Scand J Med Sci Sports 2014: 24 (Suppl. 1): 17–26
doi: 10.1111/sms.12255

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

Effect of game format on heart rate, activity profile, and player involvement in elite and recreational youth players

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Accepted for publication 16 April 2014

The purpose of this study was to evaluate activity profile, aerobic load, and player involvement in two game formats of recreational and elite youth football for two age groups. A total of 152 youth players participated, with 45 U10 players playing 5v5 and 8v8 games, and 41 U13 players playing 8v8 and 11v11 (20 min) games. Activity profile, heart rate (HR), and technical actions were measured during all games using 10 Hz GPS, video filming, and HR monitors. For U10, no difference was found in total distance covered (1754 ± 237 vs 1771 ± 314 m, $P = 0.650$, $d = 0.06$), whereas mean HR (174 ± 10 vs 168 ± 12 bpm, $P = 0.001$, $d = 0.59$) and number of technical actions (65.1 ± 24.0 vs 36.9 ± 20.4, $P < 0.001$, $d = 1.27$) were higher in 5v5 than in 8v8. For U13, lower total distance covered (1821 ± 325 vs 2038 ± 328 m, $P < 0.001$, $d = 0.66$) and higher number of technical actions (36.2 ± 14.9 vs 26.9 ± 14.1, $P < 0.001$, $d = 0.64$) were observed in 8v8 than in 11v11, with no difference in mean HR (170 ± 10 vs 171 ± 10 bpm, $P = 0.679$, $d = 0.10$). In conclusion, HR is high in youth football matches irrespective of the level of play and the game format. Playing with fewer players on smaller pitches results in minor changes to the physical loading but elevates the technical involvement of youth players both at elite level and recreational level.

International football matches are played on pitches sized 100–110 × 64–75 m, whereas pitch size varies in domestic matches, especially in recreational football. Youth football matches are generally played as small-sided games, with the pitch size and number of players adapted to different age groups. In relation to the fitness and health effects of both recreational and elite youth football, it is of interest to determine the intensity and player involvement in various types of small-sided match-play because match-play accounts one-tenth to one-third of the exposure time for youth players (Brito et al., 2012). The number of players and pitch size have been shown to influence the physical demands of the game (Rampinini et al., 2007; Hill-Haas et al., 2010, 2011; da Silva et al., 2011). Some studies have shown that heart rate (HR) is higher during small-sided games formats with fewer players (Rampinini et al., 2007; Hill-Haas et al., 2009; Katis & Kellis, 2009), whereas others have found no effect or higher HRs in game formats with more players (Capranica et al., 2001; Sampaio et al., 2007; Jones & Drust, 2007; Hill-Haas et al., 2010; Dellal et al., 2011; Castellano et al., 2013). The effect of pitch size is smaller than that of the number of players, and although most studies have shown increasing HR response with increasing pitch size (Tessitore et al., 2006; Rampinini et al., 2007; Casamichana & Castellano, 2010; Hill-Haas et al., 2011), some have not found any effect of pitch size on HR response (Capranica et al., 2001; Kelly & Drust, 2009).

Decreasing the number of players or pitch area has been shown to have minor or no effect on technical variables, but most studies have shown an increase in the total number of ball contacts per player (Jones & Drust, 2007; Katis & Kellis, 2009; Kelly & Drust, 2009; Casamichana & Castellano, 2010; da Silva et al., 2011; Abrantes et al., 2012). However, one study (Owen et al., 2011) showed a large effect on technical variables; more passes, blocks, interceptions, headers, and total ball contacts were observed during 10 vs 10 games, whereas more shots, dribbles, and ball contacts per player were seen during four vs four. The majority of these studies have been conducted on elite adult or adolescent players. Studies have shown, however, that the differences in activity profile between age groups are small, even though large differences in physical capacity has been shown (Buchheit et al., 2010), and even smaller when related to playing time and/or age-adapted speed zones (Harley et al., 2010; Mendez-Villanueva et al., 2011).

From a skill-development point of view, youth football should focus on technical skills in the youngest players, whereas tactical and physical developments are the primary focus later on. Involvement in the game, decision-making, and successful actions are therefore a major factor for technical skill development. From a public-health perspective, recreational football is an important physical activity for many children. Total distance covered and high aerobic load may therefore be central factors in relation to health.

In Denmark, five game formats (three vs three, 5v5, seven vs seven, nine vs nine, and 11v11) have been used with suggestions and guidelines for pitch size. The many pitch sizes have caused some practical problems as the length:width ratios between these game formats vary markedly (1.07–1.62). The Danish Football Association has suggested using 8v8 instead of seven vs seven and nine vs nine, thereby reducing the number of game formats from five to four. Moreover, the Danish Football Association has chosen the U10 and U13 age groups for transition from 5v5 to 8v8 (U10) and from 8v8 to 11v11 (U13). The aims of the present study were therefore to evaluate activity profile, aerobic load, and technical performance in recreational and elite youth football matches for U10 and U13 boys and to investigate whether the game format influenced exercise intensity and technical performance.

