 s intervals throughout each SSG and then filtered by dedicated software (Hosand MC-Software™, Verbania, Italy).

Rate of perceived exertion responses

Players indicated their RPE using the category rating 10 (CR-10) scale modified by Foster et al. (2001) using a standardised questionnaire. Prior to the commencement of the study, the players were familiarised with the scale and underwent a standardised anchoring procedure. The RPE scores were recorded within 30 min after the end of the last bout of each SSG regimen, in order to eliminate bias resulting from the final phase of the experimental exercise, as previously suggested (Foster et al., 2001).

Statistical analysis

All data are presented as means ± standard deviation (SD) and confidence interval (95%CI). The Shapiro–Wilk test was used to ensure normal distribution of the results. Inter-day test–retest reliability was examined using mean difference ± 95% limits of agreement (LoA) while the Intra-Class Correlation Coefficient (ICC) was used to determine the intra-day reliability of the measures. A one-way Analysis of Variance (ANOVA) was performed to examine the data differences in order to determine the effects of each condition (C-SSG vs. NC-SSG). The Cohen's d (1992) was used to assess effect-size (ES). According to Hopkins, Marshall, Batterham, and Hanin (2009) ES of above

4, between 4 and 2, between 2 and 1.2, between 1.2 and 0.6, between 0.6 and 0.2 and 0.2 and 0 were considered as huge, very large, large, moderate, small, and trivial respectively. In order to provide normative cues for metrics changes the Smallest Worthwhile Change (SWC) was considered according to Hopkins et al. (2009) Variables association, between the locomotor category distances and the RPE scores during both SSGs regimens, was assessed using Pearson's product-moment correlation coefficients (i.e., *r*). Qualitative magnitude of associations was reported according to Hopkins (2002) as follows: trivial $r < 0.1$, small $0.1 < r < 0.3$, moderate $0.3 < r < 0.5$, large $0.5 < r < 0.7$, very large $0.7 < r < 0.9$, nearly perfect $r > 0.9$ and perfect $r = 1$. The alpha test level for statistical significance level was set at $P \leq 0.05$. Statistical analysis was performed using SPSS Statistics 21 software (SPSS Inc., Chicago, IL, USA).

Results

The 95% LoAs and ICCs of the inter-day and intra-day test–retest measurements ranged are reported in Table 1 and indicate good to excellent agreements between trials. Values for all time motion and playing variables are shown in Table 2.

Significant differences were found between the two training conditions as effect of treatment on all the monitored locomotor categories: walking $P < 0.001$ (huge ES); jogging $P < 0.001$ (huge ES); fast running $P < 0.001$ (huge ES); sprinting $P < 0.001$ (huge ES); sideways movement $P < 0.001$ (huge ES); backwards movement $P < 0.001$ (huge ES) (Table 2).

As for the playing tasks, between-groups ANOVA showed differences for jumps (13.05 ± 1.35 vs. 4.65 ± 0.9 for C-SSG and NC-SSG, respectively) $P < 0.001$ (huge ES) and for the physical contacts (27.3 ± 0.25 vs. 3.75 ± 0.45 for C-SSG and NC-SSG, respectively) $P < 0.001$ (huge ES) but not for the number of throws (8.55 ± 1.2 vs. 8.4 ± 1.65 for C-SSG and NC-SSG, respectively) $P = 0.745$ (trivial ES) .

The %HRmean during the training session bouts in the SSGs ranged between 84.2 ± 1.7% and 92.2 ± 0.4% for the C-SSG and between 84.7 ± 1.3 and 92.7 ± 0.2% for the NC-SSG. The C-SSG %HRmean was not significantly different from the corresponding NC-SSG values in all bouts (all $P > 0.05$). The % HRpeak reached during C-SSG was 94.2 ± 0.2%, similar to that recorded by NC-SSG (95.1 ± 0.3% with $P > 0.05$).

Between-groups ANOVA showed differences for the RPE score $P < 0.001$ (EF = 2.54, very large).

Table 1. Descriptive and reliability statistics of inter-and intra-day test–retest of the time-motion parameters.

Variable	Mean diff. ± 95% LoA	ICC	95% CI		SWC
Walking (m)	11.1 ± 3.2	0.889	0.875	0.902	66.01
Jogging (m)	10.6 ± 2.3	0.897	0.883	0.910	60.05
Fast Running (m)	6.2 ± 1.7	0.912	0.898	0.925	29.04
Sprinting (m)	1.4 ± 0.6	0.933	0.919	0.947	15.9
Side Movements (m)	7.1 ± 2.2	0.898	0.884	0.911	63.09
Back Movements (m)	2.3 ± 0.9	0.905	0.891	0.918	18
Jumps (nr)	0.6 ± 0.2	0.912	0.898	0.925	3.54
Throws (nr)	0.4 ± 0.2	0.903	0.899	0.922	0.06
Contacts (nr)	0.3 ± 0.1	0.906	0.892	0.920	9.42

LoA: Limits of agreement; ICC: Intra-class correlation coefficient; SWC: Smallest Worthwhile Change.

