Effects of Small-Sided Soccer Games on Physical Fitness, Physiological Responses, and Health Indices in Untrained Individuals and Clinical Populations A Systematic Review

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Running head: Small-sided Soccer Games and Health

Abstract

Background: Small-sided soccer games (SSSG) are a specific exercise regime with two small teams playing against each other on a relatively small pitch. There is evidence from original research that SSSG exposure provides performance and health benefits for untrained adults.

Objectives: The aim of this systematic review was to summarize recent evidence on the acute and long-term effects of SSSG on physical fitness, physiological responses, and health indices in healthy untrained individuals and clinical populations.

Materials and Methods: This systematic literature search was conducted in four electronic databases (PubMed, Web of Science, SPORTDiscus) from inception until June 2019. The following key terms (and synonyms searched for by the MeSH database) were included and combined using the operators "AND", "OR", "NOT": ((soccer OR football) AND ("soccer training" OR "football training" OR "soccer game*" OR "small-sided soccer game*") AND ("physical fitness" OR "physiological adaptation*" OR "physiological response*" OR health OR "body weight" OR "body mass" OR "body fat" OR "bone composition" OR "blood pressure")). The search syntax initially identified 1,145 records. After screening for titles, abstracts, and full-texts, 41 studies remained that examined the acute (7 studies) and long-term effects (34 studies) of SSSG-based training on physical fitness, physiological responses, and selected health indices in healthy untrained individuals and clinical populations.

Results: No training-related injuries were reported in the 41 acute and long-term SSSG studies. Typically, a single session of SSSG lasted 12 to 20 minutes (e.g. 3x4 min with 3 min rest or 5x4 min with 4 min rest) involving 4 to 12 players (2 vs. 2 to 6 vs. 6) at an intensity ≥80% of HR_{max}. Following single SSSG sessions, high cardiovascular and metabolic demands were observed. Specifically, based on the outcomes, the 7 acute studies reported average heart rates (HR) ≥80% of HR_{max} (165–175 bpm) and mean blood lactate concentrations exceeding 5 mmol/l (4.5–5.9 mmol/l) after single SSSG sessions.

Based on the results of 34 studies (20 with healthy untrained, 10 with unhealthy individuals and 4 with individuals with obesity), SSSG training lasted between 12-16 weeks and was performed 2-3 times per week. SSSG had positive long-term effects on physical fitness (*e.g.,* Yo-Yo IR1 performance), physiological responses including maximal oxygen uptake (VO_{2max}) [+7-16%], and many health-related markers such as blood pressure (reductions in systolic [-7.5%], diastolic [-10.3%] blood pressure), body composition (decreased fat mass [-2 to -5%]), and improved indices of bone health (bone mineral density: [+5-13%]; bone mineral content: [+4-5%]), and metabolic (LDL-cholesterol [-15%] as well as cardiac function (left-ventricular internal diastolic diameter [+8%], end diastolic volume [+21%] and left ventricular mass index [+18%] left-ventricular ejection fraction [+8%]). Irrespective of age or sex, these health benefits were observed in both, untrained individuals and clinical populations.

Conclusions: In conclusion, findings from this systematic review suggest that acute SSSG may elicit high cardiovascular and metabolic demands in untrained healthy adults and clinical populations. Moreover, this type of exercise is safe with positive long-term effects on physical fitness and health indices. Future studies are needed examining the long-term effects on physical fitness and physiological adaptations of different types of SSSG training (e.g. 3 vs. 3; 6 vs. 6) in comparison to continuous or interval training in different cohorts.

Key points:

- Based on current evidence, small-sided soccer games (SSSG) may elicit high cardiovascular and metabolic demands in untrained healthy adults and clinical populations.
- SSSG is safe with positive long-term effects on physical fitness and health indices in untrained healthy adults and clinical populations.
- SSSG is suitable for health indices improvement in healthy people, untrained men and women with mild to moderate hypertension, individuals with obesity, individuals with type 2 diabetes mellitus, and men with prostate cancer.

1. Introduction

Today, sedentary lifestyle is a public health problem associated with high prevalence rates of various types of diseases such as hypertension and diabetes, obesity and stress [1]. The incongruence between World Health Organization (WHO) recommendations and actual physical activity (PA) levels has been denoted as exercise deficit disorder [2]. In the medical world, it is traditional to prescribe the evidence-based treatment known to be the most effective and entailing the fewest side effects or risks. The evidence suggests that in selected cases, exercise therapy is just as effective as medical treatment and in special situations even more effective or adds to its effect [3]. The accumulated knowledge is now extensive so that it should be implemented [3]. There is growing epidemiological evidence that a physically active lifestyle protects against the development of several diseases (e.g., metabolic diseases, cardiovascular diseases and pulmonary diseases). Moreover, PA both during and after treatment can increase quality of life and reduce fatigue in clinical polpulations [3]. Insufficient PA levels are caused by several factors including modern lifestyle, lack of spaces dedicated to sports, the school calendar, and sometimes lack of motivation to perform physical activity and exercise [4].

Motivational issues with PA contribute to an increased number of sedentary individuals. For this reason, it is important to find PA programs that motivate and stimulate sedentary people to be physically active and, at the same time, elicit intensities that are high enough to induce health benefits [5]. In order to enhance the physical activity level of a population, accessibility is important [3]. It has previously been shown that soccer, the most popular team sport in the world, compared with other more conventional training types (e.g., running or cycling), has the potential to motivate sedentary people to engage in exercise and increase their participation time [6]. Recent studies and reviews have examined the acute effects of small-sided soccer games (SSSG) on physiological parameters in trained and untrained individuals. Compared with other sports (e.g. endurance and strength training) short-term SSSG resulted in high exercise intensities inducing neuromuscular and metabolic stress and perceptual responses [5, 7-12]. In fact, the average heart rates (HR) were around and even above 80%

of individual HR_{max} and blood lactate concentrations exceeding 6 mmol/l [5, 7-10, 12]. Several long term studies and reviews demonstrated that SSSG training may represent an effective strategy of multicomponent training that can induce greater positive effects on specific skills tasks when compared with interval or agility training and moderate to large improvements in team sport-related physical fitness [5, 12]. To the authors' knowledge, 13 review articles have been published so far with regards to both acute and long-term effects of SSSG on physiological and technical parameters [5, 11, 12-22]. Among these 13 studies, only 6 [5, 11, 12, 14, 18, 22] were systematic literature reviews and seven were narrative reviews [13, 15-17, 19-21]. Eight of these 13 studies focused on both, acute and long-term effects of SSSG on physiological parameters (e.g., heart rate, blood lactate) [11, 14, 16-19, 21, 22]. Four other reviews, one systematic [12] and three narrative [13, 15, 20] considered different SSSG types on physiological, kinematic and technical parameters. The majority of these reviews examined athletes of different expertise levels [11-21] and most studies investigated acute/long-term SSSG effects in professional or amateur football players [11, 13-17, 19-22]. Less is known on the acute and long-term effects of SSSG on physical fitness, physiological parameters, and health outcomes in untrained healthy people and clinical populations.

Recently, an increased number of scientific studies has been conducted that examined the effects of regular soccer practice on markers of health in healthy individuals and clinical populations [6, 7, 23, 24]. To the best of the authors' knowledge, only one systematic review article [5] focused on the effects of regular soccer training, but not SSSG, on markers of health in untrained healthy individuals and clinical populations. Based on findings from 35 studies these authors concluded that recreational soccer training has positive effects on indices of health (e.g., blood pressure, bone mineral density) [5]. Consequently, it appears timely to conduct a systematic review on the effects of SSSG on physical fitness, physiological responses, and health indices in healthy untrained individuals and clinical populations. This review is justified given the increasing amount of research dealing with the effects of SSSG training on health outcomes in untrained individuals and clinical populations.

Accordingly, the objective of this systematic review was to summarize recent evidence on acute and long-term effects of SSSG on physical fitness, physiological responses, and markers of health in healthy untrained individuals and clinical populations. More specifically, we aimed at presenting evidence on i) the acute effects of SSSG on physiological responses (e.g., maximal oxygen uptake [VO_{2max}], lactate concentrations), ii) factors that influence intensity during acute SSSG sessions, iii) the effects of long-term SSSG on physical fitness (e.g., aerobic performance [VO_{2max}], jump performance), physiological adaptations (e.g., maximal oxygen uptake [VO_{2max}) and markers of health (e.g., bone mass density, fat mass, blood pressure, ventricle volume and ejection) in healthy untrained individuals and patient groups.