Methods

Participants

A total of 152 youth players from 16 teams representing 10 different Danish football clubs participated in the study. Only players who had a dataset from both games were analyzed and no goal keepers were included in the analysis. Thus, a total of 86 players, of whom 45 were U10 (aged 8–9) and 41 were U13 (aged 11–12), were included. In U10, 23 were elite whereas 22 were recreational players, whereas in U13, 20 were elite and 21 were recreational players. Elite players competed in the best league for their age group whereas recreational players competed at the lowest competitive level for their age group in this region (the third league). The U10 players played 8v8 and 5v5 games, whereas the U13 players played 11v11 and 8v8 games. Each game lasted for 20 min and the games were played in a randomized order on the same day for each age group. The pitch sizes were 5v5: 30×40 m (120 m^2 per player), 8v8: 52.5×68 m (223 m^2 per player), and 11v11: 105×68 m (325 m^2 per player). All games were played on artificial grass. The size of the goals was 1.5×3 m in 5v5 games, 2×5 m in 8v8 games, and 2.44×7.32 m in 11v11 games. The 5v5 and 8v8 games were played without the offside rule, whereas the 11v11 games included the offside rule. During each game, activity pattern and HR were monitored.

HR monitoring

Heart rate was recorded in 1-s intervals during each game using short-range radio telemetry (Polar Team2 System, Polar Electro Oy, Kempele, Finland). The HR data were downloaded and expressed mean HR for the full match. In addition, the HR data were divided into the following zones: < 120, 120–160, 160–170, 170–180, 180–190, 190–200, and >200 bpm.

Activity pattern

The activity pattern was measured using portable Global Positioning System (GPS) units (MinimaxX S4, Catapult Innovations, Canberra, Australia). A GPS unit was placed into the manufacturer-designed harness. During all games, the mean number of satellites was 11–14 and the horizontal dilution of precision was 0.71–1.27. A sample rate of 10 Hz was used and participants wore the same unit in both games to exclude any possible intramodel variability. After the games, the data were downloaded and analyzed using proprietary software (Sprint, Catapult Sports, Canberra, Australia).

Total distance, number of efforts, and distance covered at 0–0.2, 0.2–4, 4–8, 8–12, 12–16, 16–20, and >20 km/h were measured. Moreover, maximal speed and player load were measured. Accumulated player load is an estimate of physical demand combining the instantaneous rate of change in acceleration in three planes – forward/backward ($\mathcal{X}$), side/side ($\mathcal{Y}$) and up/down ($\mathcal{Z}$) – using the formula:

$$\text{Accumulated player load (r)} = \sum_{t=0}^{t=n} \sqrt{(\mathcal{X}_{t=n} - \mathcal{X}_{t=n-1})^2 + (\mathcal{Y}_{t=n} - \mathcal{Y}_{t=n-1})^2 + (\mathcal{Z}_{t=n} - \mathcal{Z}_{t=n-1})^2}$$

The reliability and variability of the GPS and accelerometer units (player load) and technical performance have been described elsewhere (Zubillaga, 2006; Randers et al., 2010b; Boyd et al., 2011).

All games were recorded using digital video cameras (Canon HF20E, Canon, Tokyo, Japan) and analyzed for technical performance (provided by Amisco, Odense, Denmark). The number of passes, shots, receptions, and headers were counted.

Statistics

In each age group, differences between game formats (main effect) and level of competition (main effect) and their interaction were tested using a two-way analysis of variance with repeated measures. When significance was found, a Student-Newman-Keuls post-hoc test was applied. A similar procedure was used to test possible differences between game formats for data lower and higher than the median in the game format with the highest number of players. Effect size was calculated using Cohen's d (Cohen, 1988) and interpreted as suggested by Hopkins (2004): < 0.2 trivial, 0.2–0.6 small, 0.6–1.2 moderate, 1.2–2.0 large, 2.0–4.0 very large, > 4.0 nearly perfect.

Results

Main effect – game format

In U10 games, total distance covered was not different ($P = 0.650$, $d = 0.06$) between 5v5 (1754 ± 237 m) and 8v8 games (1771 ± 314 m). Distance covered at the highest running speeds was lower in 5v5 than in 8v8 games for 16–20 km/h (50 ± 38 vs 69 ± 48 m, respectively; $P = 0.009$; $d = 0.43$) and > 20 km/h (2 ± 6 vs 6 ± 10 m respectively; $P = 0.023$, $d = 0.45$; Fig. 1). Total number of entries into running speed zones was higher ($P < 0.001$, $d = 0.53$) in 5v5 (181 ± 28) than in 8v8 games (167 ± 28). Peak speed reached during matches was not different ($P = 0.188$, $d = 0.24$) in 5v5 ($18.5 \pm$

