A comparison of workload demands in match play and small-sided games, by positional role, in youth soccer.

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ABSTRACT

The external demands of small-sided games (SSG's) according to positional role are currently unknown. Using Catapult Minimax X3 5Hz GPS, with a 100 Hz tri-axial accelerometer, we compared accumulated tri-axial player load per min ($PL_{acc.min}^{-1}$) during friendly youth MP (11 vs. 11) and SSG's (2 vs. 2, 3 vs. 3, and 4 vs. 4). Significant differences existed between all SSG's and MP for $PL_{acc.min}^{-1}$ (F = 21.91, $p<0.001$, $\eta^2 = 0.38$), and individual X (F = 27.40, $p<0.001$, $\eta^2 = 0.43$), Y (F = 14.50, $p<0.001$, $\eta^2 = 0.29$) and Z (F = 19.28, $p<0.001$, $\eta^2 = 0.35$) axis loads. Across all conditions, mean $PL_{acc.min}^{-1}$ was greater for midfielders (p = 0.004, CI: 0.68, 4.56) and forwards (p = 0.037, CI: 0.08, 3.97) than central defenders. In all conditions, greater Y axis values existed for wide defenders (p = 0.024, CI: 0.67, 1.38), midfielders (p = 0.006, CI: 0.18, 1.50) and forwards (p = 0.007, CI: 0.17, 0.15) compared to central defenders. Midfielders reported greater Z axis values compared to central defenders (p = 0.002, CI: 0.40, 2.23). We conclude SSG's elicit greater external load than MP, and previous studies may have underestimated the demands of SSG's.

Keywords: Small sided games, training games, conditioning, soccer, football, player load, tri-axial, GPS.

INTRODUCTION

Small sided games (SSG's) are widely used to improve simultaneously player fitness, tactical awareness, and specific dynamics of the game (Hill-Haas, Dawson, Impellizzeri, & Coutts, 2011). Through manipulation of various elements including, player numbers, pitch dimensions and size, the duration of work and rest periods, the rules of the game, coach encouragement, and the inclusion of goalkeepers, different physical, technical and tactical responses may be elicited (Dellal, Chamari, Pintus, Girard, Cotte, & Keller, 2008; Little & Williams, 2006; Little & Williams, 2007; Mallo & Navarro, 2008; Rampinini, Coutts, Castagna, Sassi, & Impellizzeri, 2007). Increasing pitch dimensions, while maintaining a constant number of players, increased mean heart rate, blood lactate and rating of perceived exertion (Clemente, Martins, & Mendes, 2014). In contrast, small pitch dimensions have been found to increase the technical demands, evidenced by a higher frequency of tackles and shots (Kelly & Drust, 2009). Although these studies have provided a greater understanding of the rigours of SSG's, internal physiological measures are not the most appropriate for the determination of physical demands. This has been aligned with inherent sensitivity issues and, as a result, underestimation of the internal demands of the game. For example, heart rate has been found to respond slowly to changes in exercise intensity and is, therefore, an inappropriate measuring tool (Achten & Jeukendrup, 2003; Borresen & Lambert, 2008).