The relationship between RPE responses computed by Pearson product-moment correlation coefficient (Figure 3) showed a nearly perfect correlation with fast running relative distances ($R^2 = 0.827$, $r = 0.909$, $P < 0.001$) and sprinting relative distances ($R^2 = 0.889$, $r = 0.939$, $P < 0.001$).

Discussion

The current study, using a controlled experimental design, aimed to investigate the effects of physical contact on the acute physiological responses and activity profiles of two handball SSG formats (C-SSG and NC-SSG) in highly trained male handball players. Our main findings are as follows: (1) exercise intensity induced by the two experimental approaches were similar as determined by the %HRmean and %HRpeak responses; (2) perceptual training exertion, calculated using the RPE scale, resulted in higher response to the NC-SSG when compared to the C-SSG; (3) on average, a greater amount of walking and backward movements combined with fast running and sprinting locomotor activities were featured in the NC-SSG, whereas a higher percentage of jogging and sideways movements associated with greater frequency of jumping and physical contact events characterised the C-SSG regimen.

Monitoring the HR response of players during training is a useful and reliable method for regulating exercise intensity (Povoas et al., 2012). Although this study is the first to determine the effect of physical contact in controlled SSGs, the current results are in agreement with those of previous investigations reporting comparable intensity responses when designing similar type of training used for both adult (Buchheit et al., 2009b; Dello Iacono, Ardigò et al., 2016; Dello Iacono et al., 2015) and young (Buchheit et al., 2009a) handball players. In this study, %HRmean and %HRpeak resulted in 88.6 vs. 89.2% and 94.2 vs. 95.1% for C-SSG and N-SSG, respectively. In a recent investigation, Dello Iacono, Eliakim, Padulo, et al., (2016) showed that a similar no-contact SSG training protocol resulted in exercise intensities of 90.4 and 94.2% for %HRmean and %HRpeak, respectively. Moreover, the telemetric records of both SSG training sessions were higher than those reported by Povoas et al. (2012) and Loftin, Anderson, Lytton, Pittman, and Warren (1996) concerning the physiological demands of handball players during official matches. The HR responses showed variability across the five intervals that made up the training session (Figure 1). HR responses in the first and second bouts of the SSGs were significantly lower than those associated with the third, fourth and fifth bouts. This indicates that the initial period of SSG play is associated with a gradual increase in HR to the levels required for a metabolic training stimulus. This time period is likely to be reduced in subsequent exercise bouts, especially when recovery periods limit the return of HR to baseline levels (Saltin, Essen, & Pedersen, 1976), thereby leading to a faster elevation of HR to the desired intensity. This may contribute to the higher %HRmean and %HRpeak responses observed in our study as the SSGs progressed. Therefore, relying on the physiological responses recorded during the training sessions and referring to the optimal training regimes required to improve metabolic fitness (Buchheit et al., 2009b; Gorostiaga et al.,

Table 2. The comparison of time-motion and playing activities between contact and no-contact small handball small-sided games.

Locomotor Activities							
Total distance covered	Group	Mean	SD	95% CI	F(1,22)	P	ES
Walking (m)	C-SSG	690.6	35.2	670.6 to 710.5	174.369	< 0.001*	5.21
	NC-SSG	855.6	25.1	841.3 to 869.8			
Jogging (m)	C-SSG	320.2	18.1	309.9 to 330.4	644.727	< 0.001*	9.98
	NC-SSG	180.1	9.7	174.6 to 185.5			
Fast Run (m)	C-SSG	159.7	5.7	156.2 to 162.7	594.681	< 0.001*	9.84
	NC-SSG	232.3	8.5	227.4 to 232.1			
Sprinting (m)	C-SSG	39.7	3.7	37.6 to 41.7	516.594	< 0.001*	9.09
	NC-SSG	79.5	4.7	76.8 to 82.1			
Side Mov (m)	C-SSG	315.2	14.5	306.9 to 323.4	851.414	< 0.001*	11.52
	NC-SSG	157.5	11.8	150.8 to 164.1			
Back Mov (m)	C-SSG	142.5	8.7	137.5 to 147.4	105.561	< 0.001*	4.03
	NC-SSG	187.5	12.3	180.5 to 194.4			
Playing Activities Events/min							
Jumps (nr)	C-SSG	0.87	0.09	0.81 to 0.92	296.421	< 0.001*	7.46
	NC-SSG	0.31	0.06	0.27 to 0.34			
Throws (nr)	C-SSG	0.57	0.08	0.52 to 0.61	0.107	0.745	0.1
	NC-SSG	0.56	0.11	0.49 to 0.62			
Physical Contacts (nr)	C-SSG	1.82	0.55	1.50 to 2.13	32.77	< 0.001*	5.41
	NC-SSG	0.25	0.03	0.23 to 0.26			

The values are expressed as mean and standard deviation (SD) with 95% confidence interval (95% CI) in both the contact (C-SSG) and no-contact (NC-SSG) groups. Fast Run: fast running; Side Mov: sideways movement; Back Mov: backwards movement; m: meters; nr: number; The F-value, *P*-value and effect size (ES) value are reported for the comparison of the two groups "*" – $P \le 0.05$ indicates significant inter-group differences.