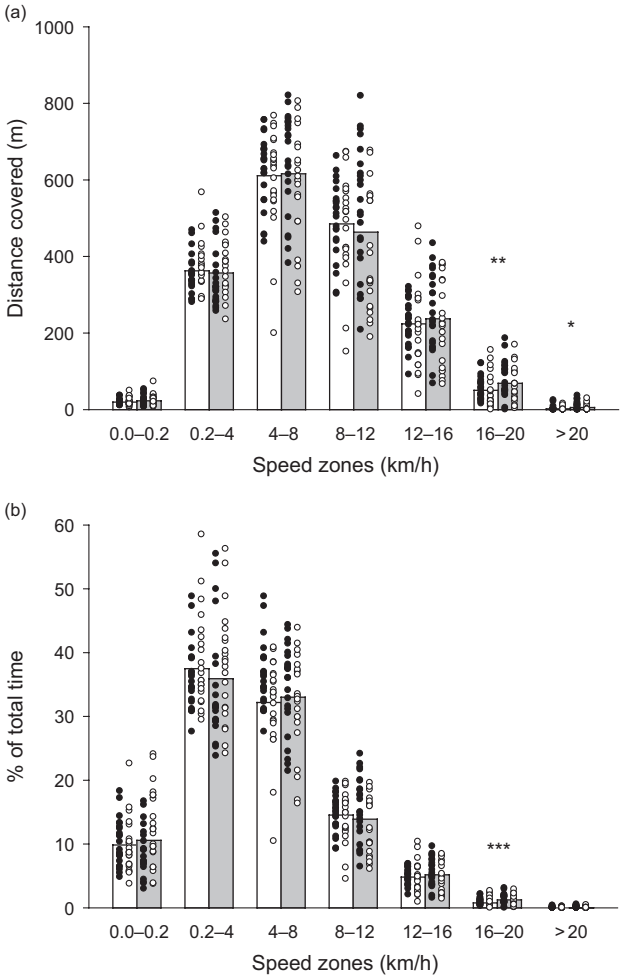

Fig. 1. Distance covered (a) and time spent (b) in various speed zones in 5v5 (white bars) and 8v8 (grey bars) U10 matches for elite players (closed symbols) and recreational players (open symbols). Mean and individual data are presented. *Denotes significant difference at $P < 0.05$, **denotes significant difference at $P < 0.01$, ***denotes significant difference at $P < 0.01$.

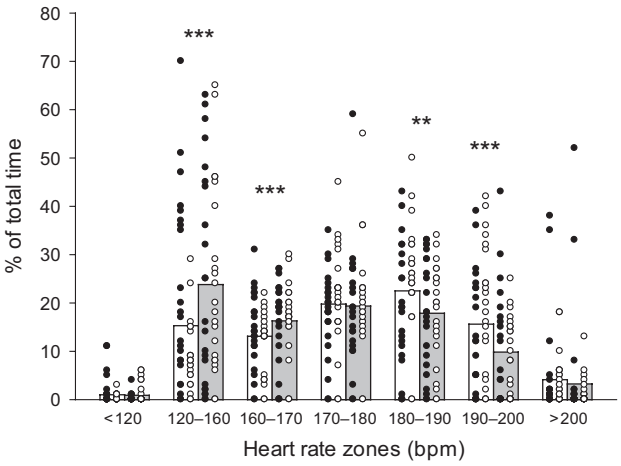

Fig. 2. Time spent in various heart rate zones in 5v5 (white bars) and 8v8 (grey bars) U10 matches for elite players (closed symbols) and recreational players (open symbols). Mean and individual data are presented. **Denotes significant difference at $P < 0.01$, ***denotes significant difference at $P < 0.001$.

1.5 km/h) and 8v8 games (18.9 ± 1.7 km/h). Player load tended ($P = 0.055$; $d = 0.24$) to be higher in 5v5 [251 ± 44 arbitrary unit (AU)] than in 8v8 games (239 ± 57 AU).

Mean HR was higher ($P = 0.001$, $d = 0.59$) in 5v5 (174 ± 10 bpm) than in 8v8 (168 ± 12 bpm) games, as was peak HR (202 ± 8 vs 198 ± 11 bpm respectively, $P = 0.015$, $d = 0.41$). The percentage of time spent within each HR zone is shown in Fig. 2.

In U13 games, total distance covered was lower ($P < 0.001$, $d = 0.66$) during 8v8 (1821 ± 325 m) than 11v11 games (2038 ± 328 m). Differences between 8v8 and 11v11 in distance covered were observed in all speed categories (Fig. 3). In brief, shorter distances were covered during 8v8 than 11v11 games in all speed categories above 4 km/h, whereas longer distances were covered in 8v8 than 11v11 games in speed categories below 4 km/h. Total number of entries into running speed zones was higher ($P < 0.001$, $d = 0.62$) in 8v8 than in 11v11 games (217 ± 22 vs 202 ± 26). Peak speed reached during 8v8 (21.3 ± 2.8 km/h) was lower ($P = 0.007$, $d = 0.46$) than during 11v11 (22.5 ± 2.4 km/h). Player load was significantly higher ($P = 0.040$, $d = 0.30$) during 11v11 (243 ± 55 AU) than 8v8 (231 ± 53 AU).

No differences were observed between 8v8 and 11v11 in mean HR (170 ± 10 vs 171 ± 10 bpm, $P = 0.679$, $d = 0.10$) or peak HR (198 ± 9 vs 199 ± 8 bpm, respectively, $P = 0.487$, $d = 0.12$), and no differences between 8v8 and 11v11 games were observed in any of the HR zones.

