









Danger zone assessment in small-sided recreational football: providing data for consideration in relation to COVID-19 transmission

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ABSTRACT

During the COVID-19 pandemic, physical inactivity has increased, and a wide range of sporting activities locked down, with possible long-term implications for public health. Football is the most popular sport worldwide, and recreational football training leads to broad-spectrum health effects. Football is, however, deemed a contact sport with frequent close contact important to consider during COVID-19 pandemic.

Objectives This study investigated time spent with close contact (danger zone (DZ) within 1.5 m), number of contacts and time per contact, and compared game formats in recreational small-sided football games for young and adult male football players.

Methods Movement analyses were performed on 10 Hz Global Positioning System (GPS) data collected during various small-sided football games prior to the COVID-19 outbreak.

Results Time spent in the DZ was 4.3–7.9 s/h per per cent infected players, corresponding to 34.3–114.8 s/h if one player was infected. Number of contacts with one infected player was 23.5–87.7 per hour, with an average contact time of 1.1–1.4 s, and a total number of contacts of 311–691 per hour with all players. 53%–65% of all contacts were shorter than 1 s and 77%–85% shorter than 2 s. Trivial to small effects were found for number of participants and area per player, whereas standard of play and playing with/without boards had no effect.

Conclusion This study demonstrated that during small-sided football limited time is spent within DZ and that player contacts are brief. Recreational football may therefore more appropriately be deemed as sporting activity with brief, sporadic contact.

INTRODUCTION

The physical inactivity pandemic is a major challenge for global public health, with more than 30% of the world's population not meeting the minimum recommendations for physical activity defined by the WHO,¹ which is causing approximately 3.2 million deaths every year.² The new COVID-19 pandemic

What are the new findings?

- ▶ During recreational small-sided football games, limited time (34–115 s/h) within a 1.5 m danger zone was observed, and ~80% of all entries in the zone were shorter than 2 s.
- ▶ Game format had no or very limited effect on time in the danger zone and on number and duration of contacts.
- ▶ Recreational small-sided football is better defined as sporting activity with brief, sporadic contact rather than a contact sport.
- ▶ Effects of game format variables were trivial to moderate, but 3v3 on a 31×15.5 m pitch had the lowest time in danger zone (within 1.5 m) and number of contacts per per cent infected player, and game format with few players also complies with the authorities' recommendation limiting the contact with a high number of people.

How might it impact on clinical practice in the future?

- ▶ Authorities and governing bodies can use these scientific data to evaluate safe reopening of football for recreational players.
- ▶ As football is the most popular sport in the world, reopening of grassroots football, when safe, may have a major impact on public health around the world during and after COVID-19.

and the home confinement imposed by the authorities in many countries have led to a major changes in the physical activity pattern.³ Several studies have shown strong associations between sedentary behaviour and risk of mortality and morbidity,^{4 5} and physical activity is considered a cornerstone in the primary prevention of at least 26 chronic diseases.⁶ This highlights the importance of physical activity even under the



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special circumstances that the world is facing during the COVID-19 pandemic and the even greater importance for people to start being physically active again.³

Sport has been mentioned as a very important contributor to the health of nations and as an evidence-based therapy for various patient groups.^{6–8} The lockdown of sporting facilities and sports participation as a consequence of the COVID-19 pandemic may therefore accelerate the inactivity pandemic and have a number of negative health consequences that will only be recognised later.⁹ Subsequently, a rapid reopening of sporting facilities and sports communities, when safe, is highly important.

Football is the most popular sport, with more than 265 million footballers around the globe, the vast majority involved in amateur and recreational football.¹⁰ There is solid scientific evidence that recreational football is an effective broad-spectrum health-promoting activity across the lifespan, and an international platform, 'Football is Medicine', has been established.^{11–15} Football is, however, considered a contact sport, with frequent and close contacts between players during training and games, which is considered to put players at high risk of disease transmission.¹⁶ Authorities may therefore be reluctant to allow sports such as football, but the consideration that football is a contact sport with frequent and close contacts is not built on scientific evidence but on an assumption. This assumption can be evaluated using high time-resolution tracking data collected for all players during training and small-sided games (SSGs).¹⁷

COVID-19 is a viral infectious disease transmitted between humans by either direct contact or by respiratory droplets produced while breathing, coughing, sneezing and talking.⁹ Larger respiratory droplets ($>5\mu\text{m}$) fall rapidly to the ground within 1 m, whereas smaller droplets can remain in the air for a longer period and distance depending on airflow, temperature and humidity.¹⁸ Authorities have therefore recommended social

distancing of 1–2 m between individuals to limit virus transmission.^{19,20} Direct contact, for example, touching hands or contact with surfaces, for example, the ball can be limited by not allowing throw-ins or touching during play and celebration, whereas keeping 1–2 m distance during match play may be more problematic.