2006), both prescribed protocols represented an efficient training stimulus to the metabolic fitness component. An interesting finding of the present study is the substantial absence of exercise intensity differences between the two experimental protocols. From a methodological viewpoint, considering the highly demanding mechanical loads and energetic expenditure associated with physical contact and collision, one may logically presume that the presence of such events may lead to significantly higher physiological responses and exercise intensities. However, despite imposing a greater theoretical training load due to the inclusion of physical contacts, the exercise constraints' manipulation had no effect on the physiological responses. A plausible explanation for these outcomes may be represented by two different self-selected pace regulation strategies adopted by the players being aware of the specific rules and constraints associated to the two SGGs formats. Research (Abbiss & Laursen, 2008) on effective pacing strategies has widely highlighted that a variable pace strategy is usually adopted in an attempt to counteract variations in external conditions of competitive environment. Therefore, it seems likely that the similar physiological responses seen during C-SSG and NC-SSG may be occurred as a consequence of the varying playing conditions associated with the experimental exercises that, in turn, led the players to respond with two activity profiles. In fact, given that players involved in NC-SSG did not have to deal with continuous and repetitive physical contacts may have put more effort into producing greater amounts of high intensity movements in the form of fast running and sprinting. Conversely, the C-SSG eliciting higher mechanical loading due to the collisions and impacts between opponents, could have simply driven players to down-regulate their effort to account for these demanding activities. In our study, data obtained through the video-analysis, referring to the physical contact counts, reported a mean of 1.84 ± 0.52 events·min^{-1} during the C-SSG. Such results are in line with those of competitive matches with adult handball players (Michalsik, 2011; Michalsik et al., 2012). In addition, it is worthy of consideration that the participants involved in the current study were highly trained handball players, well accustomed to handball specific training including physical contacts. Consequently, due to the similar relative occurrence of physical contacts with respect to official games, and the relatively high training experience of the involved sample, it is likely that the C-SSG protocol may not have exhibited a mechanical loading demanding enough to generate greater physiological responses.

The analysis of perceived effort using the RPE scale showed that both SSG regimens induced high subjective responses, with greater values for the NC-SSG compared with C-SSG. Available research suggests that RPE is a valid indicator of high-intensity intermittent exercise and demonstrates the high correlation between RPE measures and high-speed running and accelerations, both in handball (Corvino et al., 2014) and soccer (Gaudino et al., 2015) practice. Corvino et al. (2014) found that during 3-a-side SSGs, larger court dimension led the players to cover more distance in high-speed zones and to report higher scores of RPE. Our results conform to the conclusions of these authors, showing that speed and acceleration are likely to be strong predictors of RPE. Consequently, the higher values of RPE following NC-SSG found in our study were dictated by the greater amount of high intensity running activities (i.e., fast running and sprinting) compared to those reported for C-SSG (Figure 2). The difference for the RPE between the two protocols, without the same trend emphasised by the HR responses, is not novel in the scientific literature, and was also found in a rugby study by Kennett, Kempton, and Coutts (2012). The observed dissociation between HR responses and RPE could be related to the multifunctional nature of the latter method in quantifying the exercise internal loads. As previously reported, the RPE is mediated not only by physiological but also by psychological