2. Methods

2.1 Eligibility criteria

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA) Statement [25]. The PICOS approach (Population, Intervention, Comparator, Outcomes, Study design) was followed to identify inclusion criteria (Table 1). Only randomized controlled trials and controlled trials that examined the acute and long-term effects of SSSG-based training on physical fitness, physiological responses, and selected health indices in healthy untrained individuals and clinical populations were eligible for inclusion. Studies were included in the current systematic review if they were in accordance with the following criteria: (1) published in peer-reviewed journals; (2) included participants 16 years or older; (3) involved untrained and/or clinical populations; (4) used validated methods of quantification (e.g. HR monitor, lactate analyser, Borg's RPE scale, global positioning system (GPS)); (5) used SSSG-based testing sessions for cross-sectional studies and, in the case of intervention studies, SSSG-based training programmes; and (6) all intervention lasted a minimum of 4 weeks (only intervention studies). Studies were excluded if they (1) did not meet the minimum requirements of an experimental study design (e.g. case reports), (2) did not meet the minimum requirements regarding training design (e.g. lack of information on volume, frequency, game format and/or training methodology), (3) were not written in English, or (4) involved trained subjects (e.g. professional and amateur football or other team sports players). Moreover, review articles were not included in the current systematic review.

Table 1: Inclusion criteria according to the PICOS approach.

PICOS components	Details
Population	Healthy untrained humans and clinical populations
Intervention	Acute and long term SSSG studies
Comparator	Active and passive controls
Outcomes	Measures of physical fitness (e.g. aerobic performance [VO_{2max}], jumping performance), physiological responses (e.g., maximal oxygen uptake [VO_{2max}]), and health outcomes (e.g., bone mass density)
Study Design	Randomized controlled trials and controlled trials

2.2. Literature search strategy

Literature searches were conducted in four electronic databases including PubMed, ~~ISI Web of Knowledge,~~ Web of Science and SPORTDiscus from inception until June 2019. The following key terms (and synonyms searched for by the MeSH database) were included and combined using the operators "AND", "OR", "NOT": (soccer OR football) AND ("soccer training" OR "football training” OR “soccer game*” OR “small-sided soccer game*”) AND (“physical fitness” OR “physiological adaptation*” OR “physiological response*” OR health OR “body weight” OR “body mass” OR “body fat” OR “bone composition” OR “blood pressure”)). In addition, the reference lists and citations (Google Scholar) of the identified studies were explored in order to detect further relevant research papers. Since the scope of this review article is large in terms of outcome measures (e.g. performance, physiological adaptations, health indices), a systematic review and not a meta-analysis was performed. The large number of outcome parameters would have produced heterogeneity.

2.3. Study selection

The final screening was done by two investigators (AH and AJ) based on the relevance of the inclusion and exclusion criteria and the identified items for assessing the effects of acute and long-term SSSG on physical fitness, physiological responses, and markers of health in healthy untrained individuals and clinical populations using PICOS criteria. If the citation showed any potential relevance, it was screened at the abstract level. When abstracts indicated potential inclusion, full-text articles were reviewed. A third-party consensus meeting was held with a third author (HZ) if the two reviewers were not able to reach agreement on inclusion of an article.

2.4 Quality assessment

The methodological quality of the included studies was assessed using the Physiotherapy Evidence Database (PEDro) scale (http://www.pedro.fhs. usyd.edu.au), which has been shown to have good reliability and validity [26]. The PEDro scale has 11 possible points that examine external validity (criterion 1) and internal validity (criteria 2–9) of controlled trials and whether there is sufficient statistical information for interpreting results (criteria 10–11). A cut-off point of 6 on the PEDro scale was used to indicate high-quality studies, as this has been reported to be sufficient to determine high quality vs. low quality in previous studies [26]. Two independent researchers (AH and AJ) assessed the quality of the studies, if any unambiguity arose, a third researcher (HZ) was contacted and a unanimous decision was achieved.

3. Results

3.1. Study selection

Overall, our search identified 1,145 records (figure 1). After screening of titles, abstracts and full texts, 41 studies were included in our final analysis. **Table 2 and 3** illustrates characteristics of the 7 acute and 34 long-term studies. The 7 acute studies were performed in 5 different countries (Turkey, Portugal, Italy, Denmark and Tunisia) and involved 160 male participants. On average a single session of SSSG lasted 12 to 20 minutes (e.g. 3x4 min with 3 min rest or 5x4 min with 4 min rest) involving 6 to 16 players (e.g. 3 vs. 3, 6 vs. 6 or 8 vs. 8) at an intensity ≥80% of HR_{max}. The included long-term studies were classified as 'high-quality' studies (mean 6.4 in the PEDro scale score), and only two studies were classified as 'low-quality' study (mean 5.0 in the PEDro scale score) [27, 28] (**Table 3**). A total of 1,366 participants underwent SSSG programs and completed the studies. Among the 34 long-term studies 20 were carried out in Denmark, which represent more than 50% of the studies dealing with soccer and health. Twenty studies investigated male subjects, 8 studies female and 6 studies investigated both sexes. Twenty studies investigated healthy untrained participants, 10 involved unhealthy individuals and 4 studies included individuals with obesity. The training duration was at least 5 sessions [29], for several studies it was around between 12 and 16 weeks, for some studies it was around 1 year and for one study the duration was 6 years [30].

3.2. Effects of acute small-sided soccer games on physiological responses in untrained individuals

Table 4 summarizes the acute effects of SSSG on different physiological responses. Only seven studies [8, 31, 32-36] were identified that examined the acute effects of SSSG on physiological responses using percentage of maximum heart rate (%HRmax) as outcome measure. Two studies used both HR and blood lactate concentrations as physiological outcomes [33, 36]. Three studies [30, 31, 34] used young players as participants and one investigated overweight boys [35]. Two studies compared soccer with other sports [31, 35] and observed that soccer elicited higher %HRmax and one study [36] compared three different surfaces of playing (turf, asphalt and sand) and it was observed that playing on sand and turf elicited higher %HRmax than playing on asphalt surface (>85% vs. 82%). Despite the number of players used and the size of the pitch, SSSG elicited higher HR values (80%HRmax, 170 bpm) [8, 32-34]. Two studies reported lactate concentration values around 4.5 to 5.9 mmol/l [33, 36] in response to different types of SSSG (e.g. 3 vs. 3, 5 vs. 5, 7 vs.7) or to different surfaces (e.g. sand vs. turf vs. asphalt).

3.3. Effects of long-term small-sided soccer games on physical fitness and physiological responses in untrained individuals and clinical populations

Twelve studies investigated the effect of SSSG training on fitness and aerobic performances in healthy untrained subjects and two studies used individual with overweight and obesity [27, 37] **(Table 5)**. All these studies observed positive effects of SSSG on all measured physical fitness (e.g. jump tests, Yo-Yo tests, cycling time) and physiological responses (e.g., VO_2max, HRmax).

3.4. Effects of long-term small-sided soccer games on markers of health in untrained individuals and clinical populations

Table 6 depicted the 10 studies that investigated the effects of SSSG training on body composition, bone density, blood pressure, metabolic and cardiac adaptations in healthy untrained individuals. All these studies registered positive effects of SSSG on the measured parameters. In fact, SSSG training programs induced a significant decrease of body mass and body fat mass [23, 38, 39], of blood pressure [40, 41], significant increase of bone density [28, 42] and positive muscular adaptations [23, 41, 43].

3.5. Effects of long-term small-sided soccer games on markers of health obese and patient subjects

As shown in **table 7,** SSSG training induced positive effects on health indicators in obese individuals and in other patient groups as hypertensive or patient with prostate cancer. Among the 10 included studies, 5 investigated hypertensive individuals [44-48], 3 studied individuals with prostate cancer [49-51], 1 examined individuals with obesity [37], and 1 scrutinized individuals with type 2 diabetes [52].

4. Discussion

This systematic literature review showed that acute single SSSG sessions appear to induce high cardiovascular and metabolic demands in healthy untrained individuals. Moreover, there is evidence that chronic SSSG has high potential to improve physical fitness, physiological response and selected health indices in untrained healthy individuals as well as in different clinical populations.

4.1. Acute and long-term small-sided soccer games characteristics

Small-sided game sessions have received attention within the recent scientific literature [11, 12]. The acute session of SSSG is often played with modified games on reduced pitch areas, using modified rules and involving a smaller number of players than traditional games [11]. These games are less structured than traditional fitness training methods but are very popular training drills for players of all ages and levels and used by amateur and professional teams to improve physical fitness while also developing technical and tactical proficiency [11, 12]. Currently, SSSG represent one of the most common training drills used by amateur, professional teams, untrained and clinical populations to improve physical fitness while also developing technical and tactical proficiency [12]. The intensity of SSSG can be affected or manipulated to elicit different physical, technical and tactical challenges by several factors, such as, the number of players involved, the size and the shape of the pitch, the duration of exercise and rest periods, the rules of the game, coach encouragement, the availability of balls or by the way of scoring points [11, 13, 53, 54]. A better understanding of the influence of modifying those variables on SSG will help coaches, physical fitness coaches and coaches involved health coaching to better controlling the training process with trained, untrained and clinical populations.

