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# Are small-sided games an effective training methodology for improving fitness in hurling players? A comparative study of training methodologies

**Shane Malone, Brian Hughes and Kieran D Collins**

## Abstract

The current investigation compared the effects of specific small-sided games training versus generic continuous aerobic training on team sport related exercise performances. Forty-eight hurling players (age: $25 \pm 6.4$ years; height: $180.2 \pm 20.4$ cm; mass: $80.5 \pm 3.2$ kg; $\dot{V}O_{2max}$: $58.78 \pm 3.05$ ml·kg·min$^{-1}$) completed either traditional continuous aerobic training ($n = 24$) or team sport-specific small-sided game training ($n = 24$), consisting of $4 \times 4$ min with 3-min active recovery periods completed twice per week. The following outcomes were measured at baseline (pre) and after 10 weeks (post): maximum oxygen uptake (ml·kg$^{-1}$·min$^{-1}$), running economy (ml·kg$^{-1}$·min$^{-1}$), maximal aerobic speed (km·h$^{-1}$), Yo-Yo intermittent recovery test level 1 (m), Yo-Yo intermittent recovery test level 2 (m), repeated sprint ability (RSA; s), linear sprint speed over 5, 10 and 20 m (s) and counter-movement jump performance (cm). Training load was quantified by heart rate and rating of perceived exertion during all training sessions with no significant difference between groups ($P = 0.12$). Small-sided game ($P = 0.002$; $d = 1.72$; *likely beneficial*) had a *likely beneficial* effect for improving running economy (ml·kg$^{-1}$·min$^{-1}$) in contrast to the unclear effect for continuous training ($P = 0.94$; $d = 0.21$; unclear). Small-sided game ($P = 0.04$; $d = 0.80$; *likely beneficial*) had a *likely beneficial* effect for changes in $RSA_b$ (s) and $RSA_t$ (s) with these being in contrast to the likely negative effect for continuous training on similar measures ($P = 0.12$; $d = -2.01$; likely negative). Continuous training had a *trivial* ($P = 0.72$; $d = 0.30$; *trivial*) effect on Yo-Yo intermittent recovery test level 1 (m) performance in contrast to the likely beneficial effect seen for small-sided game ($P = 0.002$; $d = 1.72$; *likely beneficial*). Small-sided game ($P = 0.001$; $d = 1.69$; likely beneficial) resulted in a likely beneficial effect for Yo-Yo intermittent recovery test level 2 (m) performance with a likely negative effect for continuous training ($P = 0.004$; $d = -2.40$; *likely negative*). The current study suggests that small-sided games are a time efficient and effective method of improving fitness characteristics within hurling cohorts.

**Keywords**

Heart rate, maximal aerobic capacity, repeated sprints, running economy, vertical jump, Yo-Yo intermittent recovery test

## Introduction

Hurling is a stick and ball team based field sport that has intermittent bouts of continuous low intensity running interspersed with bouts of high intensity running.[1] During match-play, the timing of high intensity actions stochastic in nature following the ebb and flow of competitive match play.[1,2] Currently, the applied practitioner faces the challenge of improving athletic and physiological performance without encroaching on the technical and tactical training time periods.[3] Aerobic capacity is an important consideration with high maximal values correlated to work rate during match play with reported benefits to aid between bout recoveries during high intensity intermittent exercise.[4] As such, there is a need for hurling players to be exposed to training programs, which include aerobic conditioning.[5] Furthermore, as aerobic metabolism is largely involved in fuelling recovery from high speed actions, training methodologies which enhance aerobic

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capacity are important considerations for improving match play distance, work intensity, and match play involvements,[2,6,7] which can be related to improved utilisation of energetic substrates and elements of glycogen sparing.[1,6,7]

Small-sided games (SSG) represent a methodology of training which coaches prefer to utilise to increase aerobic capacity and technical performance within hurling cohorts due to this method representing a concurrent and time efficient method of training. Indeed, SSG have been used with increasing frequency in other team sports.[8–10] Previously, SSG have been used to improve the interaction among soccer players and to develop technical and tactical abilities.[11,12] During these games, players' heart rates can exceed 90% of peak heart rate ($HR_{peak}$), an intensity deemed high enough to promote aerobic capacity development (90–95% of $HR_{peak}$).[11] Additionally, as technical and tactical skills are involved and trained in conditions similar to actual match-play, this sport-specific training should promote an effective transfer to the competitive environment.[12]

The effectiveness of traditional running based aerobic training and SSG has been previously investigated.[7,12,13] Reilly and White[13] compared both SSG and traditionally aerobic training in soccer cohorts. Specifically, SSG training involved 6 × 4-min bouts (5 vs 5), interspersed with 3 min of active recovery (jogging at 50–60% $HR_{peak}$). Aerobic training involved performing 6 × 4-min periods of running at 85–90% $HR_{peak}$, interspersed with 3 min' active recovery (jogging at 50–60% $HR_{peak}$). Post the intervention period, predicted $VO_{2peak}$ increased by 0.2% (57.7 ± 3.0 to 57.8 ± 3.0 mL.kg$^{-1}$ min$^{-1}$) for the SSG group and by 0.3% (57.8 ± 3.2 to 58.0 ± 3.2 mL.kg$^{-1}$ min$^{-1}$) for the aerobic interval group showing negligible differences between methods for improvements in aerobic capacity. This highlighted the potential use of SSG as an effective training method within team sport environments. Furthermore, SSG have been presented as method of training that provides a physiological training stimulus comparable to and sometimes exceeding interval training without the ball.[14] Indeed, Dellal et al.[15] observed higher HRs were observed during SSG (178 ± 7 b·min$^{-1}$) when compared to repeated bouts of running (167 ± 4 b·min$^{-1}$), however SSG have shown higher individual variations due to these games being less controllable due to their open and self-paced nature when compared to the closed and controlled nature of generic training.[11,12,15] Finally, Impellizzeri et al.[7] observed 22.8% and 25.5% increases in time spent performing high-speed activates for generic and SSG training, respectively, highlighting that SSG type training could have a positive impact on match play running performance within soccer populations.[7,16] Unfortunately to date, no study has examined the potential effectiveness of SSG training to improve fitness characteristics within hurling cohorts.[17]