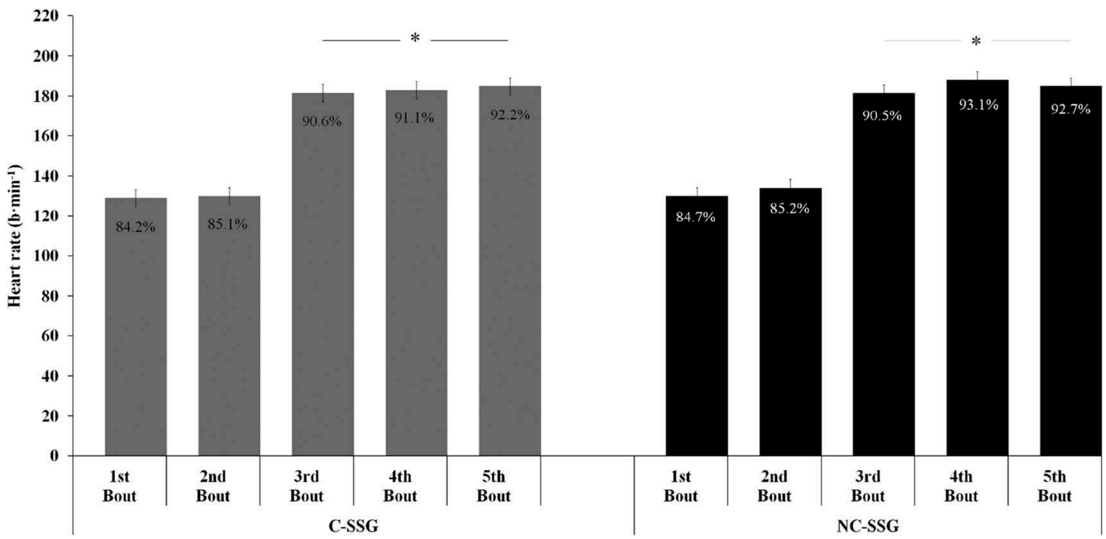

Figure 1. Mean heart rate (HR) during five exercise bouts for both contact (C-SSG) and no-contact small-sided games (NC-SSG). Data are presented as mean ±*SD*. Absolute (b·min^{-1}) and relative (%) to individual maximal HR values are shown. * means $P < 0.05$, significantly different from the 1st and 2nd bouts.

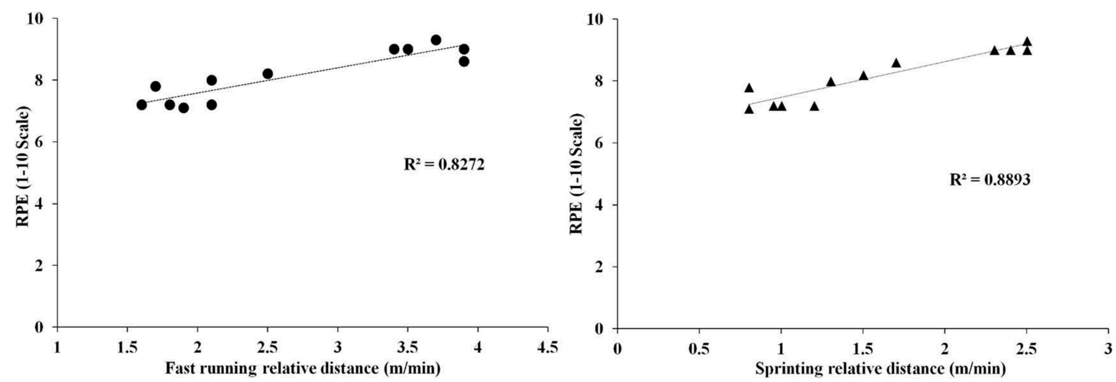

Figure 2. RPE (1–10 Scale) *vs*. fast running relative distance (m/min) relationships (black points) and RPE (1–10 Scale) *vs*. sprinting relative distance (m/min) relationships (black triangle) for both experimental groups.

factors (Borg, 1982; Morgan, 1994). Another possible reason for this outcome may be a "pacing effect", which occurred due to the relatively long duration of low intensity activities (i.e., walking, backward movements) resulting from the NC-SSG protocol (Table 2). In fact, as shown in Figure 3, NC-SSG resulted in greater amounts of relative distances for walking and backward movements, accounting for 50.8 and 10%, respectively, of the total distance covered. Therefore, this typical intermittent profile of the NC-SSG, with the presence of longer active recovery phases between high intensity running activities, may have led to a partial restoration of phosphagen stores and lower glycogen depletion, thereby reducing the physiological load monitored by the HR but not the subjective perceived exertion (Saltin, 1973).

Time-motion analysis showed that during the 15 min of each SSG protocol duration, 204 ± 12 and 237 ± 16 activity changes were performed for the C-SSG and NC-SSG, respectively. Considering the reference values reported for team handball (Povoas et al., 2012; Sibila, Vuleta, & Pori, 2004), the experimental protocol designed in our study induced a higher relative frequency between the all activity changes in comparison to those of official matches, and resulted in different and specific activity pattern profiles (Figure 3). In a previous investigation, Povoas et al. (2012) found that players from the top Portuguese handball professional league performed about 11 activity changes per minute at a mean of 6-s intervals. These findings were recently confirmed in a review of Karcher and Buchheit (2014), which collected outcomes from studies on on-court demands, game dynamics, and motion analysis of team handball players of different roles, genders and levels. In comparison with the data provided by Povoas et al. (2012), our results revealed a higher number of activity change per minute in both N-SSG [204 ± 12 (13.6/min)] and NC-SSG [237 ± 16 (15.8/min)], and this relative higher amount of cyclic activities was combined with greater relative total distance travelled during the SSG. This is not surprising given that the short duration of the games and the reduced number of players in the SSGs allowed participants to perform a relatively high amount of cyclic movements in a short period. This finding is also supported by the data obtained by Buchheit et al. (2009a) confirming the evidence that the greater the relative area per player during SSGs playing, the higher the amount of relative distance covered. From a methodological viewpoint, an additional factor that may have induced such responses is