4.2. Factors influencing the intensity of small-sided soccer games

Training intensity during SSSG can be modified by changing parameters such as pitch dimensions, number of players and game format [11]. However, only a few studies have looked at the effects of exercise intensity during SSSG in sedentary participants. Aslan, [32] observed that HR values recorded during SSSG 5 players *vs.* 5 players were higher than those for 7 *vs.* 7 (164.3±11.9 and 161.2±12.9 bpm, respectively). In addition, Randers et al. [33] studied the effect of varying the number of players during SSSG. The results of this study showed that HR during 5vs. 5 (pitch area 30x40 m) was higher than during 8 vs. 8 (pitch area 52.5x68 m). Another study by Randers et al. [34] showed that HR_{mean} values were higher in 5 vs. 5 than in 8 vs. 8 (174±10 vs 168±12 bpm, respectively) in U10 players, but similar in 8 vs. 8 and 11vs. 11 (170±10 vs 171±10 bpm, respectively) in U13 players. Another study by Toh et al. [35] showed that, in overweight children, HR was significantly lower for SSSG when conducted on a badminton court (6.1x13.4 m) compared with a basketball (14.2x26.5 m) or a volleyball (9x18 m) court. Energy expenditure was similar for SSSG played on the badminton and volleyball courts, but lower compared to the basketball court. Besides court size, playing surface was elucidated as another factor to influence training intensity. It was reported that HR was significantly higher for SSSG played on a turf-type surface (87.8%HR_{peak}) compared with an asphalt type surface (82.4%HR_{peak}). Also, the blood lactate concentrations measured during SSSG on an asphalt surface were lower than those recorded during SSSG on a sand-type surface (or so-called stabilized ground). Rating of perceived exertion (RPE) values were significantly lower in SSSG played on asphalt surfaces compared with turf- or sand-type surfaces [36].

According to recommendations of the World Health Organization (WHO), training should be conducted above 60% of peak cardiac frequency to produce health benefits. SSSG-based training could therefore be a strong stimulus to improve untrained individuals' health status. Furthermore, given the low physical fitness of sedentary and clinical populations, SSSG should be conducted in relatively small areas with a larger number of players to prevent high training intensities and high HR values that may results in cardiac problems. Hence, the number of players and the pitch area represent a useful factor for the specialist and health coaches to control game intensity according to the population type and the objective of the training sessions.

4.3. Effects of acute small-sided soccer games on physiological responses in untrained individuals

Acute physiological responses to SSSG were assessed in untrained participants using measures of heart rate (HR), blood lactate (La), and rating of perceived exertion (RPE). A recent study has shown that most of the parameters used to evaluate training load during SSSG (internal and external indicators such as HR, distance travelled, number of accelerations) are reproducible [55]. HR values recorded during SSSG in untrained subjects can exceed 80% of HR_{max} (**Table 4)**. For example, Bendiksen et al. [31] found that out of nine different physical activities applied in a physical education program, soccer practice generated the highest HR_{mean} values (156±18 bpm) in 8–9-year-old primary schoolchildren. Additionally, Castagna et al. [8] demonstrated that HR (% HR_{max}) and oxygen consumption (%VO_{2peak}) during 5 vs. 5 SSSG were 83.5±5.4% and 74.2±10.8%, respectively. It has also been reported that blood lactate levels and elapsed time at intensities greater than 90% HR_{peak} are significantly higher during SSSG sessions compared to running sessions [9]. Another recent study has also shown that a session of SSSG (5 vs. 5 for 1 hour) elicited high exercise intensities (HR_{mean} = 85±2% HR_{max}) associated with an energy expenditure of 634±92 kcal in untrained adult subjects, who covered a distance of 3412±381 m [10]. The authors of this study concluded that a single SSSG session is equivalent to 50% of the weekly physical activity recommended by the American College of Sports Medicine. When comparing SSSG-based training to strength training, it has been shown that, in untrained adult men, the SSSG requires higher HR (140 *vs.* 100 bpm), with more time over 90% HR_{peak} (17 *vs.* 0%) and lower lactate concentrations (7.2±0.9 *vs.* 10.5±0.6 $mmol.L^{-1}$) [56]. These studies clearly show that SSSG training induced higher exercise intensity than strength training. Also, in untrained adolescents, Hammami et al. [57] showed that repeated-sprint sessions and SSSG sessions produced similar mean HR values. Also, both types of effort had similar significant decreases in parasympathetic reactivation as assessed by HR variability. That decrease was explained by the moderate-to-vigorous exercise intensity achieved during SSSG. The authors suggested that for some sedentary populations, it may be advisable for participants wishing performing SSSG to first obtain physician approval or engage only in medically supervised exercise training. Of note, the same authors demonstrated that RPE was significantly lower after an SSSG session compared to repeated sprints [12].

4.4. Effects of long-term small-sided soccer games on physical fitness and physiological response in untrained individuals and clinical populations

Positive effects of SSSG training on aerobic capacities, as assessed through endurance performance or maximal oxygen uptake (VO_{2max}) were observed in healthy untrained individuals and clinical populations. Bangsbo et al. [43] compared the effects of a 16-week SSSG training versus running-based training on VO_{2max} in sedentary women aged 20-45 (table 5). The results showed a 15% increase in VO_{2max} in the SSSG group and a 10% improvement in the running-based training group. In the same study, the authors showed that performance in the Yo-Yo intermittent endurance level 2 tests improved by 37% after SSSG training and by 26% after running-based training. Similarly, these authors suggested that SSSG training produced similar or better aerobic capacity improvements compared to running-based training. More recent studies have also examined the effects of SSSG-based training on physical performance in sedentary people [24, 58]. Reports from these studies indicate larger performance improvements following SSSG compared with running-based training in the Yo-Yo intermittent endurance level 2 test (37% after 4 weeks and additional 23% from 4 to 12 weeks), 30-m sprint time test (-0.11s), and maximum hamstring strength test (+11%) in 20-43-year old untrained men [24]. Similar results were observed after 8 weeks of SSSG on sprint 20 meters (-4.1%), and Yo-Yo test level 1 (30.9%) in sedentary adolescents [58].

The effects of a 1-year SSSG program were contrasted with strength training on measures of muscle strength and balance in 68-year-old participants [59]. Similar performance improvements were found for measures of balance and strength after both intervention types [59]. In addition, physical performance in untrained men has been significantly improved after SSSG, VO_2max related to body weight increased more ($p<0.05$) in soccer group (24.2%) and running group (21.5%) than in the control one (-5.0%), partly due to large changes in body mass (-5.9, -5.7 and +2.6 kg, $p<0.05$ for soccer, running and control groups, respectively). Over the 12 weeks, squat jump and counter movement jump performance increased more ($p<0.05$) in soccer group (14.8 and 12.1%) than in running group (3.3 and 3.0%) and in control group (0.3 and 0.2%), while flexibility, evaluated through the range-of-motion of a joint (ROM) or the sit and reach test also increased more ($p<0.05$) in soccer group (94% than in running group and control group (0-2%) [60]. Additionally, in sedentary children aged 9–10 years Faude et al. [27] showed that 10 weeks of SSSG produced significant improvements in speed over 50m (-0.9s), CMJ jumping height performance (+ 7.6 cm). Furthermore, Jakobsen et al. [61] showed that center of pressure (CoP) sway length decreased by 18.2% ($p<0.01$), 14.6% ($p<0.05$) and 12.8% ($p<0.05$) in soccer, high-intensity interval running and continuous running groups respectively. CoP sway area decreased in soccer (-30.2%; $p<0.01$) and in high-intensity interval running (-23.4%; $p < 0.01$) but remained unaffected in continuous running group. In untrained type 2 diabetes individuals, VO2max was elevated by 10 ± 4% ($P < 0.05$) after 12 weeks intervention with SSSG combined with dietary restriction but not in the diet group (−3 ± 4%, $P < 0.05$), as reported by de Sousa et al [52] (table 5).

These findings illustrate that short-term SSSG interventions with submaximal, intermittent and continuous incremental exercise to exhaustion have the potential to improve components of physical fitness (i.e., endurance, muscle strength, balance) during. In SSSG, the periods of high anaerobic energy turnover and musculoskeletal impact result in a greater training stimulus compared with daily activities such as walking and shopping [7]. In conclusion, there is evidence that SSSG has high potential to improve physical performance in the untrained populations across the lifespan, providing an effective tool for preventing lifestyle diseases and lowering the mortality risk.