Alternatively, Global Positioning Systems (GPS) have been widely adopted by a multitude of team sports as a comprehensive analogue of time-motion analysis and player performance (Edgecomb & Norton 2006; Gabbett, 2010; Petersen, Pyne, Dawson, Kellett, & Portus, 2011). These devices enable temporal and kinematic variables such as distance, direction of movement and velocity to be measured (Scott, Lockie, Knight, Clark, Xanne, & Janse de Jonge, 2013). Using GPS systems, in game situations, has revealed that SSGs played on small pitch dimensions evoke the majority of the features occurring in match play (MP) but are insufficient to reproduce the high-intensity and repeated-sprint demands of high-level competitive situations (Gabbett & Mulvey, 2008; Casamichana, Castellano, & Castagna, 2012). However, SSG's played on larger pitch dimensions have been found to stimulate significantly greater high-speed running than MP (Dellal, Owen, Wong, Krustrup, van Exsel, & Mallo, 2012). In order to assess the physical demands of soccer, much attention is paid to activities completed at high-intensity (Bradley, DiMascio, Peart, Olsen, & Sheldon, 2010; Mohr, Krustrup, & Bangsbo, 2003). However, this approach is flawed because it fails to account for the low-speed movements that are energetically costly. Indeed, high-intensity activities also include accelerations and decelerations, jumps, turns and physical contacts that may be classified under low-speed activity, despite evoking high physiological load (Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010; Reilly, & Bowen, 1984; Varley, & Aughey, 2013). Despite recent improvements in sampling frequency, GPS remains insensitive to some discrete soccer specific movements, and inaccuracies are found when measuring high-speed activities and rapid changes of direction (Jennings, Cormack, Coutts, Boyd, & Aughey, 2010; Rawstorn, Maddison, Ali, Foskett, & Gant, 2014). Interestingly, increased sampling frequency may not improve sensitivity during team sports movements; in comparison to 15Hz models, 10Hz GPS demonstrated greater validity and interunit reliability (Johnston, Watsford, Kelly, Pine, & Spurris, 2014). Furthermore, measurements of acceleration and deceleration are reported to exhibit the most inter-unit variability (Buchheit, Al Haddad, Simpson, Palazzi, Bourdon, Di Salvo, & Mendez-Villanueva, 2014) leading the same authors to conclude that care should be taken when comparing data with different models and/or units.

Accelerations have been found to be more energetically demanding than movement at a constant velocity (Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010). Also, decelerations occur as frequently as accelerations in football MP (Osgnach, Poser, Bernardini, Rinaldo, & di Prampero, 2010) and have been found to induce significant mechanical stress on the body, explained by the associated eccentric muscular action (Thompson, Nicholas, & Williams, 1999). The use of GPS units with integrated tri-axial accelerometers enables the measurement of the total mechanical stress associated with discrete activities during soccer. Moreover, the summation of acceleration and deceleration movements in each cardinal plane (X: medial-lateral, Y: anterior-posterior, Z: caudal-cranial) provides an estimate of the total player load (Cummins, Orr, O'Connor, & West, 2013). These systems avoid some of the limitations previously outlined with internal measures and time-motion analysis, as they typically provide a sampling rate of 100 Hz and have been found to have excellent accuracy and reliability (CV 1.02 – 1.04 %) (Boyd, Ball, & Aughey, 2011). Despite the potential of such systems to determine mechanical load, there have been few attempts to create a truly usable profile of accelerometer-derived performance. Recent research has targeted accelerometer derived player load (PL), which is a representation of total body load experienced by the player.

Player load has been found to correlate with internal measures including HR-based and rating of perceived exertion (RPE)-based measures ($r = 0.71$-0.84), and total distance covered (r = 0.93) (Scott et al. 2013). Player load now provides an objective measure of total external load, which include non-locomotor contributing activities that have been found to differentiate SSG and competition demands of basketball (Montgomery, Pyne, & Minahan, 2010). Furthermore, PL has been used to determine positional differences in basketball and netball (Montgomery, Pyne, & Minahan, 2010; Cormack, Smith, Mooney, Young, & O'Brien, 2013).

With regards to soccer, research has reported PL values for SSGs and friendly MP (Aguiar, Bothelho, Gonçalves, & Sampaio, 2013; Casamichana, Castellano, & Castagna, 2012). However, these studies reported accumulated PL values ($PL_{acc)}$ from the summation of acceleration and deceleration movements in each plane (X: medial-lateral, Y: anterior-posterior, Z: caudal-cranial). Information regarding the contribution of each individual plane to PL_{acc} would provide a greater understanding of the discreet movements performed by players of different positional roles. The aims of this study were to determine the tri-axial external load of three SSG formats (2 vs. 2, 3 vs. 3 and 4 vs. 4) and secondly, through comparison with data derived during 11v11 competition, understand how each SSG format reflects the tri-axial activity of competition.

