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The running performance and estimated energy cost of hurling specific small-sided games

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Abstract

The current study examined the extent to which pitch dimensions can influence the physical and estimated energetic demands of hurling small-sided games. Training data ($n = 990$) were collected from 24 (age 25.5 ± 3.2 years; height 178.9 ± 3.2 cm; body mass 78.5 ± 4.5 kg) hurling players using 4-Hz global positioning system technology (VX Sport, Lower Hutt, New Zealand). Total distance (m), high-speed running distance (m; ≥ 17 km/h), very high-speed running distance (m; ≥ 22 km/h), total accelerations (n), acceleration distance (m), peak and mean velocity (km/h) were considered. In addition changes in velocity were analysed by assessing the acceleration actions during SSG. This allowed for the assessment of estimated energy expenditure (kJ/kg) and the equivalent distance covered a different metabolic power thresholds. The main findings show that traditional speed-based data increased as pitch dimensions were increased ($p = 0.002$; $d = 4.53 \pm 0.46$; very large). Furthermore, as relative player area increased there was an increase in estimated energy expenditure ($p = 0.004$; $d = 2.\ 16 \pm 0.20$; very large) and average metabolic power metrics ($p = 0.002$; $d = 1.13 \pm 0.46$; moderate). Distances covered at metabolic power categories (TP) increased with small-sided games pitch dimension ($p = 0.002$; $d = 0.3 \pm 0.06$; small). The study enables coaches to better understand the physical demands imposed on players during specific hurling small-sided games pitch dimensions, and highlights that traditional speed-based data underestimate the running demands of small-sided games.

Keywords

Energy expenditure, global positioning system, metabolic power, performance analysis, team sport

Introduction

Small-sided games (SSG) present a methodology of training that is common place within team sports[1–3] serving as an effective alternative to traditional methods of training for enhancing team specific endurance capacity.[4] Additionally, these games allow replication of the movement patterns associated with competitive play. Therefore, such methodologies of training have the advantage of concurrently enhancing the physical, cognitive and technical development of team sport players.[5–7]

In light of these methodologies popularity within team sports, there is a need for an understanding of the physical demands imposed on players during these drills. This has important implications for coaches in order to optimise training adaptation. Indeed, the manipulation of playing area, player numbers, coach encouragement and game rules have been highlighted previously as important components that influence the physical demands of SSG.[1,8,9] For example, within soccer large pitch dimensions with low player numbers have been shown to increase the physical demand experienced by players.[10] However, to date the information regarding the physiological demands in these training games has been assessed mainly by heart rate (HR), blood lactate (BLa) and rating of perceived exertion (RPE). It has been shown in many studies[4,11] that

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SSG containing smaller numbers of players elicit higher HR, blood lactate and perceptual demands. These SSG showed increased physiological demand when compared to medium and larger sized SSG. However, what must be considered is the specific sport demands and how these potentially impact on the physical and physiological demands of SSG. For example, within hurling due to the stick and ball nature of the sport the ball can travel up to 100 m/s potentially impacting the physical demands of these compressed game-type training methods.[12]

The advancement of technology now permits accurate assessment of physical demands of training through the use of global positioning systems (GPS).[7] These systems have been shown to be accurate and valid within intermittent exercise.[1,13] In this regard, recent studies have shown that larger game formats are associated with greater total distances (m) and higher maximum speeds (km/h).[5] Interestingly, game type has also been shown to impact the physical demands of SSG. Gaudino et al.[14] recently showed that possession-based play resulted in greater total distances when compared to games with goalkeepers. However, despite extensive research there is still a lack of physical demand-related information on typical SSG used within the hurling training process. Of interest are the specific physical demands of these games especially across different pitch dimensions. The unpredictable nature of SSG allows for explosive actions and changes in velocity that impacts the quantification of physical demands during these games. Recently, Gaudino et al.[7,14] have shown that SSG are more physiologically challenging than has been previously been reported in the literature, suggesting that speed-based running parameters fail to full appreciate the true demands of SSG-type training.