4.5. Effects of small-sided soccer games on markers of health in untrained individuals ~~and patients~~

Tables 6 and **7** illustrate that soccer training has positive effects on body composition in healthy, sedentary individuals and clinical populations. More specifically, SSSG lasting between 16-40 weeks resulted in a significant decrease in body fat (1.2 to 1.7%) in sedentary adult women [38,39]. Similar results have also been reported for sedentary adult men, with significant decreases in fat mass (-3%) and increases in bone mass (+1.7 kg) after 12 weeks of SSSG [23]. Other studies have shown significant decreases in body mass index (BMI) (-2.3%) and body fat (-4.9%) after 12 weeks of SSSG in obese adolescents [27]. Similarly, studies have reported a significant decrease in body fat (-2 to -5%) in individuals with arterial hypertension after 12–24 weeks of SSSG [44,45]. These positive and SSSG-related effects on body composition reflect the increase in energy expenditure during training sessions, which allows an increase in lipid metabolism (lipolysis) during and after training sessions [38,41].

On the other hand, it is well-known that good postural balance and high bone mineralisation are associated with a decrease in fall frequency and the risk of bone fractures [62]. In fact, it was observed that trained women who regularly play soccer have higher total bone mineral density (BMD) (+13%) and higher leg BMD (+24%) compared with untrained women [63]. In addition, 14 weeks of SSSG-based training produced a significant improvement in left and right tibia BMD, associated with a significant improvement in muscle strength and postural balance in premenopausal women [28]. Similarly, in men with a mean age of 68 years, an improvement in osteocalcin plasma concentrations (+46%) and a significant increase in BMD (+5.4%) were obtained after 12 months of SSSG training, with no variations in the strength training group [42]. Additionally, leg bone mass (+3.5%) and density

(+2.0%) were higher (p<0.05) after 64 weeks (1.3 sessions/week) of SSSG in 17 healthy untrained males [41].

The positive effects on BMD, strength, and balance reflect the physical requirements of soccer: intense movements in various directions, jumps, accelerations, decelerations, and rapid side-cutting movements, all of which cause mechanical impacts that stimulate bone calcification as well as enhancing vertical jumping ability and muscular strength [28]. In adolescents, cross-sectional and longitudinal studies have shown that adolescents who play soccer have higher BMD and bone metabolism-regulating hormone concentrations than sedentary peers [30,64].Seabra et al. [65] showed that a 6-month soccer intervention based on SSSG (60–90 min per session wit 4 sessions/week) resulted in beneficial changes in bone mass indicators in overweight children, who experienced significantly greater increments in lumbar spine BMD and bone mineral content (BMC) (+4.3% and +7.4%, respectively). Additionnaly, 40 weeks of workplace-initiated soccer in sedentary female hospital employees, resulted in an increase of 39.3 g (p<0.01) in total BMC in comparison to the control group [39].

Physical activity has been recommended as a non-pharmaceutical tool for preventing and treating high blood pressure [7]. Few studies have examined the effects of soccer practice on changes in blood pressure, metabolic and cardiac functions. However, Krustrup et al. [24] demonstrated in premenopausal women that 12 weeks of SSSG compared with a running group induced significant decreases in systolic blood pressure (-7 mmHg) and diastolic blood pressure (-4 mmHg) in the SSSG group. In the running group a decrease in systolic blood pressure was found (-6 mmHg).

SSSG-based training has been shown to increase citrate synthase concentrations, capillary number per fiber and activity of 3-hydroxyacyl-CoA dehydrogenase (intramuscular component) [43].

Positive effects were also observed on the structural and functional aspects of the heart using echocardiography: increases in left ventricle volume and a decrease in isovolumetric relaxation time [39]. Schmidt et al. [66] concluded that soccer training based on SSSG elicited superior cardiovascular effects compared with strength training in elderly untrained men. In fact, their results showed that, after 12 months of practice, left-ventricular internal diastolic diameter, end diastolic volume and mass index were 8%, 21% and 18% higher ($p<0.01$), respectively, in the soccer training group, with no changes in the strength training and control groups. The results also showed that left-ventricular ejection fraction and systolic longitudinal two-dimensional strain were increased ($p<0.05$) by 8%, whereas right-ventricular systolic function improved ($p<0.05$) by 22% in the soccer-training group. A short-term, school-based SSSG intervention conducted by Krustrup et al. [67] resulted in significant structural and functional cardiac adaptations in preadolescent children. Left-ventricular posterior wall diameter was increased in the soccer-training group compared with the control group [0.4±0.7 vs. -0.1±0.6 (±SD) mm; $p<0.01$], as was inter-ventricular septum thickness (0.2±0.7 vs. -0.2±0.8 mm; $p<0.001$). Global isovolumetric relaxation time increased more in the soccer group than in the control group (3.8±10.4 vs. -0.9±6.6 ms, $p<0.05$), while the change in ventricular systolic ejection fraction tended to be higher (1.4±8.0 vs. -1.1±5.5%; $p=0.08$).

In adult women and men with high blood pressure, a period of SSSG training has been shown to significantly improve (6.1%) VO_{2max}, with a significant improvement in endurance capacity involving gains ranging from 30 to 111% [44,55]. The intensity of the SSSG training was high (HR values >75% HR_{max}), which was probably the main cause of the large improvements in aerobic capacity and VO_{2max}.

4.6. Effects of small-sided soccer games on markers of health in clinical populations

The effects of SSSG training have also been studied in individuals with hypertension. Mohr et al. [46] reported in women with prehypertension that systolic blood pressure (SBP) and diastolic blood pressure (DBP) decreased significantly after 15 weeks of SSSG training (-7 and -4 mmHg, respectively).

Similar results were obtained in hypertensive men after 12 weeks of SSSG, the authors observing significant decreases in SBP (-7.5%) and DBP (-10.3%) [34]. Recently, Krustrup et al. [68] showed that 1 year of SSSG training significantly improved the health (cardiovascular, metabolic and musculoskeletal) of premenopausal women with high blood pressure. Furthermore, 16 weeks of SSSG have been reported to decrease plasma cholesterol levels in hypertensive women, but with no significant effect on low density lipoprotein (LDL) or high density lipoprotein (HDL) cholesterol levels [46].

In type 2 diabetes individuals, de Sousa et al. [52] have shown that 12 weeks of dietary advice and SSSG (3x40 min/week) can significantly lower blood glucose, triglycerides and total cholesterol. This intervention also proved more effective at reducing the risk of cardiovascular and other complications than dietary advice alone. The SSSG decreased insulin resistance, increased lipolytic activity and attenuated catabolism attested by higher IGF-1/IGFBP-3 ratio, lower ammonia concentration and preserve lean body mass of type 2 diabetes individuals as evidenced in the study of de Sousa et al. [52]. More, recently [69] have reported that 12 weeks of SSSG combined with dietary intervention enhanced insulin sensitivity in type 2 diabetes individuals evidended by lower HOMA-IR and Adipo-IR.

Krustrup et al. [47] found that, in untrained males (31–54 years) with mild-to-moderate hypertension,6 months of soccer training decreased systolic and diastolic blood pressures ($p<0.01$) from 151±10 to 139±10 mm Hg and from 92±7 to 84±6 mm Hg, respectively, increased VO_{2max} ($p<0.01$) from 32.6±4.9 to 35.4±6.6 $mL \cdot min^{-1} \cdot kg^{-1}$,lowered resting HR ($p<0.05$) by 8±11 bpm and lowered the augmentation index (a measure of arterial stiffness) ($p<0.05$) by 7.3±14.0. Additionally, Mohr et al. [48] observed after 15 weeks of soccer training in premenopausal mildly hypertensive women that plasma osteocalcin, procollagen type I N-propeptide and C-terminal telopeptide were increased ($p<0.05$) by 37±15, 52±23 and 42±18%, respectively, that leg BMC was increased ($p<0.05$) by 3.1±4.5%, and that femoral shaft and trochanter bone mineral density (BMD) were increased ($p<0.05$) by 1.7±1.9 and 2.4±2.9%, respectively.

Recently, it was concluded that community-based socceris a feasible exercise strategy for men with prostate cancer and that soccer did not improve prostate cancer-specific quality of life but did improve mental health [70]. Additionally, Uth et al. [49] showed that in men undergoing androgen deprivation therapy for prostate cancer, mean HR during soccer training based on four training sessions in weeks 2–3 and weeks 11–12 was 138±14 bpm corresponding to 84.6±3.9% of individual maximal HR. The time spent in HR zones <70%, 70–80%, 80–90%, and 90–100% was 4.6±4.3, 20.0±14.9, 48.7±13.8, and 26.8±22.2% of total training times, respectively. More recently the same authors found in similar population that significant differences between soccer training group and control group in right (0.015 g/cm^2) and left (0.017 g/cm^2) total hip and in right (0.018 g/cm^2) and left (0.024 g/cm^2) femoral shaft BMD ($p<0.05$) after 32 weeks of soccer training based on SSSG [50]. Furthermore the same authors found also in men with prostate cancer (PCa) undergoing ADT that analysis of baseline-to-12-week change scores showed between-group differences in favor of soccer training group in total body BMC [26.4 g, 95 % confidence interval (CI): 5.8–46.9 g, p=0.013], leg BMC (13.8 g, 95 % CI: 7.0–20.5 g, p < 0.001) and markers of bone formation: P1NP (36.6 μg/L, 95 % CI: 10.4–62.8 μg/L, p = 0.008) and osteocalcin (8.6 μg/L, 95 % CI: 3.3–13.8 μg/L, p<0.01) [51].