Previous team sport literature suggests that SSG offer an effective alternative to traditional methodologies of aerobic conditioning. However, the effectiveness of this method of training to improve aerobic and anaerobic conditioning has not been investigated within a hurling specific cohort. Resulting in coaches utilising team sport literature far removed from hurling to validate their own training methods. Therefore, the purpose of the current study was to investigate the efficacy of SSG within hurling players. The investigation aimed to compare the effect of continuous aerobic training (CT) and SSG training on selected physiological and performance variables in male hurling players during an in-season period. We hypothesised that while both training methods would improve player capacity, SSG training will lead to greater improvement in overall physiological capacity when compared directly to CT. The rationale for this study is that if SSG games offer a methodology that can provide the appropriate aerobic and anaerobic fitness improvements, the methodology would provide a more time efficient method of training for hurling players due to its concurrent status as a training method.

## Methods

Forty-eight ($n = 48$) hurling players (age: 25 ± 6.4 years; height: 180.2 ± 20.4 cm; mass: 80.5 ± 3.2 kg; $\dot{V}O_{2max}$: 58.78 ± 3.05 mL·kg$^{-1}$·min$^{-1}$) took part in this study. All participants were members of the same squad, competing at the top level of hurling in division 1, with a maximum senior level playing experience of 12 years. During the study, participants were randomly assigned to SSG (n = 24) or the CT control group (n = 24). All participants provided written consent to the experimental procedures after the possible benefits and risks were explained to them. Ethical consent for the study was granted by the research ethics committee of IT Tallaght.

The study was designed to best compare the physiological performance and field test performance effects of specific SSG training versus generic CT. The current investigation was conducted during the first part of the hurling in-season period (March–May). Overall, the study lasted 12 weeks and consisted of 1 week of pre-intervention testing, 10 weeks of training, and 1 week of post-intervention testing (Table 1). Participants were randomly assigned to one of the two training groups SSG (n = 24) and CT (n = 24) after matching for aerobic (Yo-YoIR1, Yo-YoIR2 results) and anaerobic (repeated sprint ability (RSA), 5-, 10- and 20-m sprint results) fitness and for specific positional role in

**Table 1.** Layout of testing protocols for both SSG and CT groupings on weeks 1 and 12.

| | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|---|
| | CMJ (cm) | | Speed: 5 m, 10 m, 20 m (s) | | | | |
| CT (n = 24) | Yo-YoIR1 (m) | Recovery day | Repeated sprints (s) | Recovery day | Yo-YoIR2 (m) | Recovery day | $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) |
| | CMJ (cm) | | Speed: 5 m, 10 m, 20 m (s) | | | | |
| SSG (n = 24) | Yo-YoIR1 (m) | Recovery day | Repeated sprints (s) | Recovery day | Yo-YoIR2 (m) | Recovery day | $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) |

SSG: small-sided game; CT: continuous training; YoYoIR1: Yo-Yo intermittent recovery test level 1; YoYoIR2: Yo-Yo intermittent recovery test level 2; CMJ: counter-movement jump.

the team. Each training intervention was completed twice a week. To isolate the effect of the two training protocols, the additional fitness training sessions (e.g. technical, tactical, strength) during the 10-week intervention were identical for both groups.

Pre and post the intervention period with at least 48 h between tests, aerobic (Yo-YoIR1, Yo-YoIR2, continuous aerobic treadmill test ($\dot{V}O_{2max}$) and anaerobic (5-, 10- and 20-m sprints, counter-movement jump (CMJ; cm), repeat anaerobic sprint test (RSA; s)) characteristics were evaluated. All testing sessions (9:00 am–7:00 pm) and training sessions were performed at the same time of the day (6:00–9:00 pm). All sessions were between 60 and 110 min in length. Twenty-four hours prior to all testing and training sessions' players were advised to avoid intense exercise and to consume their usual meal at least 3 h before the scheduled testing time. During all training sessions to best account for differences in physiological demands during SSG and CT, HR was continuously recorded using a telemetry system (Polar Team System, Polar Electro, OY, Finland).