To date, assessment of the physical demands during team sport-related activities using GPS technology has frequently centred on evaluating the distance covered or time spent at specific velocities.[7,14] This representation of the physical demands, however, fails to account for the additional distance covered or energy demands associated with accelerations and decelerations. As a consequence, since accelerations and decelerations further increase the energy demands placed on the athlete even when running within low speed thresholds, the traditional speed-based parameters logged by GPS will underestimate the total energy cost associated with team sport-related activity.[15–17]

Limited attention to date has focused on acceleration and deceleration activity in team sport players[17] and, thus, the contribution of these activities to estimates of the physical demands incurred by team sport players during SSG. In line with such observations, di Prampero et al.[15] recently introduced a new approach for estimating the energy cost of accelerated and decelerated running. When combined with traditional estimates of running speed, this method permits a more comprehensive assessment of the overall energy cost of the activity in any given moment based on metabolic power parameters.[15] Using this approach, Osgnach et al.[16] recently reported that the energy cost associated with high-intensity activity during match-play was two to three times larger than estimates based solely on running speed. In addition, studies have shown that in match play situations maximal acceleration actions are 8-fold greater than sprint actions.[18] However, to date only one study has appraised the mechanical and metabolic cost of SSG.[7] Therefore, there is a need for a comprehensive understanding as to the physical demands of SSG across varying pitch dimensions specific in hurling with no current data available for coaches to best prescribe SSG.

Therefore, the aim of this study was to provide a detailed analysis of SSG of different sizes $40 \times 20\,m^2$ ($SSG_{40\times20}$), $60 \times 20\,m^2$ ($SSG_{60\times20}$) and $80 \times 20\,m^2$ ($SSG_{80\times20}$)), these are dimensions that are currently used with regularity within the coaching process in hurling. These dimensions allow for the progression of technical skill execution such as passing, scoring and blocking in relative areas that are reflective of the demands of hurling match play. During these SSG a number of variables were considered such as total distance (m) high-speed running distance (m) ($\geq$17 km/h), very high-speed running distance ($\geq$22 km/h) (m), total accelerations (n), acceleration distance (m) peak and mean velocity (km/h). Additionally metabolic power categories defined as: high power (HP; from 20 to 35 W/kg), elevated power (EP; from 35 to 55 W/kg) and maximum power (MP; > 55 W/kg) as well as predicted energy expenditure (kJ/kg) were also examined. A more comprehensive quantification of physical demands and energy expenditure would optimise training situations, nutritional strategies and, consequently, impact upon the injury prevention strategies and physical preparation of hurling players.

Method

Twenty-four ($n = 24$) hurling players competing at the top level of club hurling (age: 25.5 ± 3.2 years; height: 178.9 ± 3.2 cm; body mass: 78.5 ± 4.5 kg) took part in the study during the in-season competition period. Players were part of a division 1 team and had a minimum playing experience of 4 years (range = 4–10 years playing experience). A total of 990 individual drill observations ($n = 990$) were undertaken on outfield players with a median of 28 observations per player. Three different formats of SSG were observed during the study period. $SSG_{40\times20}$ (player observations, $n = 330$), $SSG_{60\times20}$ (player observations, $n = 330$) and

$SSG_{80\times20}$ (player observations, $n = 330$). The game rules were the same for each format, where the objective was to keep possession and score in a touchdown zone at the end of each pitch. Once a team had scored they maintained possession and attacked the opposite end of the pitch. Each drill was performed in a continuous manner, under supervision, coaching and motivation of several coaches in order to keep the work rate of players high.[20] During all SSG free play was allowed with maximal touches, in all cases a ball was available by prompt replacement when hit out of play.[7,8] Teams were selected based on player position with players marking a player of the same position they would in match play to best reflect the man-marking nature of hurling match play. Before the study period, during training sessions these games were frequently performed to ensure a good level of familiarisation before the experimental period. All sessions were performed on the same pitch. In addition, all exercise games were performed at the same time during the day to limit to effects of circadian variations on the measured variables.[19] All SSG were completed after a standardised warm up of 15 min. All games were standardised by time (4 min) and playing number (4 v 4). All players were notified of the aims and objectives of the study, research methods, requirements, benefits and risks before giving written informed consent. The research was carried out with approved ethics consideration from the local institutes' ethics committee.