The total number of technical actions, number of successful actions, and success rate are presented in Table 1. Briefly, a higher ($P < 0.001$) number of technical actions and a higher number of successful actions were observed for games with the fewest players, but no difference in the success rate was observed between game formats.

Main effect – level of competition

Higher peak speed ($P = 0.012$, $d = 0.63$) was observed in elite U10 (19.2 ± 1.6 km/h) than recreational players (18.2 ± 1.6 km/h). No other differences in movement patterns were observed for U10 between elite and recreational players.

In U13, elite players covered a significantly ($P < 0.001$, $d = 1.07$) greater total distance than recreational players (2088 ± 299 vs 1764 ± 307 m, respectively) and a threefold greater distance at running speed > 20 km/h (69 ± 45 vs 17 ± 22 m, $P < 0.001$, $d = 1.48$) (Fig. 3). Differences between elite and recreational players were observed in distance covered within

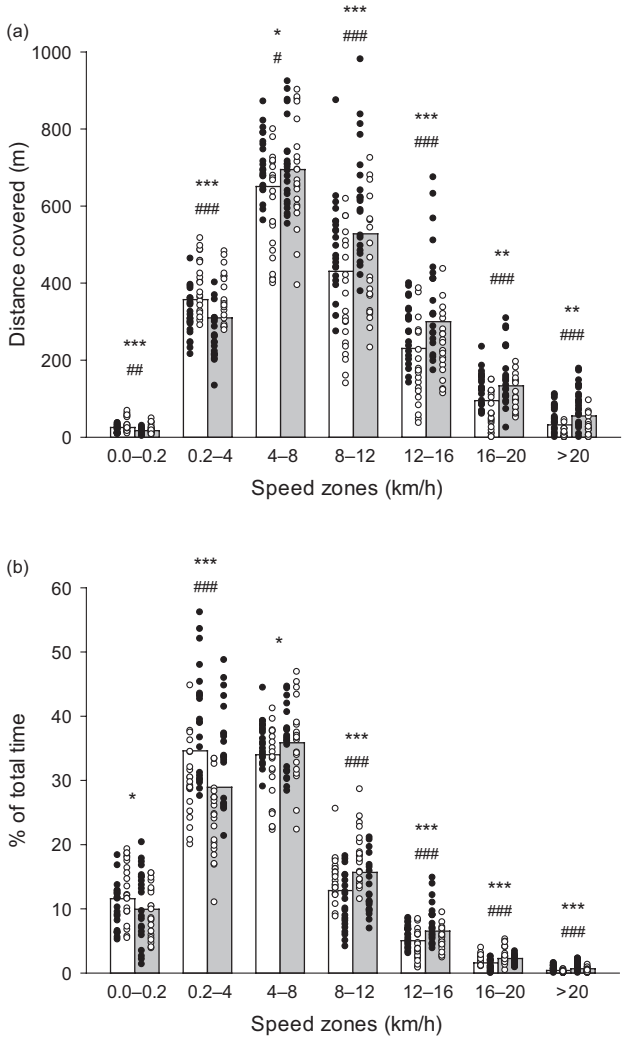

Fig. 3. Distance covered (a) and time spent (b) in various speed zones in 8v8 (white bars) and 11v11 (grey bars) U13 matches for elite players (closed symbols) and recreational players (open symbols). Mean and individual data are presented. *, ** and *** denote significant differences between game formats, with significance levels of $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively. #, ## and ### denote significant differences between competitive levels, with significance levels of $P < 0.05$, $P < 0.01$, $P < 0.001$, respectively.

all speed categories (Fig. 3). Peak speed was higher in elite than recreational players (23.2 ± 2.1 vs 20.4 ± 2.5 km/h, $P < 0.001$, $d = 1.22$) and player load tended ($P = 0.056$, $d = 0.67$) to be higher in elite than recreational players (254 ± 56 vs 220 ± 46 AU, respectively). No difference was observed in the HR response between elite and recreational players.

No difference in the total number of technical actions or successful actions where found between elite and recreational players (Table 1). However, elite players had a higher success rate in U10 ($P = 0.049$) and U13 games ($P = 0.003$) than recreational players.

Interactions (game format × level of competition)

For total distance, a significant interaction ($P = 0.024$) was found, and higher total distance was observed in U10 elite than recreational players during 8v8 (1876 ± 328 vs 1670 ± 317 m, $P = 0.017$, $d = 0.64$) but not during 5v5 (1823 ± 154 vs 1731 ± 296 m, $P = 0.571$, $d = 0.39$). For U10, a significant interaction ($P = 0.004$) was also found for player load and the post-hoc test revealed that player load was higher during 5v5 than 8v8 for recreational players (249 ± 49 vs 217 ± 51 AU, $P = 0.001$, $d = 0.64$) but not for elite players (265 ± 38 vs 268 ± 59 AU, P = 0.451, $d = 0.06$). Moreover, a difference in player load between elite and recreational players was observed during 8v8 ($P = 0.004$, $d = 0.92$) but not 5v5 ($P = 0.780$, $d = 0.36$). A significant interaction ($P = 0.012$) was found for mean HR, and the post-hoc test showed that mean HR was higher during 5v5 than 8v8 for recreational players (178 ± 6 vs 167 ± 10 bpm, $P = < 0.001$, $d = 1.33$) but not for elite players (171 ± 13 vs 169 ± 13 bpm, $P = 0.212$, $d = 0.15$).