METHODS

Participants

Forty trained sub-elite youth soccer players (age 17.0 ± 0.6 yrs, body mass 73.93 ± 5.85 kg, stature 180 ± 6 cm) volunteered for the study after providing parental consent in accordance with the Declaration of Helsinki. Players were classified by playing position, including; central defenders (CD = 10), wide defenders (WD = 10), midfielders (MF = 10) and forwards (FW = 10). Wide midfielders were not included in the study as a result of the playing formation used. Approval for the study was granted by the University of Central Lancashire Ethics Committee.

Equipment

External load was determined using a GPS system sampling at 5 Hz, which included a tri-axial accelerometer sampling at 100 Hz (Minimax X3, Catapult Innovations, Australia). The players wore neoprene harnesses securing the devices between the upper scapulae, at approximately the T3-4 junction. The devices were activated 15 minutes before use, in accordance with the manufacturer's instructions, and to allow satellites to download the required almanac data. Player load values (PL) are presented as the individual X, Y and Z cardinal plane components and represented as arbitrary units (AU). To avoid bias due to the different durations of SSG's and MP, PL values were normalized for each minute of play, as in the study of Montgomery, Pyne and Minahan (2010) and Casamichana, Castellano, and Castagna (2012) and reported as accumulated player load per min ($PL_{acc.min}{}^{-1}$).

Procedure

Specific training drills (Table 1) were chosen in accordance to previous research conducted by Rampinini, Impellizzeri, Castagna, Abt, Chamari, Sassi, and Marcora (2007) and Dellal, Hill-Haas, Lago-Penas, and Chamari (2011). The number of games per format was as follows; 2 vs. 2, n=10; 3 vs. 3, n=7; 4 vs. 4, n=5. Players were matched on technical ability and were organized so that a player from each positional role was included. Games were played without goalkeepers, with the aim to maintain possession of the ball for as long as possible while only allowing two touches per player possession. Players were also analysed during six home English College friendly fixtures during the 2013-2014 season. All games were played on a full-size synthetic 3G surface; a 4-3-3 formation was preferred, and only players completing 90 minutes were included. Before the commencement of the SSGs and the friendly games, the coach conducted a 20 min standardised warm up.

Table 1. Characteristics of SSG's.

	Game duration (min)	Duration of recovery between SSG (min)	Pitch area (m)	Pitch total area (m^2)	Pitch ratio per player (m^2)
2 vs. 2	4x2	3	20x15	300	1:75
3 vs. 3	4x3	3	25x18	450	1:75
4 vs. 4	4x4	3	30x20	600	1:75

ANALYSIS

Data was first uploaded to proprietary software (Catapult, Sprint software, 5.0). A 4x4 mixed-model repeated measures ANOVA was used to determine significant main effects for condition and playing positions for each variable. Bonferroni post hoc analyses were then used to determine where differences lay. When a significant interaction was found, a one-way ANOVA was used to identify differences between positional roles in different conditions. Statistical significance was accepted at $p \leq 0.05$, whilst Eta squared (η^2) was used to measure effect size, where <0.2 = small, 0.2-0.8 medium and >0.8 large. All statistical procedures were completed using SPSS 20.0 (SPSS Inc. Chicago, USA).

RESULTS

$PL_{acc.min}^{-1}$ and X, Y and Z PL in each SSG and MP for each positional role are presented in Table 2. A significant main effect was found for mean $PL_{acc.min}^{-1}$ $F(3, 108) = 21.91$;

$p<0.001$, $\eta^2 = 0.38$. Player load per min was significantly greater for 2 vs. 2 ($p<0.001$, CI = 3.02, 6.62), 3 vs. 3 ($p<0.001$, CI = 2.93, 6.06) and 4 vs. 4 ($p<0.001$, CI = 1.49, 5.09) SSG's than MP.