With regards to overweight children, a 5-month SSSG (4 x 60–90 min) enhanced psychological well-being but was not effective in terms of body mass and composition [71]. In contrast, Cvetković et al. [72] showed that SSSG (3 x 60 min) decreased body mass and increased lean mass, while the control group, which performed only physical education classes, increased body mass, BMI and fat mass, with a modest increase in lean mass. These results highlight a need for further long-term and large-scale studies. The implementation of additional intermittent activities such as SSSG to promote fitness, emotional and social improvements could counter the prevalence of overweight and obesity in children.

4.7. Practical recommendations for small-sided soccer games to induce health benefits

SSSG training elicits high exercise intensity, irrespective of age, fitness status and previous experience of soccer training, and has a large positive effect on health indices in sedentary healthy and unhealthy individuals. Clear evidence has been found that SSSG has positive effects on many health-related indices and variables, including VO_{2max}, blood pressure, body composition (decreased fat mass, positive muscular adaptations and improved bone health indices), and metabolic and cardiac function. These positive effects have been observed in both healthy individuals and clinical populations, irrespective of age or sex, suggesting that SSSG is potentially a highly motivational method for enhancing population health and engaging sedentary people in physical activity, since it has been demonstrated that recreational soccer training has the lowest rating of perceived exertion in comparison with other activities such as jogging, interval running and fitness training. This may be one reason why participants usually find the game enjoyable and maintain their interest in soccer training for longer periods, and why small soccer pitches have emerged in cities.

Additionally, SSSG produced similar or larger aerobic capacity improvements compared to other training methods and activities. According to the American College of Sports Medicine, a single SSSG session is equivalent to 50% of the weekly recommended physical activity, so SSSG can be considered a health-promoting activity across the lifespan, especially if it is performed for 45 min or more two to three times a week and using different types of game format, starting with the easiest formats of 7 vs. 7, 8 vs. 8 or 9 vs. 9 on medium-sized pitches and progressing to 4 vs. 4 to 7 vs. 7 formats with an ideal pitch size of 80 m^2 per player. Participants should take into account that SSSG should be slowly introduced and should avoid forceful contacts to prevent fatigue, disinterest and minor or severe injuries.

4.8. Current guidelines of SSSG for clinical populations

For clinical populations aiming to participate in recreational SSSG, and in order to optimize health and fitness improvement, twice- or thrice-weekly SSSG training sessions, especially in individuals with metabolic diseases, performed under the supervision of the patient's physician or doctor, can thus be recommended for the prevention and treatment of these diseases.

Moreover, reducing game intensity can be achieved through reducing game space while keeping the same number of players and controlling the heart rate. Keeping the exercise intensity under maximum values is also recommended to avoid any exercise-related cardiac events especially for patients with heart diseases [73]. Concerning injuries during SSSG, and despite that no injuries were reported in both acute and long-term studies, this issue should be considered especially in contact sport and exercise such as SSSG and involving sedentary and clinical populations with low physical fitness. Additionally, a recent injury cohort study reported that among 1,821 recreational soccer players (employees played each week-end), the incidence of injury was high leading to 1,196 days of labour loss, accounting for 211.5 days off per 1,000 match hours [74]. More recently, [75] showed no increase in severe injuries and the number of hospital admissions when playing soccer for one year on 200 elderly men with prostate cancer. Thus, it is recommended to avoid contact situations during SSSG. A proper warm-up should be conducted before starting the game. Future studies on this topic are warranted both on injury incidence during recreational football and prevention methods.

4.9. Study limitations

The results from the current systematic review revealed some limitations that should be reported. First, despite the fact that inclusion criteria were very strict, the reviewed studies presented a wide heterogeneity. In fact, the populations studied differed in term of sample size, sex, age and country of recruitment. Moreover, the soccer training programs varied widely concerning their frequency, duration and intensity. Hence, large differences were observed concerning the number of players enrolled for the SSSG and the pitch area. Second, to our knowledge, no study presently reviewed reported data about the persistence of the beneficial effects once the intervention was finished, or provided a more qualitative analysis of the characteristics of soccer training programs. In fact, studies only focus on statistical significance of differences within/between groups, which might be affected by sample size and variability. However, this type of follow-up would be crucial to define how much soccer training would be needed to maintain the favorable gains, as well to compare the magnitude of long-term responses as a result of different types of intervention. Third, most of the studies did not provide information about the drop-out rates across the intervention programs.

5. Conclusions

This systematic literature review showed that small-sided soccer games is an effective training method for improving physical fitness, physiological response and selected health indices in sedentary healthy individuals as well as in different patient groups. Moreover, this type of training is more attractive than other types due to social and motivational aspects. SSSG should therefore be recommended as a training method for increasing the number of people who regularly exercise. Studies from other team sports, such as handball and basketball, and their effects on markers of health in untrained people could reinforce the use of these training forms in the sports health field. Finally, it is appropriate to conduct further injury preventive studies with this type of intervention. Indeed, it is well known that the number of injuries is reduced with proper warm-up including strength and balance exercises, and by conducting small-sided soccer games avoiding forceful contacts.

Figures:

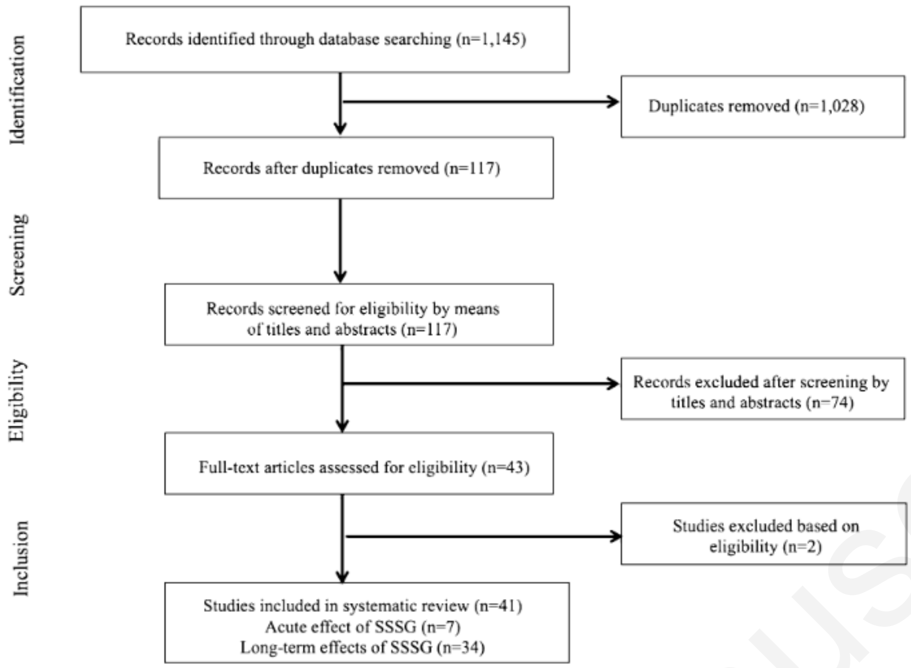

Fig. 1 Selection process for research articles (n = 41) included in this systematic review. Adapted version of the recommendations in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement [24].

SSSG: Small-sided soccer games.

Data Availability Statement

All data supporting the findings of this study are available in this published article.

Compliance with Ethical Standards

Not applicable.

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Conflicts of Interest

Hassane Zouhal, Amri Hammami, Jed Tijani, Ayyappan Jayavel, Maysa de Sousa, Peter Krustrup, Zouita Sghaeir, Urs Granacher and Abderraouf Ben Abderrahman declare that they have no conflicts of interest relevant to the content of this review.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interest

The authors declare that they have no competing interest.

Author Contributions

Hassane Zouhal, Amri Hammami and Abderraouf Ben Abderrahman were involved in the conceptualization of the study, data analysis, and the writing of the manuscript. Mohamed Jed Tijani, Ayyappan Jayavel, Maysa de Sousa and Zouita Sghaeir were involved in the data assessment, data analysis, and the writing of the manuscript. Peter Krustrup and Urs Granacher were involved in the writing of the manuscript. All authors approved the final version of the manuscript.

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Table 2. Characteristics of the studies that examined the acute and long-term effects of SSSG on physical fitness, physiological responses, and health indices in healthy untrained individuals and clinical populations.