No significant interactions were observed for the U13 players except for percentage of total time standing (0–0.2 km/h, $P = 0.006$) and the post-hoc test showed a higher percentage of time spent standing during 8v8 than 11v11 for recreational players (12.9 ± 4.6 vs 9.3 ± 3.9%, $d = 0.84$) but not elite players (10.4 ± 3.6 vs 10.5 ± 5.7%, $d = 0.02$).

Split median

Match data were divided into groups (high: above the median, low: below the median) according to the performance during games with the most players (U10: 8v8, U13: 11v11). For total distance covered, a significant interaction was found for U10 ($P < 0.001$) but not for U13 games ($P = 0.334$; Table 2). Significant interactions were observed for player load, peak speed, and mean HR for U10 players ($P = 0.002$, $P = 0.002$ and $P = 0.002$, respectively) and U13 players ($P = 0.031$; $P = 0.002$ and $P = 0.007$, respectively; Table 2).

Significant interactions were also found for total number of technical actions, successful actions, and success rate (Fig. 4).

Discussion

The main findings of this study were that HRs and high-intensity running distances are high in youth football matches irrespective of level of competition, age, and game format. For U10 players, HRs were even higher in 5v5 than 8v8 games, whereas HRs were similarly high in 8v8 and 11v11 games for U13 players. For U13 players, the scores for running distance and sprint velocities were slightly higher for 11v11 games. Another main finding was that the number of technical actions was markedly

Table 1. Total number of technical actions, number of successful actions, and success rate during 5v5 and 8v8 for under 10 (U10) and 8v8 and 11v11 for under 13 (U13) recreational and elite football players

	Total number of technical actions			Number of successful technical actions			Success rate (%)		
	Mean ± SD	*d*	CV	Mean ± SD	*d*	CV	Mean ± SD	*d*	CV
U10									
5v5	65.1 ± 24.0***		36.9	49.4 ± 20.6***		41.8	75.0 ± 9.2		12.3
8v8	36.9 ± 20.4	1.27	55.4	27.9 ± 17.5	1.13	62.7	73.2 ± 12.1	0.17	16.6
Elite	51.9 ± 26.1		50.2	40.6 ± 22.2		54.6	77.0 ± 10.8#		14.3
Recreational	50.1 ± 26.9	0.07	53.8	36.6 ± 21.7	0.18	59.3	70.9 ± 9.6	0.60	13.6
Elite – 5v5	68.4 ± 20.7		30.2	53.6 ± 19.1		35.8	77.2 ± 9.8		12.7
Elite – 8v8	35.4 ± 19.9		56.2	27.6 ± 17.0		61.4	76.8 ± 12.4		16.1
Recreational – 5v5	61.6 ± 27.4		44.4	45.1 ± 21.8		48.4	72.6 ± 8.2		11.3
Recreational – 8v8	38.5 ± 21.5		55.8	28.2 ± 18.6		65.9	69.3 ± 10.9		15.8
U13									
8v8	36.2 ± 14.9***		41.3	28.2 ± 13.4***		47.4	75.8 ± 12.9		17.0
11v11	26.9 ± 14.1	0.64	52.4	20.6 ± 12.5	0.59	60.7	73.5 ± 11.8	0.19	16.0
Elite	32.8 ± 14.9		45.5	26.4 ± 13.3		50.4	78.3 ± 11.4##		14.5
Recreational	30.3 ± 15.5	0.17	51.1	22.4 ± 13.4	0.30	59.8	71.0 ± 12.3	0.62	17.3
Elite – 8v8	37.0 ± 14.3		38.5	30.1 ± 12.5		41.5	80.9 ± 10.0		12.3
Elite – 11v11	28.6 ± 14.7		51.2	22.6 ± 13.2		58.3	75.7 ± 12.2		16.1
Recreational – 8v8	35.4 ± 15.8		44.6	26.2 ± 14.1		53.8	70.7 ± 13.6		19.2
Recreational – 11v11	25.1 ± 13.5		53.8	18.5 ± 11.5		62.5	71.2 ± 11.1		15.5

Date are presented as means ± SD. ***, denotes significant difference between game formats at $P < 0.001$; # and ##, denotes significant difference between level of competition at $P < 0.05$ and $P < 0.01$, respectively.