Thus, the aim of this study is to test the hypothesis that number of contacts and time spent within this 'danger zone' (DZ) during recreational SSG is limited. As various game formats are used in recreational football training depending on the number of participants, available facilities and pitch sizes,^{21–24} different game formats are investigated and compared.

METHODS

Design

Positional data were retrieved from various recreational SSGs that took place before the COVID-19 lockdown (table 1). Positional data were collected using GPS units (MinimaxX S4, Catapult Innovations, Canberra, Australia) sampling at 10 Hz on all participants in various SSGs using different game formatting. Data were retrieved from various groups of recreationally trained adult men aged 18–43 years and U10 boys aged 8–9 years playing SSGs, as described in table 1.

DZ calculation

X and Y coordinates from the tracking data were retrieved, and data were filtered using a Butterworth fifth-order low-pass filter with a cut-off frequency of 0.08 Hz using a built-in MatLab function (The MathWorks, Inc, New York, USA). To evaluate the risk of being infected, a DZ was constructed as a circle with a radius of 1.5 m around each player's position. In addition to the circular zone, a tail followed each player as an area of the player's position up to 6 s ago.²⁵ The tail that follows a player is modelling the decline in the amount of virus that stay airborne. Gravity pulls the droplets towards the ground,

Table 1 Game ID and game format characteristics for the included game formats

Game ID	Player format	Age (year) (mean \pm SD)	Pitch size (L \times W)	Area per player (m ²)	Playing time (min)	Number of comparisons
3v3 WOB	3v3	28.4 \pm 4.2	20 \times 13 m	43	4 \times 12	120
3v3 WB	3v3	28.4 \pm 4.2	20 \times 13 m	43	4 \times 12	120
3v3 80	3v3	32.9 \pm 6.3	31 \times 15.5 m	80	4 \times 12	120
3v3 40 \times 20	3v3	32.6 \pm 6.6	40 \times 20 m	133	4 \times 12	120
5v5 40 \times 20	5v5	32.8 \pm 6.5	40 \times 20 m	80	4 \times 12	360
7v7 40 \times 20	7v7	32.6 \pm 6.7	40 \times 20 m	57	4 \times 12	702
7v7 80	7v7	33.1 \pm 6.5	47 \times 23.5 m	80	4 \times 12	728
5v5 80	5v5	20.1 \pm 1.1	40 \times 20 m	80	2 \times 20	540
5v5 60	5v5	20.1 \pm 1.1	35 \times 17 m	60	2 \times 20	180
5v5 B	5v5	8–9	30 \times 40 m	120	1 \times 20	540
8v8 B	8v8	8–9	52.5 \times 68 m	223	1 \times 20	960

Game ID refers to player format and pitch size, area per player, with boards (WB) or without boards (WOB).