Study	PEDro scale	Year	Country	Sex / Status	Sample size	Age, years (mean ± SD or range)	SSSG characteristics	Duration (weeks)
Acute studies								
Aslan et al. [32]	8	2013	Turkey	Male Untrained	10	31.7±7.6	SSSG with different pitch size	
Brito et al. [36]	7	2012	Portugal	Male Untrained	16	22.4±4.4	SSSG played on different surfaces	
Castagna et al. [8]	7	2007	Italy	Male Untrained	16	16.7±1.2	SSSG outdoor training	
Hammami et al. [58]	7	2016	Tunisia	Male Untrained	8	15.8±0.6	SSG and resistance strength training	
Randers et al. [34]	6	2014	Denmark	Male Untrained	86	8-12	SSSG outdoor training	
Randers et al. [33]	6	2014	Denmark	Male Untrained	12	33.X±6.4	SSSG	
Hammami et al. [12]	7	2017	Tunisia	Male Untrained	12	15.8±0.6	SSSG and resistance strength training	
Long term studies								

Andersen et al. [40]	6	2010	Denmark	Male Hypertensive	25	31-54	Outdoor football training 2x/W-1-hr	12
Andersen et al. [44]	6	2010	Denmark	Female Untrained	37	36.5±8.2	Outdoor football training 2-3x /W-1-hr	16
Andersen et al. [56]	8	2014	Denmark	Male Untrained	26	68.2±3.2	Outdoor football training 2x/W-1-hr	16
Bangsbo et al. [43]	7	2010	Denmark	Female Untrained	53	19-47	SSSG outdoor training 2x/w-1-hr	16
Barene et al. [39]	6	2014	Norway	Male & Female	118	25-65	SSSG 5x/W-1hr	40
Bendicksen et al. [31]	6	2014	Denmark	Male & Female	93	8-9	Physical Education Lesson High Aerobic intensity 2/W-30min	6
Bjerre et al. [70]	8	2019	Italy	Male & Female Untrained	31	16.8±1.5	SSSG 5v5s – 1-3x/W	24
Connolly et al. [38]	6	2014	UK	Female Untrained	44	20-45	SSSG 2x/w-14 min	16
Cvetković et al. [72]	7	2018	Serbia	Male Obese	42	11-13	Football training 3x/W 1-hr	12
de Sousa et al.	6	2014	Brazil	Male &	44	48-68	SSSG 3x/W- 1-hr	12

[52]				Female Diabetics				
Faude et al. [27]	5	2010	Germany	Male & Female Untrained	22	8-12	Football training 3x/W-1-hr	24
Hammami et al. [5]	6	2016	Tunisia	Male Untrained & Unhealthy	22	15.9±0.6	SSSG outdoor training 2x/w- 30-45 min	8
Helge et al. [42]	6	2014	Denmark	Male Untrained	32	65-75	SSSG outdoor	1 year
Helge et al. [28]	5	2010	Denmark	Female Untrained	50	36.5±7.7	SSSG outdoor 2x/W-1-hr	14
Jackman et al. [63]	6	2013	Denmark	Female Untrained	27	24.4±0.4	SSSG 2x/W-50min	16
Jakobsen et al. [61]	6	2011	Denmark	Male Untrained	35	21-45	SSSG 3x/w-45min	12
Knoepfli-Lenzin et al. [45]	6	2010	Switcherland	Male Hypertensive	47	37±4	SSSG 3x/w-1hr	12
Krustrup et al. [9]	7	2010	Denmark	Male Untrained	36	20-40	Outdoor SSSG and Running	12
Krustrup et al.	7	2014	Denmark	Male	36	23-43	Outdoor training	12

[67]				Untrained			2 /3x/W-1h	
Krustrup et al. [68]	6	2017	Denmark	Female Untrained	41	45±6	SSSG 3x/W 1 -hr	1 year
Krustrup et al. [24]	6	2010	Denmark	Female Hypertensive	28	19-47	Outdoor training 2x/W-1-hr	78
Krustrup et al. [47]	7	2013	Denmark	Male Hypertensive	33	31-54	SSSG outdoor training 2x/W-1hr	24
Milanović et al. [60]	6	2015	Croatia	Male Untrained	69	20-40	SSSG 3x/W-1h	12
Mohr et al. [46]	6	2014	Uinted Kingdom	Female Untrained	41	45±3	SSSG 3x/W 1-hr	15
Randers et al. [41]	6	2010	Denmark	Male Untrained	17	33±6.4	SSSG in different pitch size	12
Schmidt et al. [66]	8	2014	Denmark	Male Untrained	26	65-75	SSSG first four month 2x/W-1hr Next eight month 3x/W-1-hr	1 year
Seabra et al. [65]	6	2016	Portugal	Male Obese	17	8-12	Footbal outdoor 4x/W 60-90 min	25
Toh et al. [35]	6	2011	Singapore	Male Obese	13	10.7±1.2	SSSG outdoor training	5 different sessions

Sundstrup et al. [59]	6	2016	Denmark	Male Untrained	27	68.2±3.2	SSSG and Strength training	52
Uth et al. [49]	6	2014	Denmark	Male Prostate cancer	57	43-74	Football training 2x/W-45min	12
Uth et al. [50]	6	2016	Denmark	Male Prostate cancer	57	67.1±7.1	Football training 3x/W-45min	12
Uth et al. [51]	7	2016	Denmark	Male Prostate cancer	57	67.1±7.1	Football training 3x/W – 45min	32
Vasconcellos et al. [37]	9	2015	Brazil	Male & Female Obese	20	14.5±1.6	SSSG outdoor training 3x/W1-hr	12
Zouch et al. [30]	6	2015	France	Male Untrained	65	10-13	SSSG and Physical educational training, 2-5 hr training/W	6 years

SSSG: Small-sided soccer games, W week, hr hour, UK United Kingdom

Table 3: Physiotherapy evidence database (PEDro) score of the included longitudinal studies.

Study	Eligibility criteria	Randomized allocation	Blinded allocation	Group homogeneity	Blinded subjects	Blinded therapists	Blinded assessor	Drop out \15 %	Intention-totreat analysis	Between-group comparison	Point estimates and variability	PEDro sum
Andersen et al. [40]	●	●	●	●	○	○	○	●	○	●	●	6
Andersen et al. [44]	●	●	●	●	○	○	○	●	○	●	●	6
Andersen et al. [56]	●	●	●	●	●	○	●	●	○	●	●	8
Aslan et al. [32]	●	●	●	●	●	○	●	●	○	●	●	8
Bangsbo et al. [43]	●	●	●	●	○	●	○	●	○	●	●	7
Barene et al. [39]	●	●	●	●	○	○	○	○	●	●	●	6
Bendicksen et al. [31]	●	●	●	●	●	○	○	○	○	●	●	6
Bjerre et al. [70]	●	●	●	●	○	○	●	●	●	●	●	8
Brito et al. [36]	●	●	●	●	●	○	○	●	○	●	●	7
Castagna et al. [8]	●	●	●	●	●	○	○	●	○	●	●	7
Connolly et al. [38]	●	●	●	●	○	○	○	●	○	●	●	6
Cvetković et al. [72]	●	●	●	●	○	○	●	●	○	●	●	7
de Sousa et al. [52]	●	●	●	●	○	○	○	●	○	●	●	6
de Sousa et al. [69]	●	●	●	●	○	○	○	●	○	●	●	6
Faude et al. [27]	●	●	●	●	○	○	○	○	○	●	●	5
Hammami et al. 2016 [5]	●	●	●	●	●	○	○	●	○	●	●	7
Hammami et al. [58]	●	●	●	●	○	○	○	●	○	●	●	6
Hammami et al. [12]	●	●	●	●	●	○	○	●	○	●	●	7

Table 4. Acute physiological responses to SSSG in untrained healthy individuals.