The participants wore an individual GPS unit (VXsport, New Zealand, Issue: 330 a, Firmware: 3.26.7.0) sampling at 4 Hz and containing a triaxial acceloremter and magnetometer in all training sessions. The GPS unit (mass: 76 g; 48 mm × 20 mm × 87 mm) was encased within a protective harness between the player's shoulder blades in the upper thoracic-spine region. Fifteen minutes before the commencement of training, the GPS device was fixed to the athlete, to establish a satellite lock training.[20] The validity and reliability of this device has previously been communicated.[13]

The proprietary software provided instantaneous raw velocity data at 0.25 s intervals, which was then exported and placed into a customised Microsoft Excel spreadsheet (Microsoft, Redmond, USA). The spreadsheet allowed analysis of distance covered (m) in the following categories; total distance (TD); high-speed distance (HSD; m; ≥17 km/h); very high-speed distance (VHSD; m; 22 km/h). Finally, the mathematical model proposed by di Prampero et al.[15] was integrated into the spreadsheet in order to calculate total estimated energy expenditure, average metabolic power and the distance covered in different metabolic power categories as reported in the previous studies.[7,14,16]

The following activity profiles were calculated during each game: TD, HSD and VHSD running. During SSG only accelerations lasting 1 second ($\Delta t = 1$ s) were considered and were categorised based on the number of efforts. Based on the findings of Minetti et al.[21] who demonstrated the constancy of metabolic cost of running at speed oscillating up to 1 m/s, in this study as with previous[7] only changes in velocity >2 m/s were considered. With regards to the predicted metabolic variables, total energy expenditure (EC) and average metabolic power (P_{met}) was calculated.[14,16] In addition, the categories of metabolic power were defined as the distance covered (m) at high power (HP; from 25 to 35 W/kg), elevated power (EP; from 35.1 to 55 W/kg) and maximal power (MP; > 55 W/kg).

Data are presented as mean ± standard deviation. A repeated measures ANOVA was performed in order to understand the main effect of format type ($SSG_{40\times20}$, $SSG_{60\times20}$ or $SSG_{80\times20}$) on the physical parameters between drills. Significant main effects and interaction between factors were followed up with a least significant difference (LSD) post hoc analysis.[22] Statistical significance was set at $p \le 0.05$. Effect size (d) was determined by the magnitude of the difference across the variable analysed with effect determination identified using < 0.2 = trivial, 0.2–0.6 = small, 0.6–1.2 = moderate, 1.2–2.0 = large, and 95 >2.0 = very large.

Results

The total distance and distance covered at different running speeds are shown in Table 1. Total distance was greater when the area per player increased within prescribed SSG ($p = 0.002$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 4.53 \pm 0.46$; very large). A similar trend was noted for high-speed distance ($p = 0.004$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 1.23 \pm 0.16$; moderate), very high-speed distance ($p = 0.04$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 1.23 \pm 0.16$; large), and maximum velocity ($p = 0.001$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 0.60 \pm 0.26$; small). Acceleration distance also increased with increases in pitch dimensions ($p = 0.002$; $80 \times 20\,m^2 = 60 \times 20\,m^2 = 40 \times 20\,m^2$; $d = 3.10 \pm 0.02$; very large). Similar trends were observed for total accelerations completed with these increasing with increases in pitch dimensions ($p = 0.002$; $80 \times 20\,m^2 = 60 \times 20\,m^2 = 40 \times 20\,m^2$; $d = 3.10 \pm 0.02$; very large). Predicted metabolic parameters are reported in Table 2. The total energy cost (EC) ($p = 0.001$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 2.23 \pm 0.06$; large) and the average metabolic power (P_{met}) ($p = 0.04$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 1.23 \pm 0.16$; large) was pitch dimension dependant being higher in larger pitch dimensions respectively. Distance covered

Table 1. Distance and speed parameters calculated during SSG. Results are presented as mean ± SD.

SSG	$40 \times 20\,m^2$	$60 \times 20\,m^2$	$80 \times 20\,m^2$	Follow up Tests (LSD)
Total distance (m)	298 ± 89	509 ± 145	729 ± 185	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
High-speed distance (m; ≥17 km/h)	76 ± 26	198 ± 93	298 ± 100	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
Very high-speed distance (m; ≥22 km/h)	20 ± 10	85 ± 14	100 ± 35	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
Total accelerations (n)	12 ± 4	20 ± 6	25 ± 4	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
Acceleration distance (m)	72 ± 26	120 ± 42	148 ± 56	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
Maximum velocity (km/h)	24.2 ± 2.5	26.1 ± 3.5	30.1 ± 2.6	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*
Mean velocity (km/h)	4.4 ± 0.5	5.4 ± 0.4	6.1 ± 0.4	$80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$*

*Significant difference ($p < 0.001$).