Statistical analysis also revealed a significant main effect for mean physical load in the X axis per min $F(3, 108) = 27.40$; $p<0.001$, $\eta^2 = 0.43$). Physical load in the X axis per min was significantly greater for 2 vs. 2 ($p<0.001$, CI = 1.12, 1.96), 3 vs. 3 ($p<0.001$, CI = 0.87, 1.73) and 4 vs. 4 ($p<0.001$, CI = 0.51, 1.42) SSG's than MP. Similarly, a significant main effect was found for mean physical load in the Y axis per min $F(3, 108) = 14.50$; $p<0.001$, $\eta^2 = 0.29$). Physical load in the Y axis was significantly greater for 2 vs. 2 ($p<0.001$, CI = 0.69, 1.98), 3 vs. 3 ($p<0.001$, CI = 0.76, 1.84) and 4 vs. 4 ($p<0.001$, CI = 0.48, 1.67) SSG's than MP. A significant main effect was found for physical load in the Z axis per min $F (3, 108) = 19.28$; $p<0.001$, $\eta^2 = 0.35$). Physical load in the Z axis was significantly greater for 2 vs. 2 ($p<0.001$, 1.18, 2.83), 3 vs. 3 ($p<0.001$, CI = 1.17, 2.62) and 4 vs 4 ($p = 0.001$, CI = 0.42, 2.09) SSG than MP.

When mean $PL_{acc.min}{}^{-1}$ was examined across all conditions, a significant main effect was found for positional role $F(3, 36) = 5.19$; $p = 0.004$, $\eta^2 = 0.30$). Mean $PL_{acc.min}{}^{-1}$ was significantly greater for MF than CD ($p = 0.004$, CI = 0.68, 4.56) and FW than CD ($p = 0.037$, CI = 0.08, 3.97). A significant main effect was also found for positional role when the physical load in the X axis per min was examined across all conditions $F(3, 36) = 3.26$; $p = 0.032$, $\eta^2 = 0.21$. However, post hoc tests revealed no significant differences between positional roles. When mean physical load in the Y axis per min was examined across all conditions, a significant main effect was found for positional role F(3, 36) = 5.85, p = 0.002; $\eta^2 = 0.33$. Mean physical load in the Y axis per min was significantly greater by WD than CD (p = 0.024, CI = 0.66, 1.38), MF than CD (p = 0.006, CI = 0.18, 1.50), and FW than CD (p = 0.007, CI = 0.17, 1.49). A significant main effect was also found for positional role when the physical load in the Z axis per min was examined across all conditions F(3, 36) = 5.45; p = 0.003, $\eta^2 = 0.31$. Mean physical load in the Z axis per min was significantly greater for MF than CD (p = 0.002, CI = 0.40, 2.23).

Table 2. Mean ± SD values for accumulated player load and individual axial load per condition.

		$PL_{acc.min}^{-1}$ (AU)	$X.min^{-1}$ (AU)	$Y.min^{-1}$ (AU)	$Z.min^{-1}$ (AU)
MP	CD	8.15 ± 1.28	2.21 ± 0.39	1.86 ± 0.62	4.09 ± 0.50
	WD	10.57 ± 1.84	2.69 ± 0.58	2.86 ± 0.45	5.03 ± 1.05
	MF	11.34 ± 1.95	2.86 ± 0.48	2.87 ± 0.69	5.63 ± 0.90
	FW	10.65 ± 2.06	2.70 ± 0.54	3.08 ± 0.60	4.86 ± 0.97
	Total (n = 40)	**10.18 ± 2.12**	**2.61 ± 0.54**	**2.66 ± 0.75**	**4.90 ± 1.01**
2 vs. 2	CD	13.64 ± 2.96	3.76 ± 0.69	3.57 ± 1.10	6.29 ± 1.41
	WD	15.32 ± 3.95	4.09 ± 1.03	4.23 ± 1.36	7.01 ± 1.68
	MF	14.98 ± 3.20	4.03 ± 0.82	4.04 ± 1.41	6.89 ± 1.26
	FW	16.08 ± 4.02	4.54 ± 1.14	4.16 ± 1.37	7.43 ± 1.74
	Total (n = 40)	**15.00 ± 3.53[a]**	**4.10 ± 3.94[b]**	**4.00 ± 1.29[c]**	**6.90 ± 1.53[d]**