Table 2. Split median values of total distance covered, player load, peak speed, and mean heart rate for U13 and U10 recreational and elite football players

	U10						U13					
	Lower			Higher			Lower			Higher		
	Mean ± SD	*P*	*d*	Mean ± SD	*P*	*d*	Mean ± SD	*P*	*d*	Mean ± SD	*P*	*d*
Total distance (m)												
Large	1518 ± 215			2035 ± 125			1792 ± 149			2295 ± 257		
Small	1610 ± 212	0.035	0.43	1906 ± 155	0.005	0.91	1613 ± 283	0.003	0.79	2040 ± 201	< 0.001	1.11
Player load (AU)												
Large	193 ± 24			287 ± 38			202 ± 18			286 ± 46		
Small	226 ± 28	0.001	1.27	278 ± 42	0.331	0.22	200 ± 30	0.747	0.08	264 ± 53	0.001	0.44
Peak speed (km/h)												
Large	17.6 ± 1.1			20.3 ± 0.7			20.8 ± 1.3			24.7 ± 1.8		
Small	17.9 ± 1.1	0.216	0.27	19.3 ± 1.8	0.002	0.73	20.7 ± 2.9	0.753	0.04	22.0 ± 2.6	< 0.001	1.21
Mean heart rate (bpm)												
Large	160 ± 8			178 ± 6			164 ± 7			179 ± 6		
Small	171 ± 10	< 0.001	1.21	179 ± 9	0.661	0.13	167 ± 9	0.123	0.37	174 ± 11	0.021	0.56

Date are presented as means ± SD. *P*-values and Cohen's *d* are presented. Lower and higher refers to players performing lower or higher than the median during large (U10, 8v8; U13, 11v11) game formats, respectively. Lower refers to players with values below the median during large-sided games whereas higher refers to players with values higher than the median during large-sided games. For U10, large refers to 8v8 and small to 5v5, whereas for U13, large refers to 11v11 and small to 8v8.

higher during the game formats with fewer players both for recreational and elite players in the two age groups, with the greatest effect of game format for the players with low technical involvement.

Mean HR rate was high (168–174 bpm) in all game formats for both age groups. These values are higher than observed in 9- and 12-year-old schoolchildren playing three vs three indoor football on small pitches (Randers et al., 2010a) and in 12-year-old recreational football players during 11v11 matches (Stroyer et al., 2004). A high HR during football match-play irrespective of age and game format is important for the health profile of children participating in recreational and elite football. Aerobic high-intensity training has been shown to be superior to moderate continuous training in improving cardiorespiratory fitness (Helgerud et al., 2007; Nybo et al., 2010), which has been identified as a strong independent predictor of the risk of cardiovascular diseases and mortality (Blair et al., 1996; Katzmarzyk et al., 2005). Several studies have shown

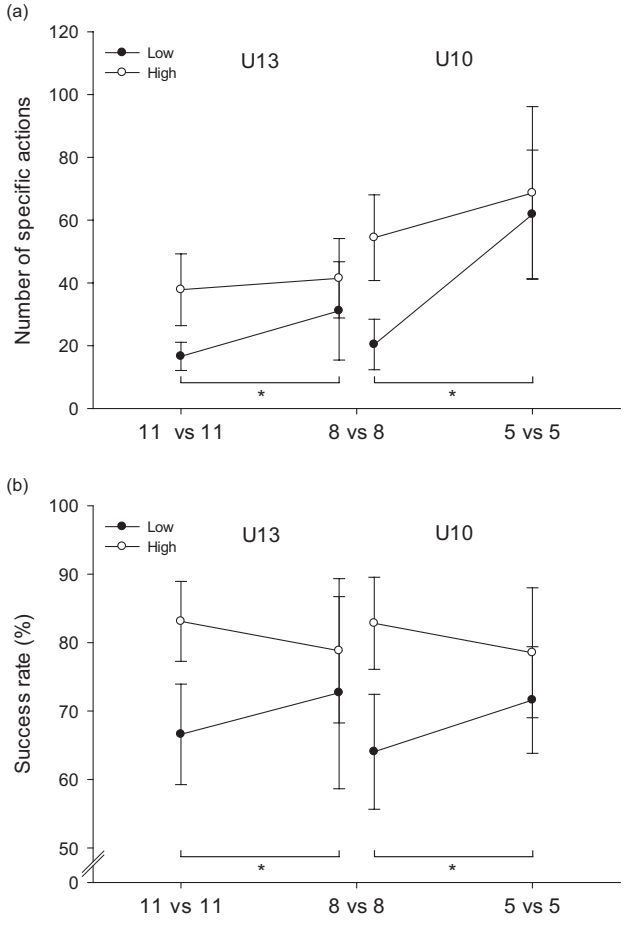

Fig. 4. Number of specific actions (a) and successful specific actions (b) in 5v5 and 8v8 U10 matches and 8v8 and 11v11 U13 matches for players with a lowest (closed symbols) and highest (open symbols) number of specific intense actions in the large game format for each of the two age groups. Date are presented as means ± SD. *Denotes significant difference at $P < 0.05$.

positive health effects of participation in recreational football for untrained adults (Krustrup et al., 2009, 2010; Randers et al., 2010a, 2012), whereas less evidence of health-related effects of participation in football training for children is available.