Table 2. Predicted metabolic parameters related to the three different SSGs. Results have been normalized by time (for a 4 min period) expressed as mean ± SD.

SSG	$40 \times 20\,m^2$	$60 \times 20\,m^2$	$80 \times 20\,m^2$	Follow-up tests (LSD)
Total EC (kJ/kg)	3.6 ± 0.5	4.0 ± 0.3	4.2 ± 0.4	$80 \times 20\,m^2 > 60 \times 20\,m^2$** $> 40 \times 20\,m^2$*
Avg P_{met} (W/kg)	14.9 ± 1.1	15.3 ± 1.2	16.5 ± 1.6	$80 \times 20\,m^2 > 60 \times 20\,m^2$** $> 40 \times 20\,m^2$*
TP Distance (m)	202 ± 51	430 ± 43	560 ± 54	$80 \times 20\,m^2 > 60 \times 20\,m^2$** $> 40 \times 20\,m^2$*
HP Distance (m)	142 ± 25	170 ± 28	400 ± 35	$80 \times 20\,m^2 > 60 \times 20\,m^2$** $> 40 \times 20\,m^2$*
EP Distance (m)	40 ± 10	40 ± 10	40 ± 10	$80 \times 20\,m^2 = 60 \times 20\,m^2$** $= 40 \times 20\,m^2$
MP Distance (m)	20 ± 5	20 ± 5	20 ± 5	$80 \times 20\,m^2 = 60 \times 20\,m^2$** $= 40 \times 20\,m^2$

EC = Energy cost (kJ/kg); P_{met} = metabolic power (W/kg); TP = total high-power distance (>25 W/kg); HP = high power (25–35 W/kg); EP = elevated power (35–55 W/kg); MP = maximal power (>55 W/kg).
*Significant difference ($p < 0.001$).
**Significant difference ($p < 0.05$).

at TP increased as SSG pitch dimension increased ($p = 0.02$; $80 \times 20\,m^2 > 60 \times 20\,m^2 > 40 \times 20\,m^2$; $d = 0.63 \pm 0.16$; moderate). Interestingly distance at EP ($p = 0.112$; $80 \times 20\,m^2 = 60 \times 20\,m^2 = 40 \times 20\,m^2$; $d = 0.10 \pm 0.02$; trivial) and MP ($p = 0.152$; $80 \times 20\,m^2 = 60 \times 20\,m^2 = 40 \times 20\,m^2$; $d = 0.12 \pm 0.04$; trivial) were similar for all SSG despite increases in pitch dimension and area per player.

Discussion

The major findings of the present study were that the total distance covered, high-speed distance and sprint distance were increased when the area per player increased. In addition, maximal speed production was also found to be pitch dimension dependant. This is the first study to report these trends in hurling. These findings are similar to those reported in elite soccer populations.[7] To the best of our knowledge this is the first study to comprehensively examine the estimated metabolic (EC, average P_{met}, and distance covered at different P_{met}) and traditional speed zone based metric demands of differing SSG pitch dimensions in hurling players. A detailed analysis of these SSG is pivotal in contemporary hurling as it enables an in-depth understanding of the workload imposed on each player, which has an impact on the practical prescription of the adequate amount of stimulus during training sessions for this population.

The total distances at high speed (≥17 km/h) and at high power (>25 W/kg) as well as the average metabolic power were greater when the relative area per player was increased, this finding is in line with previous SSG studies reporting more elevated work rate and exercise intensities with increased pitch dimensions and reduced player numbers.[3,7,8] This suggests that in practical terms smaller relative player areas tax different components of running performance when compared to larger relative player areas. Furthermore, with distances covered at different metabolic power thresholds increased when compared to traditional speed-based metrics (TP distance vs. High-speed distance; see Figure 1) this suggests that the full extent of SSG physical demands may not be best measured by distances covered and speed attained alone.