3 vs. 3	CD	12.39 ± 2.76	3.32 ± 0.58	3.25 ± 1.31	5.83 ± 1.21
	WD	15.18 ± 3.45	3.99 ± 0.94	4.39 ± 1.21	6.79 ± 1.44
	MF	16.08 ± 2.90	4.22 ± 0.81	4.03 ± 0.74	7.83 ± 1.42
	FW	15.06 ± 3.17	4.14 ± 1.01	4.20 ± 0.70	6.75 ± 1.61
	Total (n = 40)	**14.68 ± 3.27[a]**	**3.92 ± 0.89[b]**	**3.97 ± 1.08[c]**	**6.80 ± 1.55[d]**
4 vs. 4	CD	12.97 ± 1.88	3.74 ± 0.70	3.30 ± 0.82	5.90 ± 0.70
	WD	12.22 ± 1.86	3.22 ± 0.45	3.39 ± 0.61	5.64 ± 0.88
	MF	15.23 ± 5.04	3.80 ± 1.21	4.40 ± 1.71	7.02 ± 2.28
	FW	13.46 ± 3.30	3.56 ± 0.79	3.86 ± 1.01	6.06 ± 1.58
	Total (n = 40)	**13.47 ± 3.35[a]**	**3.58 ± 0.83[b]**	**3.74 ± 1.16[c]**	**6.17 ± 1.53[d]**

Values mean ± SD. NB. N=10 per positional role; Post-hoc significant differences: [a] Significantly greater $PL_{acc.min}^{-1}$ for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$); [b] Significantly greater physical load in the X axis per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$); [c] Significantly greater physical load in the Y axis per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$); [d] Significantly greater physical load in the Y axis per min for 2 vs. 2 than MP ($p<0.001$), 3 vs. 3 than MP ($p<0.001$), and 4 vs. 4 than MP ($p<0.001$).

Table 3. Mean ± SD values for accumulated player load and individual axial load by playing position.

		$PL_{acc.min}^{-1}$ (AU)	**$X.min^{-1}$ (AU)**	**$Y.min^{-1}$ (AU)**	**$Z.min^{-1}$ (AU)**
CD	MP	8.15 ± 1.28	2.21 ± 0.39	1.86 ± 0.62	4.09 ± 0.50
	2 vs. 2	13.64 ± 2.96	3.76 ± 0.69	3.57 ± 1.10	6.29 ± 1.41
	3 vs. 3	12.39 ± 2.76	3.32 ± 0.58	3.25 ± 1.31	5.83 ± 1.21
	4 vs. 4	12.97 ± 1.88	3.74 ± 0.70	3.30 ± 0.82	5.90 ± 0.70
	Total (n = 10)	**11.79 ± 3.11**	**3.26 ± 0.86**	**2.99 ± 1.17**	**5.53 ± 1.31**
WD	MP	10.57 ± 1.84	2.69 ± 0.58	2.86 ± 0.45	5.03 ± 1.05
	2 vs. 2	15.32 ± 3.95	4.09 ± 1.03	4.23 ± 1.36	7.01 ± 1.68
	3 vs. 3	15.18 ± 3.45	3.99 ± 0.94	4.39 ± 1.21	6.79 ± 1.44
	4 vs. 4	12.22 ± 1.86	3.22 ± 0.45	3.39 ± 0.61	5.64 ± 0.88
	Total (n = 10)	**13.32 ± 3.48**	**3.49 ± 0.95**	**3.72 ± 1.14[b]**	**6.12 ± 1.50**
MF	MP	11.34 ± 1.95	2.86 ± 0.48	2.87 ± 0.69	5.63 ± 0.90
	2 vs. 2	14.98 ± 3.20	4.03 ± 0.82	4.04 ± 1.41	6.89 ± 1.26
	3 vs. 3	16.08 ± 2.90	4.22 ± 0.81	4.03 ± 0.74	7.83 ± 1.42