During the intervention period players ($n = 24$) played 4 vs 4 SSG on a pitch size of $80 \times 20\,m^2$. Teams for each SSG were chosen based on player position to best reflect the man marking nature of hurling match play. SSG game rules were standardised, where the objective was to keep possession and score in a touchdown zone at the end of each pitch. Once a team had scored by working the ball into the touchdown zone, they maintained possession of the ball and tried to work the ball to the opposite end of the pitch. Each drill was performed with coaching supervision and motivation to keep the work rate of players high.[18–20] During all SSG, free play was allowed with maximal touches of the ball. During all SSG in a ball was available by prompt replacement when hit out of play to maintain a high work-rate within all SSG.[8,9,18,19] All sessions were performed on the same pitch. All SSG were completed after a standardised warm up of 20 min containing both technical and dynamic movements. Specifically at the start of the warm up, players engaged in elements of dynamic stretching and low-intensity running. Players were then split into groups of six and completed six repeated shuttles over 45 m to expose players to maximal speed. After this, players began technical elements of the warm up, specifically this included conditional elements with regard to the number of ball touches authorised per individual in possession, which was fixed for a period of time (from one to six touches). Finally, players engaged in a small element of free play within a condensed pitch of $20 \times 20\,m^2$ for 3 min similar to previous hurling based literature.[1,18,19] All games were standardised by time ($4 \times 4$ min, 3-min active recovery). During this period, the CT group ($n = 24$) engaged in time matched ($4 \times 4$ min, 3 min active recovery) continuous aerobic based running training (90–95% of $HR_{peak}$). This training consisted continuous laps running around a hurling pitch (Figure 1).

To best control for increased aerobic stimulus within different methods of training, peak HR of each player was recorded continuously via short-range radio telemetry (Polar Electro, Oy, Kempele, Finland). Exercise intensity during each SSG and CT was assessed using percentage of $HR_{peak}$ and classified into time spent in following zones of intensity: Zone 1 (<80% $HR_{peak}$), Zone 2 (80–84.9% $HR_{peak}$), Zone 3 (85–89.5% $HR_{peak}$), Zone 4 (90–94.9% $HR_{peak}$), and Zone 5 ($\geq$95% $HR_{peak}$).[20] Incremental test peak HR was used to determine players' relative HR zones.[21] In addition, session rating of perceived exertion (RPE) was collected after every session using the Borg's CR-10 scale and RPE-based training load was calculated as training duration × RPE score.[7]

Pre and post the intervention period, all participants undertook an incremental $\dot{V}O_{2max}$ test. The protocol and consisted of five (8, 10, 12, 14, and 16 km $h^{-1}$), 4-min stages (1-min recovery between stages) followed by a ramp to exhaustion, which increased at a rate of $0.2\,km \cdot h^{-1}$ every 12 s until exhaustion was reached. The running economy of players was assessed at $16\,km \cdot h^{-1}$. This allowed for representation of the energy demand for a given velocity of sub-maximal running, expressed

***Touchdown SSG Game Description***

**Game Design:** Normal Hurling play, the team that scores must keep possession and move the ball into space.

**SSG Area:** 80 x 20-m

**Number of Players:** 4 v 4 – 8 total

**SSG Relative Area:** 200 – $m^2$

**Typical Match Play Relative Area:** 410 – $m^2$

**Game Description:** Ordinary match play rules. Team must transfer the ball from one touchdown zone (T) to the other touchdown zone to score. The team that scores retains possession

**Scoring:** A point is scored when a team manages to score by carrying the ball into the touchdown zone (T) after scoring a point the team retains possession and aims to score in the opposite touchdown zone (T)

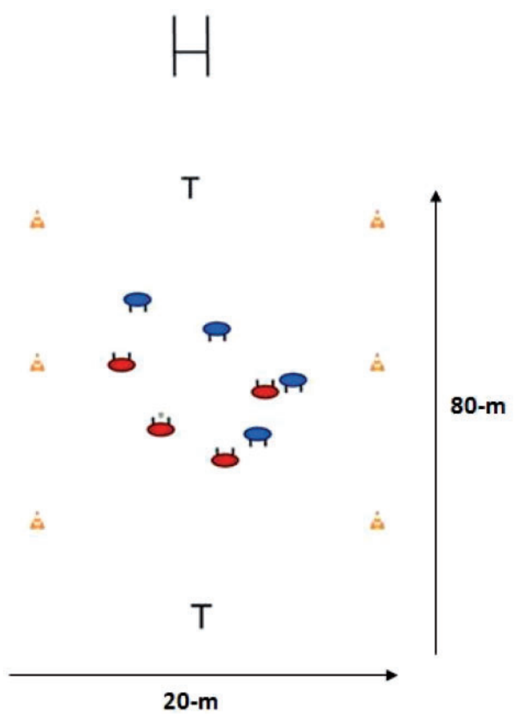


**Figure 1.** Representation and description of the specific hurling SSG played by the SSG training group during the 10-week training intervention.
SSG: small-sided game.

as the sub-maximal $VO_2$ at a given running velocity.[22] Maximal aerobic capacity ($\dot{V}O_{2max}$; $mL \cdot kg^{-1} \cdot min^{-1}$) was assessed during the tests through breath by breath analysis (Cosmed K4$b_2$, Rome, Italy). Velocity at $\dot{V}O_{2max}$ ($v\dot{V}O_{2max}$; $km \cdot h^{-1}$) was determined as the speed at which $\dot{V}O_{2max}$ occurred. The system was calibrated before each test according to the manufacturer's instructions. $\dot{V}O_{2max}$ was recorded as the highest mean $VO_2$ obtained for a 1-min period, with the following criterion met: (a) a plateau in $VO_2$ despite increasing treadmill speed, (b) respiratory ratio above 1.10, and (c) attainment of age predicted HR.[23] HR was recorded using HR belts (Polar Team System, Polar Electro, OY, Finland).