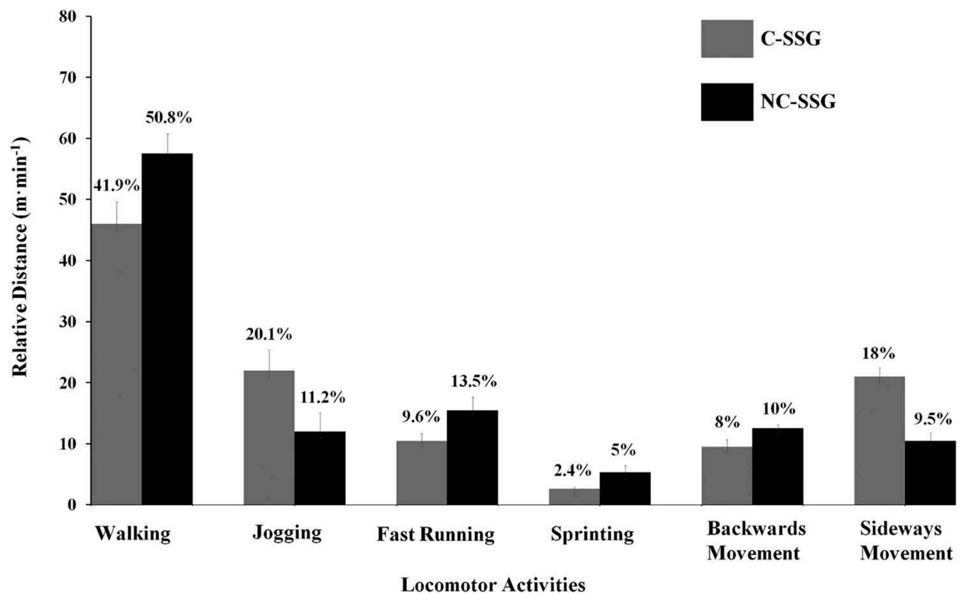

Figure 3. Relative and percentage distances covered in each locomotor activity during five exercise bouts of both contact (C-SSG) and no-contact small-sided games (NC-SSG). Data are presented as mean ±*SD*.

represented by the specific constraint applied in our experimental design, referring to the maximal time for build-up phases. In fact, as detailed above, players involved in both SSG regimens were required to complete an attack before losing ball possession within a maximal time of 20 s. Therefore, it is reasonable that the short pre-set time allowed for completing each build-up phase had a direct effect on the pacing strategies adopted by both the offensive and defensive players. Such an interpretation is further confirmed by the parallel higher physiological responses for the HR and RPE values, as shown in Figure 1. In light of these outcomes, both SSG protocols used in our study may represent a viable means for optimal training regimes designed to induce long-term adaptation of the metabolic fitness component as previously proposed (Buchheit et al., 2009a; Dello Iacono, Ardigò, 2016, Dello Iacono et al., 2015).