Study	Population (number / sex / age)	Intervention (game format)	Exercise intensity (HR / $\%HR_{max}$/ La^- (mmol / L)	
Aslan et al. [32]	10 / M / 31.7±7.6	5v5: Small Pitch	79.4±3.7%	-
		5v5: Large Pitch	81.7±4.7%	-
		7v7: Small Pitch	76.8±4.4%	-
		7v7: Large Pitch	78.7±4.3%	-
Bendiksen et al. [31]	93 / (50 M - 43 F) / 8-9	Physical education program		-
		A) Soccer	A) 76±9% A> C, D*	-
		B) Basketball	B) 77±8% B> C, D*	-
		C) Circuit training	C) 62±1%	-
		D) Walking	D) 57±5%	-
Beato et al. [55]	16 / M / 22	Surface type		
		A) Sand	A) 84.8±1.5%	4.7 ± 0.6

		B) Turf	B) 87.8±0.8% B>C*	4.2 ± 0.6
		C) Asphalt	C) 82.4±1.3%	2.8 ± 0.3
Castagna et al. [8]	16 / M/ 16.8±1.5	5v5	83.5±5.4%	-
Randers et al. [34]	45 / M / (U10) with 22 soccer players	A) 5v5 (30x40 m)	A) 174±10 bpm A >B*	-
		B) 8v8 (52.5x68 m)	B) 168±12bpm	-
	41 / M/ (U13) with 21 soccer players	C) 8v8 (52.5x68 m)	C) 170±10bpm	-
		D) 11v11 (68x105 m)	D) 171±10bpm	-
Randers et al. [33]	12 / M / 33.0 ± 6.4	Soccer: 4x12 min (80 m^2 per player)		
		A) 3v3	A) 84.1±3.9 A=B=C	5.9±2.9 A=B=C
		B) 5v5	B) 84.5±5.0	5.9±2.4
		C) 7v7	C) 82.8±5.1	5.5±2.9
Toh et al. [35]	13 / M / 10.7 ± 1.2 overweight	Soccer		

		A) Badminton court (6.1x13.4 m)		-
		B) Volleyball court (9x18 m)	A<B*	-
		C) Basketball court (14.2x26.5m)	A<C*	-

% percent, M Male, F Female, * significant difference, La lactate concentration, bpm beats per minute.

Table 5. Effects of long-term SSSG on fitness and aerobic performance in healthy subjects as well as clinical populations.

Study	Participants (number / sex / age)	Intervention		Adaptations (intermittent endurance, VO_2max, balance, fitness)		
Andersen et al. [56]	26/ M /68.2	16 wks: 2 x 1 h sessions /wk		Yo-Yo test 1	VO_2max	Cycle time to exhaustion
		A) RS	84% HR_{max}	A) ↑43%*	A) ↑15%*	A) ↑7%*
		B) ST	61% HR_{max}	B) NC	B) NC	B) NC
		C) Control	-	C) NC	C) NC	C) NC
Bangsbo et al. [43]	53 / F / 19-47	16 wks: 2 sessions / wk		Yo-Yo IE2	VO_{2max}	
		A) RS	83% HR_{max}	A) ↑37±6% A>B, C*	A) ↑15% A>B, C*	
		B) RN	82% HR_{max}	B) ↑26 ± 6% B>C*	B) ↑10% B> C*	
		C) Control	-	C) NS	-C) ↑3%	

Barene et al. [39]	118 / F / 45.8	40 wks: 2-3 h / wk		VO_{2max}		
		A) RS	78.3% HR_{max}	A) NS		
		B) Zumba	75%HR_{max}	B) ↑2.2 B>C*		
		C) Control	-	C) NS		
Connolly et al. [38]	44 / F / 39±6	16 wks: 2 x 13.5 min /wk		HRmax		
		A) RS	159 bpm	A) ↓6% A>B, C*		
		B) VT	92 bpm	B) NS		
		C) Control	-	C) NS		
Faude et al. [27]	22/ 14 M /8F/10.8/ overweight	6 months: 3 x 1 h / wk		20 m shuttle run test (min)	Max power (w)	
		A) RS	80% HR_{max}	A) ↑50% A=B	A) ↑ 8.66% A=B	
		B) STD	77% HR_{max}	B) ↑44.8%	B) ↑7.2%	
Helge et al. [28]	50 / F / 36.5	14 wks: 2 x 1 h / wk		Balance	Pic jump height	Pic jump power

		A) RS	83% HR_{max}	A) ↓29.4%*	A) ↑6.3%*	A) ↑3%
		B) RN	82% HR_{max}	B) ↓33.3%*	B) ↑6.8%*	B) ↑2.4%
		C) Control	-	C) ↓16.8%	C) ↓5%	C) ↓5.1%
Jakobsen et al. [61]	35 / M / 21–45	12 wks: 3 x / wk		Balance (CoP sway length)	Balance (CoP sway area)	
		A) RS	NR	A) ↓18.2%*	A) ↓30.2%*	
		B) RN	80% HR_{max}	B) ↓14.6%*	B) NC	
		C) INT	>90% HR_{max}	C) ↓12.8%*	C) ↓23.4%*	
		D) Control	-	D) NS	D) NS	
Krustrup et al. [9]	36 / M /20-43	12 wks: 2-3 x /wk		Hamstring peak power	VO_{2max}	30 m sprint
		A) RS	82% HR_{max}	A) ↑11%*	A) ↑13%*	A) ↑0.11s*
		B) RN	82% HR_{max}	B) NC	B) ↑8%*	B) NC
		C) Control		C) NC	C) NC	C) NC

Knoepfli-Lenzin et al. [45]	47 / M / 25–45 /	12 wks: 2.4 x 1 h /wk:	VO_{2max}	Yo-Yo IR 2	
		A) RS	A) ↑6.08%*	A) ↑27.8%*	
		B) RN	B) ↑10.5%*$	B) ↑33.2*$	
		C) Control	C) NC	C) NC	
Milanović et al. [60]	69 / M / 33 /	12 wks: 3 x 60 min / wk A) RS B) RN C) Control	VO_{2max} A) ↑24.2%* B) ↑21.5%* C) ↓5%	CMJ A) ↑12.1%*$ B) ↑3.0%* C) ↑0.2	SJ A) ↑14.8%*$ B) ↑3.3%* C) ↑0.3
Mohr et al. [46]	41 / F / 30-50 /	15 wks: 3±0.1 sessions /wk	Yo-Yo IE1	FCsubmax	
		A) RS	□□□111 ± 18% *	A) ↓7.2 *	
		B) Control	□□□NS	B) NS	
Randers et al. [41]	17 / M / 20–43	12 wks: 2.4 x / wk	□□□m sprint	VO_{2max} (ml/kg/min)	Yo-Yo IR2

		54 wks: 1.3 x / wk			
		A) RS: 81-82% HR_{max}	□□□↑□□□□□	A) ↑3.1*	A) ↑49%*
		B) Control	B) NC	B) NC	B) NC
Schmidt et al. [66]	26 / M / 65–75	12 wks: 2 x 1 h /wk	VO_{2max}		
		A) RS	A) ↑18%*		
		B) ST	B) NC		
		C) Control	C) NC		
de Sousa et al. [52]	44 (27 F/ 17 M) 48–68 y/ type 2 Diabetes	12 wks: 3 x 40 min /wk	VO_{2peak}		
		A) RS+ diet	↑ 10 ± 4%		
		B) diet	↓ 3 ± 4%		
Vasconcellos et al. [37]	20 (14 M /6 F) / 12-17/ Obese	12 wks: 3 x 60 min / wk	VO_{2peak}		

		A) RS	A) ↑31.3%*		
		B) Control	B) ↑5.3%		

RS soccer training, ST strength training, RN running, HR heart rate, H hypertensive, M male, F female, submax submaximal, BL blood lactate, VO_2 maximal oxygen uptake, NC non-significant change, ↑ increase, ↓ decrease, * significant change compared to control group.

Table 6. Effects of long-term SSSG on body composition, bone density, blood pressure, metabolic and cardiac adaptations in healthy subjects.

Study	Participants (number / sex / age)	Intervention: ype/duration/volume/intensiy (HR_{max})	Adaptations: body composition, bone density, blood pressure, metabolic and cardiac adaptations		
Andersen et al. [40]	**37 / F/ 36.5±8.2**	**16 wks**	**Blood pressure**	**Right ventricle diameter**	**Peak systolic velocity**
		A) RS	A) ↓6%	A) ↑12%*	A) ↑26%*
		B) RN	B) ↓3.7%	B) ↑10%*	B) ↑17%*
		C) Control	C) NC	C) NC	C) NC
Bangsbo et al. [43]	**53 / F / 19-47**	**16 wks, 2 x 1 h / wk**	**Muscular Enzyme**		**Number of capillaries per fibre**
			CS	HAD	
		A) RS	A) ↑9%	A) ↑8%	A) ↑18%*
		B) RN	B) ↑12%	B) NC	B) NC
		C) Control	C) NC	C) NC	C) NC

Barene et al. [39]	**118 / F / 45.8**	**40 wks** **0-12 wks: 5 x 1 h / wk** **12-40 wks: 2-3 x 1 h / wk**	**Fat (%)**	**BMC (g)**	**Plasma osteocalcin (μg·L^{-1})**	**Plasma leptin (μg·L^{-1})**
		A) RS	A) ↓1.2%*	A) ↑39.3 *	A) ↑6.6*	A) ↓6.6*
		B) Zumba	B) ↓2.2% *	B) NC	B) NC	B) NC
		C) Control	C) NC	C) NC	C) NC	C) NC
Connolly et al. [38]	**44 / F / 20-45**	**16 wks: 2 x 13.5 min / wk**	**Fat (%)**	**Muscular PCR**		
		A) RS	A) ↓ 1.7 ± 2.4% *	A) ↓ 4 ± 8%		
		B) Vibration training	B) NC	B) NC		
		C) Control	B) NC	B) NC		
Helge et al. [28]	**50 / F / 36.5**	**14 wks**	**Left tibia BMD volume**	**Right tibia BMD volume**		
		A) RS: 1.8±0.3 h / wk	A) ↑ 2.6%*	A) 2.1%*		