The Yo-YoIR1 and Yo-YoIR2 consisted of 20-m shuttle runs performed at increasing speeds, with 10 s of active recovery between runs (intermittent recovery version). The Yo-YoIR1 has been reported to assess a player's endurance capacity with a high aerobic energy contribution. The Yo-YoIR2 however assesses a player's ability to repeat high intensity exercise with a high aerobic and anaerobic contribution. This test is similar in nature to the Yo-YoIR1 but starts at a higher speed within larger increases in speed.[24] The audio cues of the tests were broadcast using a portable CD player (Philips, Az1030 CD player, Netherlands). The test ended when the participant either stopped voluntarily or twice failed to reach the front line in time with the audio cue. Prior to the Yo-YoIR1, players completed a CMJ assessment (OptoJump, Mircrogate, Bolzano, Italy). The players then performed a single CMJ. The CMJs were performed with hands held firmly on the hips and subjects were instructed to jump as high as possible. All jumps were performed at a self-selected countermovement depth and no instruction was given on what countermovement depth to use. A RSA test was also conducted. Specifically, this test consisted of six repeated 35-m shuttles with 10 s of passive recovery.[6] Best sprint ($RSA_b$; s) and total sprint time ($RSA_t$; s) were recorded. Additionally, linear sprint speed was assessed by a 5-, 10-, and 20-m sprint speed (s) (Witty, Mircrogate, Bolzano, Italy).

### Statistical analysis

Statistical analyses were performed with analytical software (version 22.0; SPSS, Inc., Chicago, IL, USA). Each data variable was examined for normality distribution using a Shapiro–Wilks test. Within intervention effects, pre to post changes were examined with paired t-tests. A two-factor repeated-measure analysis of variance (ANOVA) was used to detect differences in the post test performance measurements between groups and to investigate within participant differences between pre and post intervention measurements. When a significant main effect was detected, a student Newman–Keuls post hoc analysis was applied for pairwise multiple comparison. Quantitative chances of beneficial, trivial, or harmful changes were evaluated qualitatively as follows: <1%, almost certainly not; 1–5%, very unlikely; 5–25%, unlikely; 25–75%, possibly; 75–95%, likely; 95–99%, very likely; and >99%, almost certainly. If the chances of having beneficial or harmful performance changes were both >5%, the true difference was defined as unclear.[25] Moreover, to calculate the effect size (ES) of changes in each performance parameter between CT and SSG group, the pooled pre-training standard deviation was used.[26] Threshold values for Cohen ES statistic were >0.2 (small), 0.5 (moderate), and > 0.8 (large). The level of statistical significance was set for all analyses at $P < 0.05$. Raw data are presented as means (90% CLs).

## Results

### Training load measures

The $\%HR_{peak}$ during the training sessions in the SSG training group ranged between 91.6 ± 1.4% and 93.1 ± 1.1% $\%HR_{peak}$, which was not significantly different ($P = 0.12$; $d = 0.01$; *trivial*) than the corresponding CT group (Figure 2) values (90.4 ± 1.1% and 92.5 ± 0.9% $\%HR_{peak}$). The $\%HR_{peak}$ reached during SSG was 94.3 ± 1.4%, which was similar to that recorded by the CT group (94.1 ± 1.6%). The mean time spent by the two groups in various intensity zones,

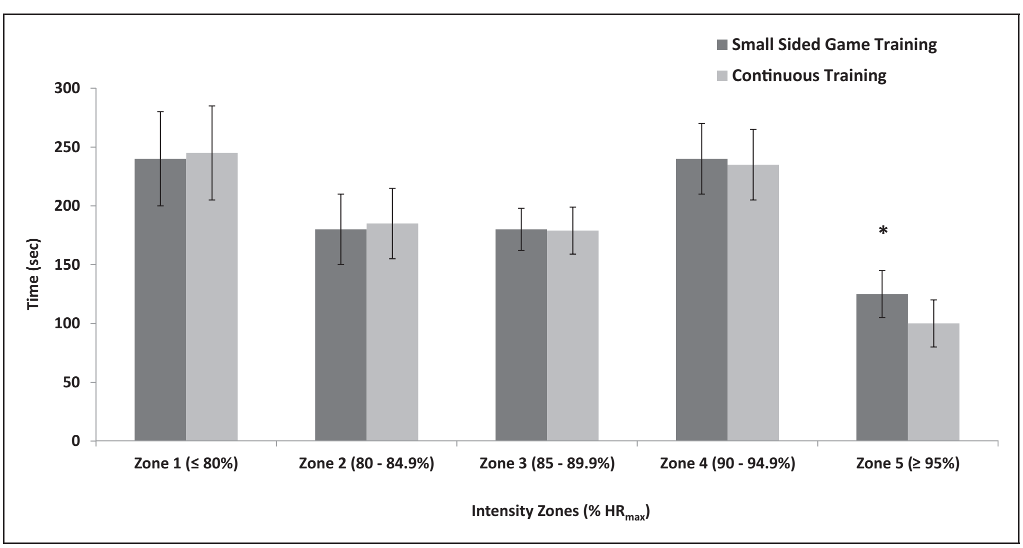


**Figure 2.** Average time spent at different intensities as expressed in percent of $HR_{peak}$ during the training sessions of the 12 training weeks of the study. *Significant difference from continuous training ($P = 0.015$).