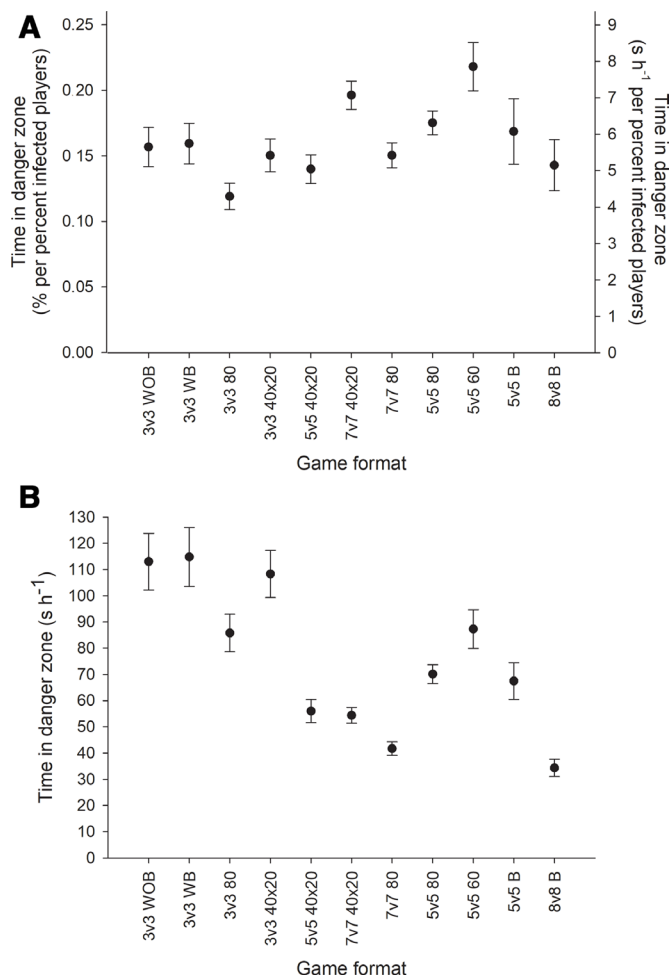


Figure 1 Time in danger zone (A) as % per percent infected players and as s/h per percent infected players and (B) as s/h if one player is infected for various game formats. Data are presented as means \pm 95% CIs.

and air resistance opposes this motion. This is modelled as an exponential decline in exposure score, and our function is based on the studies by Wells (1934)²⁶ and Wang *et al* (2020)²⁷. The danger value of this tail exponentially declines with a half-life of 2s. Thus, being within the area of 1.5m from the other player returns a danger score of 1, while being in the area where the other player was 2 and 4s ago equates to danger scores of 0.5 and 0.25, respectively.

If a player is within multiple zones at the same time, the score is determined as the maximal score of the zones. Accordingly, the maximal danger score at any time and position is 1. An exposure score is calculated based on the sum of all danger scores divided by the sample frequency (10Hz), which is then translated to how much time a player spent in DZ throughout the game. The calculations were performed with one infected player in each game and repeated until all participants had acted as the infected player, as previously described.²⁵ Moreover, number of contacts was evaluated as the number of times a player entered in DZ, and the time of each entry was noted.

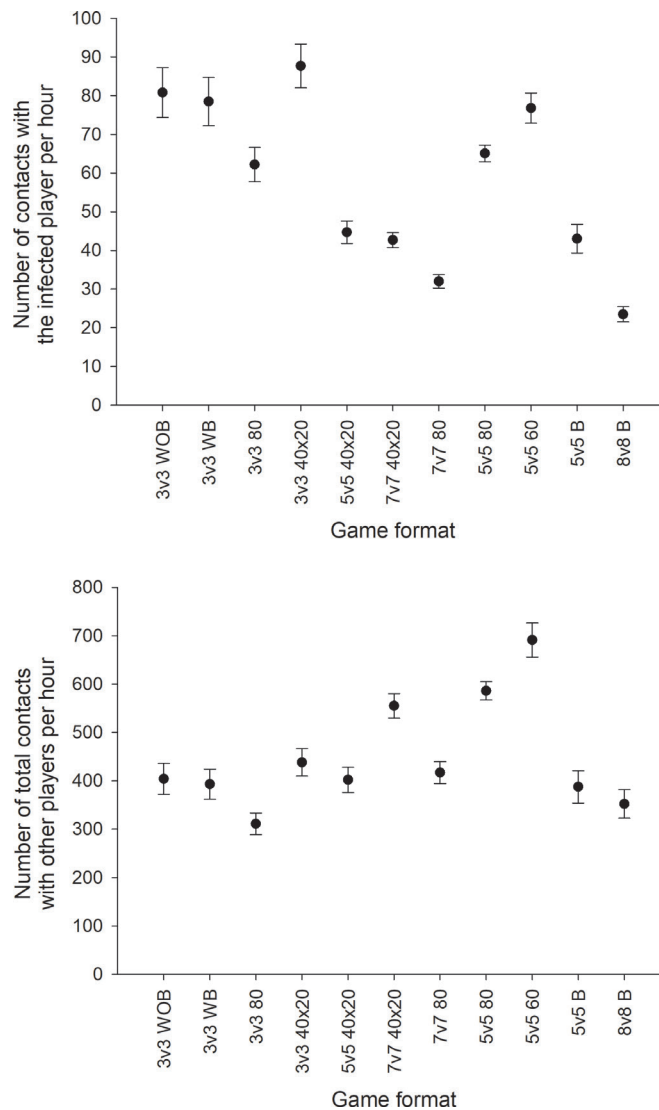


Figure 2 Number of contacts with the infected player assuming one player is infected (A) and total number of contacts with other players for various game formats (B). Data are presented as means \pm 95% CIs.