	4 vs. 4	15.23 ± 5.04	3.80 ± 1.21	4.40 ± 1.71	7.02 ± 2.28
	Total (n = 10)	**14.41 ± 3.80[a]**	**3.73 ± 0.99**	**3.83 ± 1.31[b]**	**6.84 ± 1.69[c]**
FW	MP	10.65 ± 2.06	2.70 ± 0.54	3.08 ± 0.60	4.86 ± 0.97
	2 vs. 2	16.08 ± 4.02	4.54 ± 1.14	4.16 ± 1.37	7.43 ± 1.74
	3 vs. 3	15.06 ± 3.17	4.14 ± 1.01	4.20 ± 0.70	6.75 ± 1.61
	4 vs. 4	13.46 ± 3.30	3.56 ± 0.79	3.86 ± 1.01	6.06 ± 1.58
	Total (n = 10)	**13.81 ± 3.72[a]**	**3.73 ± 1.11**	**3.82 ± 1.04[b]**	**6.27 ± 1.74**

Values mean ± SD; Post-hoc significant differences: [a] Significantly greater $PL_{acc.min}^{-1}$ by MF than CD (p=0.004) and FW than CD (p=0.037); [b] Significantly greater physical load in the Y axis per min WD than CD (p=0.024), MF than CD (p=0.006), and FW than CD (p=0.007); [c] Significantly greater physical load in the Z axis per min by MF than CD (p=0.002).

DISCUSSION

The main finding from this study was that $PL_{acc.min}^{-1}$ was greater during each SSG modality than MP indicating that the external demands of SSG's are greater than MP. Research by Casamichana, Castellano, and Castagna (2012) is in agreement with the present study, in which $PL_{acc.min}^{-1}$ was significantly greater during SSG's (15.8 ± 2.7 AU) in comparison with MP (13.5 ± 1.5 AU). However, the current study provides more detailed information regarding the mechanical stress imposed on players of different positional roles through quantifying the discrete actions that occur during soccer.

During MP, MF reported the greatest $PL_{acc.min}^{-1}$ value, whereas CD reported the lowest values. As PL quantifies the total external load experienced by players, including the discrete, non-locomotor contributing activities such as jumping and collisions, these results provide further evidence that MF indeed elicits greater work rate demands, with CD requiring the least work rate (Di Salvo, Baron, Tschan, Calderon Montero, Bachl, & Pigozzi, 2007). A possible explanation for the greater $PL_{acc.min}^{-1}$ reported by MF during

MP could be due to the greater total distance covered by this position in comparison to others.

Across the SSG drills, an inverse relationship was observed between the number of players and external load, whereby formats with the fewest players elicited the greatest $PL_{acc.min}^{-1}$ values. A possible reason for this could be the reduction in technical demands as the number of player increase. The results of Aguiar, Bothelho, Gonçalves, and Sampaio (2013) are in contrast to the findings of the present study, in which 2 vs. 2 SSG's reported a PL value of 88.63 ± 20.37 AU that increased linearly with an increase in the number of players with 4 vs. 4 SSG's reporting a PL value of 95.18 ± 17.54 AU. A possible reason for these findings could be attributed to the different methodology employed to that of the present study. For example, the duration of the 2 vs. 2, 3 vs. 3 and 4 vs. 4 SSG modalities used in the present study were 8, 12 and 16 min, respectively, whereas the duration for all SSG in the study by Aguiar, Bothelho, Gonçalves, and Sampaio (2013) was 18 min (6 x 3 min bouts). It is expected that fatigue may have influenced the results in the aforementioned study as the ability to maintain high-intensity exercise would have been difficult in the later stages of the 2 vs. 2 SSG. In contrast, during 3 vs. 3 and 4 vs. 4, players have a greater opportunity to recover allowing higher-intensities to be sustained for a longer period. The ability to maintain higher intensity exercise during 3 vs. 3 and 4 vs. 4 in comparison to 2 vs. 2, is likely the reason explaining the increase in $PL_{acc.min}^{-1}$ as the number of players increase. Elsewhere, Gaudino, Giampietro, and Iaia (2014) reported that moderate (2-3 $m \cdot s^{-2}$) and high accelerations (> 3 $m \cdot s^{-2}$) were significantly more frequent in 5 vs. 5 and 7 vs. 7 compared to 10 vs. 10. A similar pattern was evident for moderate and high decelerations, supporting the findings of the present study, that fewer players and smaller pitches elicit higher external load.