including the recovery phases ($3 \times 3$ min), during the 10 weeks of each training method is presented in Figure 3. No difference between groups were found in time spent in the selected HR zones, except for the $\geq 95\%$ of $HR_{peak}$ intensity zone where SSG spent 24.4 s per training session more than CT, no significant group differences were found. Interestingly, peak HR achieved during the last CT session was $91.1 \pm 1.1\%$ $HR_{peak}$, which was significantly lower ($P < 0.01$) than with SSG ($94.6 \pm 1.2\%$ $HR_{peak}$). Additionally, no differences were found for the mean weekly training load, determined using the session-RPE method (Figure 3), during the training period $1540 \pm 210$ AU vs. $1553 \pm 249$ AU ($P = 0.87$; $d = 0.01$; *trivial*).

## Physiological and performance measures

The ES ($d \pm 90$ CI) and inference for laboratory-based physiological measures are reported in Figure 3. SSG ($P = 0.03$; $d = 1.80$; *possibly beneficial*) had a *possibly beneficial* effect for changes in $v\dot{V}O_{2max}$ ($km \cdot h^{-1}$; $15.5\,km \cdot h^{-1} \pm 1.5\,km \cdot h^{-1}$ to $17.0\,km \cdot h^{-1} \pm 1.0\,km \cdot h^{-1}$; 90% confidence limit (CL): 0.5 to 1.5) with the effects of CT ($P = 0.77$; $d = 0.04$; *unclear*) being *unclear* ($15.5\,km \cdot h^{-1} \pm 1.5\,km \cdot h^{-1}$ to $15.7\,km \cdot h^{-1} \pm 1.5\,km \cdot h^{-1}$; 90% CL: −0.1 to 0.2). SSG ($P = 0.02$; $d = 1.72$; *possibly beneficial*) had a *possibly beneficial* effect for improving running economy ($mL \cdot kg^{-1} \cdot min^{-1}$; $46.71 \pm 5.40$ to $43.23 \pm 3.12\,mL \cdot kg^{-1} \cdot min^{-1}$; 90% CL: 1.75 to $4.31\,mL \cdot kg^{-1} \cdot min^{-1}$) in contrast to the *unclear* effect ($46.73 \pm 5.4$ to $45.71 \pm 3.1\,mL \cdot kg^{-1} \cdot min^{-1}$; 90% CL: 0.75 to $1.31\,mL \cdot kg^{-1} \cdot min^{-1}$) for CT ($P = 0.94$; $d = 0.21$; *unclear*). For $\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) changes SSG ($P = 0.001$; $d = 1.91$; *possibly beneficial*) had *possibly beneficial* ($54.68 \pm 3.05\,ml \cdot kg \cdot min^{-1}$ to $58.78 \pm 2.05\,ml \cdot kg \cdot min^{-1}$; 90% CL: 2.75 to $4.31\,mL \cdot kg^{-1} \cdot min^{-1}$) effects with CT ($P = 0.411$; $d = 0.11$; *unclear*) resulting in *unclear* effects ($54.58 \pm 3.05\,mL \cdot kg \cdot min^{-1}$ to $55.18 \pm 3.05\,mL \cdot kg \cdot min^{-1}$; 90% CL: 0.45 to $1.11\,mL \cdot kg^{-1} \cdot min^{-1}$). Similar effects were reported for $VO_{2peak}$ ($mL \cdot kg^{-1} \cdot min^{-1}$) measures, with SSG ($P = 0.001$; $d = 1.45$; *possibly beneficial*) having a *likely beneficial* ($64.68 \pm 3.05\,mL \cdot kg \cdot min^{-1}$ to $68.18 \pm 2.15\,ml \cdot kg \cdot min^{-1}$; 90% CL: 2.45 to $5.11\,mL \cdot kg^{-1} \cdot min^{-1}$) effect in contrast to the *unclear* ($61.68 \pm 3.05\,mL \cdot kg \cdot min^{-1}$ to $62.18 \pm 3.05\,mL \cdot kg \cdot min^{-1}$; 90% CL: 0.45 to $1.11\,mL \cdot kg^{-1} \cdot min^{-1}$) effect for CT ($P = 0.42$; $d = 0.01$; *unclear*; Figure 4).

The ES ($d \pm 90$ CI) and inference for the performance measures are shown in Figure 5. SSG ($P = 0.04$; $d = 1.80$; *possibly beneficial*) had a *likely beneficial* effect for changes in $RSA_b$ (s) ($6.22\,s \pm 0.52\,s$ to $5.12\,s \pm 0.12\,s$; 90% CL: 0.52 to 1.10) and $RSA_t$ (s) ($37.32\,s \pm 3.12\,s$ to $35.12\,s \pm 2.12\,s$; 90% CL: 1.52 to 3.10 s) with these being in contrast to the *likely negative* effect for CT on similar measures ($P = 0.02$; $d = -2.01$; *likely negative*). CT had a *trivial* ($P = 0.72$; $d = 0.30$; *trivial*) effect on Yo-Yo intermittent recovery test level 1 (YoYoIR1; m) performance ($1998 \pm 279$ to $2068 \pm 309$ m; 90% CL: 0 to 120 m) in contrast to the *likely beneficial* effect ($1998 \pm 279$ to $2368 \pm 409$ m; 90% CL: 237 to 498 m) seen for SSG ($P = 0.002$; $d = 1.72$; *likely beneficial*). SSG (0.001; $d = 1.69$; *likely beneficial*) resulted in a *likely beneficial* effect ($1641 \pm 199$ m to $1961 \pm 209$ m; 90% CL: 217 to 498 m) for Yo-Yo intermittent recovery test level 2 (YoYoIR2; m) performance with a *likely negative* ($1591 \pm 199$ to $1291 \pm 409$ m; 90% CL: −137 to