Statistical analysis

Data are presented as means (\pm 95% CIs). Data are presented as per cent time in DZ and s/h in order to compare SSGs of different duration. Moreover, to compare SSGs with different numbers of participants, data are presented as per per cent infected players (PPIP). If one player is infected, the likelihood of transmission is higher during 3v3 than 11v11 as a higher percentage is infected (16.7% vs 4.5%). However, the likelihood that one player is infected is larger in a group of 22 than 6 random people, and therefore, to be able to compare the game format, data are presented as PPIP. If more players are infected, results can simply be multiplied with the percentage of infected players. Effect size (ES) was calculated using Cohen's *d* and interpreted as suggested by Hopkins and colleagues.²⁸

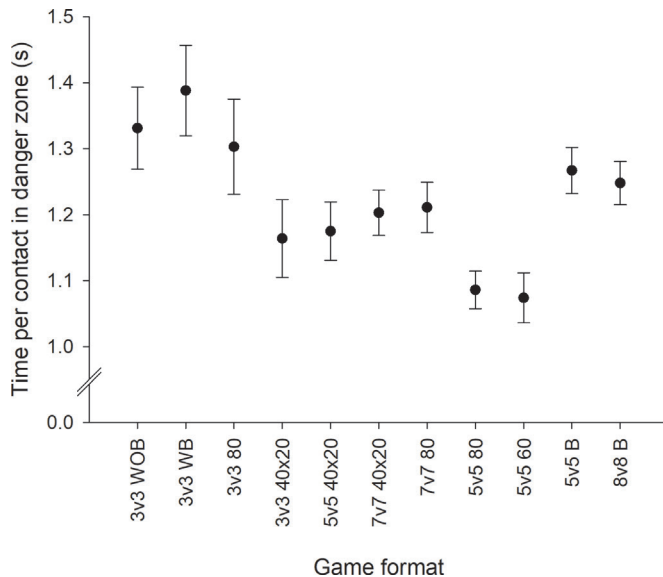


Figure 3 Time per contact in danger zone for various game formats. Data are presented as means±95% CIs.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

RESULTS

Per cent time spent in DZ PPIP ranged from 0.119 (0.109–0.129) to 0.218 (0.200–0.237) %, which corresponds to 4.3 (3.9–4.7) to 7.9 (7.2–8.5) s/h PPIP (figure 1A). Assuming one participant in each game format is infected, time in DZ ranged from 34.3 (31.0–37.6) to 114.8 (103.7–126.0) s/h (figure 1B).

Average number of contacts with the infected player, assuming one participant is infected, ranged from 23.5 (21.5–25.5) to 87.7 (82.0–93.3) contacts per hour (figure 2A), while the total number of contacts per player with all other players ranged from 311 (189–333) to 691 (656–726) contacts per hour (figure 2B).

Time per contact ranged from 1.1 (1.0–1.1) to 1.4 (1.1–1.4) s (figure 3), with maximal observed contact time ranging from 11.0 to 61.0s. 53%–65% and 77%–85% of all contacts were shorter than 1 and 2s, respectively. Of all contacts, 1.9%–3.5% and 0.1%–0.4% lasted more than 5 and 10s, respectively (figure 4).

Comparing number of players: fixed area per player (80 m²)

Players spent less time in DZ PPIP when playing 3v3 80 than 7v7 80, while 5v5 40×20 did not differ from the two other formats (figure 1A), showing trivial to small effect sizes (ES=0.09–0.30). Number of contacts with the infected player (assuming one player was infected) was higher in 3v3 80 than in 5v5 20×40 and 7v7 80 (ES=0.66 and ES=1.25, respectively) and higher in 5v5 20×40 than in 7v7 80 (ES=0.49; figure 2A). Conversely, adjusted for the number of participants, a lower number of contacts PPIP was observed in 3v3 80 than in 5v5 20×40 and 7v7 80 (ES=0.46 and ES=0.45, respectively), with no difference

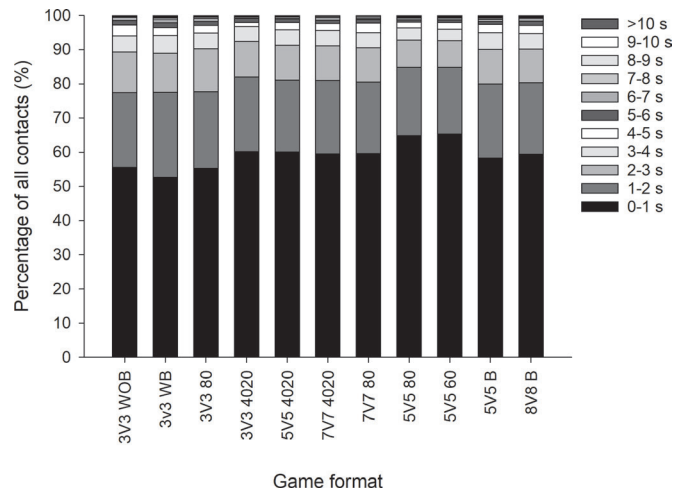


Figure 4 Distribution of time per contact for various game formats.