The physical load in the X axis was relatively homogenous across positional roles during MP. However, post hoc tests revealed that mediolateral load was greater in all SSG formats compared to MP. Importantly, during SSG's the aim was to retain possession necessitating frequent changes of direction to evade opponents and find space to receive the ball. These discreet movements elicited a higher multi-directional load, consistent with the observations of Gaudino, Giampietro, and Iaia (2014) unlike a goal-orientated focus that provides a direction for play characterized by more linear movement.

With regards to the physical load values in the Y axis, FW reported the greatest values with CD reporting the lowest values during MP, although not significantly. A possible explanation for the differences could be that FW covered greater distances in acceleration / deceleration during speeding up and slowing down movements and / or rapid changes of direction. During MP, FW are obligated to move at high-speeds to evade defenders, whereas the CD has to track the FW movement and position himself strategically (Faude, Koch, & Meyer, 2012). Movement at these high intensities would likely result in anterior-posterior changes of upper body position (i.e. forward and backward lean), and, therefore, a greater distance covered during high-intensity activities would increase the acceleration values in the Y axis. Cormack, Mooney, Morgan, and McGuigan (2013) observed an inverse relationship between anterior-posterior acceleration and high-speed running in a fatigued state and suggested that fewer anterior-posterior changes of upper body position could indicate a less total distance covered in high-speed running. This is supported by the significantly greater Y axis values reported during all SSG's than MP with values decreasing as the number of players increase. Furthermore, a greater distance covered at >1 $m{\cdot}s^{-2}$ and > - 1 $m{\cdot}s^{-2}$ was reported for 2 vs. 2 and 3 vs. 3 in comparison to 4 vs. 4 suggesting that a greater number of accelerations in the SSG's and, therefore, greater changes in upper body positions.

Midfielders reported the greatest physical loads in the Z axis with CD reporting the lowest values during MP, although not significantly. Although the data do not provide a definite conclusion to why MF report the greatest values, it is possible that accelerations measured in the vertical plane reflect PL accumulated from running and the associate vertical displacement. If, as previous work in netball, hockey and Australian football suggested, players that run at a higher intensity (including high-speed running and accelerating/decelerating during changes in velocity which involve more rapid vertical displacement than slower speed running), this could account for the greater contribution from the vertical vector (Brewer, Dawson, Heasman, Stewart, & Cormack, 2010; Jennings, Cormack, Coutts, Boyd, & Aughey, 2012).

This notion is supported by the significantly greater physical loads in the Z axis during SSG's in comparisons to MP. Indeed, results from the present study have demonstrated that although SSG's do not evoke high-speed running, they impose a large physical demand on players through a greater accumulation of accelerations and decelerations. Cormack, Mooney, Morgan, and McGuigan (2013) found reductions in the Z-vector accelerometer in the fatigued state, and, given that neuromuscular fatigue directly impairs the ability to sprint or accelerate / decelerate; this provides further support to the contribution of high-intensity activities such as acceleration / deceleration and sprinting to Z-vector accelerometer. In order to improve player's capacity regarding match demands, an association of SSG's and specific high-intensity training is needed.

CONCLUSION

In conclusion, this study provides insight into the differences in tri-axial $PL_{acc.min}^{-1}$ during SSG's and MP for different playing positions. Midfielders reported the greatest PL values during MP providing further support for the considerably greater work-rate demands of this positional role. SSG's evoked considerably greater $PL_{acc.min}^{-1}$ values for all positional roles in comparison to MP, suggesting that previous time-motion analysis research using traditional constant-speed zones have underestimated the demands of soccer. Whilst the relative contribution of the X, Y and Z axes to PL does not appear practically different between positional rules during MP, the greater values reported in SSG's suggest these games may provide a 'density' type-training stimulus, by imposing relative demands of acceleration and deceleration activities in excess of those experienced during MP. Coaches should therefore, carefully consider the scheduling of SSG's, particularly in the lead up to competitive fixtures and during early pre-season when players may not, necessarily, be conditioned to the high external workload demands.

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