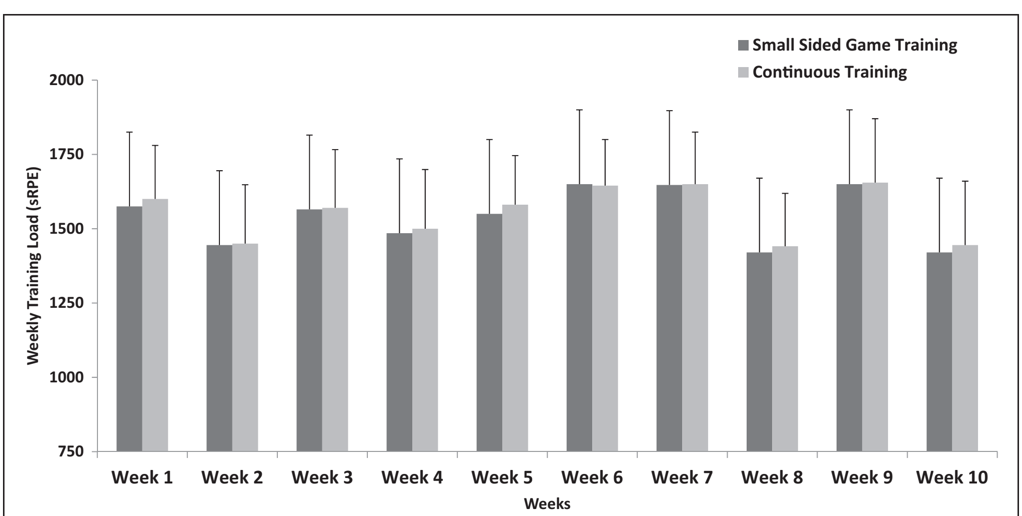


**Figure 3.** Training load measures across the intervention period for SSG and CT (sRPE ± SD).
SSG: small-sided game; CT: continuous training; sRPE: session rating of perceived exertion; SD: standard deviation.

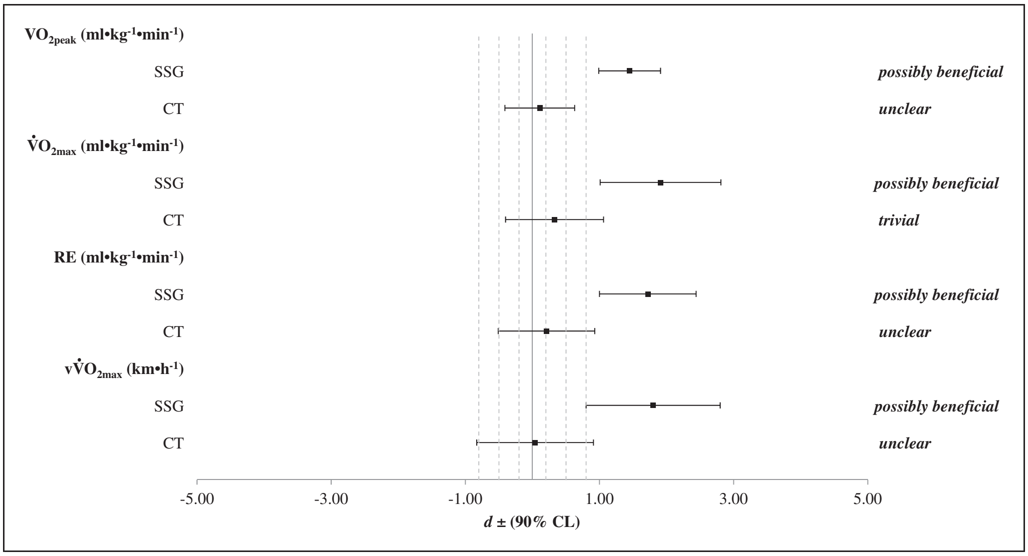


**Figure 4.** Forest plot for the effect of SSG and CT on laboratory based testing measures post the intervention period. Data presented as $d \pm 90\%$ CL.
SSG: small-sided game; CT: continuous training; RE: Running Economy; CL: confidence limit.