The results obtained in our study regarding the time-motion features of the two SSG regimens provide an insight into the specific activities profile and demands pattern related to these handball-based training methods. As shown in Table 2, the C-SSG was characterised by higher amounts of medium-intensity locomotor activities' distances, such as for jogging (330.2 ± 18.1 vs. 180.1 ± 9.7 m for C-SSG and NC-SSG, respectively), combined with short-term neuromuscular-based actions like sideways movements (315.2 ± 14.5 vs. 157.5 ± 11.8 m for C-SSG and NC-SSG, respectively), jumps (13.08 ± 0.42 vs. 4.7 ± 0.25 m for C-SSG and NC-SSG, respectively) and physical contacts (1.82 ± 0.24 vs. 0.25 ± 0.13 m for C-SSG and NC-SSG, respectively). These outcomes may have resulted from the recurring "one-on-one" situations, which forced players to withstand and to overcome an opponent that tried either to score or to prevent goals. In terms of practical applications, the high occurrence of actions such as hitting, blocking, holding, jumping, and change in direction occurring in the C-SSG may generate an efficient overloading effect on the neuromuscular upper and lower body muscles properties (Dello Iacono, Martone, & Padulo, 2016; Dello, Martone, Milic, 2016), targeting this training regimen as appropriate for long-term performance improvements. There is clear evidence from the literature on the chronic effects of contact SSG on the upper and lower body neuromuscular performance in handball players. Specifically, Dello Iacono et al. (2015), using a similar training setup as that the one involved in this study, indicated that physical contact between players in SSG training creates a cumulative training stimulus that produces improvements in upper body strength, as demonstrated in the 1RM bench press test (Padulo, Laffaye, Chaouachi, & Chamari, 2015). In the same study (Dello Iacono, et al., 2015), the SSG regimen was proven to have practical advantages over a high-intensity intermittent training protocol, and was more effective in inducing performance gains in vertical jumps and agility skills. Therefore, the contact events occurring in the C-SSG protocol are likely to provide neuromuscular overloads (Dello Iacono, Eliakim, Padulo, et al., 2016) that, when adequately planned in the handball conditioning agenda, may result in long-term adaptations and functional gains. Moreover, this finding could also help athletes in developing certain physical abilities according to the demands of their playing position, with pivot and back defenders identified as the optimal target, requiring of more muscle hypertrophy and strength type of work (Karcher & Buchheit, 2014). On the other hand, the NC-SSG resulted in higher relative distances of low-intensity locomotor activities such as walking (855.6 ± 25.1 vs. 690.6 ± 35.2 m for NC-SSG and C-SSG, respectively), coupled with a greater distance for both fast running activities (232.3 ± 8.5 vs. 159.7 ± 5.7 m for NC-SSG and C-SSG, respectively) and sprinting (79.5 ± 4.7 vs. 39.7 ± 3.7 m for NC-SSG and C-SSG, respectively). These results outline a different and specific activity profile for the NC-SSG in comparison with the C-SSG. In fact, the higher relative distance covered during high-intensity locomotor activities (i.e., fast running and sprinting), interspersed with more frequent and longer distances of low-intensity locomotor activities (i.e., walking and backwards movement), profile this SSG regimens as similar to repeated sprint training (RST). RST is commonly used to improve neuromuscular qualities such as maximal sprinting speed and muscle explosive power, given that a strong correlation exists between RSA and sprint qualities (Pyne, Saunders, Montgomery, Hewitt, & Sheehan, 2008). Previous investigations, describing similar types of training designed for adult handball players (Dello Iacono, Ardigò, et al., 2016), basketball (Attene et al., 2015), and soccer players (Gorostiaga et al., 2004), have reported beneficial effects on maximal sprinting and explosive-like performances. Considering these pieces of evidence and referring to the current position-related motion analysis demands (Karcher & Buchheit, 2014), the outcomes of our study may have direct implications for the design of specific training programmes. Studies (Karcher & Buchheit, 2014) reporting between-position differences in running demands of handball players have shown very large disparities with wing players largely performing more high-intensity runs than backs and pivots, while their sprinting distance was moderately higher than backs and greatly higher than pivots. Wings also covered a much greater backwards distance than the other outfield players did with their lower involvement in duels and physical contact events. Accordingly, the activity pattern of the NC-SSG seems to match the playing demands of wing players during regular matches, thus targeting this training regimen as the most specific and appropriate means according to the specific discipline and the performance model.

Finally, in addition to the advantage of producing a higher physiological response and specific activity pattern profiles, both SSGs designed in our study induced a higher number of ball contacts per individual and a greater relative amount of throws per minute. With regard to the current literature on regular handball games (Karcher & Buchheit, 2014; Povoas et al., 2012), our data revealed that in both SSGs players threw a mean of 8.6 ± 0.9 and 8.4 ± 0.5 shoots for C-SSG and NC-SSG, respectively. This means that the average relative throwing events per minute were 0.57/min and 0.56/min, thus about 5 times greater than the occurrence of the same technical skill during official games. The similarity in the frequency of the playing actions between the two SSG formats used in the current investigation presumes that the designed pitch size and the number of players represent major determinants of the number of technical actions performed, whereas neither the inclusion nor the prohibition of physical contacts produced effects on playing demands. This would suggest that pitch size and game format should be carefully considered by coaches in their organisation of practice if the drill is required in order to combine a physical training stimulus with technical work on throwing, or if reducing physical contact within training is important.

However, the current study presents some limitations and its findings should be considered with caution for few main reasons. Firstly, the adopted research design, including male elite handball player as sample, may limit the opportunity to make broader generalisations from our results to other populations represented by different age-groups athletes of different level or gender. In addition, we acknowledge that the present study design could have been more powerful with a greater sample. However, the population from which well-trained handball players can be drawn, belonging to the same team and with a common conditioning background, is limited and, therefore this dictated the approach we utilised. Finally, a careful generalisation of the responses of the experimental SSGs used in our study is warranted in light of the potential variable effects induced by alternative SSGs formats of with different, volume, duration and technical/tactical constrains. Therefore, further studies are needed to provide clear recommendations on the design and implementation of C-SSG and NC-SSG which could be implemented during the season to improve specific handball physical, physiological and technical abilities.

Conclusions

The findings of the current study have important practical implications. Firstly, they indicate that both contact- and no-contact SSG are equally effective in inducing the physiological responses and exercise intensity required for developing metabolic capabilities. Secondly, they suggest that the controlled inclusion or prohibition of physical contact between players in such a training format is important for facilitating the attainment of desired activity profiles. Specifically, C-SSG was characterised by higher amounts of medium intensity locomotor distance combined with short-term neuromuscular-based actions, such as sideways movement jumps. Conversely, NC-SSG elicited greater distances of low intensity locomotor activities coupled with greater distances for both fast running activities and sprinting. Consequently, during the in-season period, handball coaches may integrate these conditioning methodologies into their training strategies, given that they represent a viable means for inducing higher physical demands than those presented in an official match-play, while encompassing the technical and tactical elements of the handball performance model and position-related playing demands.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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References

Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine*, *38*, 239–252. doi:10.2165/00007256-200838030-00004

Attene, G., Laffaye, G., Chaouachi, A., Pizzolato, F., Migliaccio, G. M., & Padulo, J. (2015). Repeated sprint ability in young basketball players:

One vs. two changes of direction (Part 2). *Journal of Sports Science*, *33*, 1553–1563. doi:10.1080/02640414.2014.996182

Barris, S., & Button, C. (2008). A review of vision-based motion analysis in sport. *Sports Medicine*, *38*, 1025–1043. doi:10.2165/00007256-200838120-00006

Borg, G. A. (1982). Psychophysical bases of perceived exertion. *Medicine & Science in Sports & Exercise*, *14*, 377–381. doi:10.1249/00005768-198205000-00012

Buchheit, M., Laursen, P. B., Kuhnle, J., Ruch, D., Renaud, C., & Ahmaidi, S. (2009a). Game-based training in young elite handball players. *International Journal of Sports Medicine*, *30*, 251–258. doi:10.1055/s-0028-1105943

Buchheit, M., Lepretre, P. M., Behaegel, A. L., Millet, G. P., Cuvelier, G., & Ahmaidi, S. (2009b). Cardiorespiratory responses during running and sport-specific exercises in handball players. *Journal of Science and Medicine in Sport*, *12*, 399–405. doi:10.1016/j.jsams.2007.11.007

Cohen, J. (1992). Quantitative methods in psychology: A power primer. *Psychological Bulletin*, *112*, 155–159. doi:10.1037/0033-2909.112.1.155

Corvino, M., Tessitore, A., Minganti, C., & Sibila, M. (2014). Effect of court dimensions on players' external and internal load during small-sided handball games. *Journal of Sports Science and Medicine*, *13*, 297–303.

Dellal, A., Chamari, K., Wong, D. P., Ahmaidi, S., Keller, D., Barros, M. L. R., … Carling, C. (2011). Comparison of physical and technical performance in European professional soccer match-play: The FA Premier League and La LIGA. *European Journal of Sport Science*, *11*, 51–59. doi:10.1080/17461391.2010.481334

Dello Iacono, A., Ardigò, L. P., Meckel, Y., & Padulo, J. (2016). Effect of small-side games and repeated shuffle sprint training on physical performance in elite handball players. *The Journal of Strength and Conditioning Research*, *30*, 830–840. doi:10.1519/JSC.0000000000001139

Dello Iacono, A., Eliakim, A., & Meckel, Y. (2015). Improving fitness of elite handball players: Small-sided games vs. high-intensity intermittent training. *The Journal of Strength and Conditioning Research*, *29*, 835–843. doi:10.1519/JSC.0000000000000686

Dello Iacono, A., Eliakim, A., Padulo, J., Ben-Zaken, S., & Meckel, Y. (2016). Neuromuscular and infiammatory responses to handball small-side games: The effects of physical contact. *Scandinavian Journal of Medicine and Science in Sports*. [Epub ahead of print]. doi:10.1111/sms.12755

Dello Iacono, A., Martone, D., Milic, M., & Padulo, J. (2016). Vertical- vs. horizontal-oriented drop-jump training: Chronic effects on explosive performances of elite handball players. *The Journal of Strength and Conditioning Research*. [Epub ahead of print]. doi:10.1519/JSC.0000000000001393

Dello Iacono, A., Martone, D., & Padulo, J. (2016). Acute effects of drop-jump protocols on explosive performances of elite handball players. *The Journal of Strength and Conditioning Research*, *30*, 3122–3133. doi:10.1519/JSC.0000000000001393

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., … Dodge, C. (2001). A new approach to monitoring exercise training. *The Journal of Strength and Conditioning Research*, *15*, 109–115.

Gaudino, P., Iaia, F. M., Strudwick, A. J., Hawkins, R. D., Alberti, G., Atkinson, G., & Gregson, W. (2015). Factors influencing perception of effort (session rating of perceived exertion) during elite soccer training. *International Journal of Sports Physiology and Performance*, *10*, 860–864. doi:10.1123/ijspp.2014-0518

Gorostiaga, E. M., Granados, C., Ibanez, J., Gonzalez-Badillo, J. J., & Izquierdo, M. (2006). Effects of an entire season on physical fitness changes in elite male handball players. *Medicine & Science in Sports & Exercise*, *38*, 357–366. doi:10.1249/01.mss.0000184586.74398.03

Gorostiaga, E. M., Izquierdo, M., Ruesta, M., Iribarren, J., Gonzalez-Badillo, J. J., & Ibanez, J. (2004). Strength training effects on physical performance and serum hormones in young soccer players. *European Journal of Applied Physiology*, *91*, 698–707. doi:10.1007/s00421-003-1032-y