A recent study of 8–9-year-old schoolchildren completing twice weekly 30-min football and unihockey training sessions with high HR showed a 25% increase in Yo-Yo IR1C performance after only 6 weeks of training (Bendiksen et al., 2014). Faude et al. (2010) have also shown improved performance and endurance capacity as well as lower HR during submaximal exercise after 6 months of football training for 8–12-year-old overweight boys. It has also been shown that football training has considerable effects on cardiac structure and function (Hansen et al., 2013; Krustrup et al., 2014) and important positive effects on self-esteem and attraction to physical activity (Faude et al., 2010; Seabra et al., 2014). Thus, the available studies on the health effects in children after football participation indicates that football training for children has several positive health-related effects as observed for adults (Krustrup et al., 2009, 2010; Randers et al., 2010a, 2012).

It may be argued that the mean HR of the football games is reflecting a moderate intensity, but football is intermittent in nature and the intensity is therefore repeatedly near maximal during match-play. The individual maximal HR was not measured in this study, but HR was above 180 bpm for 32–46% of the total playing time. Moreover, 1.5 to 2 runs at speed > 12 km/h were performed per minute and 6–9% of the playing time was spent at running speed above 12 km/h, so the intensity is high several times and for a significant amount of time during football games irrespective of game format and age.

Game format had small to moderate effect ($d = 0.41$–0.63) on HR for U10 players, with higher mean HR, peak HR, and time spent in the highest HR zones in 5v5 than 8v8 games. Split median analysis revealed that game format had a large effect ($d = 1.21$) on mean HR for players with the lowest mean HR during 8v8 games, who had markedly higher mean HR during 5v5 games (11 bpm), whereas no difference between game formats was observed for U10 players with higher mean HR than the median in 8v8 games. The observation that mean HR was higher during 5v5 than 8v8 games is interesting as no difference was found in the total distance covered or distance covered in speed zones < 16 km/h. For U13 players, higher total distance and distance covered in all speed zones > 4 km/h were observed during 11v11 than 8v8 games, but mean HR, peak HR, and HR distribution were not different between game formats. Activities other than the running-based activities are therefore likely to have influenced the physiological demands of all game formats. Studies have shown that sideways and backwards running as well as dribbling a ball increase the energy cost compared with normal forward running at the same speed (Reilly & Ball, 1984; Reilly & Bowen, 1984). Thus, the greater involvement in the game (technical actions) and more frequent changes in activity during game formats with the fewest players may have contributed significantly to the HR load. In line with this, player load was higher ($P = 0.040$) or tended ($P = 0.055$) to be higher during game formats with the fewest players, which has also been shown during three vs three compared with 5v5 and seven vs seven in recreational adult players (Randers et al., 2014). Player load is a measure of summarized accelerations and accumulates the extra load from all the specific movements, such as sideways and backwards running, dribbling, ball contacts and tackles with other players and may therefore be a better measure of the physical demands of the game (Casamichana et al., 2013).

More sprinting and intense running were observed in game formats with more players for both age groups. It

may be argued that there is more room for sprinting and high-intensity running on larger pitches, which is supported by a study (Casamichana & Castellano, 2010) that found significantly greater distance covered at high-intensity running and higher peak speed during games on large compared with small pitches. In the present study, a significant small difference in peak sprinting speed between the two game formats was only found for U13 players. For both age groups, players with higher peak sprinting speed than the median had lower peak sprinting speed during the game format with the fewest players, thus our findings support the hypothesis that the pitch size influences the possibility of reaching the highest running speeds.

In contrast to U10 players, marked differences were found between competitive levels in U13 players. A significant moderate effect on total distance was found, with elite players covering 15% more than recreational players and more distance in all speed categories > 4 km/h. A large effect on peak speed was observed, with elite players having a 2.8 km/h higher peak speed than recreational players. These observations are in line with the study by Stroyer et al. (2004) and a study by Waldron and Murphy (2013), the latter showing marked differences between 14-year-old elite and sub-elite players in total distance and high-intensity running. Elite players have been shown to spend more time on individual and team practice than sub-elite players (Williams & Hodges, 2005). U10 players have not had several years of different exposure to training, which may explain the lack of difference between levels observed for the slightly older players in the present and other studies (Stroyer et al., 2004; Waldron & Murphy, 2013).

Although U13 players covered a greater distance and played at higher intensity measured by running speeds, no differences were observed in mean HR or HR distribution. These findings indicate that in U13, elite players are fitter than recreational players as they are able to perform a higher external workload with similar internal load. It should, however, be mentioned that the individual maximal HR is unknown, although it is unlikely that there is any difference between levels as no difference was observed in peak HR between U13 elite and recreational players during games. Also in U10, no competitive level differences were found in mean HR and HR distribution. These observations differ from earlier studies that have shown higher HR in elite than in non-elite and sub-elite 12–14-year-old players (Stroyer et al., 2004; Waldron & Murphy, 2013).

In both age groups, the game format had a moderate (U13) to large (U10) effect on the total number of technical actions, which was higher (35–76%) in game formats with the fewest players. It may seem logical that the involvement and the number of ball contacts are higher during games with fewer players, and these observations are also in line with previous findings (Jones & Drust, 2007; Katis & Kellis, 2009; Abrantes et al., 2012). The success rate of the technical actions was, however, the same during all game formats, which may seem surprising as it has been suggested that game formats with higher number of players lead to higher success rate because of less stress than in game formats with more players (Abrantes et al., 2012).