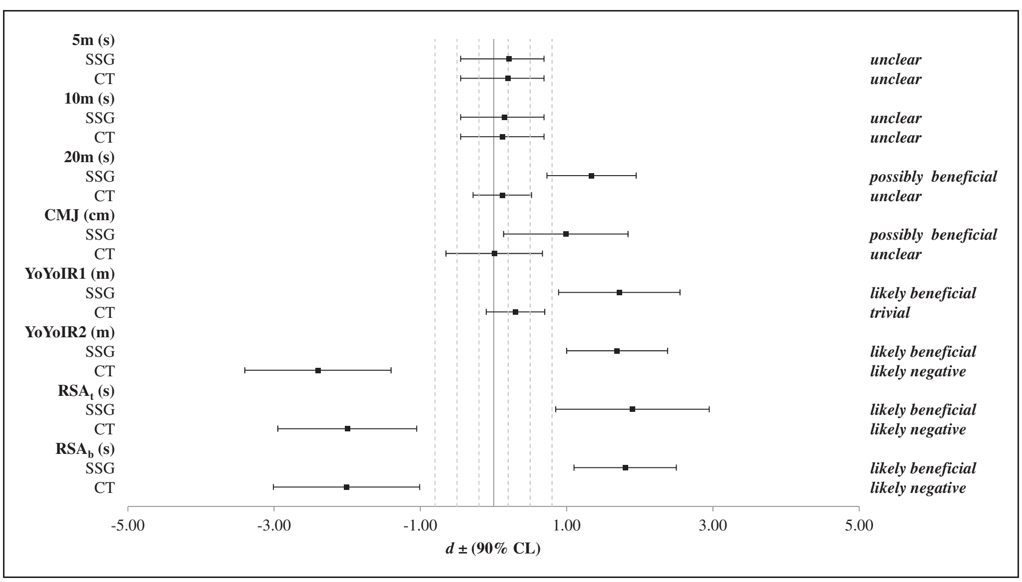


**Figure 5.** Forest plot for the effect of SSG and CT on field based testing measures post the intervention period. Data presented as $d \pm 90\%$ CL.
SSG: small-sided game; CT: continuous training; CL: confidence limit; CMJ: counter-movement jump; YoYoIR1: Yo-Yo intermittent recovery test level 1; YoYoIR2: Yo-Yo intermittent recovery test level 2; RSA: repeated sprint ability.

−398 m) effect for CT ($P = 0.004$; $d = -2.40$; *likely negative*). SSG ($P = 0.05$; $d = 0.99$; *possibly beneficial*) had a *possibly beneficial* (47 ± 4 cm to 51 ± 4 cm; 90% CL: 1 to 7 cm) effect on CMJ (cm) performance in contrast CT ($P = 0.42$; $d = 0.01$; *unclear*) had an *unclear* (45 ± 4 cm to 46 ± 4 cm; 90% CL: 1 to 3 cm) effect on similar measures. Similar *unclear* effects were found for SSG ($P = 0.69$; $d = 0.20$; *unclear*) and CT ($P = 0.74$; $d = 0.21$; *unclear*) for improving 5-m (s) sprint speed, again similar *unclear* effects were found for both SSG ($P = 0.88$; $d = 0.12$; *unclear)* and CT ($P = 0.77$; $d = 0.15$; *unclear*) for 10-m (s) sprint speed. Interestingly, while *unclear* (1.06 ± 0.15 s to 1.05 ± 0.18 s; 90% CL: 0.01 to 0.3 s) effects for 20-m (s) sprint speed were found for CT ($P = 0.88$; $d = 0.12$; *unclear*), SSG ($P = 0.04$; $d = 1.64$; *possibly beneficial*) had *possibly beneficial* (2.19 ± 0.15 s to 2.16 ± 0.12 s; 90% CL: 0.2 to 0.6 s) effects for improving 20 -m sprint speed.

## Discussion

The current study examined the efficiency of generic CT compare to SSG training at improving physiological and performance measures in hurling players. Although several studies have compared the effectiveness of traditional running based aerobic training with sport-specific SSG training in team sport players,[7,13,14] the current study is the first to report the characteristics of these methodologies in a hurling cohort. The main findings showed that SSG and CT had no differences with regard to player's perceptual weekly training load as reported by sRPE (CT: 1553 ± 249 AU vs. SSG: 1540 ± 210 AU; Figure 2). However, SSG produced slightly higher peak HR responses when compared to CT of the duration of the intervention, however these were non-significant ($P = 0.12$) and *trivial* in nature at a whole group level. Interestingly, when analysed across relative intensity zones, SSG resulted in a 24.4 s per training increase in time spent at above 95% $HR_{peak}$ (Figure 1). Interestingly, it appears that this small increase in internal response resulted in differential improvements in a number of physiological and performance measures, highlighting the value of monitoring the internal responses to training methods. Despite differences between training methodologies with regard to intensity, SSG had a *likely* to *possibly likely beneficial* effect physiological performance measures (Figure 3). This is in contrast to CT that had *trivial* to *likely negative* effects on performance measures post the intervention period (Figure 4). The current study therefore shows that SSG present an effective training methodology that can be used either in conjunction with or in place of CT depending on the seasonal period, with SSG shown to have a *beneficial* impact on performance measures for hurling players.

We observed that SSG training is more efficient at improving linear shuttle speed, RSA and neuromuscular performance measures when compared to CT. Indeed, SSG were shown to have a *possibly beneficial* effect for CMJ performance improvements when compared to the *unclear* effects of CT. In addition to these findings, similar *unclear* effects were found for SSG and CT for improving 5 -m (s) sprint speed, again similar *unclear* effects were found for both SSG and CT for 10 - m (s) sprint speed. However, SSG showed significant improvements in sprint speed over 20 m, which is in contrast to CT. The current findings are in agreement with previous studies in soccer that have shown SSG as an effective methodology of training to improve jump and sprint performance.[13,27] A possible explanation for the above can be related to the physiological effects of SSG that result in a higher amount of high-to-maximal intensity actions when compared to CT. Actions such as changes of direction, jumps, blocks, sprints, accelerations and decelerations occur more often within SSG when compared to CT. These actions involve intense muscular activity and high eccentric efforts, which may have represented an efficient method to increase linear shuttle speed, RSA and neuromuscular performance.[28–30] Increases in shuttle speed are important within a match-play context for hurling players given the high degree of short sprint actions that take place over distances between 20 m and 40 m.[1,2]