		B) RN: 1.9±0.3 h/ wk	B) ↑ 0.7%*	B) 1.1%*
		C) Control	C) NC	C) NC
Helge et al. [42]	**36 / M / 68.2**	**12 months: 2-3 x 40-50 min / wk**	**Femoral BMD**	**Plasma osteocalcin**
		A) RS	A) ↑5.4%*	A) ↑46%*
		B) RST	B) NC	B) NC
		C) Control	C) NC	C) NC
Krustrup et al. [9]	**36 / M / 20-43**	**12 wks: 2-3 x / wk**	**Muscular fiber surface**	**Number of capillaries per fiber**
		A) RS	A) ↑15%*	A) ↑22%*
		B) RN	B) NC	B) ↑16%*
		C) Control	C) NC	C) NC
Krustrup et al. [9]	**36 / M / 20-43**	**12 wks: 2-3 x / wk**	**Fat mass**	**LDL-cholesterol**

		A) RS	A) ↓3.0%*		A) ↓14.81%*	
		B) RN	B) ↓1.8%*		B) NC	
		C) Control	C) NC		C) NC	
Krustrup et al.. [67]	**97 / (43M, 54F) / 9-10**	**10 wks: 3 x 40 min / wk**	**Left ventricle diameter (mm)**		**Global isovolumetric relaxation time (ms)**	
		A) RS	A) ↑ 0.4 ± 0.7		A) ↑3.8 ± 10.4 *	
		B) Control	B) ↓ 0.1± 0.6		B) ↓0.9 ± 6.6	
Randers et al. [41]	**17 / M / 20-43**	**12 wks: 2.4 x / wk** **54 wks: 1.3 x / wk**	**Mean fibre surface**	**PAS (mmHg)**	**Leg bone density**	**Leg bone mass**
		A) RS: 81-82% HR_{max}	A) ↑10%*	A) ↓8*	A) ↑2%*	A) ↑3.5%*
		B) Control	B) NC	B) NC	B) NC	B) NC

RS = soccer training, ST = strength training, RN running, HR heart rate, M male, F female, PAS systolic blood pressure, PAD diastolic blood pressure, BMD bone mineral density, NC non-significant change, ↑ increase, ↓ decrease, LBM lean body mass, BMC bone mineral content, LDL low density lipoprotein, HDL high density lipoprotein, HAD 3-hydroxyacyl-CoA dehydrogenase, CS citrate synthase.

Table 7. Effects of long-term SSSG in overweight and obese individuals and other patient groups.

Study	Participants (number / sex / age)	Intervention: duration/volume/intensity (HR_{mean})	Adaptations: body composition, bone density, blood pressure, metabolic and cardiac adaptations			
Andersen et al. [44]	**25 / M / 31-54 Hypertensive**	**6 months: 2 x 1 h /wk**	**Total fat %:**	**Mean blood pressure**		
		A) RS: (83% HR_{max})	A) ↓5 ± 2%	A) ↓10 *		
		B) Control	B) NC	B) ↓5		
Krustrup et al. [47]	**33/ M / 31-54 Hypertensive**	**6 months: 2 x 1 h /wk**	**Total BMC**	**PAD**		**LDL, HDL, CRP**
		A) RS: (85% HR_{max})	A) NC	A) ↓8 ± 6*		A) NC
		B) Control	B) NC	B) ↓ 3 ±3		B) NC

Knoepfli-Lenzin et al. [45]	**47 / M / 20-45 Hypertensive**	**12 wks: 3 x /wk**	**DBP (%)**	**PAS (%)**	**Total cholesterol**	**Total fat mass (kg)**
		A) RS: 79.9% HR_{max}	A) ↓10.3*	A) ↓7.5%	A) 5.2%	A) ↓2
		B) RN: 79.4% HR_{max}	B) ↓6.9%	B) ↓ 5.9%	B) NC	B) ↓1.6
		C) Control	C) ↓4.7	C) ↓6%	C) NC	C) NC
Mohr et al. [46]	**41 / F / 35-50 Hypertensive**	**15wks: 3 x /wk**	**Total BF%**	**PAD**	**PAS**	**Total cholesterol**
		A) RS: 80.5% HR_{max}	A) ↓2.1 ± 0.7% *	A) ↓12 ± 3*	A) ↓6 ± 2 *	A) ↓0.4 ± 0.1
		B) Control	B) ↓0.5 ± 0.4%	B) ↓1 ± 1	B) ↓1 ± 2	B) ↓0.1 ± 0.2
Mohr et al. [48]	**83 / F / 45±6 Hypertensive**	**15 wks : 3 x /wk**	**Plasma osteocalcin**	**Leg BMC**	**Femoral BMD**	**Trochanter BMD**

		A) RS	A) ↑37±15%*	A) ↑3.1±4.5 %*	A) ↑1.7±1.9 *	A)↑2.4 ±2.9 %*
		B) Swimming: high intensity	B) NC	B) NC	B) NC	B) NC
		C) Swimming: moderate intensity	C) NC	C) NC	C) NC	C) NC
		D) Control	D) NC	D) NC	D) NC	D) NC
		E) Soccer	A) ↑4.3%*	A) ↑28.9%	A) 20%	
		F) Control	B) 0%	B) 0.6%	B) 10%, A>B*	
De Sousa et al. [52]	**44 / (27F, 17M) / 48-68 Diabetic (type 2)**	**12 wks: 3 x 40 min /wk**	**Fat (%)**	**Glucose (mmol/L)**	**Cholesterol (mmol/l)**	**Triglycerides (mmol/l)**
		A) RS (70-90% HR_{max}) + nutrition intervention	A) ↓2.4 ± 0.1%*	A) ↓1.1 ± 0.1	A) ↓ 0.6 ± 0.2*	A) ↓0.4 ± 0.1*

		B) Nutrition intervention	B) ↓2.4 ± 0.1%	B) ↓1.1± 0.2	B) NC	B) NC	
Vasconcellos et al. [37]	**20 / (14M, 6F) / 12-17 Obese**	**12 wks : 3 x 1 h /wk**	**BMI (%)**	**Fat (%)**	**PAS**	**Cholesterol ($mg.dl^{-1}$)**	**Triglycerides ($mg.dl^{-1}$)**
		A) RS (84.5% HR_{max})	A) ↓2.3*	A) ↓4.9*	A) ↓3.9*	A) ↓16.2 ± 5.8	A) ↓20.5 ±12.9
		B) Control	B) ↑3.7*	B) ↓0.8	B) NC	B) NC	B) NC
Uth et al. [49]	**57/M/67(43-74) PCa**	**2 to 3 45-60 min /12 weeks**	**VO2max**	**Fat mass %**	**Lean mass**	**Knee-extensor muscle strength**	
		A) RS	A) ↑5.5%	A) ↓2.7%	A) ↑1.6%	A) ↑14.1%	
		B) Control	B) ↑1.8%	B) ↔	B) NC	B) ↑3.0%	
Uth et al. [51]	**57/M/67(43-74) PCa**	**2 to 3 45-60 min /12 weeks**	**Osteocalcin ($\mu g.L^{-1}$)**	**Tandem balance (mm2)**	**Bilateral balance (mm^2)**	**P1NP**	
		A) RS	A) ↑33.8%	A) ↑1.1%	A) ↑3.0%	A) ↑43.1%	

		B) Control	B) NC	B) ↓2.7%	B) ↓6.3%	B) ↓9.8%
Uth et al. [50]	**57/M/67(43-74) PCa**	**2 to 3 45-60 min /32 weeks**	**Osteocalcin**	**Jump height performance**	**Bipedal stance**	**P1NP**
		A) RS	A) ↑7.3%	A) ↑6.8%	A) ↑28.8%	A) ↑17.7%
		B) Control	B) ↓12.2%	B) ↓5.5%	B) ↓2.1%	B) ↓10.9%

RS soccer training, ST strength training, RN running, HR heart rate, M male, F female, PAS systolic blood pressure, PAD diastolic blood pressure, BMD bone mineral density, NC non-significant change, ↑ increase, ↓ decrease, LBM lean body mass, BMC bone mineral content, H hypertensive, BP blood pressure, BMI body mass index, BG blood glucose, PCa prostate cancer, P1NP procollagen type 1 amino-terminal propeptide.