between 5v5 20×40 and 7v7 80 (figure 2B). Total number of contacts was lower for 3v3 80 than for 5v5 20×40 and 7v7 80 (ES=0.46 and ES=0.45, respectively), while no difference was observed between 5v5 20×40 and 7v7 80. Average time per contact was lower in 5v5 40×20 than in 3v3 80 (ES=0.08), with no other differences between game formats (figure 3).

Comparing area per player

Players spent more time in DZ PPIP when playing in game formats with less area per player in 7v7 (7v7 40×20 compared with 7v7 80; ES=0.32) and 5v5 (5v5 80 vs 5v5 60; ES=0.37; figure 1A,B), while in 3v3 more time in DZ PPIP was found in 3v3 without boards (WOB) and 3v3 40×20 than in 3v3 80 (figure 1A,B; ES=0.53 and ES=0.49, respectively). Number of contacts with the infected player was higher in game formats with less area per player in 7v7 (ES=0.43) and 5v5 (ES=0.45; figure 2A) but not clear for 3v3, with higher number of contacts in 3v3 WOB and 3v3 40×20 than in 3v3 80 (ES=0.60 and ES=0.90, respectively). Time per contact did not differ for game formats in 7v7 and 5v5 but was lower in 3v3 40×20 than in 3v3 WOB and 3v3 80 (figure 3; ES=0.12 and ES=0.17, respectively). In U10 boys, no differences were observed between 120 m² and 223 m² (5v5 B vs 8v8 B) for time in DZ PPIP, number of contacts with the infected player PPIP or average time per contact.

Comparing with boards (WB) or WOB

No differences were observed in time in DZ PPIP, number of contacts with the infected player, total number of contacts or average time per contact in SSGs on very small pitches (43 m² per player) with or without boards (3v3 WB vs 3v3 WOB).

DISCUSSION

The main findings of the present study were that time within DZ was low, with 4–8s per hour PPIP. This corresponds to less than 2 min per hour, assuming one infected player, during 3v3 to 8v8 games. Moreover, assuming one

infected player, the average number of contacts with the infected player was 23–88 per hour, with a total number of contacts with all other players of 311–691 per hour. Of these contacts, 53%–65% were shorter than 1 s and 77%–85% shorter than 2 s. Common SSG format variables such as number of players, area per player and with or without boards keeping the ball in play seem to have very little effect on time spent in DZ PPIP, number of contacts or average time per contact.

Although football is considered a contact sport with frequent and close contacts,¹⁶ the present study showed by detailed analysis of tracking data that time spent within DZ was surprisingly low, at 34–115 s per hour, assuming one participant was infected. Obviously, SSGs with the fewest players are those with most time spent in DZ if the assumption is that one player is infected. In contrast, the likelihood that one player is infected is lower when few players gather for a football game compared with larger number of players. Data were therefore presented as PPIP in order to calculate a risk score based on per cent infected in each population and to make a direct comparison between game formats with various numbers of players.

A contact with the infected player, assuming one player was infected, occurred once every 0.7–2.6 min depending on game format. Each of these contacts was, however, rather short, with around 80% shorter than 2 s and less than 0.5% longer than 10 s. It should be noted that the calculated number of contacts is the number of entries into the DZ and not direct contact, which is also considered a critical pathway of transmission of virus.²⁹ In this study, direct contacts were not evaluated, but a few video analyses have demonstrated that the scarce direct contacts were primarily shoulder to shoulder or contacts with the feet/legs (data not shown).