Greater involvement in the game imposes more situations where players have to make decisions, which may lead to increased skill acquisition and thereby enjoyment (Williams & Hodges, 2005). Split median analysis showed that, for U10 players who had a lower number of technical actions during 8v8 games than the median, the game format had very large effect, with a threefold increase in 5v5 games, whereas for U10 players with a higher number than the median, the effect was moderate, with a tendency ($P = 0.055$) to a 20% increase in the number of technical actions from 8v8 to 5v5 games. The effect of game format on the success rate was moderate, with an increase in 5v5 games for those with the lowest success rate during 8v8 games, whereas the effect was small for players with the highest success rate in 8v8 games as the success rate tended ($P = 0.078$) to decrease in 5v5 games. In U13 players, a similar pattern was observed, but the changes from 11v11 to 8v8 games were only significant for players with lower values than the median in 11v11 games, on whom the effect was large. Thus, for both age groups, changing the game format to fewer players had a significant large to very large effect on the number of technical actions for the players who had the fewest technical actions and lowest involvement, whereas the effect on the success rate was only small to moderate. Interestingly, the variation in the total number of technical actions decreased with a decreasing numbers of players, giving more homogeneous involvement when games are played with fewer players.

Regarding technical performance and involvement in the game, there was no difference between levels in the total number of technical actions for either U10 or U13 players, but a moderate effect of level on the success rate was found for both age groups, with the higher success rate seen in elite. This is in line with a study on professional and amateur adult football players (Dellal et al., 2011). In contrast to the present study, studies on elite/experienced and sub-elite/non-experienced youth players have shown more ball contacts (both successful and unsuccessful) in elite compared with sub-elite (Waldron & Murphy, 2013) and more passes and greater involvement for experienced than non-experienced (Almeida et al., 2013). It is, however, well documented that elite players have superior game intelligence and make better decisions, which thereby logically leads to a higher success rate in technical performance (Williams & Hodges, 2005).

The significant interaction between game format and level of play found in U10 players for total distance showed greater distance covered for elite players than recreational players during 8v8 but not 5v5 games. This adds to the previous finding that game formats with fewer players are more homogeneous. Moreover, a large effect of game format on mean HR was found, with higher mean HR during 5v5 than 8v8 games for recreational players but not elite players. Thus, it seems that the most inexperienced players may benefit in terms of higher HR load, which reflects a higher energy turnover during 5v5 compared with 8v8 games.

A limitation to the study is that individual maximal HR was unknown for all the players, thus HR is presented as absolute values. Peak HR during games may be used as individualized peak HR as a study by Silva et al. (2013) have shown good reliability between peak HR during games and age-predicting equations. However, peak HR between games varied between game formats, and as the main purpose of this study was to compare physical load and technical performance for the same player in different game formats, the absolute HR values are appropriate for these comparisons. Another limitation is that not all players completed both game formats which lowered the number of players included in the present study from 152 to 86. Moreover, only one game was analyzed per player in each format. Game-to-game variability has been shown to be high especially in high-speed running zones for adults (Gregson et al., 2010), and it is likely that a similar pattern would be observed for youth players. In support of this, a study by Hill-Haas et al. (2008) showed that variability was high for running with speed > 8 km/h in adolescent players during different formats of small-sided games.

In summary, the HR and high-intensity distances are high in youth football matches irrespective of the level of play and the game format. Playing with fewer players on smaller pitches results in minor changes to the physical loading but elevates technical involvement of players at elite and recreational level, which speaks in favor of using small-sided games for youth players. In support of this, it was shown that the players who had the lowest involvement and fewest technical actions in the game formats with the higher number of players had a twofold to threefold higher number of technical actions during the game format with fewer players. The effect of level was negligible in U10, except for a higher technical success rate in elite players, whereas several differences between elite and recreational players were found in U13 players.

Perspectives

Match-play is often considered a motivating and teambuilding supplement to football training for youth players. The present data provide insight into how different game formats influence the activity pattern and the physical loading and provide evidence that various types of match-play can contribute significantly to the improvement in the musculoskeletal and cardiovascular fitness of 9–13 years old boys because of high HR and high-intensity running distances along with multiple accelerations and specific actions with considerable impact. It should be emphasized that the injury risk is five to seven times higher in match-play compared to training, leading to the recommendation that match-play should be an addition to regular training sessions (Faude et al., 2013). Interestingly, the present project showed that involvement of youth players is higher and more homogenous when playing small-sided games and that the physical demands were roughly similar. Together, this speaks in favor of promoting small-sided games for youth players in order to maintain a high involvement and motivation for all players including recreational players and elite players.

Key words: GPS, high-intensity running, soccer, U13, U10, movement pattern.

Acknowledgements

We would like to thank Morten Nielsen, Anders Rørtoft-Madsen, and Steen Jørgensen from the Danish Football Association (Dansk Boldspil-Union, DBU) for their excellent collaboration, the involved football clubs, and all the players for their committed participation. We would also like to thank Christina Ørntoft and Henrik Pedersen for technical assistance. Nordea-fonden, Denmark, supported the study financially.

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