The novel aspect of this study is the utilisation of a mathematical model for the calculation of the estimated energetic cost and metabolic parameters across

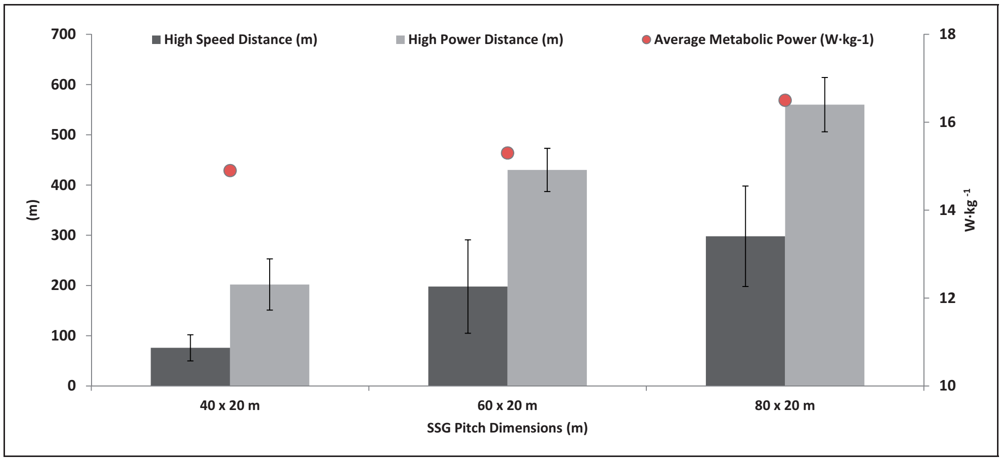

Figure 1. The average metabolic power (W/kg), high-speed (m) and high-power distance (m) reached during each SSG pitch dimension.
High-speed distance (m; ≥ 17 km/h), high-power distance (m; ≥ 25 W/kg) covered and average metabolic power (W/kg) reached during each SSG pitch dimension (mean ± SD).

differing SSG pitch dimensions. This approach was previously utilised in elite soccer during official match play[16] and in training situations[7,14] briefly this model considers accelerated running on a flat surface to be metabolically equivalent to incline running at a constant speed, where the incline is equal to the forward acceleration.[16,17] This approach has since been adapted for use in team sports[16] to complement traditional speed-based classifications. It provides data, which are able to account for demands imposed from accelerated running during team sport match and training play. In accordance with these investigations, we observed a greater distance covered at high power (>25 W/kg) across all dimensions of SSG when compared to high-speed distance (≥ 17 km/h), with this difference more pronounced as the pitch dimension was decreased in size. The data from the current investigation have shown that the distance covered at high power when compared to high speed was 61% ($SSG_{40\times20}$), 57% ($SSG_{60\times20}$) and 47% ($SSG_{80\times20}$) higher for high-power distance. This indicates that the use of metabolic power zones become more valuable when assessing the physical demands of SSG played across smaller pitch dimensions. Previous studies have suggested a systematic bias between speed zone based and metabolic power based data with Gaudino et al.[14] reporting that speed-based data can under-report the true external load of training by up to 85% depending on position.

The differences between estimated metabolic power parameters and traditional variables can be explained by the fact that the estimated metabolic power parameters are also dependant on speed. Therefore, despite greater velocity changes in smaller SSG pitch dimensions,[7] distance covered at high speed in smaller pitch dimensions seen in this study was higher. This can be related to different game dynamics between soccer and hurling and the need for increased relative player areas in hurling to account for the speed at which the ball can travel. These increased relative areas allow for high-power distances to exponentially increase, which is in line with previous SSG investigations.[3,10,23] The current data showed that as the relative player area was increased players covered more distance. Less distance was covered during $40 \times 20\,m^2$ dimensions in comparison to all other SSG pitch dimensions. Interestingly, $60 \times 20\,m^2$ pitch dimensions were shown to best replicate the physical demands of match play with players covering 127 m/min during these SSG. This is similar to relative match play demands reported by Malone et al.[24] during hurling match play. Future research is needed to better understand the technical component of these SSG. Whilst further analysis is needed on the impact contextual factors of SSG such as winning or losing during SSG have on the physical demands of these training methodologies.

Conclusion

The current investigation has important practical implications as it provides novel guideline of how best to utilise scientific information to maximise training situations. We have shown that different pitch dimensions generate different data and, therefore, target different performance outcomes. As a consequence, during field-based conditioning it is important that training load is fully understood for the given physiological and performance outcome. In the current study, medium pitch dimensions were shown to best replicate the physical demands of match play with players covering 127 m/min during these SSG. In summary the main finding of the study was that both traditional and predicted metabolic power data are dependent on relative player area. Finally there appears to be an underestimation of traditional speed-based data within SSG with this more pronounced within smaller pitch dimensions.

Declaration of Conflicting Interests

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