Halouani, J., Chtourou, H., Gabbett, T., Chaouachi, A., & Chamari, K. (2014). Small-sided games in team sports training: A brief review. *The Journal of Strength and Conditioning Research*, *28*, 3594–3618. doi:10.1519/JSC.0000000000000564

Hopkins, W. G. (2002). Probabilities of clinical or practical significance. Retrieved from: sportsci.org/jour/0201/wghprob.htm

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise*, *41*, 3–13. doi:10.1249/MSS.0b013e31818cb278

Jackson, A. S., & Pollock, M. L. (1978). Generalized equations for predicting body density of men. *British Journal of Nutrition*, *40*, 497–504. doi:10.1079/BJN19780152

Karcher, C., & Buchheit, M. (2014). On-court demands of elite handball, with special reference to playing positions. *Sports Medicine*, *44*, 797–814. doi:10.1007/s40279-014-0164-z

Kennett, D. C., Kempton, T., & Coutts, A. J. (2012). Factors affecting exercise intensity in rugby-specific small-sided games. *The Journal of Strength and Conditioning Research*, *26*, 2037–2042. doi:10.1519/JSC.0b013e31823a3b26

Loftin, M., Anderson, P., Lytton, L., Pittman, P., & Warren, B. (1996). Heart rate response during handball singles match-play and selected physical fitness components of experienced male handball players. *The Journal of Sports Medicine and Physical Fitness*, *36*, 95–99.

Michalsik, L. B. (2011). Match performance and physiological capacity of male elite team handball players. In F. Táborský (Ed.), *European Handball Federation Scientific Conference* (pp. 162–168). Vienna: European Handball Federation.

Michalsik, L. B., Aagaard, P., & Madsen, K. (2012). Physical demands in elite team handball: Comparisons between male and female players. In R. Meeusen, J. Duchateau, B. Roelands, M. Klass, B. De Geus, S. Baudry, & E. Tsolakidis (Eds.), *17th Annual ECSS Congress* (pp. 102–111). Bruges.

Morgan, W. P. (1994). Psychological components of effort sense. *Medicine & Science in Sports & Exercise*, *26*, 1071–1077. doi:10.1249/00005768-199409000-00001

Padulo, J., Attene, G., Migliaccio, G. M., Cuzzolin, F., Vando, S., & Ardigo, L. P. (2015). Metabolic optimisation of the basketball free throw. *Journal of Sports Science*, *33*, 1454–1458. doi:10.1080/02640414.2014.990494

Padulo, J., Haddad, M., Ardigo, L. P., Chamari, K., & Pizzolato, F. (2015). High frequency performance analysis of professional soccer goalkeepers: A pilot study. *The Journal of Sports Medicine and Physical Fitness*, *55*, 557–562.

Padulo, J., Laffaye, G., Chaouachi, A., & Chamari, K. (2015). Bench press exercise: The key points. *The Journal of Sports Medicine and Physical Fitness*, *55*, 604–608.

Povoas, S. C., Seabra, A. F., Ascensao, A. A., Magalhaes, J., Soares, J. M., & Rebelo, A. N. (2012). Physical and physiological demands of elite team handball. *The Journal of Strength and Conditioning Research*, *26*, 3365–3375. doi:10.1519/JSC.0b013e318248aeee

Pyne, D. B., Saunders, P. U., Montgomery, P. G., Hewitt, A. J., & Sheehan, K. (2008). Relationships between repeated sprint testing, speed, and endurance. *The Journal of Strength and Conditioning Research*, *22*, 1633–1637. doi:10.1519/JSC.0b013e318181fe7a

Rannou, F., Prioux, J., Zouhal, H., Gratas-Delamarche, A., & Delamarche, P. (2001). Physiological profile of handball players. *The Journal of Sports Medicine and Physical Fitness*, *41*, 349–353.

Saltin, B. (1973). Metabolic fundamentals in exercise. *Medicine & Science in Sports & Exercise*, *5*, 137–146. doi:10.1249/00005768-197323000-00010

Saltin, B., Essen, B., & Pedersen, P. K. (1976). Intermittent exercise: Its physiology and some practical applications. In E. Jokl, R. L. Anand, & H. Stoboy (Eds.), *Advances in exercise physiology* (pp. 25–51). Basel: Karger.

Schulz, K. F., & Grimes, D. A. (2002). Blinding in randomised trials: Hiding who got what. *The Lancet*, *359*, 696–700. doi:10.1016/S0140-6736(02)07816-9

Sibila, M., Vuleta, D., & Pori, P. (2004). Position-related differences in volumes and intensity of large-scale cyclic movements of male players in handball. *Kinesiology*, *36*, 58–68.

Souhail, H., Castagna, C., Mohamed, H. Y., Younes, H., & Chamari, K. (2010). Direct validity of the Yo-Yo intermittent recovery test in young team handball players. *The Journal of Strength and Conditioning Research*, *24*, 465–470. doi:10.1519/JSC.0b013e3181c06827