The current studies results showed a significant improvement for $RSA_b$ and $RSA_t$ for SSG groups with decrements in $RSA_t$ and $RSA_b$ for CT groupings. SSG had a *likely beneficial* effect for changes in $RSA_b$ (s) and $RSA_t$ (s) with these being in contrast to the *likely negative* effect for CT on similar measures. The present study is the first to demonstrate the beneficial effect of hurling specific SSG on RSA. Although many studies have shown that interval training offers an appropriate stimulus to improve RSA,[15,31] very few studies have shown SSG as a sufficient method.[15,31] The current study is one of the few investigations to observe improvements in RSA performance during SSG interventions. Additionally, it has been hypothesised that linear running drills do not offer the motivation or enjoyment for players[1,32] compared to those including the ball while also failing to imitate the unorthodox movements commonly associated with SSG.[8,30] It is very likely that the higher intensity and repetitive nature of sprint actions within SSG created a sufficient stimulus that resulted in improved RSA, in contrast CT is continuous in nature with minimal repeated efforts therefore resulting in reduced RSA for players in the CT group. This is the first study to show *likely negative* effects for CT on RSA in hurling players and as such it is recommended that CT be avoided by hurling coaches to improve physical performance measures in hurling cohorts.

Our data suggest that SSG had *possibly beneficial* effect for improvement in $\dot{V}O_{2max}$ values for hurling players with CT resulting in *trivial* effects; previous studies have shown similar effects for SSG improving $\dot{V}O_{2max}$ values of team sport players.[7] An improvement in $\dot{V}O_{2max}$ allow players to cover a large total running distance,[16,33] improve the ability to repeat sprints and perform high-intensity actions both with and without the ball.[16,34,35] Running economy is an important physical determinant of team sport athletes and can be related to the fact that changes in fitness experienced during the season may be better detected through submaximal indices of aerobic fitness, such as running economy.[7] Impellizzeri et al.[7] found SSG to be equally as effective as training without the ball in improving running economy, the results are in line with the current study's findings that SSG had a *possibly beneficial* effect for improving running economy. Therefore, SSG can result in a decreasing of energetic cost at a sustained workload that may culminate in reduced oxygen demand, which may allow players to either exercise at a lower or similar HR but with greater intensity.[7]

The maximum work rate or workload during an incremental running exercise test has become a popular marker of performance in endurance athletes,[22,23] and it has recently been shown to correlate well with prolonged, high-intensity running performance.[16,35] The current investigation showed that SSG had a *possibly beneficial* effect for changes in maximal work rate during incremental testing ($v\dot{V}O_{2max}$; $km{\cdot}h^{-1}$) with the effects of CT being *unclear*. These observations can be related to SSG resulting in increased time spent above 95% of $HR_{peak}$. Previously, linear relationships have been observed between HR and $VO_2$ responses.[33] Therefore, SSG likely resulted in increased time spent at a higher % of $\dot{V}O_{2max}$, which have been shown to be beneficial to improve $v\dot{V}O_{2max}$.[16,28]

## Conclusion

In the current study, SSG and CT were compared to assess the efficiency of these methods to improve physiological and performance measures. SSG have been shown to represent a time efficient methodology of hurling training allowing for *likely* to *possibly likely* beneficial improvements in specific field-based measures across a 10-week in-season training period in hurling cohorts. Additionally, SSG training resulted in significant improvements in aerobic fitness measures as expressed by *possibly beneficial* increases in running economy, $v\dot{V}O_{2max}$ and $\dot{V}O_{2max}$ when contrast against the *unclear* to *trivial* effects of CT. Given the lack of information on the efficiency of these methodologies within hurling and team sports, it may be suggested that SSG can be used in conjunction or in place of CT depending on the seasonal period within team sports. In agreement with previous studies, the current investigation has shown that SSG result in subtle changes in internal response highlighted by more time spent at a higher %HRpeak, when contrast to CT. Although the importance of exercise intensity individualisation has been recognised for many years as a determinant of successful training, the current findings suggest that SSG with appropriate rules and pitch dimensions can be effective at enhancing aerobic and anaerobic capacities in hurling players. Interestingly, the study found that small increases in internal responses may result in significantly different performance outcomes. The current data highlight the importance of objective internal physiological measurement for team sport. Overall, the current study observed that SSG represent a time efficient methodology of training within hurling specific cohorts. The current data have shown that 10 weeks of SSG training can provide beneficial improvements in physical and physiological performance in hurling players. This is in contrast to the *unclear* to *likely negative* effects of CT. Additionally, our study has shown that small increases in objective internal responses may result in significantly different performance outcomes. Practitioners can utilise SSG to optimise the development of cardiorespiratory fitness within hurling players while also allowing for the development of technical and tactical skills. CT, while a widely used method of training, within hurling cohorts appears to reduce players' ability to perform repeated sprints and only results in *unclear* to *likely negative* effects in cardiorespiratory fitness and performance important qualities for hurling players. Finally, the selection of a SSG training methodology can be utilised to optimise technical and tactical demands of the game in conjunction with facilitating the attainment of desired fitness levels.

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