Various gaps for social distancing have been proposed by authorities; the WHO suggests 1 m, the Centers for Disease Control and Prevention (USA) 1.8 m and the National Health Service (UK) 2 m. These gaps are based on the distances that droplets from sneezing, coughing or talking travel before gravity pulls them to the ground in normal settings, whereas distances may be slightly longer in special environments.³⁰ In the present study, it was decided to use 1.5 m as the radius for the distance zone and, in addition, to consider the tail from the player's run. A study by Blocken and colleagues³¹ used computer simulation of aerodynamics of droplet movements in a wind tunnel to show that exposure is up to 5 m when walking at 4 km/h and 10 m when running 14.4 km/h in the slipstream of an infected person, but exposure dropped markedly when running side by side or staggered. Unlike track or trail running, running in the slipstream for several seconds is unusable in football. Moreover, previous studies have demonstrated that, for adults, speed exceeds 13 km/h 30–70 times during a training session, with each high-speed run lasting only a few seconds.^{21–24} In U10 players, less than 10% of the total time was spent at speeds above 12 km/h.³² Thus, the

increased exposure due to slipstream dynamics for a footballer may be negligible.

Across SSG formats, intensity is high, with 10%–40% of the total time spent with heart rate above 90% HRmax^{22–24 33} and a significant distance at high speed. Breathing is therefore considerably elevated during SSGs, slightly increasing the risk of inhaling virus via droplets.³⁴ Regular moderate-intensity training, however, is generally associated with decreased risk of respiratory tract infections, whereas a low physical activity level increases this hazard.³⁵ Thus, the overall benefits of SSGs may counteract this increased risk from excessive breathing.

Effects of game format

Different SSG formats were analysed to investigate the effect of number of players, relative pitch area and playing with or without boards.

Number of players had very little effect on time in DZ and number of contacts. Fewer players led to more time in DZ and more contacts but, when adjusting for the higher risk of one infected player in a larger rather than a smaller group, 3v3 had the most favourable values. Effect sizes were, however, trivial to small.

The less available area per player, the higher the density, so it is expected that time spent in DZ and number of contacts will be elevated when the area per player drops. This was also confirmed in the 5v5 and 7v7 game formats, while in 3v3, the highest time in DZ and highest number of contacts were observed during 3v3 with 43 m² and 133 m² compared with 80 m². It is possible that more man-marking is practised when pitch size increases, resulting in a more run-based style of play. It has previously been shown that 3v3 on a 40×20 m pitch (133 m²) is more demanding than 5v5 or 7v7 on a similar pitch (40×20 m).²³ The effects were small to moderate in adults, while no effects of area per player were observed in U10 boys.

In many larger cities, there is limited availability of football pitches or grass areas in parks, so football in urban areas is often played as very small-sided games on pitches surrounded by boards. This keeps the ball in play, but it also limits the players' movement area²²; however, no effect of boards was observed in time within DZ and number of contacts with the infected player.

All the analysed SSGs are typical game formats and have previously been shown to elicit high heart rates and impact on the body,^{21–24 32 33} which is expected to lead to several beneficial health parameters if conducted regularly over a 12-week period.^{11 12 15}

Limitations

The current study only investigated recreational adults during SSGs and not 11v11. Based on the current study, transmission risk in competitive grassroots football cannot be evaluated. Movement patterns in professional players in the Danish Premier League have been analysed using similar methodology to that applied in the present study, demonstrating that the average time in DZ was

87.8s for 90 min.²⁵ Adjusted for the number of players on the pitch, time in DZ was approximately 37%–150% higher during professional 11v11 matches than observed in the current study, partly due to a ~3 times higher time per contact.²⁵ Thus, even though the current study cannot deem competitive grassroots 11v11 safe, time in DZ is likely to be comparable with data presented for professional or recreational SSGs.

The data were collected prior to the COVID-19 outbreak, thus not reflecting the new reality. However, these tracking data reflect normal player behaviour before any engagement with official guidelines, meaning that the players came together to celebrate goals and in general may be expected to have had more close contacts than under COVID-19. Only game periods were analysed, and it is very likely that players gather together during breaks. It is, nevertheless, easier to follow official guidelines during breaks than during match play, when players may be expected to act more intuitively and based on the game routines. It should be emphasised, however, that activities around the sporting activity usually include close and prolonged social contact, such as transportation, changing room activities and meetings, which were not evaluated in this study.

CONCLUSION

This study presented data on time spent within a 1.5m DZ and on number and duration of contacts in relation to the risk of COVID-19 transmission in recreational football. The study revealed that only a short time is spent within the DZ and that the contacts are brief irrespective of game format. The present results suggest that recreational small-sided football is better defined as sporting activity with brief, sporadic contact rather than a contact sport.

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Competing interests PK is employed by the Danish Football Association as fitness coach for the women's national team. MM is fitness coach for the Faroese men's national football team.

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Data availability statement Data are available on reasonable request. Please contact the corresponding author for access to tracking data.

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